Geology Final Exam

Chapter 1

- **Dinosaurs:** Extinct about 66 million years ago.
- **Planet Earth:** 4.6 billion years old.
- **Law of Superposition:** Younger rocks layers are deposited over older rock layers.
- **Core-Inner layer**: Dense, iron-rich
- **Crust–Outer layer:** Solid, thin
- **Mantle**: Largest layer between core and crust composed of iron, magnesium and oxygen-seeking elements
- **Divergent Boundary**:
    - Two plates move apart, resulting in the upwelling of material from the mantle to create new seafloor.
    - Occurs mainly at mid-ocean ridges.
    - Can occur under continents at rift valleys.
- **Convergent Boundary:**
    - Two plates move towards each other.
    - Continental settings: Two continental plates collide.
    - Oceanic settings: Oceanic crust descends into the mantle. This margin of crust consumption into the mantle is called a "subduction zone".
- **Transform Fault Boundary:**
    - Plates slide past each other without either generating new lithosphere or consuming old lithosphere.
    - These faults form in the same direction as plate movement
- **Two Types of Defining Earth's Internal Structure:**
    1) Composition: Crust, Mantle, Core
    2) Physical Properties: Lithosphere, Asthenosphere, Mesosphere, Inner Core, Outer Core
- **Earth's Four Interacting Spheres:** Hydrosphere, Atmosphere, Biosphere, Geosphere
- **The Rock Cycle:** The process by which one rock changes to another rock: metamorphic, igneous, sedimentary. Each rock type is linked to the other.
- **Basic Cycle:**
    - Molten *magma* becomes igneous rock
    - Weathering creates sediments
    - Sediments *lithify* into sedimentary rock
    - Burial and heat produce metamorphic rock
    - Metamorphic rock can be heated to produce magma, or eroded to form sediments.

Chapter 2

- **Definition of a Mineral:**
  Naturally occurring, Inorganic Solid, Ordered internal molecular structure, Definite chemical composition. (NISOD).
- **Chemical bonds:** Strong attractive force forms compounds
- **Ionic bonds:** One atom gives up electron(s), and another receives them. These now oppositely-charged atoms attract each other, bond, and become electrically neutral.
- **Covalent bonds:** Bonds that *share* electrons.
- **Mineral:** Consists of an ordered array of atoms chemically bonded to form a particular crystalline structure.
- **Polymorth:**
  - Some elements can join in more than one geometric arrangement
  - Chemical composition stays the same.
  - Physical properties differ
  - Example: diamond (deeply buried=high pressure) and graphite (shallowly buried=low pressure)
- Because of the presence of slight impurities, minerals, such as quartz, occur in a wide range of colours.
- Quartz can exhibit developed hexagonal crystals with pyramid-shaped ends.
- **Streak:** Colour of a mineral in its powdered form, when rubbed on an unglazed porcelain tile (=streak plate).
- **Hardness:** Resistance to a mineral to abrasion or scratching. All minerals are compared to a standard scale called the Mohs scale of hardness:
  - **Diamond:** 10 (hardest)
  - **Wire Nail:** 4.5
  - **Copper Penny:** 3
  - **Fingernail:** 2.5
  - **Gypsum:** 2
  - **Talc:** 1 (softest)
- **Cleavage:**
  - Tendency to break along planes of weak bonding
  - Produces flat, shiny surfaces
  - Cleavage is described as:
    - Number of planes exhibited

      &
    - Angles between adjacent places
- **Fracture:**
  - Absence of cleavage when a mineral is broken
  - Conchoidal Fracture: Breaks to form smooth curved surfaces like broke glass

- **<u>Specific Gravity:</u>** Ratio of the weight of a mineral to the weight of an equal volume of water & The average value is approximately between 2.5 and 3.
- **<u>The eight most abundant minerals in Earth's continental crust:</u>** In order of abundance: oxygen, silicon, aluminum, iron, calcium, sodium, potassium, and magnesium.

- **<u>Ferromagnesian (Dark) Silicates:</u>**
    - Minerals containing ions of iron and/ or magnesium
    - Most common are:
        - Olivine
        - Pyroxenes (most common in Augite)
        - Amphiboles (most common in Hornblende)
        - Biotite
        - Garnet
        -

- **<u>Nonferromagnesian:</u>**
    - Minerals containing various amounts of aluminum, potassium, calcium, and sodium.
    - Most common are:
        - Muscovite
        - Feldspar
            - Orthoclase (Potassium Feldspar)
            - Plagioclase
        - Quartz (Silica)
        - Clay (Variety of complex minerals that have a sheet structure i.e. most common: kaolinite)

Chapter 3

- **<u>Magma can be generated by:</u>**
    - The addition of heat
    - A decrease in pressure (without added heat), causing decompression melting
    - The introduction of volatiles, which lowers the melting temperature

- **<u>Three distinct components of magma:</u>** Liquid portion, Solids & Volatiles (gases dissolved in the melt, which include water vapour, carbon dioxide and sulphur dioxide.

- **<u>Felsic versus Mafic Compositions</u>**
    Classified by proportions of light and dark minerals:
    - **Felsic** (*granitic* composition)
        - Composed of light-coloured silicates
        - Rich in silica ($SiO2$) ≈ 70%

        - Major constituents of continental crust
    - **Mafic** (basaltic composition)
        - Composed of dark silicates, Ca-rich feldspar
        - Denser than granitic rocks
        - Comprise the ocean floor, volcanic islands

- **Silica content as an indicator of composition:**
    - Silica (SiO_2) content in crustal rocks exhibits a considerable range
    - A low of 40% in ultramafic rocks
    - Over 70% in felsic rocks
    - Silica content influences magma behaviour

- **Three Factors affecting crystal size**
    - Rate of cooling:
        - Slow rate promotes the growth of fewer, but larger crystals
        - Fast rate forms many small crystals
        - Very fast rate forms glass (unordered ions)
    - Amount of silica (SiO_2) present
    - Amount of volatiles (dissolved gases)
- **Aphanitic Texture:**
    - Fine-Grained texture
    - Rapid rate of cooling of lava or magma
- **Phaneritic Texture (coarse-grained):**
    - Slow cooling
    - Crystals can be identified without a microscope
- Two rocks may have similar compositions, but different textures. Thus, different names.
    - Example: Granite & rhyolite
- **Granite:**
    - Felsic (granitic)
    - Phaneritic
    - Composed of about 20% quartz and about 65% or more feldspar
    - May exhibit a porphyritic texture
    - The term granite covers a wide range of mineral compositions
- **Rhyolite:**
    - Extrusive equivalent of granite
    - Felsic (granitic)
    - Aphanitic texture
    - May contain glass fragments and vesicles
    - Less common and less voluminous than granite

Chapter 5

- ***Weathering:*** The physical breakdown (disintegration) and chemical alteration (decomposition) of a rock at or near Earth's surface.

- **<u>Two types of weathering:</u>**
    - <u>Mechanical weathering:</u> Breaking of rocks into smaller pieces by physical forces. Moreover, It does not change chemical composition of rock
    - <u>Chemical weathering:</u> Involves chemical transformation of rock into one or more new compounds

- **<u>Mechanical Weathering(3) :</u>**
    - <u>Frost Wedging:</u>
        - Water works its way into cracks in rock, freezes, expands, and enlarges the openings, thus breaking rock.
        - Most pronounced in mountainous regions, where there are daily freeze-thaw cycles.
        - Creates large piles of broken rock called talus slopes.
    - <u>Biologic Activity</u>

    - <u>*Sheeting:</u>
        - The process by which large masses of igneous rock such as granite are exposed by erosion, and concentric slabs begin to break loose.
        - Likely occurs by a reduction in pressure when overlying rock is eroded away.
        - Continued weathering causes slabs to separate and spall (flake) off, creating exfoliation domes.
- **<u>Chemical Weathering (4):</u>**
    - <u>Weathering & Soil</u>
    - <u>Hydrolysis:</u>
        - Silicates primarily decompose this way.
        - The reaction of any substance with water.
        - Hydrogen ion attacks and replaces other positive ions in the mineral causing the crystal structure to collapse.
            - Example: K-feldspar in granite generates clay minerals, soluble salt and some silica.
        - One of the most water-soluble minerals is halite.
    - <u>Oxidation:</u>
        - Any chemical reaction in which an element loses electrons.
        - Important in decomposing ferromagnesian minerals.
        - Presence of water speeds the process.
            - Example: O2combines with Fe in olivine, pyroxene or amphibole to form *hematite* or *goethite.*
    - <u>Dissolution:</u>
        - Easiest type of decomposition *(chemical weathering).*
          The addition of even small amounts of acid to water aids significantly in breaking down minerals.

- Example: carbonic acid created when CO2dissolves in raindrops.

- **Alterations Caused by Chemical Weathering:**
  - Decomposition of unstable minerals.
  - Generation or retention of materials that are stable.
  - Spheroidal weathering: Physical changes such as the rounding of corners or edges caused by water flowing through joints.
- **Rock Characteristics:**
  - Rocks containing silicate minerals (granite) are relatively resistant.
  - Rocks containing calcite (marble and limestone) readily dissolve in weakly acidic solutions.
- **Climate:** Chemical weathering is ineffective in polar regions and arid regions.

(Rock Characteristics & Climate affect rate of weathering)

- **Controls of Soil Formation:**
  - Parent Material
  - Time
  - Climate
  - Plants and animals
    - *Microorganisms like fungi and bacteria play an active role in the decay of plant and animal remains.
    - Burrowing animals mix the soil.
  - Topography
    - Optimum terrain is a flat-to-undulating upland surface, well drained with minimum erosion.

Chapter 6

- **Diagenesis**:
  - All the chemical, physical, and biologic changes that occur after sediments are deposited, but prior to metamorphism.
  - Occurs in upper few kilometers of Earth's crust at temperatures generally less than 200˚C.
- **Diagenesis includes:**
  - Re-crystallization: Development of more stable minerals from less stable ones.
  - *Lithification: Unconsolidated (aka loose) sediments are transformed into solid sedimentary rock by basic processes of *compaction* and *cementation*.
- **Sediment has three principal sources:**
  - Mechanical/Chemical weathering of existing rock.
    - These are called detrital sedimentary rocks.
  - Soluble material produced by chemical weathering.
    - These are called chemical sedimentary rocks.
  - Organic matter from once-living organisms.
    - These are rich in carbon.
    - Example: plant remains accumulating in a swamp.
- **The chief constituents of *detrital* sedimentary rocks include:**

- Clay minerals, quartz, feldspars, micas
- Referred to as *siliciclastic* sediment

- Shale and other mud rocks:
  - Consists of clay to silt-sized particles that deposit in by gradual settling in quiet water.
  - As silt and clay accumulate, they form thin layers called "laminae".
  - Shale exhibits fissility (splits into thin layers); but siltstone does not. Mudstone breaks into chunks.
  - Most common type of detrital sedimentary rock.

- **Sorting:** Degree of similarity in particle size (well-sorted, poorly sorted).
- **Roundness:** The degree to which corners and edges of grains have been smoothed down.
- **Limestone:**
  - Most abundant chemical sedimentary rock.
  - Composed mainly of the mineral calcite.
- **Dolostone (chemical sedimentary rock):**
  - Composed of calcium-magnesium carbonate mineral dolomite (Mg replaces some Ca).
- **Classification of Sedimentary Rocks:**
  - Divided into two groups: detrital & chemical.
  - Two major *texture* subdivisions:
    - Clastic ("broken"):
      - Mainly for detrital rocks with discrete sized fragments and particles.
      - Bioclastic: Rocks with skeletal remains.
    - Non-clastic (aka crystalline texture):
      - Mainly for chemical rocks with interlocking crystals; may resemble an igneous rock.
- **Types of sedimentary structures:**
  - Bedding: Layers of sedimentary rock. The most common characteristic. Separated by bedding planes.
  - Cross-bedding: Inclined layers.
  - Graded bedding: Rapid deposition from water; coarse material settles first.
  - Mud cracks: Shrinkage on exposure to air.

Chapter 7

- **Controlling factors in metamorphism:**
  - Composition of parent rock
    - Clay minerals can re-crystallize to form micas, and the calcite in marble is derived from a limestone parent.
    - Only in extreme cases of fluid migration do metamorphic rocks change in composition from their parent rocks.
  - Heat as a metamorphic agent

        - The most important agent of metamorphism.
        - Influences the mobility and reactivity of chemically active fluids.
        - Heating can occur:
            - From intrusive igneous bodies
            - From Earth's internal heat
        - Different minerals are stable at different temperatures, so change occurs at different times. When T is beyond 200°C, clay minerals become unstable and start change to micas.
    - Pressure as a metamorphic agent
        - Changes the physical characteristics of rocks.
            - <u>Confining Pressure (uniform stress):</u> Applies forces equally in all directions; harder and denser metamorphic rocks.
            - <u>Directed Pressure (differential stress):</u> Unequal pressure in different directions; results in distortion of a body.
    - Chemically Active Fluids
        - *Fluids with different chemical makeup may change the composition of surrounding host rock. This is called "metasomatism".
- Three basic types of directed pressure:
    - Compressional
    - Tensional
    - Shear

  Rocks are *brittle* at the surface and fracture when subjected to directed pressure. Rocks are *ductile* at depth, and can flatten and elongate, depending on conditions.
- Directed pressure forms a layered or banded texture called "foliation":
    - Foliation is the preferred orientation of platy and elongate minerals in a metamorphic rock; it is oriented parallel to the direction of minimum stress.
- Three factors influence foliation:
    - Rotation of platy and/or elongate mineral grains into a new orientation.
    - Changing the shape of equi-dimensional grains into elongate shapes aligned in the preferred orientation.
    - Re-crystallization of minerals to form new grains growing in direction of preferred orientation.

- *Metamorphic grade* is the intensity/degree of metamorphism that rocks have experienced.
- *Index minerals* are stable under specific ranges of pressure-temperature (P-T).
- Low grade = chlorite (around 200ºC).
- High grade = sillimanite (around 600ºC).

Example questions

1. What are the controlling factors that determine the type of metamorphism and the texture of the rocks that are formed?

   Answer: The type of metamorphic rock that is formed depends on the pressure, temperature, fluids, and original parent rock composition.

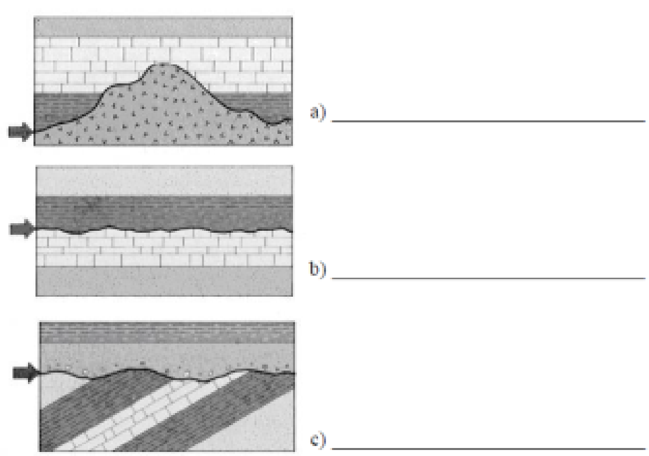
2. What are two ways that pressure (stress) drives metamorphism?
   Answer: 1) forms new, generally denser minerals stable at higher pressure conditions. 2) reorients mineral grains to accommodate the stress or increased pressure.

3. What *three factors or* processes govern the development of foliation?
   Answer: 1) rotation of platy or elongate grains, 2) changing the shape of equidimensional grains, 3) re-crystallization to grow new grains in preferred orientations that reflect the new stress field.

Chapter 8

- **Unconformities**:
  - An unconformity is a break or gap in the rock record caused by erosion and/or non-deposition of rock units.
  - When there is no break in the rock record, the rocks are considered conformable.
  - Unconformities represent significant geologic events in Earth's history.
- **Types of Unconformities**:
  - Angular unconformity: Tilted rocks are overlain by younger, flat-lying rocks.
  - Disconformity: Strata on either side of the unconformity are parallel.
  - Nonconformity: Separates older metamorphic or igneous rocks from younger sedimentary strata.

On the blank provided beside each geologic cross section below, write the name of the specific type of unconformity that is labeled with an arrow. The v-pattern indicates igneous rocks. All other patterns are different types of sedimentary rocks.



Answer: a) nonconformity b) disconformity c) angular unconformity

Chapter 9

- **Deformation**:

  - Deformation is a general term that refers to all changes in the original form and/or size of a rock body.
  - Can also produce changes in the location and orientation of a rock.
  - Most crustal deformation occurs along or near plate margins.
- **Force:** Tends to put stationary objects in motion, or changes the motions of moving bodies.
- **Stress:** Forces that deform rock.
- **Strain:** Visible response to stress; changes in the shape or size of a rock body caused by stress.
- **Types of stress:**
  - *Differential stress* is applied unequally from different directions.
  - *Compressional stress* shortens a rock body.
  - *Tensional stress* elongates a rock body.
  - *Shear stress* is similar to slippage between individual playing cards when the top of the deck is moved relative to the bottom.
- ****How rocks deform: Two stages**
  - Solid rocks first respond by deforming elastically. Changes that result from elastic deformation are recoverable.
  - Rocks subjected to stresses greater than their own strength (exceed the elastic limit) begin to deform usually by folding, flowing, or fracturing (plastic deformation).

- *****Factors affecting rock deformation:**
  - 1) Temperature and confining pressure:
    - Brittle failure (brittle deformation): Low temperatures and pressures near the surface (like glass breaking).
    - Ductile deformation: Where temperatures and pressures are high, rocks exhibit *ductile* behaviour, a type of solid state flow.
  - 2) Rock Type:
    - Mineral composition and textures of rock influence deformation style.
    - Example: Rocks with minerals with strong molecular bonds tend to fail by brittle fracture.
  - 3) Time:
    - Small amounts of stress over geologic time cause large changes.

- **Strike (bearing):**
  - The compass direction of the line produced by the intersection of an inclined rock layer or fault with a horizontal plane.
  - Generally expressed in azimuth form, as an angle clockwise from north.

- **Dip (inclination):**
  - Angle of inclination of surface of a rock unit or fault measured from a horizontal plane.

- Includes both the inclination and the direction toward which the rock is inclined (direction that water will run down the rock surface).
- Dip will always be at 90˚ to the strike.

- During crustal deformation, rocks are often bent into a series of wave-like undulations called “folds”.
  - Most folds’ result from compressional stresses, which shorten and thicken the crust.

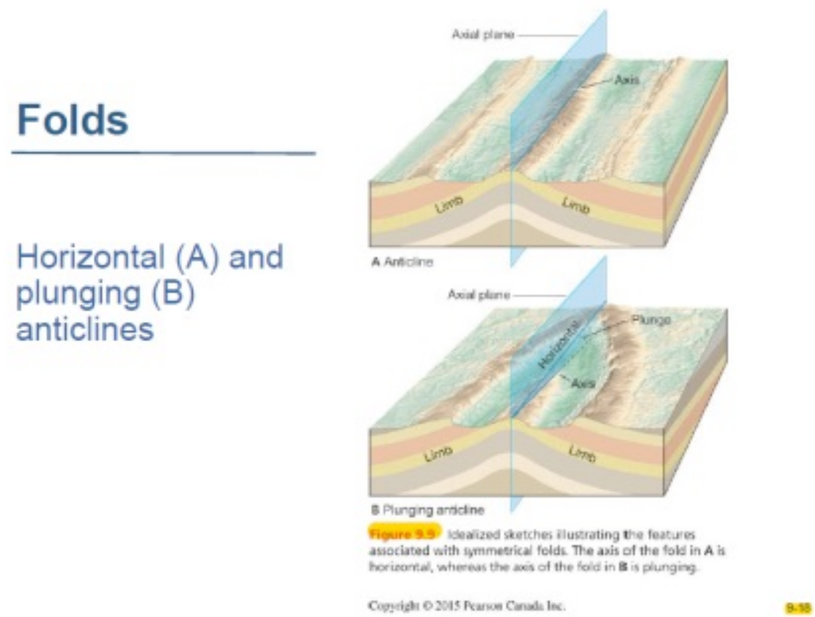
- **Parts of a fold:**
  - Limbs: Refers to the two sides of a fold.
  - Axis: A line drawn down crest of the fold.
  - Plunge: A fold axis inclined at an angle (complex folding).
  - Axial plane: An imaginary surface that divides a fold as symmetrically as possible.
- **Types of folds:**
  - Anticline: Up-warped or arched rock layers.
  - Syncline: Down-warped or troughs of rock layers.
- **Dome:**
  - Up-warped displacement of rocks.
  - Circular or slightly elongated structure.
  - Oldest rocks in centre, younger rocks on the flanks.
- **Basin:**
  - Down-warped displacement of rocks.
  - Circular or slightly elongated structure.
  - Youngest rocks are found near the centre, oldest rocks on the flanks.
- Circular outcrop patterns are typical for both domes and basins.
- ***Joints:**
  - Joints are fractures that result from brittle deformation. There is typically no displacement.
  - One of the most common rock structures.
  - Most occur in roughly parallel groups.
  - Causes of Joint types:
    - Columnar joints (igneous)
    - Gently curved due to sheeting
    - Brittle fracture due to crustal deformation
- *****Significance of joints:**
  - Chemical weathering tends to be concentrated along joints.
  - Many important mineral deposits are emplaced along joint systems.
  - Highly-jointed rocks often represent a risk to construction projects.
- *Faults* are fractures in rocks along which appreciable displacement has taken place.
  - Sudden movements on faults cause most earthquakes.
- **Dip-slip faults:**
  - Movement is mainly parallel to the dip of the fault surface.
  - Fault scarps are long low cliffs produced by up and down displacement.

- Hanging wall: Rock above the fault surface.
- Footwall: Rock below the fault surface.
- Two major types of dip-slip:
    - Normal faults
    - Reverse faults (thrust when low angle)

Normal Faults:

- Hanging wall block moves down relative to the footwall block.
- Most have steep dips that flatten with depth.
- Accommodate lengthening (extension) and thinning of the crust.
- Normal faulting is also prevalent at spreading centres where plate divergence occurs.
- Graben: Central block bounded by normal faults; drops as plates separate.
- Horst: Raised blocks between grabens, also bounded by normal faults.

KNOW THE DRAWINGS BELOW!



Faults

Figure 9.24 Diagrammatic sketch of down-faulted (graben) and up-faulted (horst) blocks.

9-29

- **<u>Reverse and thrust faults:</u>**
    - Hanging wall block moves up relative to the footwall block.
    - Reverse faults have dips greater than 45o and thrust faults have dips less then 45o.
    - Accommodate shortening of the crust due to compression.
- **<u>Strike-slip faults:</u>**
    - Transform Fault
        - Special type of large strike-slip fault that cuts through the lithosphere.
        - Accommodates motion between two large lithospheric plates.
        - Links spreading oceanic ridges.
        - <u>Example:</u> The San Andreas fault, California

Chapter 10

- The *hypocentre* is point of energy release, and radiates in all directions from its source.
- The *epicentre* is the location on the surface, directly above the hypocentre.
- **<u>Earthquakes & Faults:</u>**
    - Movements that produce earthquakes are usually associated with large faults in Earth's crust.
    - Most of the motion along faults can be explained by plate tectonics theory.
    - Most earthquakes occur along faults associated with plate boundaries.
- **<u>Elastic rebound:</u>**
    - Mechanism for earthquakes was first explained by H.F. Reid (early 1900s).
    - Rocks on both sides of an existing fault are deformed by tectonic forces.
    - Rocks bend and store elastic energy.

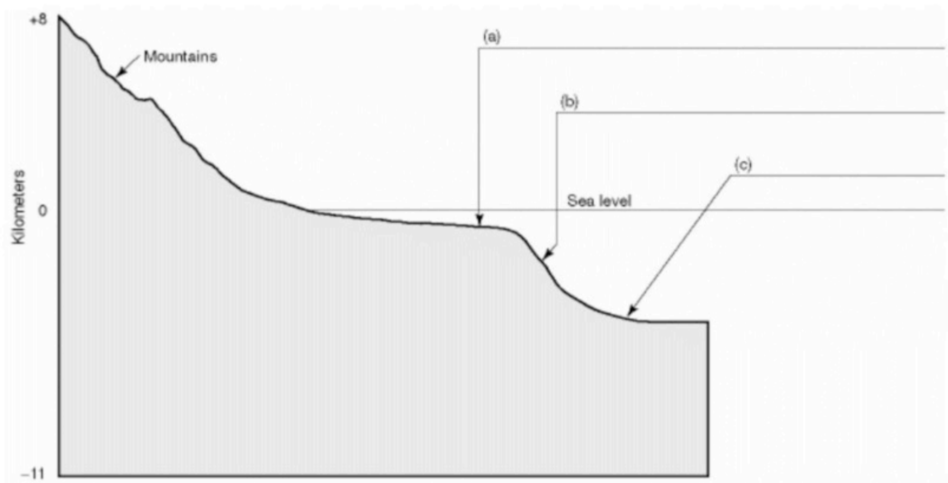
  - The springing back of the rock after stress is overcome is called elastic rebound.
- Aftershocks: Adjustments that follow a major earthquake often generate smaller earthquakes.
- Foreshocks: Small earthquakes often precede a major earthquake by days or even by as much as several years.
- **Types of seismic waves:**
  - Waves that are generated by the slippage of rock mass are divided into two categories:
    - Body waves: Waves that travel through Earth's interior (P and S Waves).
    - Surface waves: Waves that travel along the outer part of the Earth (L waves).
- **Body waves:**
  - Primary (P) waves:
    - Push-pull (compress and expand) motion, changing the volume of material.
    - *Travel through solids, liquids, and gases.
  - Secondary (S) waves:
    - Shear motion at right angles to their direction of travel.
    - Slightly greater amplitude than P waves.
    - *Travel only through solids.
- **Surface (L or long) waves:**
  - Travel along outer part of Earth.
  - Complex motion, cause greatest destruction.
  - Exhibit greatest amplitude, slowest velocity.
  - Have the longest periods (time interval between wave crests).
- **Two measurements that describe the size of an earthquake are:**
  - Intensity
  - Magnitude: estimates the amount of energy released at the source of the earthquake
- **Destruction from seismic vibrations:**
  - ***Liquefaction:
    - In areas where unconsolidated (loose) materials are saturated with water, earthquake vibrations can generate liquefaction.
    - Not capable of supporting buildings.
    - Underground structures like sewers and storage tanks can float to the surface.
- **The nature of seismic waves:**
  - To understand Earth's composition, we must study wave transmission (*propagation*).
  - Seismic energy radiates from source in *waves.* The pathway of the waves is called "*rays*".
- **The nature of seismic waves:**

- Velocity of waves depends on the density and elasticity of earth material.
- Wave speed generally increases with depth due to pressure forming a more compact elastic material.
- Compressional waves (P waves) are able to propagate through liquids and solids.

- **The nature of seismic waves:**
  - S waves cannot travel through liquids.
  - In all materials, P waves travel faster than S waves.
  - When seismic waves pass from one material to another, the path of the wave is refracted (bent).
  - The boundary between two layers where waves are refracted and reflected is called a discontinuity.

Chapter 11

The illustration below is a topographic profile of a passive continental margin. Fill in the blanks with the correct name of the feature labeled.



Answer: a) continental shelf b) continental slope c) continental rise

https://www.youtube.com/watch?v=p47V6-x0YAE

Chapter 14

- **<u>Controls and Triggers of Mass Wasting:</u>**
  - Gravity is the controlling force.
  - The trigger is not the sole cause; it is the "last straw".
  - <u>Other Contributing Factors:</u>
    - Saturation of the material with water
    - Over-steepened slopes –unstable
    - Loss of anchoring vegetation
    - Earthquake ground vibration
- **<u>The role of water:</u>**
  - Saturation of the material with water
  - May occur from heavy rainfall or snowmelt
  - Reduces particle cohesion and friction
  - Water adds weight to the sediment and gravity pulls it downwards
- **<u>Removal of vegetation:</u>**

    - Root systems bind soil and regolith; leaves protect slope surface from raindrops.
- **Earthquakes as triggers:**
    - Can dislodge large volumes of rock and unconsolidated material.
    - Water-saturated surface materials behave as fluid-like masses that flow. (**Liquefaction)**

- ***Classification of Mass Wasting Processes:**
    - **Type of motion**
        - Fall:
            - Movement of detached particles dropping through the air.
            - Forms talus slopes.
        - Slide:
            - Material moves along a surface as a coherent mass.
        - Flow:
            - Material moves down as a viscous fluid.
    - **Type of material:**
        - Descending mass may begin as unconsolidated material or bedrock.
        - If soil and regolith dominate, we call it debris or earth. If it is mainly bedrock, we call it rock.
    - **Rate of movement:**
        - Can be sudden or gradual.

- **Slump (Rotational Slide):**
    - Downward sliding of a mass of rock or unconsolidated material as a unit along a curved surface.
    - Common along rivers and eroding shorelines.
    - Rupture forms spoon-shaped scarp at the head.
    - Block tilts backward due to rotation.
    - Common on over-steepened slopes.
- Rockslides are generally very fast and destructive.
- **Debris Flow:**
    - Rapid event that involves a flow of soil and regolith with large amount of water.
    - Characteristic of mountainous regions, including volcanoes.
    - Often confined to canyons and channels.
    - Excessive rain or snow melt creates a flood, and large quantities of soil and regolith are washed into streams. The result is a mixture of mud, soil, rock, and water.
- **Slow Movements:**
    - Slow moving mass wasting can move much more material than rapid.
    - Can occur on both steep and gentle slopes.
    - Forms can be creep, soliflution, and other types of periglacial movement.
- **Creep (Slow movement):**

- Gradual downhill movement of soil and regolith.
- Involves alternate expansion and contraction of the surface material (freezing/thawing or wetting/drying).
- Results in tilted fences, utility poles, and trees with J-shape in trunks.

1) What is the major and immediate controlling force in mass wasting?
A) Chemical weathering as bonds fall apart, weakening minerals.
B) Convection, as this drives mantle convection and tectonic uplift.
C) Coriolis force, as it controls cyclonic winds and transport of precipitation.
D) Gravity, as this pulls matter downhill.

2) What two properties of rain water and snow melt have the greatest effect on soil strength and slope stability?
A) acidity and strong dipole forces
B) electric conductivity and viscosity
C) increased lubrication and added weight
D) solvation properties and surface tension

3) How does water affect the internal cohesion of clay-bearing soils and regolith?
A) The soil or regolith has more internal cohesion when wet than when dry.
B) The soil or regolith has less internal cohesion when wet than when dry.
C) The soil or regolith has equal internal cohesion when wet or dry.
D) The soil or regolith has no internal cohesion when wet or dry.

4) What are some preventive measures that can be done to reduce or lessen the impact of mass wasting? (Hint: Think about the controls and triggers of mass wasting.)

- ✓ Drain the slopes using drainage tiles and holes drilled into the slope.
- ✓ Insert rock bolts (anchors) to keep rock faces in place;
- ✓ cover faces with wire mesh;
- ✓ spray cement on unstable rock faces;
- ✓ install retaining walls to keep debris off road, railway etc.;
- ✓ plant vegetation with strong root systems to keep soil and regolith in place;
- ✓ prevent undercutting of the slopes

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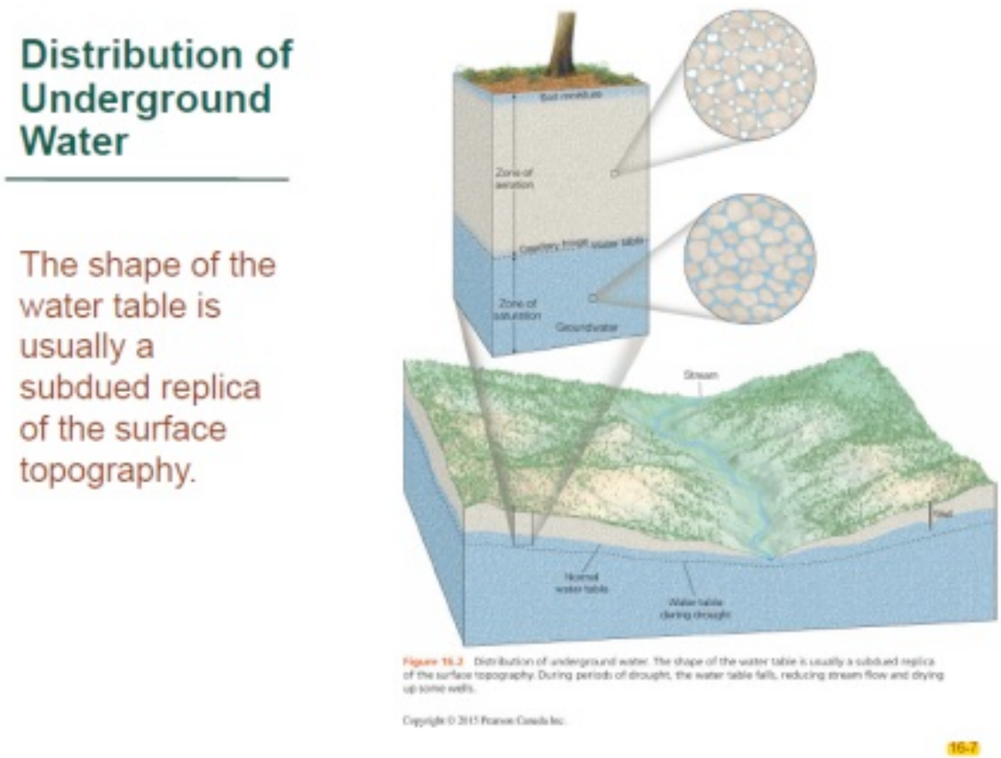
Chapter 15

- **Two types of water flow:**
  - Laminar flow (slow, smooth channel):
    - Water molecules flow in straight paths, parallel to channel.
  - Turbulent flow (fast, rough channel):
    - Water moves in a chaotic and erratic fashion, as whirlpool-like eddies.

Chapter 16

Distribution of Underground Water:

- Belt of soil moisture:
  - Water held by molecular attraction on soil particles near the surface.
- Zone of saturation:
  - Also called the phreatic zone.
  - Water that percolates downward to a zone where all open spaces are completely filled with water.
  - Water within this zone is called *groundwater*.
- Water table:
  - The upper limit of the zone of saturation is the water table.
- Capillary fringe:
  - Extends upward from the water table.
  - Groundwater is held by surface tension in tiny spaces between grains of sediment.
- Zone of aeration:
  - Also called the *vadose zone*.
  - Area above the water table.
  - Consists of both the capillary fringe and the belt of soil moisture.
  - Water cannot be pumped by wells.



The Water Table:

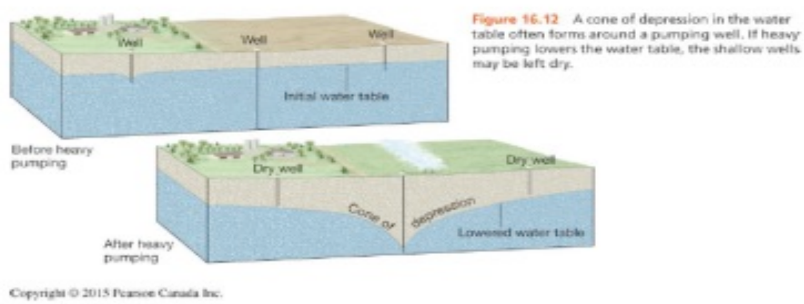
- Water table helps to predict productivity of wells.
- Depth is highly variable, varying seasonally and from year to year.

- Water level of wells coincides with level of water table.
- Mapping shows that the water table is usually a subdued replica of the surface topography.
- Water tends to “pile up” beneath high areas between stream valleys.
- In times of extended drought, the water table may drop enough to dry up shallow wells.
- Uneven water tables may also result from variations in rainfall, and permeability from place to place.

- **Factors Influencing the Storage and Movement of Groundwater**
  - ********Porosity:**
    - Percentage of total volume of rock or sediment that consists of pore spaces.
    - Determines how much water can be stored.
    - Pore space depends on:
      - Size and shape of grains
      - How grains are packed together
      - Degree of sorting
      - Amount of cementing material
  - **Permeability, aquitards, and aquifers:**
    - Permeability: The ability of a material to transmit a fluid.
    - The smaller the pore space, the slower the groundwater moves.
    - Groundwater is divided into two categories:
      - Specific yield: portion that will drain with gravity.
      - Specific retention: portion retained as film on rock surfaces.
    - *Aquitard: An impermeable layer that hinders or prevents water movement (such as clay).
    - *Aquifer: Permeable rock strata or sediment that transmits groundwater freely (such as sands and gravels).
    - Remember that porosity is not always a reliable guide to the amount of groundwater.
- **How Groundwater Moves:**
  - Most groundwater movement is slow –a few centimeters per day, due to gravity.
  - Darcy’s Law: If permeability remains uniform, the velocity of groundwater will increase as the slope of the water table increases.
  - Hydraulic head: The vertical difference between the recharge and discharge points.
  - Hydraulic gradient: “Slope of the water table”: to calculate divide the hydraulic head by the length of flow.
  - Hydraulic conductivity: Factor that takes into account the permeability of the aquifer and the viscosity of the fluid.
- **Wells:**
  - Most common way to remove groundwater.

- To ensure a continuous supply of water, a well must penetrate below the water table.
- Pumping of wells can cause:
  - *Drawdown* (lowering) of the water table.
  - *Cone of depression* in the water table, which can cause nearby wells to become dry.

Wells



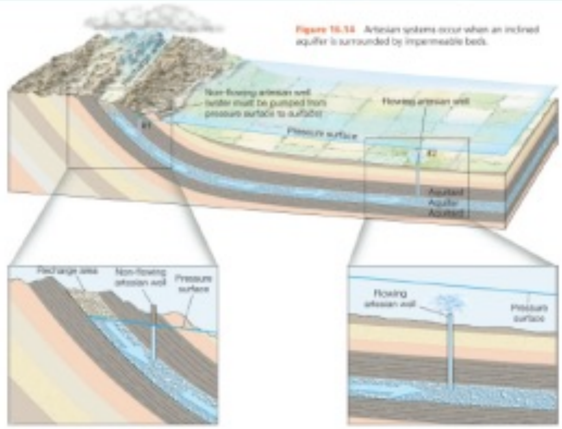
Formation of a cone of depression in the water table around a well.

Cone-of-depression.m4v

16-26

- **<u>Artesian Wells:</u>**
  - Water in artesian wells rises above the aquifer on its own, due to pressure.
  - In an artesian system:
    - Water must be confined to an aquifer that is inclined so one end can receive water.
    - Aquitards above and below the aquifer prevent water from escaping, and the weight of the water forces the water to rise in the well.
- **<u>Types of artesian wells:</u>**
  - <u>Non-flowing:</u> Pressure surface is below ground level.
  - <u>Flowing:</u> Pressure surface is above the ground.
  - Artesian springs occur when water rises to surface through natural fractures in the rock. In the desert, this creates an oasis.

Artesian Wells



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Artesian systems occur when an inclined aquifer is surrounded by impermeable beds.

Artesian-systems.m4v

16-29

- **<u>Environmental problems:</u>**
  - **<u>Mining Groundwater:</u>**
    - Height of water table is a balance between rate of infiltration and rate of discharge.
    - Groundwater is considered a non-renewable resource in some places.
    - The water available to recharge the aquifer is much less than the amount being withdrawn.
  - **<u>Subsidence:</u>**
    - Ground sinks when water is pumped from wells faster than natural recharge processes can replace it.
    - More pronounced in areas underlain by thick sediments.
    - As water is withdrawn, the water pressure decreases, and the weight of overlying material pushes down.

Chapter 20

- **<u>Petroleum traps:</u>**
  - An underground geologic environment that allows the accumulation of oil and gas.
  - Must have two basic conditions:
    - A porous, permeable reservoir rock.
    - A cap rock that is impermeable to oil and gas.
- Cap rock and reservoir strata are associated with accumulations of petroleum.