

Mass Wasting: The work of Gravity

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Mass wasting: landslide, the downslope movement of rock, regolith, and soil under the direct influence of gravity

- Mass wasting does not require a transporting medium such as water, wind, or glacial ice
- Mass wasting carries the debris downslope, where a stream, acting as a conveyor belt, usually carries it away.
- Most extreme mass wasting events occur in areas of rugged, geologically young mountains

Controls and Triggers of Mass Wasting

- Gravity is the controlling force of mass wasting
- Eventually the strength of the slope is weakened to the point that something's **trigger**, or initiates, downslope movement
- **The Role of Water**
 - Mass wasting is sometimes triggered when heavy rains or periods of snowmelt saturate surface materials
 - When the pores in sediment become filled with water, the cohesion among particles is destroyed allowing them to slide past one another with relative ease
- **Over steepened Slopes**
 - Over steepened slopes can also trigger mass movements
 - **Angle of repose:** the steepest angle at which loose, dry material remains stationary without sliding downward
 - Angle varies from 25-40 degrees
- **Removal of Vegetation**
 - Plants contribute to the stability of slopes because their root systems bind soil and regolith together and hold water
 - Leaves protect the ground
 - When anchoring vegetation is removed by forest fires or by people, surface material frequently move downslope.
- **Earthquakes as triggers**
 - Earthquakes shake the ground which loosen the sediment and trigger movement
- **Liquefaction**
 - Intense ground shaking can cause water-saturated surface materials to lose their strength and behave as a fluid-like masses that flow.

- Major problem in the Ottawa-Saguenay region of Eastern Ontario

Classification of mass wasting processes

- Type of motion
 - Fall, slide, or a flow or topple and spreads
 - **FALL:** when the movement involves detached individual particles of any size dropping through the air
 - Common form of movement on slopes that are so steep that loose material cannot remain on the surface
 - **SLIDE:** material remains fairly coherent and moves along well-defined surface
 - **Slump:** the downward slipping of a mass of rock or unconsolidated material moving as a unit along a curved surface
 - "Landslide"
 - **FLOW:** which occurs when material moves downslope as a viscous fluid
 - Most flows are saturated with water and typically move as lobes or tongues that experience internal deformation
- Type of material
 - The descending mass may begin as unconsolidated material or as a bedrock
 - if soil and regolith dominate such terms as *debris* and *earth* are used in the description
 - in contrast, when a mass of mainly bedrock breaks loose and moves downslope, the term *rock* is commonly part of the description
- Rate of Movement
 - Rapid or slow
 - Velocity
 - "creep"

Slump

- SLUMP: refers to the downward sliding of a mass of rock or unconsolidated material rotating as a unit along a curved surface.

- Common along rivers valleys and eroding shorelines, especially in thick accumulations of cohesive materials, such as clay.
- Slumping commonly occurs because a slope has been oversteepened.
- Material that is on top is usually held up by the bottom of the slope
- Commonly occurs when a slope is overloaded, changing the weight on the material below, occurs where weak, clay-rich material (shale) underlies layers of stronger, more resistant rock such as sandstone

Rockslide

- Rockslides occur when blocks mainly bedrock break loose and travel rapidly down a slope
- Fastest and most destructive
- Triggered when rain or snow destabilizes the underlying surface to the point where friction is no longer sufficient to hold the rock unit in place
- Common in the spring

Debris Flow

- Is a relatively rapid type of mass wasting that involves a flow of soil and regolith containing a large amount of water
- Mountainous regions, including some volcanoes
- A flowing tongue of well mixed, soil, mud, rock and water
- Removal of native vegetation by brush fires increase the frequency of these destructive events
 - Lahars
 - Debris flow composed of mostly of volcanic materials on the flanks of volcanoes are called **lahars**
 - Take place when highly unstable layers of ash and debris become saturated with water and flow down steep volcanic slopes
 - Heavy rainfall trigger these flows

Earth Flow

- Slow, viscous earthflows most commonly form on hillsides in humid areas during times of heavy precipitation or snow melt
- When water saturates the soil and regolith on a hillside, the material may slump leaving a scarp on the upper part of a slope

- The materials most commonly involved are rich in clay and silt and contain only small proportions of sand and coarser particles
- **Earthflows:** are characterized by a slow and persistent movement and can remain active for days or even years

Slow movements

- **Creep**
 - Is a type of mass wasting that involves the gradual downhill movement of soil and regolith
 - A factor that contributes to creep is the alternative expansion and contraction of surface material caused by freezing and thawing or wetting and drying
 - Freezing and wetting lifts particles at right angles to the slope, and thawing or drying and gravity allow the particles to fall back vertically to a slightly lower level
 - Creep is aided by anything that disturbs the soil, such as raindrop impact, plant roots, burrowing animals and water saturation
 - Cause fences and utility poles to tilt and undrained retaining walls to be displaced
- **Solifluction**
 - The slow downslope flow of water-saturated (thawed) materials common to permafrost areas
 - Common where water cannot escape from the saturated surface layer by infiltrating to deeper levels
 - Common in regions underlain by **permafrost**
- **Other Periglacial Feature**
 - Periglacial: an environment in which frost action is the main process shaping the landscape
 - Periglacial processes often initiate mass wasting events in cold environments,
 - **PINGOES:** lakes gradually freeze to form ice-cored mounds covered with tundra vegetation
 - a large conical mound of soil-covered ice raised mainly by water pressure within or below permafrost in Arctic regions
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- PALSAS:
 - They re mounds of peat with ice lenses instead of a solid ice core
 - A domelike frost mound with ice lenses, commonly found in the Arctic
- FELSENMEER: a thin accumulation of angular blocks on bedrock, produced by frost wedging, where no steep slopes occur nearby
- PATTERNED GROUND: the general term for circle, polygons, nets and stripes in surface material subjected to intense frost action
- THERMOKARST: the karst like ponds produced in a permafrost region by the local melting of ground ice and resultant settling of the ground

Chapter 15

Running Water

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Floods: the overflow of a stream channel that occurs when discharge exceeds the channels capacity

- Are among the most destructive of all geological hazards

Earth as a system: the hydrological cycle

- The water content of the hydrosphere is about 1.36 billion cubic km
- 97.2 percent is stored in the global oceans
- glaciers and ice sheets account for another 2.15 percent leaving only 0.65% to be divided among lakes, streams, subsurface water and the atmosphere
- **hydrological cycle:** the circulation of earth's water supply. The cycle is powered by energy from the sun and is characterized by continuous exchanges of water among the hydrosphere, atmosphere, biosphere and geosphere.
- **Infiltration:** moving downward, then laterally, and finally seeping into lakes and streams, or directly into the ocean.
 - The movement of surface water into rock or soil through cracks and pore spaces
- **Runoff:** when the rate of rainfall is greater than the land's ability it, the additional water flows over the surface into lakes and streams
- **Transpiration:** the release of water vapor to the atmosphere by plants
 - Evapotranspiration: the combined effect of evaporation and transpiration
- Running water is the single most important agent sculpting Earth's land surface
- The hydrological cycle represents the continuous movement of water from the oceans to the atmosphere, from the atmosphere to the land, and from the land back to sea.
- From runoff to Stream Flow
 - Runoff initially flows in broad, thin sheets across the ground, appropriately termed **ice sheets**
 - Ice sheets: a very large, thick mass of glacial ice flowing outward in all directions from one or more accumulation centers

- the amount of water that runs off in this manner rather than sinking into the ground depends on the **infiltration capacity**
 - infiltration capacity: the maximum rate at which soil can absorb water
 - controlled by: 1. The intensity and duration of the rainfall 2. The prior wetted condition of the soil 3. The soil texture 4. The slope of the land 5. The nature of the vegetative cover
- After flowing as a thin, unconfined sheet for a short distance, threads of current typically develop, forming tiny channels called **rills**. Rills direct water flow to prominent **gullies** that in turn, feed larger and more stable channels of streams.
- To be considered a true **stream**, a body of water must be confined to one or more trough like linear depressions, called **channels**, and to flow along a definite course.

Basic components of a stream

- **Floodplain**: the flat, low lying portion of a stream valley subject to periodic flooding
- **Longitudinal profile**: (or side view) a cross section of a stream channel along its descending course from the head to the mouth

Characteristics and controls of stream flow

- Water can flow in one or two ways, either as **laminar flow** or as **turbulent flow**
 - when the movement is laminar, the water molecules flow in straight paths that are parallel to the channel.
 - When the flow is turbulent, the water moves in a chaotic and erratic fashion that is commonly characterized by swirling, whirlpool eddies
 - The stream's velocity is a primary factor that determines whether the flow is laminar or turbulent
- **Laminar flow**:
 - Laminar flow is only possible only when water is moving very slowly through a smooth channel.
- **Turbulent flow**:
 - If the velocity increases or the channel becomes rough, laminar flow changes to turbulent flow.

- Water movement is faster
- The multi-directional movement of turbulent flow is very effective both in eroding a stream's channel and in keeping sediment suspended within the water so that it can be transported downstream.
- When the channel is **straight**, the highest velocities occur in the center just below the surface. It is here that friction is least.
- When a stream channel is crooked or curved, the fastest flow is not the center the zone of maximum velocity shifts toward the outside of each bend
- The ability of a stream to erode and transport material is directly related to its velocity, several factors determine the velocity of a stream and therefore control the amount of erosional work a stream can accomplish
 - **Factors determining**
 - 1. The gradient
 - 2. The shape, size, roughness of the channel
 - 3. The discharge

Gradient and Channel characteristics

- Most obvious factor controlling velocity is the gradient of the stream channel because gravity works most effectively on slopes
- A smooth channel promotes a more uniform flow, whereas an irregular channel creates enough turbulence to slow the stream's forward motion

Discharge

- Is the amount of water flowing past a certain point in a given time
- Discharge is determined by multiplying a stream's cross-sectional area by velocity
 - Discharge (m³/s) = channel width (m) X Channel depth (m) X velocity (m/s)

Changes from upstream to downstream

- A stream can therefore maintain a higher velocity near its mouth, where it has lower gradient than upstream, because of the greater discharge than upstream because of the greater discharge, larger channel, and smoother bed

Stream Discharge

- Stream erode their channels mainly by plucking of loosened particles from their beds and by abrasion
- Streams transport their loads of sediment in three ways
 - 1. In solution **dissolved load**
 - 2. In suspension **suspended load**
 - 3. Along the bottom of the channel **bed load**
- Dissolved load
 - Supplied by groundwater
 - The portion of a stream's load carried in a solution
- Suspended Load
 - Usually only fine sand, silt, and clay particles can be carried this way
 - The fine sediment carried within the body of flowing water or air
 - Settling velocity: is defined as the speed at which a particle falls through a stationary fluid
 - The larger particles fall toward the bed more rapidly than do less dense particles of the same size and shape
- Bed load
 - Sediment moved along the bottom of a stream by moving water, or particles moved along the ground surface by wind
 - Sediment that is too large to be carried in suspension
 - Coarser particles move along the bed of the stream and constitute the *bed load*
 - Saltation: the transportation of sediment through a series of leaps or bounces
- Capacity and Competence
 - A stream's ability to carry solid particles is typically described by using two criteria
 - 1. The maximum load of solid particles that a stream can transport is termed as **capacity**
 - the **competence** of a stream indicates the maximum particle size that a stream can transport

- the stream's velocity determines its competence; the stronger the flow, the larger the particles it can carry in suspension and as a bed load

Deposition of sediment by streams

- Whenever a stream's velocity slows, its competence is reduced, and particles of sediment are deposited in definite order by size
- **Channel deposits**
 - Sand and gravel is usually deposited in the channel
 - **Bars:** a common terms for sand and gravel deposits in a stream channel
 - **Intrachannel bars:** a sand and gravel bar within the channel of a stream
 - **Point bar:** a crescent-shaped accumulation of sand and gravel deposited on the inside of a meander
- **Floodplain deposits**
 - Part of a valley that is inundated when stream flow overtops riverbanks during a flood
 - **Natural Leves:** are subtle, snake like topographic features that flank the channels of some streams
 - A elevated landform composed of alluvium that parallels

The Graded stream concept and base level

- Streams tend to naturally evolve toward a state of equilibrium, in which the parameters influencing their behavior are in the balance with one another and have reached their maximum efficiency
- **Graded stream:** a stream that has the correct channel characteristics to maintain exactly the velocity required to transport the material supplied to it
- **Base level:** the lowest elevation to which a stream can erode its bed
 - Corresponds to the elevation at which a stream enters another water body where, on especially the confinement of its channel. It rapidly loses velocity and, in turn, loses its ability to erode
- Sea level is regarded as **ultimately base level:** the lowest level to which stream erosion could lower the land

Stream Valleys

- Valleys are the most common landform on Earth surface

- Streams are very narrow compared with their valleys called misfits

Narrow Valleys

- The sides of valley's are shaped primarily by the combined processes of weathering, sheet flow, and mass wasting
- V shaped valley: indicated that the primary work of the stream has been down cutting

Wide valleys

- as a stream approaches base level and its gradient has decreased. Less energy is expended in downcutting and more in lateral erosion
- the result is the development of a meandering channels that widens the valley as it erodes first one bank and then the other

Types of Stream Systems

- Braided
- Meandering
- Anastomosed
 - Braided streams
 - A broad channel containing a complex network of converging and diverging flow paths that thread their way among the bars
 - Commonly form when the load supplied to a stream exceeds its competence or capacity
 - 1. Is a steeper turbulent tributary enters a main stream, its rock bed load may be deposited at the junction because of the velocity abruptly decreases
 - 2. Excessive load can be provided when debris from barren slopes is flushed into a channel during a heavy downpour
 - 3. Excessive load can occur at the terminus of a glacier where ice-eroded sediment flowing away from the glacier
 - common in areas adjacent to highlands, where steep gradient promote the supply of large volumes of coarse sediment through
 - Meandering

- Occur in areas of relatively low gradient and their channels carry both fine-grained suspended sediment and coarser-grained bed load
- Back swamp: a poorly drained area on a floodplain that results when natural levees are present
- Yazoo tributaries: a tributary that flows parallel to the main stream because a natural levee separates the two
- **Anastomosed**
 - Look superficially like braided streams but differ greatly in their behavior
 - Produced by the development of multiple true channels rather than by the local diversion of flow around buildups of sediment within a single channel
 - Occur in areas of extremely low gradient and therefore possess little energy to carve their banks

Alluvial Fans and deltas

- Two of the most common landforms composed of alluvium are alluvial fans and deltas
- Alluvial fans are deposited on land whereas deltas are deposited in a body of water

Alluvial Fans

- Typically develop where a high gradient stream leaves a narrow valley in mountainous terrain and comes out suddenly onto a broad, flat plain or valley floor
- Dump its load of sediment quickly in a distinctive cone or fan shaped accumulation

Delta

- Forms when a stream enters an ocean or a lake
- Foreset beds: are composed of coarser particles that drop almost immediately on entering the lake to form layers that slope down current on the *delta plain*

Chapter 16

Ground water

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Zone of saturation: the zone where all open spaces in sediment and rock are completely filled with water.

- This is often called **ground water**

Zone of aeration: the area above the **water table** that includes the **capillary fringe** and the belt of soil moisture

The water table is the upper limit of the zone of saturation, is a very significant feature of the ground water system

Porosity: the quantity of groundwater that can be stored depends on the porosity of the material, which is the percentage of the total volume of rock or sediment that consists of pore space

Permeability: a measure of a materials ability to transmit fluid

Aquifers: impermeable layers that hinder or prevent water movement

- Example: clay

Aquifers: the rock or sediment through which groundwater moves easily

Darcy's law: $V = \frac{K}{L} H$ groundwater velocity

- N = the porosity
- H = the head
- L = length of flow
- K = coefficient that accounts for a materials permeability

Geysers: are intermittent hot springs or fountains in which columns of water are ejected with great force at various intervals, often rising at 30-60 meters

When water contains dissolved calcium carbonate a form of limestone *travertine* or *calcareous tufa* is deposited "spongy and porous"

When dissolved silica, a material called *siliceous sinter* or *geyserite* is deposited around spring

Cone of depression: a cone shaped depression in the water table immediately surrounding a well

Karst topography: dissolving power of groundwater

- A type of topography formed on soluble rock especially limestone primarily by dissolution
- it is characterized by sinkholes, caves and underground drainage

sinkholes: a depression produced in a region where soluble rock has been removed by groundwater

Chapter 17

Glaciers and Glaciation

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chapter summary

a glacier is a thick mass of ice forming on land by compaction and recrystallization of snow.

ice sheets: are continental in scale

- a very large, thick mass of glacial ice flowing outward in all directions from one or more accumulation centers

valley glaciers: usually follow mountain valleys formed by streams in the zone of *fracture* ice is brittle. Below just about 50 m ice floes like plastic. Ice can also slip across its bed or deform it
glacial flow is slow except during rapid surges

- snow is gained in the *zone of accumulation* and lost in the *zone of ablation*
- **glacial budget:** is the net gain or loss between the zones

Glaciers erode by *plucking* (lifting) and *abrasion* (scraping)

Valley glaciers produce *glacial troughs, hanging valleys, fjords, cirques, arêtes, horns and Roche mountains*

Glacial drift includes *till* poorly sorted sediment deposited by ice, and *stratified drift*, well sorted sediment deposited by meltwater

lateral moraines: are formed along valley sides

medial moraines: are form between two merging glaciers

end moraine; Is a ride shaped deposit of till that forms at the front of a glacier and is sometimes molded into streamlined, teardrop-shaped hills called **drumlins**

and **outwash plain** of sand and gravel forms beyond and end moraine, and a similar *valley train* occupies in tunnels under the ice,

Kames: are deposited as gravelly hills

Glacial drift: in all embracing term for sediments of glacial origin, no matter how, where, or in what shape they were deposited

Chapter 18

Deserts and Winds

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desert: deserted or occupied

- one of the two types of dry climate; the driest of the dry climates
- barren rocky outcrops with steep angular slopes are common

Distribution and causes of dry land

- Dry regions of the world encompass about 42 million square kilometers or 30% of earth's land surface
- Two climatic types are commonly recognized: **desert**, or arid, and **steppe**, or semi arid.
 - Steppe: a marginal and more humid variant of the desert that separates it from bordering humid climates

Low-latitude deserts

- The heart of the low-latitude dry climates lies in the vicinities of the tropics of Cancer and Capricorn
- In the Southern hemisphere, dry climates dominate Australia. Almost 40% of the continent is desert, and much of the remainder is steppe
- **Causes:**
 - The global distribution of air pressure and winds
 - Earth general atmospheric circulation

mid latitude deserts

- these are not controlled by the subsiding air masses associated with high pressure
- exist principally because they are sheltered in the deep interiors of large landmasses
- leeward side of mountains are usually much drier
- **rain shadow desert:** a dry area on the lee side of a mountain range, may middle latitude deserts are of this type.

Polar deserts

- the coldest of the world's desert occur in the Earth's polar region, where the constant descent of cold, dry air associated with stable high pressure cells prevent the formation of rain clouds
- annual precipitation is also very low, ranging mostly between 10 and 20 centimeters, with a few sites registering greater values

Geological Processes in Arid Climates

Weathering

- in humid regions, relatively fine-textured soils support an almost continuous cover of vegetation that mantles the surface
- here the slopes and rock edges are rounded, reflecting the strong influence of chemical weathering in humid climates.
- Lack of moisture and the scarcity of organic acids from decaying plants

The role of water

- Permanent streams are normal in humid regions, but practically all desert stream beds are dry most of the time
- **Ephemeral** (short-lived) **streams**: a stream that is usually dry because it carries water only in response to specific episodes of rainfall, most desert streams are of this type
 - Might flow for only a few days or perhaps just a few hours during the year

Transportation of sediment by wind

- Moving air is turbulent and able to pick up loose debris and transport it to other locations
- The transportation of sediment by wind differs
 - 1. Winds low density compared with water renders it less capable of picking up and transporting coarse material
 - 2. Wind is not confined to channels, it can spread sediment over large areas, as well as high in the atmosphere

bed load

- bed load carried by wind consists of sand grains.

Wind moves sand mainly by saltation (grain collisions)

Wind erodes by *deflation* (removing fine sediment), leaving *blowout* and *desert pavements* (stone layers) and by abrasion, creating *ventifacts* (stones) and *yardangs* (ridges)