Chapter 12: Earth's Interior Study Guide

Terms to Know & Define

- **Asthenosphere**: a.k.a. the weak sphere; located in the upper mantle, beneath the lithosphere. Small amount of melting in the upper portion of it mechanically detaches it from overlying lithosphere. Also known as the low velocity zone because seismic waves slow down within the upper asthenosphere.
- **Oceanic Crust**: 3-15 km thick; consists primarily of basalt
- **Continental Crust**: 40-65 km thick; average composition of granite--lower density than basalt-->lighter (more buoyant) than oceanic crust.
- **Moho**: the boundary that separates the lower crust from the upper mantle; occurs in both continental and ocean, but shallower in the ocean. Base of the crust=the Moho, "Mohorovicic Discontinuity"
- **Seismic refraction**: the bending of seismic waves while passing through the Earth. When seismic waves encounter a boundary between materials with different properties, the energy splits into reflected and refracted waves. When the velocity increases, the refracted wave bends upward toward the boundary separating the layers. When the velocity of seismic waves decreases between layers, waves refract (bend) downward.
- **Conduction**: the transfer of heat through matter by molecular activity.
- **Geothermal gradient**: the curve showing the increase of temperature with depth; the gradual increase in temperature with depth in the crust. The average is 30 degrees celsius per kilometer in the upper crust.
- **Mantle**: the solid rocky shell that extends from the base of the crust to a depth of 2900 km
- **Outer Core**:
  - slows down P-waves
  - S-waves cannot travel through the outer core at all--the outer core stops them
    - this indicates that the outer core is liquid
- **Geoid**: a representation of the sea level and is distorted relative to a perfect spheroid formed solely by earth's rotation
  - the difference in height of the geoid, relative to the perfect spheroid, is caused by differences below Earth's surface
- (mantle) **Convection**: very important process in Earth's interior; provides the force that moves rigid lithospheric plates; the mantle transmits S-waves and at the same time flows, it is referred to as exhibiting plastic (both solid and fluid) behavior.
- **Inner core**: composed of solid iron and nickel; P- and S-waves speed up again, S-waves can travel through the inner core-->tells us that it is solid. Sphere with a radius of 3486 km; stronger than the outer core (b/c of the way it transforms S & P waves); behaves like a solid. Seems to be rotating a little faster than the rest of the planet--slight variations in travel times of seismic waves through the core as measured over many decades.
- **Magnetic field**: liquid iron in the outer core is stirred into convective motion by Earth's internal heat; circulation of liquid iron in outer core produces electric currents; these electric currents, in turn, generate the earth's magnetic field.
  - Earth's rotation-->spiral flow in the liquid outer core aligns with spin axis; electrically charged spiral flow generates Earth's magnetic field.
- **Shadow zones**:
  - P-wave shadow zone: 100 degree --> 140 degree quadrant; seismic stations will not record many P waves if at all in shadow zones because of the refraction in the P-wave shadow zone
  - S-wave shadow zone: 100 degree --> 100 degree; b/c S-waves cannot travel through the outer core, the S-wave shadow zone is much larger than the P-wave shadow zone
- **Core**:
  - **outer core**: composed mostly of an iron-nickel alloy; liquid layer; 2270 km thick; convective flow w/in it generates Earth's magnetic field
    - P waves slow down, but still pass through
    - S-waves cannot pass through it.
  - **inner core**: sphere w/ a radius of 3486 km; stronger than the outer core (b/c of the way it transforms s and p waves); behaves like a solid
- **Lithosphere** (sphere of rock): earth's outermost layer; consists of the crust and uppermost solid mantle; relatively cool rigid shell; average 100 km in thickness, but may be 250 km or more thick beneath the older

portion of the continents

- **Mesosphere** (a.k.a. lower mantle): rigid layer between depths of 660 km and 2900km; rocks are very hot and capable of very gradual flow
- Seismic reflection: the redirection of some waves back to the surface when seismic waves hit a boundary b/t different Earth minerals.
  - reflected seismic waves are used in the search for underground oil and gas reserves
- **D'' layer**: comprises the bottom few hundred km of the lower mantle, just above the outer core; recognized because of the changing velocities of both P- and S-waves ; exhibits large horizontal variations in both temperature and composition; possible graveyard of subducted oceanic lithosphere; birthplace of some mantle plume

Concepts to Know

1. ***How do the velocities of P- and S-waves change with depth in passing through the following layers:***
   1. Crust: considerably slower rates of velocities in the crust; which can reveal the thickness of Earth's crust. The crossover point of where the direct wave no longer reaches a seismograph station more quickly than the refracted wave can be used to determine/calculate the overall crustal thickness in this particular region.
   2. Asthenosphere: the low velocity zone b/c seismic waves slow down within the upper asthenosphere. This is because the upper asthenosphere consists of peridotite and contains a few % partial melt, but not engouh to completely stop S-waves.
   3. Transition Zones: there are two transition zones marked by increases in seismic wave velocities
      1. at 400 km depth: olivine changes to the spiral crystal structure of increased density
      2. at 660 km depth: spinel transforms into the higher density perovskite crystal structure; this transition zone makes the base of the upper mantle and top of the lower mantle
   4. Lower Mantle (a.k.a. mesosphere): velocities of S- and P-waves increase with depth in the lower mantle
   5. Outer Core:
      1. Slows down P-waves
      2. Stops S-wave--they cannot travel through the outercore (indicating that the outercore is liquid)
   6. Inner Core: S-waves travel in the inner core suggesting that it is solid b/c S-waves are an indication of how rigid (stiff) the material is) They travel at about 4 km/sec while P-waves travel a little faster than they do in the outer core (10 km/sec vs. 11 km/sec)
2. ***What is seismic refraction? Why do seismic rays bend outward with depth in the mantle?***
   1. Seismic refraction is the bending of seismic waves while passing through the earth (e.g., the refraction of a beam of light through a fish bowl)
   2. Seismic rays bend outward with depth in the mantle because when the velocity of seismic waves increases as they pass from layer to layer, it will result in the wave bending toward the boundary separating the layer (and velocity usually increases w/ depth into Earth's interior)
3. ***What is seismic reflection?***
   1. When a seismic wave hits a boundary such as the one between the crust and the mantle and part of the energy is reflected back to the surface instead of refracted (bent) through passing through the boundary into the next layer.
4. ***What causes P-wave and S-wave shadow zones? Which is wider and why?***
   1. The bending of P-waves in the outer core creates the P-wave shadow zone (quadrant 100 degrees to 140 degrees away from hypocenter of earthquake)
   2. The S-wave shadow zone is MUCH wider because S-waves cannot pass through the outer core (100 degrees to 100 degrees on the other side of the earth from where the hypocenter of EQ)
5. ***How does continental crust differ from oceanic crust in terms of composition and thickness?***
   1. continental crust is thicker (40-65 km thick) than oceanic crust (3-15 km thick). continental crust's composition is more buoyant because the average composition is granite, versus oceanic crust which is primarily basalt (basalt is more dense a material than granite)
6. ***What is the Moho and where does it occur?***
   1. The moho is short for Mohorovičić discontinuity, study concluded that at about 50 km depth there was a change in physical properties that marked the base of the crust--the moho is defined as the base of the crust.

7. ***Where is the asthenosphere? How do S-waves behave when passing through the asthenosphere? What does the behavior of S-waves tell us about the asthenosphere?***
    1. The asthenosphere is just below the lithosphere. Also known as the low velocity zone b/c seismic waves slow down within the upper asthenosphere. The behavior of S-waves tells us that the asthenosphere does not contain enough partial melt (liquid) to completely stop S-waves, and that it is a mostly solid (made of peridotite) layer
8. ***What is the composition of the mantle? How do P- and S-waves generally behave when traveling deeper into the mantle?***
    1. the mesosphere is the lower mantle. it is a rigid layer b/t the depths of 660 km and 2900 km. rocks are very hot here and capable of gradual flow. P- and S-waves velocities' generally increase with depth in the lower mantle (also, 660 km marks one of the transition zones where increased velocity of seismic waves occurs, so that makes sense)
9. ***Why do seismic waves speed up within the 400 km and 670 km transition zones?***
    1. at 400 km depth, olivine changes to the spinel crystal structure of higher density
    2. at 660 km depth, spinel changes to the higher density perovskite crystal structure
        1. this means that seismic waves travel faster through higher density materials. (duh, thats why s-waves don't even exist in the outer core, which is made of liquid)
10. ***Where is the D'' layer? What are its characteristics?***
    1. The D'' layer comprises the bottom few hundred km of the lower mantle, just above the outer core
    2. exhibits large horizontal variations in both temperature and composition
        1. possible graveyard of subducted oceanic lithosphere
        2. birthplace of some mantle plumes
11. ***What is the composition of the outer core? How does the velocity of P-waves change when entering the outer core? What happens to S-waves in the outer core?***
    1. outer core composed mostly of an iron-nickel alloy; when P-waves enter the outer core they are slowed down; S-waves are stopped by the outer core and cannot travel through them b/c it is a liquid layer.
12. ***What is the composition of the inner core?***
    1. solid iron with trace amounts of other elements (lecture says solid iron and nickel composition)
13. ***What produces earth's magnetic field? Do the geographic poles coincide with the magnetic poles?***
    1. As iron-rich fluid in the outer core rises, its path becomes twisted because of Earth's rotation. As a result, the fluid moves in spiraling columns that align with Earth's axis of rotation. Because the iron-rich fluid is electrically charged and flowing, it generates a magnetic field--a phenomenon called a geodynamo.
        1. put simply: earth's rotation creates a spiral flow in the liquid outer core aligns with spin axis, and the electrically charged spiral flow generates Earth's magnetic field.
    2. NO; magnetic poles are inclined at an angle to Earth's geographic poles
        1. magnetic lines of force exit @ magnetic South Pole and enter again at magnetic North Pole; magnetic lines of force parallel with Earth's surface @ equator.
14. ***What is the geothermal gradient? List three processes that have contributed to Earth's Internal heat.***
    1. The geothermal gradient is earth's temperature gradually increases w/ depth @ a rate. This rate varies considerably rom place to place, average b/t 20 degrees celsius and 30 degrees celsius per km in the crust. The rate of increase of heat w/ depth is significantly less in the mantle and core.
    2. Three processes that have contributed to Earth's internal heat:
        1. heat released by colliding particles during the formation of Earth 4.5 billion years ago
        2. heat released as iron crystallized to form the solid inner core of early Earth
        3. heat emitted by radioactive decay of isotopes
15. ***Describe the process of conduction. Which of Earth's layers transfers heat mainly by conduction?***
    1. Conduction is the flow of heat *through a material*. It conducts in two ways: 1. through the collisions of atoms and 2. through the flow of electrons. Most rocks are poor conductors of heat, so conduction would not work in these areas. However, it is an important mechanism in places such as the lithosphere, the D'' layer, and the core.
16. ***Describe mantle convection and how this process transports heat through the mantle***
    1. Mantle convection is the transfer of heat in a fluid-like manner where hot materials displace cooler materials