Earth Systems 3209

Possible Long Answer Topics

UNIT 1

1. Describe the process of segregation.

- It is thought that Earth was not always layered as it is today. Some scientist suggest that Earth was a lot like the moon in appearance billions of years ago.
- Shortly after Earth formed, the interior of Earth segregated and took on a layered structure. Heat generated from the ***collision of particles*** and the decay of ***radioactive isotopes*** produced heat in Earth's interior which was responsible for melting the heavier elements (Ni and Fe) within Earth.
- Gravitation caused great streams of hot heavy liquids moved toward Earth's center and melted the lighter rock material and forced it to the surface
    - The heavier material (nickel and iron) which concentrated close to Earth's center formed the inner and outer core.
    - The lighter and less dense material which moved upwards closer to the surface formed Earth's crust
    - The material in between formed earth's mantle
    - Atmosphere and oceans formed as a result of the gases given off by volcanic out gassing throughout Earth's history.

2. Which factors allowed for segregation to occur?

- Billions of years ago, the decay of radioactive elements coupled with heat generated by the colliding of particles, caused Earth's interior to melt. This allowed a differentiation of Earth's interior based on density. The denser elements, nickel and iron, would sink to the interior while the lighter rocky components floated toward the surface. This segregation by density is thought to still occur today on a smaller scale and was responsible for the apparent layering of Earth's interior into spheres or shells of material with different physical properties. **(Heat and Density)**

3. **Describe the four spheres. Give examples that demonstrate the interaction of the four spheres. (E.g., earthquakes, volcanic eruptions, water cycle.)**

- Four spheres are Geosphere, Atmosphere, hydrosphere and Biosphere.
    - Interaction:
        - Geosphere-Atmosphere/Hydrosphere: Volcanic Eruptions send gases from inside the earth up into the atmosphere adding to the gases already present. Volcanic outgassing helped create our atmosphere.
        - Geosphere/Hydrosphere-Biosphere: provides habitat for living things (Geosphere-humans: Hydrosphere-Fish/mammals)

UNIT 2

1. **Use uniformitarianism to explain why certain events will occur again in the future**.

   Uniformitarianism is the assumption that the same natural laws and processes that operate in the universe now have always operated in the universe in the past and apply everywhere in the universe

2. **Understand relative dating techniques/principals/laws, which include: superposition; cross-cutting relations; inclusions; horizontality; fossil succession (index fossils); and unconformities (angular unconformity, disconformity, and nonconformity)**

   - Law of Superposition - states that in any undisturbed sequence of sedimentary rocks, a sedimentary layer is older than the layers above it and younger than the layers below it. The youngest is always at the top
   - Principal of Original Horizontality - states that most layers of sediment are deposited in a horizontal position. If rock layers are folded or inclined, then the layers must have been moved into that position by crustal disturbances
   - Law of Crosscutting Relationships - states that an igneous rock or geologic feature is younger than the rocks it has intruded, or cuts across
   - Law of Included Fragments - states that pieces of one rock found in another rock must be older than the rock in which they are found

3. **Understand absolute dating techniques/processes/features, which include: varves; growth rings; and radioactive dating**.

   - Tree Rings - The age of a tree is found by counting the total number of rings
   - Varves - any sediment layer that shows a yearly cycle. Varves are often seen in glacial lakes dating back to the ice age
   - Radiometric Dating - calculating absolute ages of rocks and minerals that contain radioactive isotopes

4. **Know how to do the different radioactive dating problems**.
   Worksheet attached to the website

UNIT 3

1. **Define a mineral (5 Points).**
    - A naturally occurring
    - inorganic
    - solid
    - definite chemical composition
    - molecular structure

2. **Know the seven different mineral groups (Rules).**
    - Silicates
    - Carbonates
    - Sulfates
    - Oxides
    - Halides
    - Sulfides
    - Native

3. **Explain the process in determining the specific gravity of an unknown mineral.**
    - The mass of a mineral compared to that of an equal volume of water
        - To determine specific gravity you need to carry out the following three steps:
            - weigh the specimen in air and record the weight
            - weigh the specimen submerged in water and record the weight.
            - calculate specific gravity (S.G.) using the following formula.
                - Specific Gravity = $\frac{\text{weight in air}}{\text{weight in air - weight in water}}$.

4. **Compare and contrast minerals.**

5. **Which mineral properties are useful? / Which mineral properties are not as useful as the others?**
    - Useful

i. Specific Gravity (Best)

ii. Hardness (Moh's scale)

iii. Cleavage/Fracture

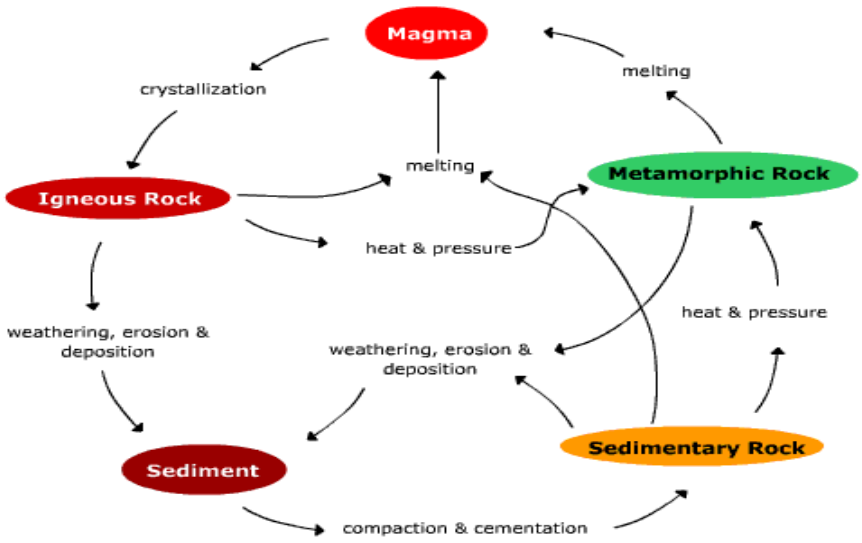
iv. Streak

v. Luster

- Not as useful
  i. Color
  ii. Feel

6. Be able to draw and explain the rock cycle.

- Igneous, sedimentary and metamorphic rocks are all related to one another in a process called the Rock Cycle.
- In this cycle these rocks are, through exposure to weathering, erosion, heat and pressure, constantly changing over time.



7. Brother-sister igneous rocks.

- Granite (Coarse Grain/Felsic) –Rhyolite (Fine Grain/Felsic)
- Diorite (CG/Medium) –Andesite (FG/Medium)
- Gabbro (CG/Mafic) –Basalt (FG/Mafic)

8. Describe the sequence of formation of coal.

- Formation of Peat
    i. Swamps are areas where organic matter from plants accumulate. As the plants die and get buried they compact to become peat. With time and more compaction, almost all of the water is lost and three different grades of coal result.

- Lignite
    i. Compaction of the peat due to burial drives off volatile components like water and methane, eventually producing a black-colored, organic-rich coal called lignite .
    ii. Soft brown coal which consist of about 40% carbon and do not burn efficiently.
- Bituminous
    i. Further compaction and heating results in a more carbon- rich coal called *bituminous* coal.
    ii. Soft coal which consist of about 85% carbon and burns readily but produces a lot of smoke.

- Anthracite
    i. If the rock becomes metamorphosed, a high grade coal called *anthracite* is produced.

ii. Hard dark coal which consist of 90% to 95% carbon and burns very hot and clean. Forms as a result of metamorphic conditions.

iii. Anthracite coal produces the most energy when burned.

9. Distinguish between contact metamorphism and regional metamorphism.

Regional:

- Occurs where tectonic plates collide, mainly at ocean – continent collision boundaries
- This type of environment produces extensive mountain building.
- The greatest volume of metamorphic rocks are formed in this way.
- This type of metamorphism is caused by two main conditions; 1) extreme pressure, and 2) extreme heat

Contact:

- This type of metamorphism occurs when rock is in contact with, or near, a mass of magma (Heat).
- The changes are caused primarily by the high temperatures of the molten rock, which in effect “bake” the surrounding rock.

UNIT 4

1. Describe the Theory of Continental Drift. Be sure to understand how Wegener thought that the continents were moving. What were the causes of the "drifting" continents as proposed by Wegener?

- A German scientist, Alfred Wegener, proposed that continents had once been together. His publication was called, "The Origin of Continents and Oceans

- There was a commonly held belief that continents simply 'drifted' through the ocean floor pushing up material in front, forming mountain belts.

  THINK OF A BOAT MOVING THROUGH WATER PUSHING WATER UP IN FRONT OF IT!

  1) Fit of the continents – match up continental shelves,

  2) Fossil correlation – match same fossil on neighboring continents,

  3) Paleoclimatic evidence – parts of continents in southern hemisphere and India have glacial evidence,

  4) Matching of rock types and mountains – rock composition and mountain chains appear to be continuous on neighboring continents

2. Understand the evidence that supports the Theory of Continental Drift.

Answered above

3. **Describe the evolution of the Theory of Plate Tectonics. Be sure to understand the contributions of the various scientists involved.**

Frank Taylor	1910 – Explained the formation of the Himalayan Mountains by moving continents (no evidence given).
Alfred Wegener	1915 – Proposed the theory of continental drift (evidence given, but no mechanism provided).
Alexander DuToit	1937 – Proposed that Earth's continents would fit more closely together at the continental margins.
Arthur Holmes	1950s – Proposed the existence of a mechanism for movement; mantle convection.
Harry Hess and Robert Deitz	1960s – Proposed the theory of seafloor spreading.
Fredrick Vine and Drummond Matthews	1963 – Proposed the idea of magnetic reversals as evidence to support the theory of seafloor spreading.
J. Tuzo Wilson	1965 - Proposed the existence of "plates" on Earth's surface as a result of mapping the world's volcanoes and earthquakes. He also proposed the existence of transform faults along plate boundaries; and that stationary hotspots in Earth's mantle caused volcanism within plates.
Xavier Le Pichon and Dan McKenzie	1970s – Proposed the theory of plate tectonics

4. **Describe the three types of collisions (i.e. convergent plate boundaries). Understand the molten composition that relates to each collision**.

This was done in class on your foldable

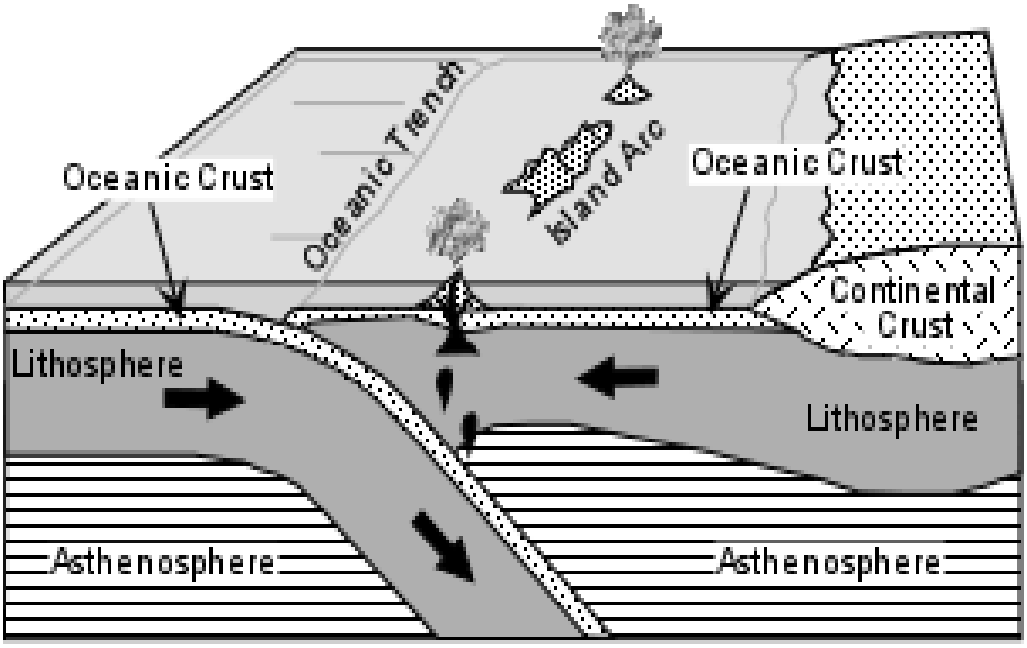
Ocean to Ocean

- Compressional forces cause plates to move together (both of equal density), one slab of lithosphere is subducted into the mantle initiating volcanic activity which creates volcanoes. (i.e. Island Arcs) Curved arc on the surface!

- Ocean trenches are formed at these boundaries

- Subducting plate is basaltic. Subducting sediments are granitic. Mix the two and the result is andesitic magmas and lavas (diorite and andesite). SHIELD VOLCANOES

- Examples: Japan arc, Japan, Mariana Arc, Philippines, Aleutian Arc, Aleutian Islands.



Ocean - Ocean Convergence

Ocean to Continent

- Compressional forces cause an ocean plate and a continent plate to move together. The more dense ocean plate sinks into the asthenosphere. This region called a subduction zone.

- Lithosphere is destroyed

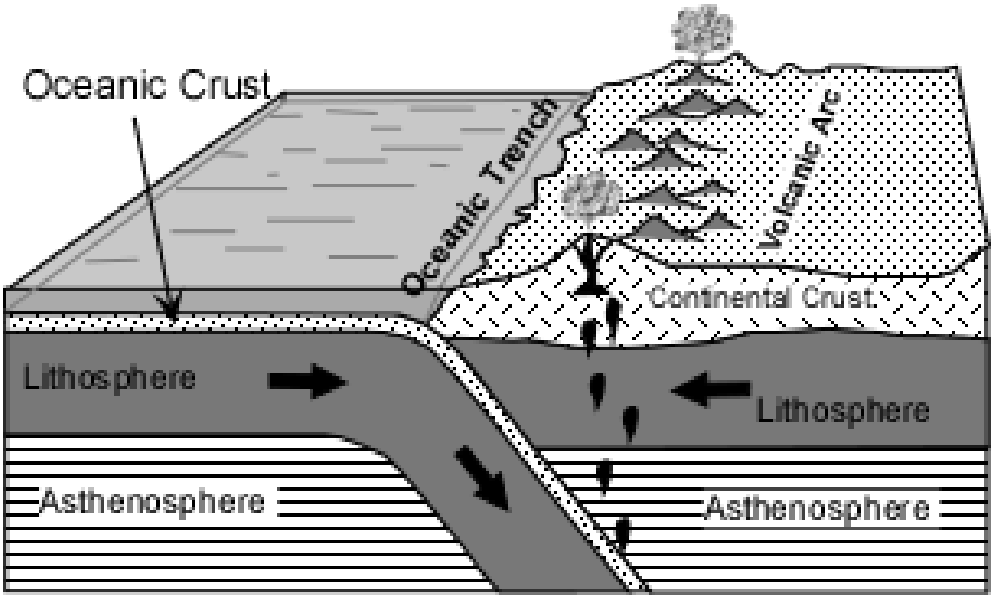
- At depths, the oceanic plate melts producing magmas, which rise and melts its way up through the continental crust. The basaltic mantle and basaltic oceanic crust melts together with continental rocks (granitic) to produce granitic magma and lava (granite and rhyolite).

- Some magma may reach the surface and erupt through composite volcanoes as violent volcanic eruptions.

- A volcanic arc is created on the surface of the continent.

- Examples include Rocky Mountains and Andes Mountains.

- If the subduction occurs beneath continental crust, a continental volcanic arc is produced. Composite volcanoes that are granitic in composition (granite and rhyolite).

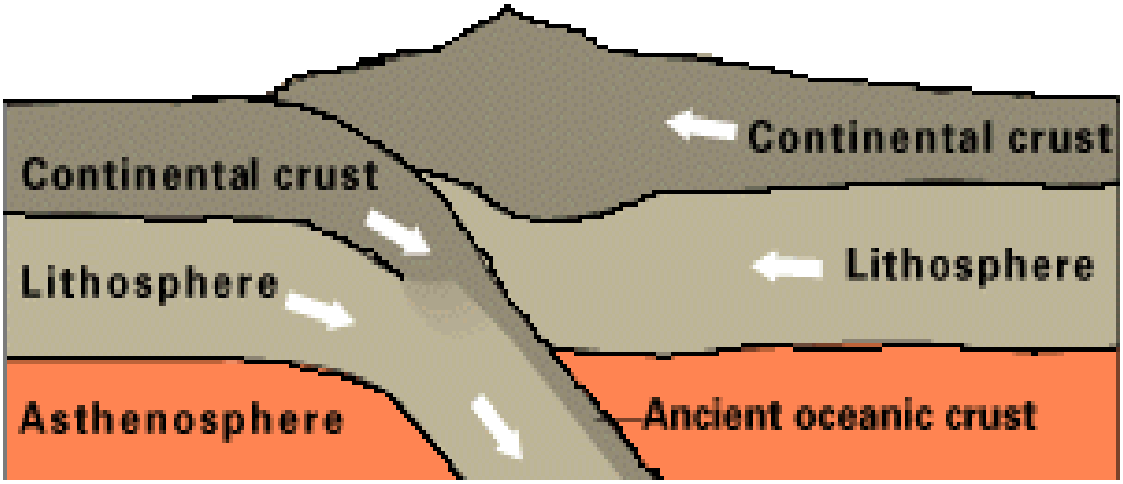


Ocean - Continent Convergence

Continent to continent

- Compressional forces cause two continental plates to move together. Because of the low density of continental crust neither plate will subduct and the two plates ram into one another forming mountains.

- Such a collision occurred when India collided with Asia forming the Himalayas. An ocean existed between two continents and both had continental shelves. The compressed shelves create the mountains once the oceanic crust has been subducted and the process of subduction ceases! The Appalachians in Newfoundland is another example



5. Describe a rift valley and how it evolves into a divergent plate boundary.

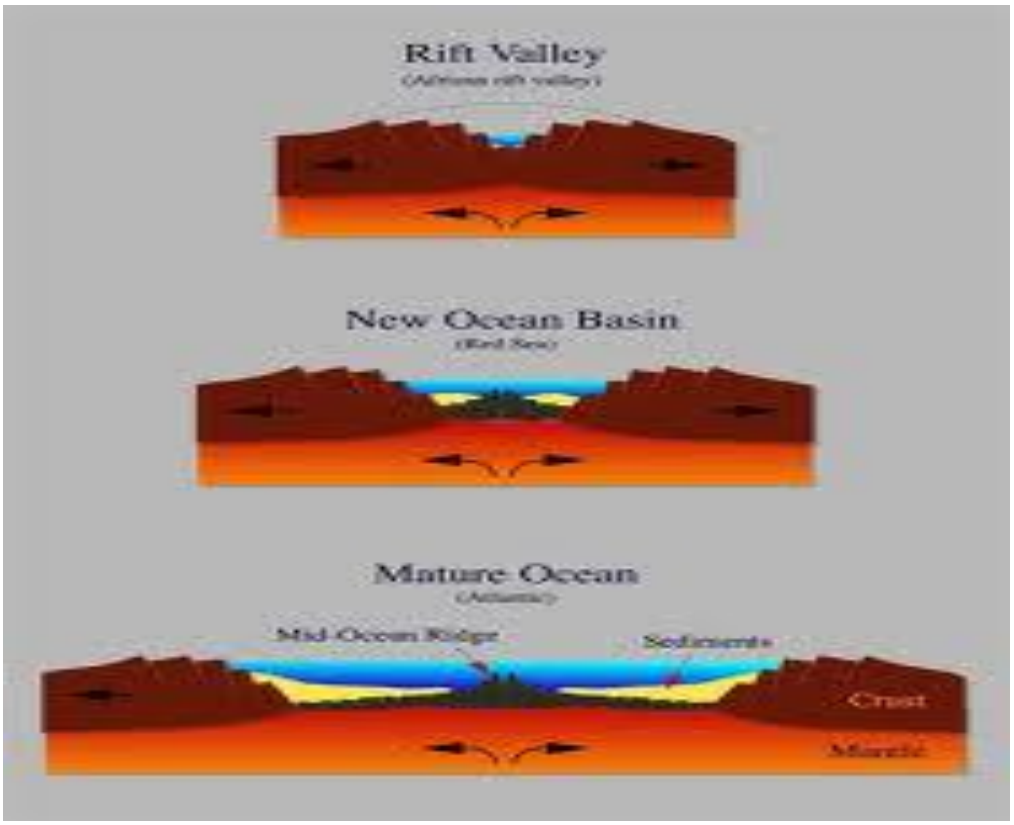
- Upwelling of molten material from the mantle creates tensional forces.

- This tension pulls the continents apart causing the central region to drop down (normal faulting) forming a Rift Valley (top diagram). Continents split!

- Tensional forces cause the plates to continually move apart forming new ocean crust and a new ocean when the crust thins enough (middle diagram).

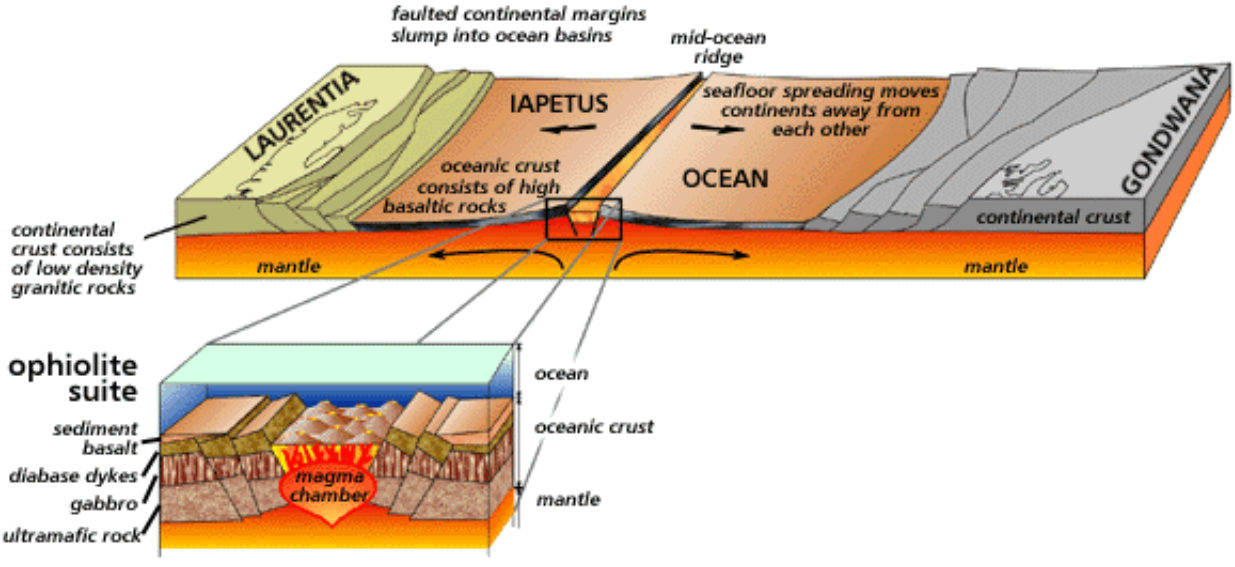
- A rift valley has evolved into a divergent plate boundary when ridge volcanism and seafloor spreading is occurring. Two segments move apart continually in opposite directions.

- E.g. East African Rift Valley

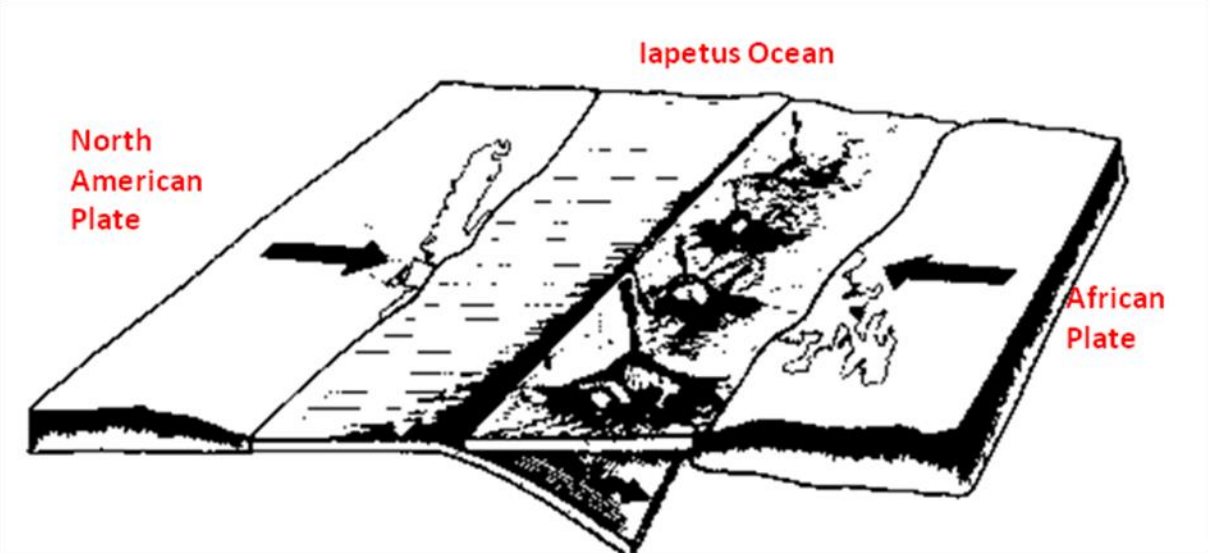


6. Describe the geology of the island of Newfoundland.

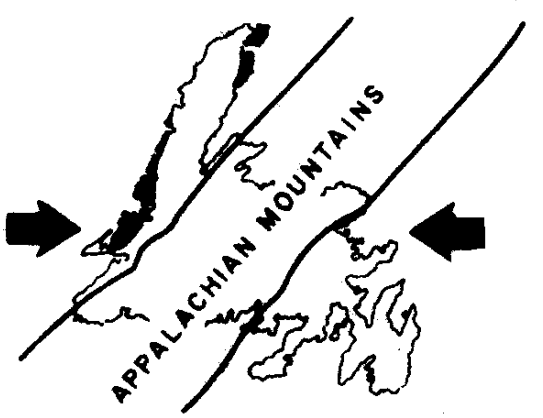
- 600 million years ago, North America was part of a much larger supercontinent (Rodina). This supercontinent broke apart. A mid-ocean ridge developed along the break and the Iapetus Ocean began to open.



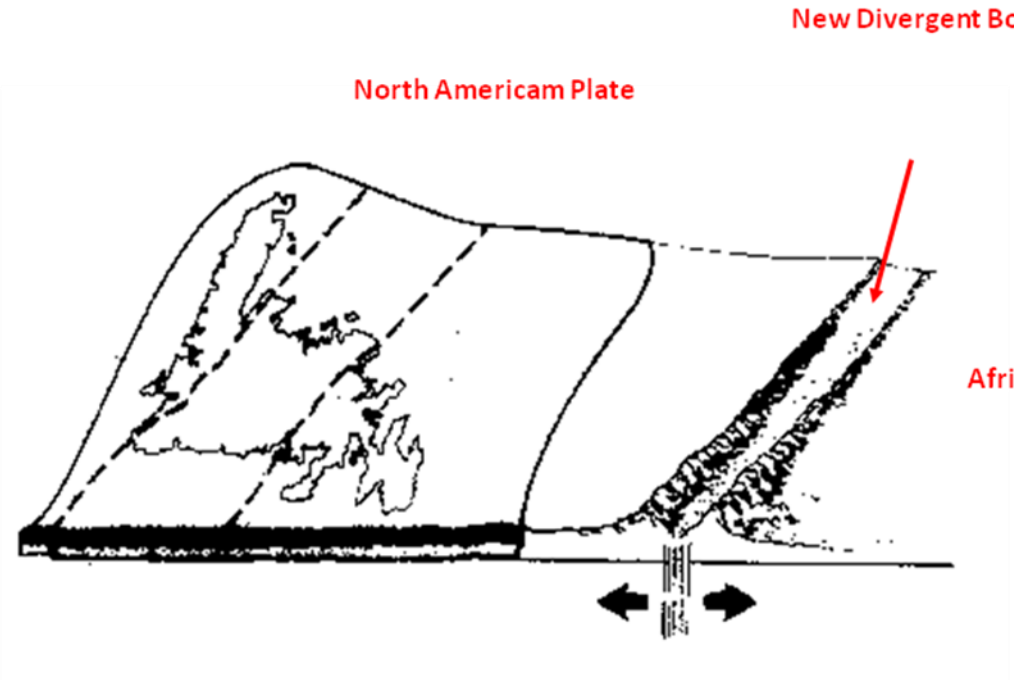
- 540 million years ago, the convection currents shifted and subduction began. As the continents "drifted" or pushed together, the ocean floor was squeezed and then pushed upward to form the Appalachian Mountains. Subduction and abduction occurred! Volcanoes were also occurring! Once the Iapetus Ocean had been subducted and abducted, a new supercontinent formed called Pangaea.



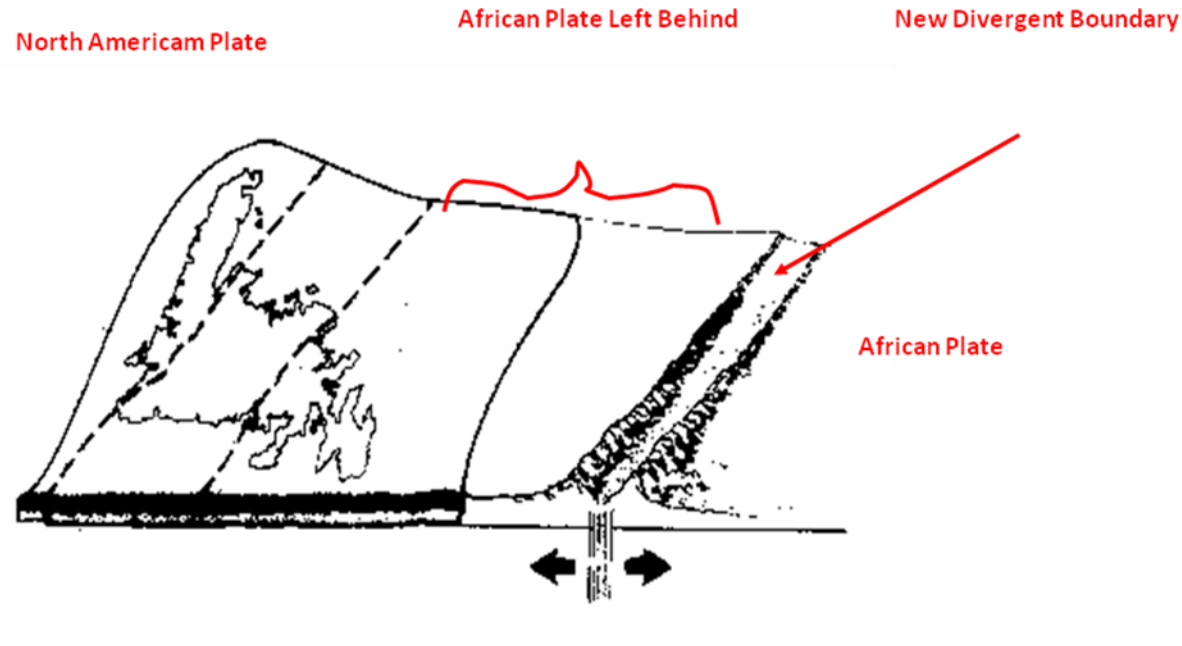
- This mountain range now exists throughout central and western Newfoundland; however, it has been weathering and eroding for quite some time.



- ~225 million years ago, the forces in Earth's mantle again reversed and slowly began to pull the continents apart again (divergent plate boundary again). The Atlantic Ocean began to open and is still opening (to the east of the island).



- During this process a small bit of Africa got left behind! The eastern part of Newfoundland was once a part of the African plate



7. Describe the three types of forces/stresses that produce crustal deformation.

1.) Compressional - A force or pressure that attempts to flatten or squeeze a material. (reduces volume). Stresses or forces that shorten a rock body.

2.) Tensional - A stretching force on an object. Stresses or forces that elongate a rock body.

3.) Shear- Any external force acting perpendicular to the material. Stresses that cause two separate rock bodies to slide past one another.

8. Describe the three types of deformation.

1.) Elastic- A temporary shape change that is self-reversing after the force is removed. The object returns to its original shape.

2.) Brittle- Deformation that results in fracturing or breaking and is permanent.

3.) Ductile- When rocks bend or flow, like clay, it is permanent. (solid state flow)

9. Understand the two categories of faulting, the specific types of faults, and the forces/stresses involved.

Two categories: Dip Slip and Strike Slip

<u>Dip-Slip</u>

1) Normal (i.e. tensional forces)
2) Horst and graben (i.e. tensional forces)
3) Reverse (i.e. compressional forces)
4) Thrust (i.e. compressional forces)

<u>Strike-Slip</u> (i.e. transform)

1) Left-lateral (shear forces)
2) Right-lateral (shear forces)

10. Describe the properties of earthquake waves

- Body waves
  - P or primary waves
    - fastest waves
    - travel through solids, liquids, or gases
    - compressional wave, material movement is in the same direction as wave movement
  - S or secondary waves
    - slower than P waves
    - travel through solids only
    - shear waves - move material perpendicular to wave movement
- Surface Waves (R and L waves)
  - Travel just below or along the ground's surface
  - Slower than body waves; rolling and side-to-side movement
  - Especially damaging to buildings

11. Distinguish between the Richter scale and the Modified Mercalli scale

Richter scale

- Magnitude
  - Richter scale measures total amount of energy released by an earthquake; independent of intensity
  - Amplitude of the largest wave produced by an event is corrected for distance and assigned a value on an open-ended logarithmic scale

Modified Mercalli

- Intensity
  - subjective measure of the kind of damage done and people's reactions to it
  - isoseismal lines identify areas of equal intensity

12. Describe the eruption type that relates to the three different types of volcanoes, and relate each to the different plate boundaries.

Volcano Type	Eruption Style	Plate Boundary
Shield	Quiet free flowing lava	Divergent
Ash and cinder	Violent and explosive, pyroclastic	Convergent and divergent
Composite	Alternating quiet, free flowing lava and violent and explosive, pyroclastic	Convergent

UNIT 5

1. Describe the different types of economic mineral deposits. Be able to draw and label diagrams of each of the economic mineral deposits.

There are 5 types of economic mineral deposits:

i. Magmatic

- Many of the world's most valuable metallic mineral resources are directly associated with magma that ultimately forms igneous rocks.
- Certain metals are naturally enriched in certain magmas, but most only reach economically viable concentrations upon further enrichment during the cooling process

ii. Hydrothermal

- Among the best-known and most important ore deposits are those generated from hydrothermal **(hot-water)** solutions, which may be produced during the late-stage cooling of magma, by the heating of groundwater or seawater, or by metamorphic processes
- The deposits are forming where heated seawater, rich in dissolved metals and sulphur, gushes from the seafloor as particle filled clouds called *black smokers*
- *Vein Deposits*
- Hydrothermal fluids generated by cooling magmas can rise to the surface through fractures, faults, and other features resulting from the brittle deformation of the overlying rocks. Fluids passing through the fractures eventually cool, allowing minerals to precipitate

iii. Placer

- The formation of placer deposits relates to the sorting action of running water.
- Mineral particles of high density can be concentrated due to the sorting out and washing away of mineral particles of lower density
- Gold, Platinum and Diamonds

iv. Secondary Enrichment

- Weathering creates many important mineral deposits by concentrating minor amounts of metals that are scattered through unweathered rock into economically valuable concentrations.
- Such a transformation is often termed **secondary enrichment** and takes place in one of two ways.
- In one situation, chemical weathering coupled with downward-percolating water removes undesirable materials from decomposing rock, leaving the desirable elements enriched in the upper zones of the soil.
- The second situation is basically the reverse of the first. That is, the desirable elements that are found in low concentrations near the surface are removed and carried to lower zones, where they are re-deposited and become more concentrated.

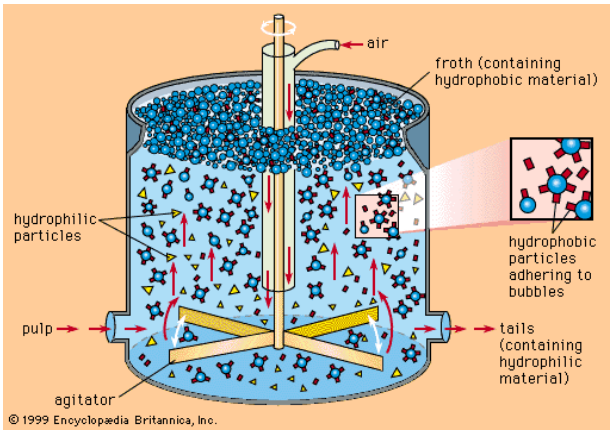
v. Metamorphism

- The role of metamorphism in producing mineral deposits is frequently tied to igneous processes.
- Many of the most important metamorphic ore deposits are produced by contact metamorphism.
- Here the host rock is re-crystallized and chemically altered from heat, pressure, and hydrothermal solutions emanating from an intruding igneous body.
- The most common metallic minerals associated with contact metamorphism are zinc, lead, copper and iron.

2. Describe techniques for processing ore deposits. Be able to draw and label diagrams for floatation, gravity separation, and heap leaching.

Flotation

- Floatation involves mixing grounded ore with water, oil, and chemicals.
- The grounded ore becomes suspended in the water and is subjected to bubbles of air.
- This causes the minerals and/or elements of value to float to the top where they can be skimmed off.



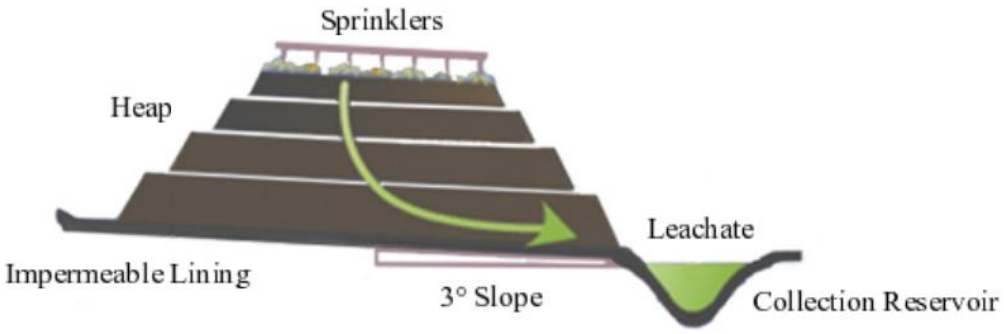
Gravity Seperation

- Gravity separation involves feeding grounded ore into a pulsating body of water, which serves to settle out the heavy material while floating away the light material.
    - If the heavy material is what you wishes to keep, then it is taken from the bottom.
    - If the light material is what you wishes to keep, then it is taken from the top.

Heap Leaching

- Heap leaching commences by placing the grounded ore as a layer onto impermeable material.

- The "heap" of material is sprayed with a liquid, which percolates down through dissolving away the valuable minerals and/or elements



3. Describe the origin and the process of formation of petroleum. Be sure to include (1) organic matter and (2) and preservation potential.

The origin of petroleum comes from microscopic marine animals (zooplankton) and plants (phytoplankton).

They are the main sources of *organic matter* in the production of petroleum.

- Examples of such microscopic species are:
  - Diatoms
  - Foraminifera
  - Radiolarian
  - benthic algae

The abundance of organic matter is determined by the amount of light, water depth, latitude, water temperature, water turbidity, and the abundance of nutrients preferred by plants (e.g. phosphates and nitrates).

Preservation potential means the conditions that favour the preservation of organic matter.

- The two most important conditions are:
  - 1. anaerobic conditions (low oxygen content)
  - 2. rapid sedimentation by fine-grained material.

- Anaerobic conditions can exist in swamp and lagoon environments.
  Examples of fine-grained material include mud-size, silt-size, and sand-size particles

4. Understand how kerogen evolves into petroleum as a result of diagenesis, catagenesis, and metagenesis.

Kerogen

- a mixture of organic matter in sediments from which petroleum is released.

- Diagenesis:
  - During diagenesis there is shallow burial of organic matter at near normal temperature and pressure as well as some decay.
  - Methane, carbon dioxide, and water are released leaving behind the complex hydrocarbon called kerogen.

- Catagenesis:
  - Deeper burial results in increased temperature and pressure.
  - Petroleum is released from the kerogen
    - first oil is released
    - second gas is released.

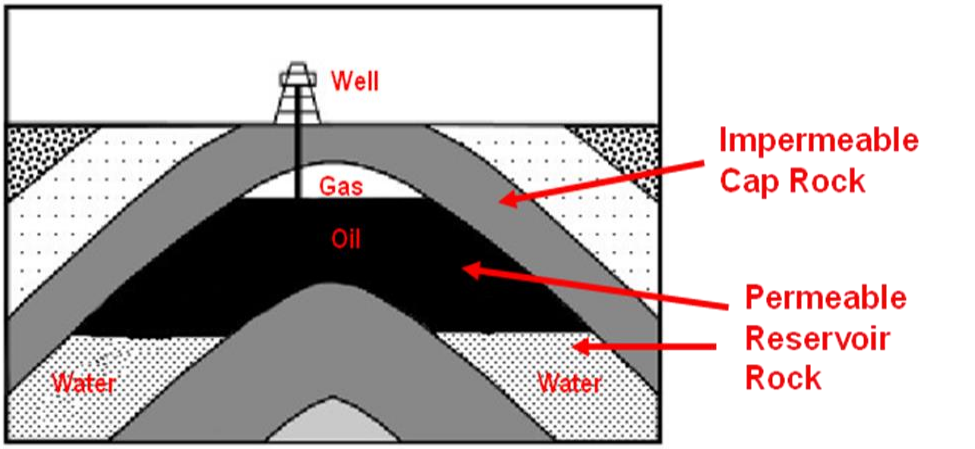
- Metagenesis:
  - *The metagenesis phase involves even higher* temperature and pressure verging on metamorphism.
  - The only hydrocarbon that is released during this phase is methane.

At this point the petroleum has matured enough to migrate to traps

5. **Draw and describe the three different petroleum traps. On each trap be able to identify source rocks, reservoir rocks, cap rocks, good drill locations, presence of gas, presence of oil, and presence of water.**

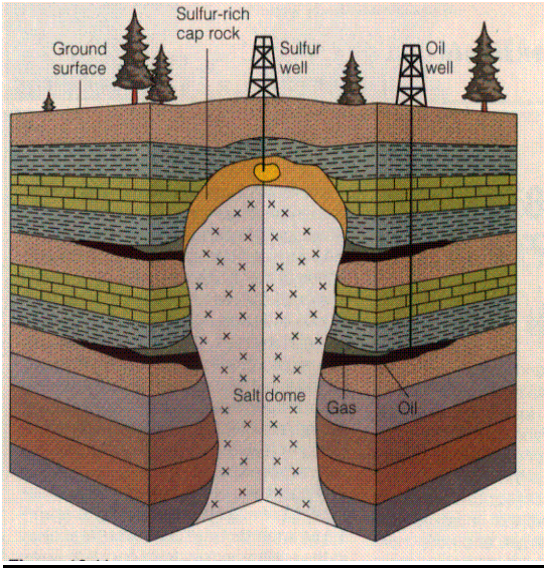
Anticline Trap:

If a permeable rock like sandstone or limestone is located between impermeable rock layers like shale and the rocks are folded into an anticline, oil and gas can move upward in the permeable reservoir rocks, and accumulate in the upper region of the anticline.



Salt Dome Trap

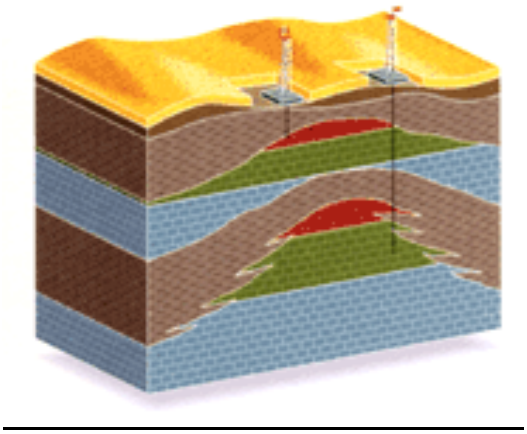
Here we see salt that has moved up through the Earth, punching through and bending rock along the way. Oil can come to rest right up against the impermeable salt, which makes salt an effective trap rock.



Limestone Reef Trap

Limestone reef trap is a type of stratigraphic trap.

When coral reefs become buried by other impermeable sediments they can form excellent oil sources and reservoirs



6. Describe the 3 methods of refining petroleum.

a) Distillation

- Crude oil contains hundreds of different types of hydrocarbons all mixed together.
- Different hydrocarbon chain lengths all have progressively higher boiling points, so they can all be separated by distillation(heating).

b) Cracking

- Cracking processes breaks down heavier hydrocarbon molecules (high boiling point oils) into lighter products such as petrol and diesel. This is done by catalytic cracking, thermal cracking .

c) Reforming

- The conversion of straight chain hydrocarbon into branched chain hydrocarbon such as gasoline. Involves heat, pressure, and the use of catalysts (speed up reaction rates) to reform different hydrocarbon compounds.