Chapter 14-Geology and Nonrenewable Mineral Resources- Part 1

Formation of the Earth

- Nearly all of the elements found in the Earth today are as old as the Earth itself.
- Earth formed roughly 4.6 billion years ago from the accretion of cosmic dust in our solar system.
- The early Earth was a hot molten sphere.
- For a period of time, additional debris from the formation of the sun and our solar system bombarded Earth.
- As this molten material slowly cooled, elements within it separated in layers according to their mass.

Layers of the Earth

- Earth cooled and differentiated into distinct vertical zones. Heavy elements, such as iron, sank toward the core, and lighter elements, such as silica, floated toward the crust.
- Some gaseous elements left the solid planet and became part of Earth's atmosphere.
- Because Earth's elements settled into place according to their mass, the planet is characterized by four distinct vertical zones.
    - Crust
    - Mantle
    - Outer core
    - Inner core

Crust

- *Continental crust*: extends 20-30 miles below surface; composed largely of silica-rich rocks such as granite and sandstone; therefore, less dense than oceanic crust.
- *Oceanic crust*: extends about 7 miles below surface; composed largely of rocks such as basalt that are rich in heavier elements such as iron and magnesium; thus, it is more dense than continental crust.
    - *Lithosphere*: outermost solid rocky crust; i.e. lithospheric crust
    - *Asthenosphere*: semi-molten rock with fluid qualities; flows very slowly, like a stiff liquid.

Mantle

- Most of Earth's mass is in the mantle; composed of iron, magnesium, aluminum, and silicon-oxygen compounds (silica).
- The mantle is thick semi-solid zone surrounding the core (approx. 2,900 km).
- Mostly solid rock but in the "plastic-like" asthenosphere (upper mantle) partially melted rock flows slowly forming convection currents as hotter less dense rock being heated by core rises.

Outer Core: Extremely hot; composed of molten/liquid iron and nickel.
Inner Core: Also, extremely hot yet solid iron and nickel due to extreme pressure.

Most of the Earth's internal heat is remnant heat from planetary formation. However, a contributing factor that accounts Earth's internal heat is the radioactive decay of K, U, Th in the core, which releases heat.

Geologic Time Scale

- Earth's past has been organized into various units according to events that took place in each period.
- Different spans of time on the time scale are usually separated by major paleontological events, such as mass extinctions.
- For example, the boundary between the Cretaceous period and the Paleocene period is defined by the extinction of the dinosaurs and many marine species.
- The largest defined unit of time is the eon.
- Eons are divided into eras, which in turn are divided into periods, epochs, and stages.

Eon → Eras → Periods → Epochs → Stages

The Continental Drift Theory

In 1915, Alfred Wegener proposed that all of the continents had drifted from their original positions in a supercontinent that he called Pangaea over the last 225-250 million years.

Chapter 14-Geology and Nonrenewable Mineral Resources- Part 1

Evidence to support continental drift theory:

1. Fossilized tropical plants were discovered beneath Greenland's icecaps.
2. Glaciated landscapes occurred in the tropics of Africa and South America.
3. Tropical regions on some continents had polar climates in the past, based on paleoclimate data.
4. The continents fit together like a puzzle.
5. Similarities existed in rocks between the east coast of North and South America and the west coasts of Africa and Europe.

Plate Tectonics

Plate Tectonics: the theory that Earth's lithosphere is divided "plates" that are pushed and pulled across the earth's surface by convection cells.

Sea Floor Spreading Theory

- During the 1960's, alternating patterns of magnetic properties were discovered in rocks found on the seafloor.
- This magnetic striping locked in Earth's periodic magnetic pole reversals (approx. every seven million years) as iron magma oriented towards the poles while during the formation of igneous rock. Matching patterns were discovered on either side of mid-ocean ridges found near the center of the ocean basins.
- Dating the rocks indicated that as one moved away from the ridge, the rocks became older. This suggested that magma was rising at volcanic rift zones at the ridges, creating new crust, and displacing the existing crust, pushing it outward and causing the seafloor to spread slowly over time.

Convection Cells

- Within the asthenosphere hot semi-molten rock slowly rises to Earth's surface (10 cm/yr), as the core heats it.
- When the semi-molten rock reaches the base of the lithosphere it cools and solidifies creating new oceanic crust as; i.e. igneous rock. This process is known as ***sea floor spreading.***
- The cooled rock then turns sideways and moves parallel to the earth's surface before descending back into the earth at ***subduction zones*** to become reheated.

Convection Currents **provide the force that drives the movement of Earth's lithospheric plates.**

Plate boundaries: the area where two plates meet.

3 Types of Plate Boundaries

- **Divergent Boundary:** two plates moving apart
- **Convergent Boundary**: two plates moving towards each other
- **Transform Boundary:** two plates moving sideways past each other

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3 Types of Convergent Plate Boundaries

Continent-continent convergence

- When two continental plates collide, mountain ranges are created as the colliding crust is compressed and pushed upward.
- Example. Indian subcontinental plate being thrust under a portion of the Eurasian plate, lifting it and creating the mountains of the Himalaya.
- Powerful earthquakes are generated when stuck plates slip.

Ocean-continent convergence

- When a denser oceanic plate moves underneath a less-dense continental plate; creating a deep ocean trench and a subduction zone.
- The subducted plate melts and magma rises beneath the continental plate forming a continental volcanic arc; i.e. chain of volcanic mountains.
- Powerful earthquakes are generated when stuck plates slip, often creating Tsunami's.

Ocean-ocean convergence

- When two oceanic plates collide the denser of the two subducts.
- The subducted plate melts, magma rises creating a volcanic island arc; i.e. chain of volcanic islands.
- Powerful earthquakes are generated when stuck plates slip, often creating Tsunami's.

Chapter 14-Geology and Nonrenewable Mineral Resources- Part 1

Divergent Plate Boundary

- When two plates move away from each other; rising magma from convection cells in the mantle exert pressure on Earth's crust causing rifting or cracks in the crust.
- This molten rock or magma rising from convection fills in the cracks, cools and solidifies forming igneous rock, such as basalt.
- Slow, continual process that results in the gradual expansion of the sea floor; ***Seafloor Spreading***.
- Examples of areas of oceanic divergent plate boundaries include the Mid-Atlantic Ridge and the East Pacific Rise (mid-ocean ridges).
- Examples of areas of continental divergent plate boundaries include the East African Great Rift Valley.

Transform Plate Boundary

- When two plates slide sideways past each other.
- The San Andreas Fault, which is found near the western coast of North America, is where the Pacific and North American plates slide past each other.
- The friction and stress buildup from the sliding plates frequently causes earthquakes.

Hot Spots

- Hot spots are located within the interior of lithospheric plates. Thus, they are not at plate boundaries.
- Earth's internal heat causes plumes of hot magma to well upward.
- Hot spots are places where molten material from mantle asthenosphere reaches lithosphere.
- As plate moves over a hotspot, heat from mantle plume melts crust forming a volcano.

Volcanoes

- Active volcanoes produce magma (molten rock) and lava at the surface. The majority of volcanoes—95%—occur at ***subduction zones*** and ***mid-ocean ridges***.
- The remaining 5% occur at ***hotspots***.

Volcanic Gases & Global Climate

- In addition to ejecting lava and rocks, volcanoes also eject ash and release gases into the atmosphere.
- The most common gases released by volcanoes are steam, carbon dioxide, sulfur dioxide, and hydrogen chloride.
- Volcanoes affect the climate by releasing large quantities of sulfur dioxide (SO_2) into the atmosphere that is later converted into sulfate ions in the stratosphere (SO_4^{2-}).
- These sulfate particles reflect solar radiation and serve as condensation nuclei for high clouds, resulting in increased albedo, i.e. reflection of solar radiation back to space.
- The net result is global cooling. In 1992, the year after the Mt. Pinatubo eruption in the Philippines, the effect of stratospheric sulfate particles decreased the average global temperature by 1°F.

Volcanic Gases & Earth's Atmosphere

- Volcanic gases played an important role in formation Earth's Systems.
- Volcanoes are largely responsible for the formation of the atmosphere and the oceans.
- Most of Earth's surface water was released from the Earth's interior by volcanoes in the form of water vapor.
- Volcanoes gave the early Earth much of its early atmosphere, specifically, the gases carbon dioxide & nitrogen.
- Carbon dioxide, on the early earth, was emitted from volcanoes and converted to oxygen by photosynthetic algae.

Earthquakes

- Earthquakes occur during abrupt movement on a fault, along tectonic plate boundary zones or mid-ocean ridges.
- **Seismic Waves:** energy is released during earthquakes in the form of seismic waves.
- **Focus:** the place in the Earth along the fault where rupture occurs
- **Epicenter:** the geographic point on the surface directly above the focus
- **Seismometer**: an instrument used to measure seismic waves
- **Seismograph**: the record of earthquake vibrations made by a seismometer

P-waves travel fastest through the Earth so they arrive first at a distant seismograph station.
S-waves arrive shortly after.

Chapter 14-Geology and Nonrenewable Mineral Resources- Part 1

- **The Richter scale:** The logarithmic Richter scale measures the strength or magnitude of an earthquake.
- **Amplitude:** The measure of the height of the wave from its rest position; basically half of the wave.
- **Magnitude**: Earthquake magnitude, using the Richter scale, is a measure of the amplitude of the largest seismic wave recorded on a seismogram.

Earthquakes- Tsunami

- Largest recorded earthquake: 9.5 in Chile in 1960. It is referred to as the "Great Chilean Earthquake" and the "1960 Valdivia Earthquake".
- Most of the damage and deaths were caused by a series of tsunamis that were generated by the earthquake.

Tōhoku Earthquake & Tsunami

- March 11, 2011, northern Japan was hit by a 9.0 magnitude earthquake that triggered a deadly 23-foot Tsunami.
- Northern Japan's coastal Fukishima Daiichi nuclear power plant suffered catastrophic damage from the tsunami.
- Cooling systems failed causing a nuclear reactor failure, followed by an explosion and partial meltdown in the nuclear reactors.
- This released radiation into the ocean and the atmosphere. This disaster is considered one of the worst nuclear disasters of all time; on par with Chernobyl's nuclear reactor explosion in 1986.

The Rock Cycle

- **Mineral**: element or inorganic compound that occurs naturally, is solid with a crystalline structure. Au, Ag, diamond (C), quartz (SiO_2)
- **Rock**: any material that makes up a large, natural, continuous part of the Earth's crust. May be composed of a single mineral type (limestone-$CaCO_3$) but most are two or more minerals (granite-feldspar, quartz, mica)
- **Ore**: a rock that contains a large enough concentration of a mineral-often a metal-that it can be mined and processed to extract the mineral.

Three Major Types of Rocks

Sedimentary

- Sediments from existing rocks are broken down by *weathering* and *erosion*; transported by water, wind, gravity; deposited in layers in the bottom of lakes, rivers, and oceans (river delta & continental shelf) where they are *compacted* and *cemented* to form solid rock;
- Or plant material is compressed through deep burial; or shells from marine organisms are deposited on the ocean floor and compacted.
- Example: Sandstone, Limestone, coal

Igneous

- Igneous rocks form when **minerals** *crystallize* and *solidify* as magma or lava cools and solidifies to form solid rock;
- Magma within the earth *cools* slowly forming larger crystals and coarse grained rock (intrusive), while, lava on Earth's surface *cools* quickly forming smaller crystals and fine-grained rock (extrusive);
- Example: Granite (intrusive), basalt (extrusive)

Metamorphic

- Preexisting rock subjected *high temperatures* and *pressures*, often from deep burial or mountain building episodes form metamorphic rock over long periods of time.
- Example: gneiss, schist

Weathering and Erosion

- **External Processes:** Powered by energy from the sun and Earth's gravity; tend to wear down earth surface.
- **Erosion:** Material is dissolved, loosened, worn away, then carried and deposited somewhere else. Work of streams: creates valleys, canyons, deltas.
- **Weathering:** physical, chemical, & biological break down of rocks/minerals into smaller particles that build soil.
- **Chemical Weathering**: One or more chemical reactions slowly decompose rock. Most reactions involve rock reacting with O_2, CO_2, H_2O, moisture in atmosphere. Accelerated by rain and high temperatures.
- **Mechanical or Physical Weathering:** large rock mass is broken into smaller fragments. Agents are wind and rain. More rapid in tropical areas with high temps.
- **Biological Weathering:** work of burrowing animals and insects; movement of soil by earthworms