

THE DYNAMIC CRUST

There are 4 major sub-divisions to the Earth's interior:

1. The Crust

- a. it's thickness varies from **5** to **60** kilometers
- b. **continental crust** is **thicker**, especially under **mountain ranges**, it's **granitic**, intrusive, **low density** and basically the same age throughout
- c. **oceanic crust** is **thinner**, it's **basaltic**, extrusive, high density and it's age varies with location

2. Mantle

- a. it's the thickest of the 4 sub-divisions at 2900 kilometers and it's divided into 2 parts
- b. upper mantle - asthenosphere - it's a plastic - it has the properties of both a liquid and a solid - huge convection cells circulate in the asthenosphere and those power continental drift and sea floor spreading - the asthenosphere contributes material to the oceanic crust - up to 100 kilometers thick
- c. lower mantle - stiffer mantle - it's composed of dense, ultra mafic minerals like olivine and pyroxene - it's probably more solid than plastic

3. Outer Core

- a. it's thickness is 2200 kilometers
- b. it's liquid in state and probably a nickel-iron mixture

4. Inner Core

- a. it's thickness is 900 kilometers
- b. it's a solid nickel-iron mixture - basically a ball-bearing

B. Facts about the crust:

1. It's the solid outer layer of the Earth that is composed of solid rock
2. The term lithosphere includes both the crust and *uppermost* mantle.
3. It's very thin compared to the other sub-divisions - like the skin on an apple
4. Even though the crust is solid, it's very unstable
 - a. diastrophism - refers to the movement of solid rock
5. The dividing line or interface between the crust and the mantle is a gradational or transitional one - there is a slow change from one to another - no sharp boundary

Crustal Instability - evidence is based on the Law of Original Horizontality

Law of Original Horizontality - all sedimentary and extrusive igneous rocks form in

flat lying, horizontal layers called strata

Observations show this Law is commonly violated

1. **Anticlines & Synclines** - folded rock strata - anticlines are upfolds while synclines are downfolds - folding occurs after the rocks formed horizontally
2. **Tilted Strata** - rock layers found to be resting at some angle - the tilting occurred after the rocks formed horizontally
3. **Faulted Strata** - a crack or a break in or across a series of rock layers along which slippage or movement takes place
 - a. normal fault - produced by tension - forces moving in opposite directions - one side drops down relative to the other side
 - b. reverse fault - produced by compression - forces moving towards one another - one side rises up relative to the other side
 - c. lateral/strike-slip fault - no vertical displacement - rocks are sliding past one another with a side-to-side motion
 - d. thrust/overthrust fault - produced by compression - a low angle reverse faultall faulting occurred after the rocks formed horizontally
4. **Displaced Fossils** - finding fossils where they shouldn't be
 - a. finding shallow water marine fossils in rocks thousands of feet above sea level is evidence for crustal uplift after the fossil-bearing rock layers formed on the sea floor
 - b. finding shallow water marine fossils in rocks thousands of feet below sea level is evidence for crustal subsidence (sinking) after the fossil-bearing rock layers on the sea floor in shallow water

Earthquakes - the natural shaking of the lithosphere caused by faulting

1. There are 2 ways to measure earthquakes:
 - a. on a scale of intensity - based on the reports of people that indicate the earthquake's human impact - **Mercalli Scale**
 - b. on a scale of magnitude - based on the energy level of the earthquake -
Richter Scale
 - 1) the energy level is recorded by a seismograph
 - 2) magnitude scales are logarithmic - each one unit increase mean a 10-fold increase in shaking
2. **Earthquake Terminology**
 - a. Origin Time - the exact time that the earthquake began
 - 1) you can calculate this if you know the arrival time of the P and S wave

as well as the distance to the epicenter (travel time)

- b. **Focus** - the location deep within the Earth where the faulting actually takes Place
- c. **Epicenter** - the location on the Earth's surface directly above the focus
 - 1) you can determine the epicenter if you have the arrival times of 3 sets of P and S waves
- d. **Seismic Wave** - the energy that is released by an earthquake and travels through the Earth in the form of waves
 - 1) primary, compressional, **P-wave** - a wave that makes rock particles vibrate in the same direction that the wave travels
 - a) Newton's cradle
 - b) a line of parked cars being struck from behind
 - c) a slinky being struck on one end
 - 2) secondary, shear, **S-wave** - a wave that makes rock particles vibrate at right angles to the direction that the wave travels
 - a) a transverse wave
 - b) like corks bobbing on ocean waves
 - 3) surface waves - P and S waves that travel along the Earth's surface and cause the surface to move violently

Facts about seismic waves:

1. **P-waves always travel faster than S-waves**
2. **P-waves can pass through solids, liquids, or gases**
3. **S-waves can pass through solids, only**
 - a. this is how seismologists know that the outer core is a liquid - all S-waves are absorbed at 2900 kilometers beneath the surface
 - b. this is how seismologists know that the asthenosphere is a plastic and not a true liquid - S-waves **will** pass through the asthenosphere
4. Both P and S waves are refracted (bent) towards the Earth's surface as they travel along
 - a. this is how seismologists explain the existence of a shadow zone
5. The actual speed of seismic waves depends on 2 factors:
 - a. rock density - as rock density increases, seismic wave speed increases
 - b. depth/pressure - as depth/pressure increases, seismic wave speed increases
 - c. as a result, as time passes, seismic wave speed actually increases
 - d. **Seismograph** - an instrument that detects and records the passage of seismic

Waves

- f. **Seismogram** - the record of the passage of seismic waves produced by a seismograph
- g. **Shadow Zone** - the area on the Earth's surface, 102° to 143° from the epicenter where no seismic waves are received
 - 1) the point on the surface directly opposite the focus will receive P-waves, only. The S-waves were absorbed when they reached the outer core.
- h. the Mohorovicic discontinuity - the Moho - the crust/mantle interface - it was discovered as a result of a sudden change in seismic wave speed and direction at the interface

It is the study of seismic waves that allows seismologists to learn much about the Earth's interior

E. Seismic Hazards

- 1. Buildings and bridges collapse
 - a. improved building codes call for reinforcements to such structures
 - 2. Roads and railroad tracks are displaced
 - 3. Fire - underground gas lines rupture
 - 4. Broken water pipes - no drinking water, unable to fight fires
 - 5. Landslides
 - 6. Falling debris
 - 7. Tsunamis - large waves which sweep inland and cause great damage
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F. Zones of Instability - "Circumpacific Ring of Fire"

- 1. earthquakes, mountain ranges, and volcanoes are all found in the same areas- especially around the edge of the Pacific Ocean
- 2. Volcanic Hazards
 - a. hot lava - buries cities
 - b. hot ash - buries cities
 - c. toxic or poisonous gases - suffocate people
 - d. explosive eruptions
- 2. The theory of plate tectonics accounts for this phenomenon

G. Continental Drift - the continents are moving around on the surface of the Earth - they're floating on a circulating asthenosphere - the source of heat energy for

circulating convection cells in the asthenosphere is **internal** - radiating outward from the center

Lines of evidence:

1. The outlines of the continents appear to fit together like pieces of a jig-saw puzzle
 - a. this suggests that at one time all the continents were one and later broke apart and moved to their present locations
 - b. the west coast of Africa and the east coast of South America is the best example of this
2. **Rocks on opposite sides of the Atlantic Ocean “match up” in terms of type, sequence, age, thickness, and composition**
 - a. this suggests that these widely separated rocks were, at one time, one cohesive unit that was pulled apart when Africa and S. America split
 - b. the Appalachian mountains of N. America, the Caledonian Mountains of Great Britain, and mountains on the west coast of Greenland appear to be part of one large mountain chain
3. **Fossils of the same species of plants and animals are found on widely separated continents**
 - a. this suggests that all the continents were one, plant and animal life flourished all over it and that fossils of these species were carried with the continents as they drifted apart
 - b. large deposits of coal (a fossil fuel formed from plant remains) are found in Antarctica show that it had a much warmer climate than it has now and must have been near the equator in the past
4. **Evidence of ancient glacial episodes of the same age are found on widely separated continents**
 - a. grooves, scratches, and striations match up in orientation when the continents are reassembled into one giant land mass
5. Oceanographers have shown that the age of the ocean floor grows as the distance from the center increases
 - a. this suggests that the sea floor is spreading - that huge sections of the crust are moving

H. Sea Floor Spreading

1. There is a long chain of volcanic mountains running down the middle of the Atlantic Ocean floor - called the Mid-Atlantic Ridge/Rift System (MARRS)
2. High heat flow values at MARRS suggest that convection cells are circulating in the

- asthenosphere in a manner that would bring material from the mantle **up** to the crust
3. The sea floor is spreading out **from** MARRS - the age of the floor supports this idea
 4. Molten material from the asthenosphere is oozing up through a crack (rift or tear) in the Atlantic Ocean floor - direct observations support this idea as does the high heat flow data directly above the rift
 5. Rock strips on opposite sides of MARRS match up in terms of age, width, sequence, and **magnetic polarity**
 6. New oceanic crust is “born” at MARRS while old oceanic crust “dies” at zones of subduction
 - a. it’s not unlike the conveyor belt at the checkout line of a supermarket
 - b. zone of subduction - places where pieces of moving crust collide and one piece dived down under the other to enter the mantle
 - 1) zones of subduction are commonly located at continental margins
 - 2) igneous rock produced at the edge of a melting plate accounts for contact metamorphism as the magma rises to the surface
 - 3) regional metamorphism is also common at such zones of subduction
 7. **Sea Floor Spreading** explains several other features of the ocean floor:
 - a. island arc systems - crescent shaped series of volcanic islands located near zones of subduction
 - 1) molten material from melting ocean plates rises back to the surface
 - 2) Japan and the Aleutian Islands are good examples of such systems
 - b. deep ocean trenches - at zones of subduction, when 2 oceanic plates meet they pull each other downward into the asthenosphere
 - c. zones of instability - the Pacific Ocean floor is composed of many sections - zones of subduction, earthquakes, and volcanic activity occur where these sections meet
 - l. **The Plate Tectonic Theory** - the crust of the Earth is divided into many moving sections called plates - it’s a combination of continental drift and sea floor spreading
 1. **Plate Boundaries** - the lines along which plates meet - 3 different types of plate boundaries
 - a. **converging plate boundaries** - places where 2 plates collide
 - 1) if 2 ocean plates collide, a deep ocean trench is formed
 - 2) if an ocean plate collides with a continental plate, a zone of subduction is formed
 - 3) if 2 continental plates collide, folding, faulting, and mountain

building will occur

- b. **diverging plate boundaries** - places where 2 plates pull apart
 - 1) a mid ocean ridge develops if the divergence is between ocean plates
 - 2) new ocean crust is created here
 - 3) diverging continental plates can form a rift valley
- c. **transform plate boundary** - 2 plates sliding past one another
 - 1) lateral/strike-slip faults form here
 - 2) the San Andreas Fault is a good example

Note: earthquakes, faults, volcanoes, and mountain building are all associated with plate boundaries

J. **Hot Spots** - places where plates pass over a stationary source of rising magma

Plume - the name given to the rising column of magma

- 1. The movement of a plate leads to the formation of a chain of volcanoes of differing ages
 - a. The Hawaiian Islands are the best example
- 2. Analysis of the age of the chain of volcanoes tells which direction the plate is moving and at what rate

K. **Mountain Ranges** - form in one of 3 ways

- 1. Folding - usually at a convergent plate boundary between 2 continental plates
 - a. Himalayas are an example
- 2. Faulting
 - a. Grand Tetons or the Basin & Range Province are examples
- 3. Volcanic Activity
 - a. Cascades are an example

L. **The Composition of the Earth's Interior**

- 1. The cores (outer and inner) are believed to be nickel iron mixtures
 - a. meteorite evidence - the composition of many meteorites is Fe/Ni so there must be a lot of these elements in the Solar System
 - b. density evidence - the Earth has a high overall density (5.5g/cc) yet the crust and mantle have lower densities than that
 - c. simple logic - the highest density material present at the Earth's formation would sink to the center of the body
- 2. We know the outer core is a liquid because S-waves won't pass through it
- 3. The inner core must be a solid because the pressures there preclude a liquid phase
- 4. Also, the speed at which P-waves pass through support a solid state theory