The Dynamic Planet

Physical Geography Lecture - GEOG B1

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Endogenic/Exogenic System(s)

Endogenic system - a system of processes which operate inside the planet - internal processes driven by heat and radioactive decay

Exogenic system - a system of processes which operate on our planet's surface - external processes driven by solar energy and the movement of air, water, and ice

Geomorphology

Geomorphology - the study of the planet's surface landforms - specifically their origin, evolution, form, and spatial distribution *

*Geomorphology is a subfield of both physical geography and geology

Uniformitarianism

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.

The phrase "the present is the key to the past" describes the principle.

*Though an unprovable postulate that cannot be verified using the scientific method, uniformitarianism has been a key first principle of virtually all fields of science.
EXAMPLE: the processes by which streams carved out a valley in the present are the same processes from million years ago
Covers gradual as well as sudden processes.

Geologic time scale

Geologic time scale - a summary timeline of Earth's full history - breaking the 4.6 billion years down into: **Fig. 12.1**

- *eons* (largest time span)
- eras
- periods
- epochs *

Used by geologists, paleontologists, and other Earth scientists to describe the timing and relationships of events that have occurred during Earth's history.

*Major events in Earth's history determine boundaries between the intervals which are not equal in length.
EXAMPLE: 6 mass extinctions

Stratigraphy

Stratigraphy is a branch of geology concerned with the study of rock layers (strata) and layering (stratification). *

- It is primarily used in the study of sedimentary and layered volcanic rocks, and important time clues like fossils. **

*Study the sequences of the geologic time scale and where things are placed along that timeline
** fossils are the remains of something that was once living

Evidence for Earth's Structure

Direct evidence of internal structure:

- Core samples from the land and ocean floor *

Indirect evidence of internal structure:

- Scientists are now able to identify the boundaries between different layers within Earth by measuring the depths of changes in **seismic wave**** velocity and direction.

*sediment cores from about 2 km deep
** shock waves from earthquakes that reverberate around the world - speed of the waves varies ass it passes through different materials - cooler, more rigid areas transmit waves a higher velocities that do hotter areas.
Plastic zones don't transmit some waves - they absorb them.
Waves may also be refracted (bent) or reflected depending on the density of the material.

Earth's Structure

- The interior structure of the Earth is layered in spherical shells, like an onion. These layers can be defined by their composition or temperature.
- As the planet formed - heavier, denser substances, like iron, gravitated toward the center, while lighter, less-dense, substances, like silica, welled upward to the surface and were concentrated in the outer shell.
- Heat energy migrates outward from the center by conduction and convection

Earth's Core & Mantle

Core - center / has two layers **Fig. 12.2**

- Inner Core: super-heated solid iron *
- Outer Core: molten iron with less density than inner core - the flow of this layer generates Earth's magnetic field

Mantle - lower portion has higher temp & greater density - rocks able to *slowly* flow & deform at depth ** - 80% of planet's volume

*should be liquid because its temperature is well above the melting point - but it remains solid because it is under tremendous pressure
** Temperatures and density decrease as you move toward the surface

Mohorovicic Discontinuity

- usually referred to as the **Moho**, is the boundary between the Earth's crust and the mantle.
- The Moho lies almost entirely within the lithosphere; only beneath mid-ocean ridges does it define the lithosphere–asthenosphere boundary.

The Crust

Continental crust - 30-60 km (19-37 mi)

- all the land masses and continental shelves that reach out into the oceans
- lower in density than oceanic crust
- Composed mainly of granite

Oceanic crust - averages 5 km (3 mi)

- all the ocean floors
- higher density
- composed mainly of basalt

Lithosphere

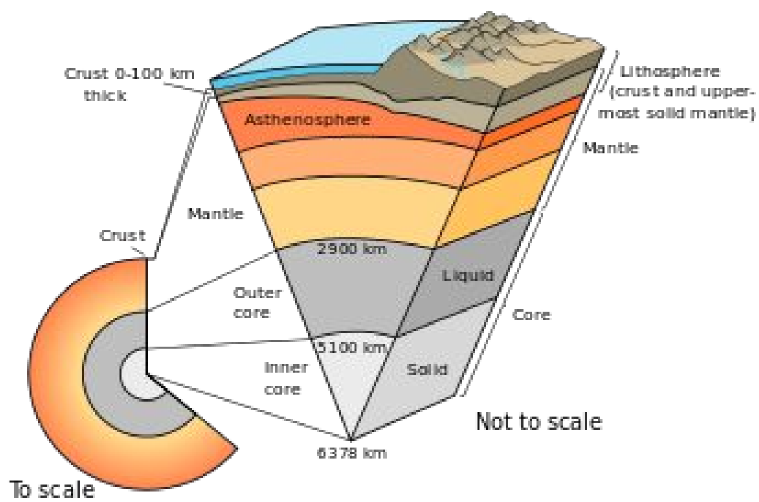
- Earth's lithosphere includes the crust (both continental and oceanic) and the uppermost mantle to about 70 km (43 mi), which constitute the hard and rigid outer layer of the Earth.
- The lithosphere is subdivided into tectonic plates.
- The lithosphere is underlain by the asthenosphere which is the weaker, hotter, and deeper part of the upper mantle.

Asthenosphere

- The **asthenosphere** is the highly viscous* region of the upper mantle of the Earth. It lies below the lithosphere, at depths between approximately 70-250 km (43-155 mi) below the surface.
- The asthenosphere is almost solid, although some of its regions could be molten (e.g., below mid-ocean ridges).

*viscous - thick and sticky - like hot plastic

Layers



Crust 0-100 km thick
Asthenosphere
Lithosphere (crust and upper-most solid mantle)
Mantle
Mantle
Crust
2900 km
Liquid
Outer core
Core
5100 km
Inner core
Solid
Not to scale
6378 km
To scale

Isostasy

Isostasy is the state of gravitational equilibrium between Earth's crust and mantle such that the crust "floats" at an elevation that depends on its thickness and density.

If a load is placed on the surface*, the lithosphere tends to sink, or ride lower in the asthenosphere. The lithosphere bends, and the asthenosphere flows out of the way. **
Fig. 12.4

*like a glacier, a mountain range, or even sediment accumulation
**If the load is removed, such as when a glacier melts or a mountain is weathered down, the lithosphere rides higher and the asthenosphere flows back toward the region of uplifting lithosphere

Earth’s Magnetism

- A **geomagnetic reversal** is a change in a planet's magnetic field such that the positions of magnetic north and magnetic south are interchanged. *
- The Earth's field has alternated between periods of *normal* polarity (same as the present direction) and *reverse* polarity (the opposite direction). **

*but geographic north and geographic south stay the same.

** It’s taken place 9 times in the last 4 million years, and hundreds of times in Earth’s history.
The reasons are unknown, but this phenomena is key to understanding the evolution of landmasses and the movement of the continents. All over Earth, rocks of the same age beart identical alignments of magnetic materials (such as iron particles). Across the ocean floor, scientist have found a record of magnetic reversals in the form of measurable rock “stripes” indicating periods of normal polarity and reversed polarity

Minerals & Rocks

Mineral - a naturally occurring chemical compound, usually of crystalline form, and inorganic.

- A mineral has one specific chemical composition. *

Rock (**stone**) - a solid aggregate of one or more minerals, or organic material. **

- The Earth's outer solid layer, the lithosphere, is made of rock. ***

*Mineralogy - the study of the composition, properties, and classification of minerals

**One example, granite, a common rock, is a combination of the minerals quartz, feldspar and biotite. Another example is coal, a solid material made from material made from the decayed, heated and pressurized remains of ancient swamp organisms.

***Rock has been used by mankind throughout history. The minerals and metals found in rocks have been essential to human civilization.

Rock

Three major groups of rocks are defined:

- **Igneous** - formed from molten material
- **Sedimentary** - formed from compaction or chemical processes
- **Metamorphic** - altered by heat and pressure

Igneous Rock

Igneous rock is formed through the solidification and crystallization of magma or lava.

- **Magma** - molten rock beneath the surface *
- **Lava** - magma that emerges at the surface **

Table 12.2 (p. 334)
Classification of Igneous Rocks

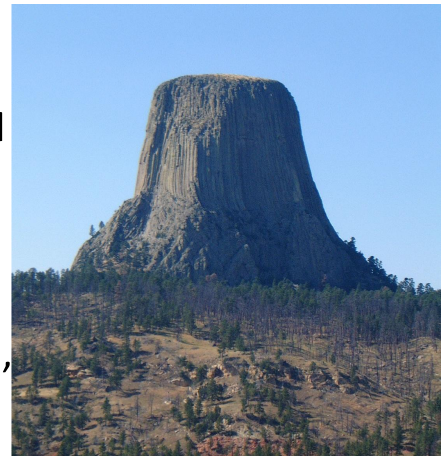
*Besides molten rock, magma may also contain suspended

crystals, dissolved gas and sometimes gas bubbles.

**igneous rocks makeup approximately 90% of Earth's crust - although sedimentary rocks, soil or oceans frequently cover them

Intrusive Igneous Rock

Intrusive rock (also called **plutonic rock**) is formed when magma crystallizes and solidifies underground to form *intrusions*. *
Example: plutons, batholiths, dikes, sills, & volcanic necks



Granite - forms underground, slow cooling creates this coarse-grained rock**

*The location and rate of cooling determine the crystalline structure of a rock - whether it is made of coarser (larger) or finer (smaller) materials. Therefore, the texture indicates the environment in which the rock formed.
** even though granite cools and forms below the surface, subsequent lisft of the landscape, or simply weathering in the area of the granite, will expose it **Fig. 12.5 a**
- El Capitan and Half Dome in Yosemite
- Great Trango Tower in Pakistan

Extrusive Igneous Rock

Extrusive refers to the mode of igneous volcanic rock formation in which hot magma from inside the Earth flows out (extrudes) onto the surface as lava or explodes violently into the atmosphere to fall back as pyroclastics or tuff.

- Lava cools much more quickly in the open air or under seawater, and there is little time for the growth of crystals.
- **Basalt** - finer-grained and most common form of extrusive rock * **Fig. 12.5 b**

*Makes us the bulk of the ocean floor

Igneous Landforms

Pluton - igneous rock that cools and hardens slowly in the crust.* There are several plutonic forms: **Fig. 12.6**

- **Batholith** - largest, irregularly shaped, forms mountain ranges **
- **Sill** - intrudes between layers, like a shelf
- **Dike** - intrudes across layers
- **Volcanic neck** - magma cooled inside the pipe of a volcano -later exposed

*Named after Roman god of the underworld - Pluto
** Sierra Nevadas, Idaho, Coast Range of British Columbia and WA


Coastal Range Batholith
Idaho Batholith
Sierra Nevada Batholith
Baja California Batholith
Batholiths of the Western United States

Sedimentary rock

- **Sedimentary rocks** are types of rock that are formed by the deposition and subsequent cementation of that material at the Earth's surface and within bodies of water.
- **Sediment** is a naturally occurring material that is broken down by processes of weathering and erosion, and is subsequently transported by the action of wind, water, or ice, and/or by the force of gravity acting on the particles. *

Table 12.3 p. 336

*Sediment can include: sand, shells, organic material, and the precipitation of minerals from water solution

Clastic Sedimentary Lithification

Lithification - occurs as loose sediment is hardened into solid rock.

- involves compaction of buried sediments as overlaying weight of material squeezes out water and air between clasts* and cementation by minerals, which fill any remaining spaces and fuse the clasts together
- Cementing minerals are usually quartz, feldspar, and clay minerals **

Fig. 12.7 a

*clasts are loose grains or fragments
**Most common cement is Calcium Carbonate ($CaCO_3$)

Chemical Sedimentary Rocks

- Not formed from pieces or broken rock (although it can have bits cemented with it)
- Formed from shells that contain calcium carbonate, or from dissolved minerals that precipitate out of water solutions and build up to form rock. *

Fig. 12.7 & **12.8**

Chemical precipitation is the formation of a separate solid substance from a solution - such as when water evaporates and leaves behind a residue of salts. **Fig. 12.10**

Chemical Sedimentary - Limestone

Limestone - most common

- marine organisms extract calcium carbonate from the water to build their shells
- when they die, their shells build up on the ocean floor
- shells are lithified to become limestone

Can also be formed when calcium carbonate in solution is precipitated out of groundwater that has seeped to the surface (near springs)* or into caves **

Fig. 12.8 & **12.9** ***

*At springs, it turns into terraces or mounds called travertine.
** In caves it forms speleothems - stalagtites and stalagmites
*** Also Hydrothermal deposits - consisting of metallic minerals accumulated by chemical precipitation from hot water - deposits accumulate around vents to form towers around the underwater vents

Metamorphic Processes

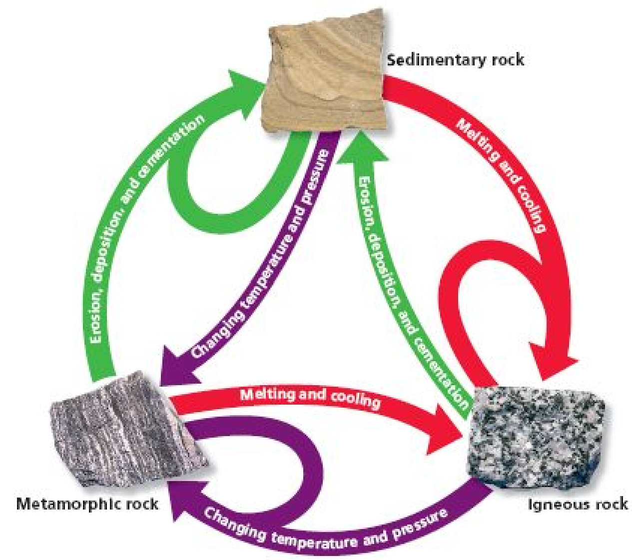
Metamorphic rock - after intense heat and/or pressure has been applied to igneous or sedimentary, it is transformed into metamorphic rock

- Heat breaks and reforms chemical bonds
- Pressure changes shape and mineral alignments *

Table 12.4 - p. 339 **Fig. 12.1**

*More compact, hard, and resistant to weathering

The Rock Cycle



The continuous alteration of Earth materials from one rock type to another. **Fig. 12.12**

Plate Tectonics - The Start

- Alfred Wegener - 1912- **Continental Drift**
  - Fit of continents
  - fossil evidence
  - landform evidence
  - climate evidence
- Continents were once connected as a supercontinent he called Pangaea* and have since drifted apart
- Was denounced because he couldn’t explain how the continents moved

*means “all Earth”

Plate Tectonics - Confirmed

Plate Tectonics - the theory that the lithosphere is divided into plates that move independently over the mantle due to the pushing and pulling motion of convective currents in the mantle*

Fig. 12.13

How did we figure this out?

* along the plate boundaries occur the formation of crust, the building of mountains, seismic activity, and the destruction of crust

They've smasshed together and torn apart many times since Earth formed

Seafloor Spreading - Discovered

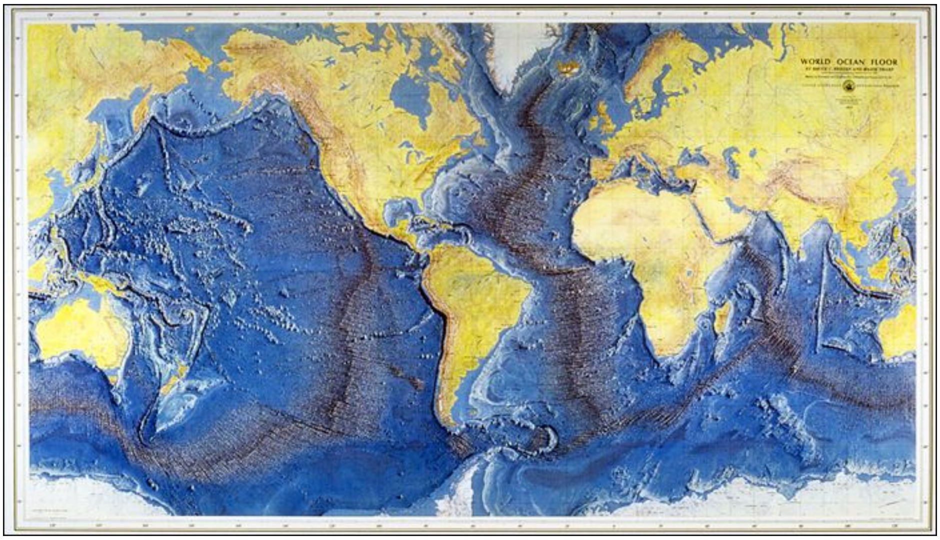
*Scientists discovered a 64,000 km (40,000 mi) interconnected mountain chain along the ocean floor - they were called the **mid-ocean ridges**.

****Seafloor spreading** - the process associated with upwelling flows of magma along the mid-ocean ridges

- creating new crust
- mechanism driving the movement of the lithospheric plates

*After WWII scientists wanted to know what the ocean floors looked like so they used sonar to map it - going back and forth
** In the early 1960s, geophysicist Howard H. Hess proposed that these mid-ocean ridges were areas where new ocean floor was being created. It was later called seafloor spreading…..

Mid-Ocean Ridges



Evidence for Seafloor Spreading

Magnetic reversals - as magma emerges and hardens at the mid-ocean ridge, its magnetic particles orient themselves towards the poles

- using dating methods, scientists have established a chronology of the polarity reversals - matches patterns on either side of the ridge **Fig. 12.15**

Age of Seafloor - youngest crust is at the spreading centers of the ridge *

- crust gets progressively older as one moves away from the ridge **Fig. 12.16**

*multiple samples were taken from the ocean floor at equal distances from the mid-ocean ridges

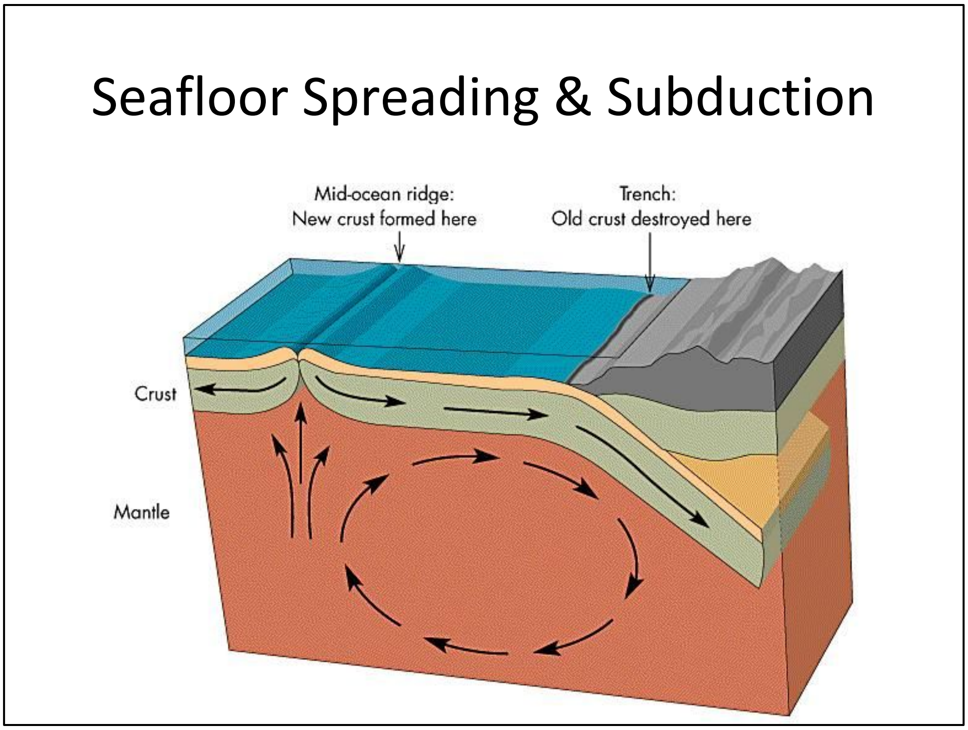


Fig. 12.17 - Mid-Atlantic Ridge (part of the mid-ocean ridge system)
Scientists think that the upwelling of the magma is a consequence of the plates are being pulled apart by convective currents in the mantle, that push the asthenosphere, which the lithosphere rides on top of. As the plates move apart, the magma oozes up into the crack

Subduction

*<u>Deep-ocean trenches</u> - where one lithospheric plate is descending beneath another in the process called *subduction*.

- Lowest features on the surface **

Subduction zones - where plates collide and the denser plate subducts beneath the other and is destroyed/consumed.

- Ocean crust will always subduct below continental crust

*Crust was being continuously created at the mid-ocean ridges, but where did it go? Scientists determine that if it's being created somewhere, it has to be consumed somewhere else - otherwise the planet would keep expanding. Started looking at the plates outward from the ridges. They saw deep-ocean trenches
** Mariana Trench near Guam -11,030 m (-36,198 ft) Tonga Trench in Pacific -10,862 m (-35,702 ft)
Puerto Rico Trnch in Atlantic -8,605 m (-28,224 ft) Java Trench in Indian Ocean -7,125 m (-23,376 ft)

Plate Boundaries *

Fig. 12.18 - **Three Types of Boundaries**

- *Convergent boundaries* - colliding plates
  - leads to subduction or mountain building **
- *Divergent boundaries* - plates spread apart and new crust is created by upwelling magma
  - happens on the ocean floor and on land***
- *Transform boundaries* - plates grind past one another
  - form a type of fault/fracture called a **transform fault** **Fig. 12.19**

*Earth's present crust has 14 plates. The boundaries where plates meet are dynamic places, even though the process is SLOW to humans.
**The Indian continental plate is colliding with the Eurasian plate and the Himalayas are the result - Growing every year by a few cm
*** Divergent boundaries on land are called rift valleys - Great Rift Valley in East Africa

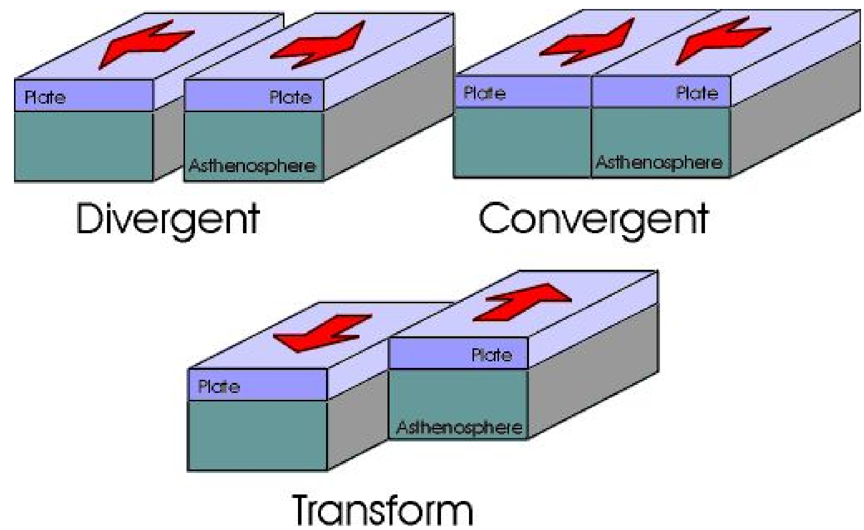


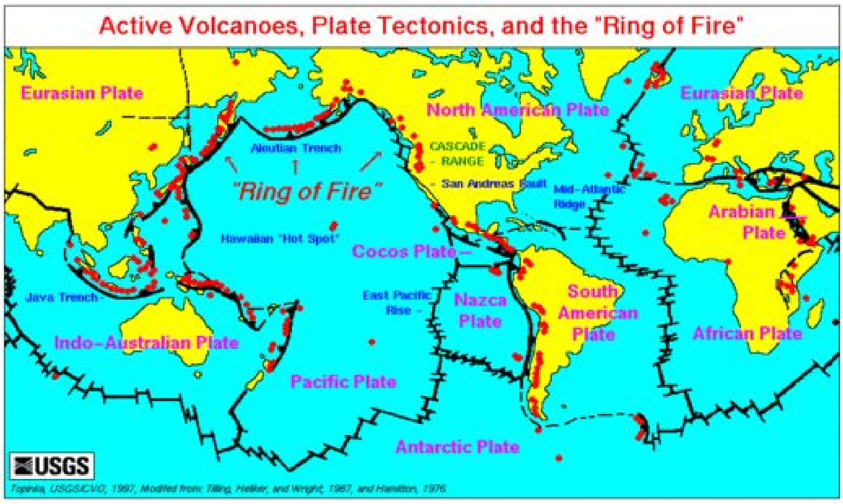
Plate
Plate
Asthenosphere
Divergent
Plate
Plate
Asthenosphere
Convergent
Plate
Plate
Asthenosphere
Transform

Earthquake & Volcanic Activity

Fig. 12.20 - Locations of Earthquakes & Volcanoes

"Ring of Fire" - around Pacific

Plate boundaries are the primary locations of earthquake and volcanic activity.


Active Volcanoes, Plate Tectonics, and the "Ring of Fire"
Eurasian Plate
North American Plate
Eurasian Plate
Aleutian Trench
CASCADE
RANGE
San Andreas Fault
Mid-Atlantic
Ridge
"Ring of Fire"
Arabian
Plate
Hawaiian "Hot Spot"
Cocos Plate
Java Trench
East Pacific
Rise
Nazca
Plate
South
American
Plate
African Plate
Indo-Australian Plate
Pacific Plate
Antarctic Plate
USGS
Topinka, USGS/CVO, 1997, Modified from: Tilling, Heliker, and Wright, 1987, and Hamilton, 1976

Hot Spots

There is volcanic activity outside of plate boundaries:

Hot spots - places where plumes of magma rise from the mantle, producing volcanic activity as well as thermal effects **Fig. 12.21** *

- Occur below oceanic and continental plates. **
- Plate moves over it, and the plume punches through the plate creating a string of volcanoes.
- Some hot spots do occur on plate boundaries ***

*Hawaiian islands
** Yellowstone Caldera
*** Iceland - hot spot along the mid-ocean ridge in the Atlantic - great example of an area of the mid-ocean ridge rising above sea level

Geothermal Energy

Some volcanic sites produce enough heat from Earth's interior, or geothermal energy, for humans to safely use.

Groundwater is heated by pockets of magma.

This groundwater may bubble up as a *hot spring*, or erupt explosively as a geyser.

Focus Study 12.1 - p. 348