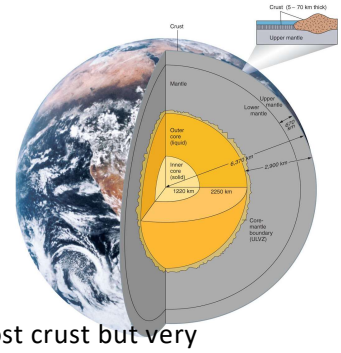
Chapter Outlines

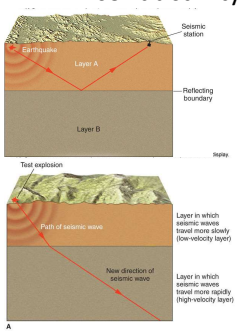


NOTE: This is intended to help students 'organize' their understanding of each topic. It is <u>not</u> a comprehensive study guide for quizzes or midterms, i.e. <u>study your text!</u>

Earth's Interior

The rocks that can be studied on the earth's surface tell us much about the earth's uppermost crust but very little about the other 99 percent of the planet. Drilling has reached a maximum depth of about 12 kilometers. Samples of rock from the deeper crust and mantle are sometimes included as xenoliths in deep-seated intrusives that moved along structural zones to the surface. Rare segments of ultramafic rocks in complex tectonic settings at Earth's surface are thought to have originated from the lower crust or upper mantle.

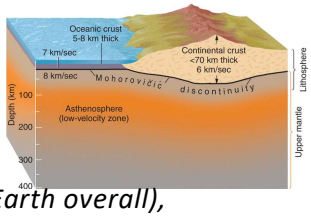
Fortunately, the field of **geophysics**—the application of the laws of physics to the dynamics of the earth—provides compelling data that allow us to interpret how the inner earth is constructed. The principal characteristics that geophysicists study are seismic waves, gravity, heat flow, magnetism, and electrical conductivity. When integrated, the data allow us to construct a realistic picture of how the inner earth works.



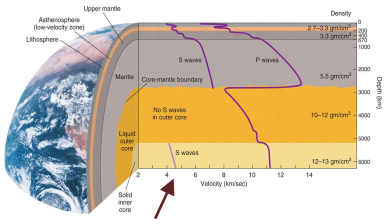
Changes in density affect seismic waves

- **<u>Seismic Waves</u>**
  - Vibrations ***(seismic waves)*** from large earthquakes *(or underground nuclear tests)* will pass through the entire Earth.
  - **Seismic reflection** – when a seismic wave encounters a sharp boundary between rock layers, some of the energy from the waves will reflect back to Earth's surface.
  - **Seismic refraction** – seismic waves will bend and change direction whenever they pass from one material to another having different densities.

Upper mantle & crust

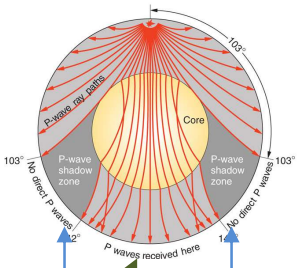


- **<u>The Structure of the Earth</u>** – seismic waves have been used to determine there are three main zones within the Earth:
  - The **Crust** – is the outer layer, an extremely thin skin *(when compared to Earth overall),* brittle, and relatively cold. Seismic wave studies indicate crust is thinner beneath the oceans than the continents. Ocean crust is ***mafic*** gabbro *(7 km/sec seismic velocity),* while continental is mostly ***felsic*** granite *(≈ 6 km/sec seismic velocity).*
    - The **Mantle** – is a thick shell of dense rock. Seismic waves indicate it is solid with only isolated pockets of magma. It mostly has the properties of rock, but don't think of it as rock you know on the surface, but rather as a very thick and viscous material that will flow rather than break *(but still a 'solid').* Higher seismic velocities *(8 km/sec)* indicate it is denser, ***ultramafic***, than crustal rock. The crust and upper mantle together form the ***lithosphere***, the brittle outer shell of Earth that makes up the tectonic plates *(70 km beneath oceans and 125-250 km beneath continents).* Beneath the lithosphere, seismic wave speeds abruptly decrease in a 'plastic' low-velocity zone called the ***asthenosphere.***



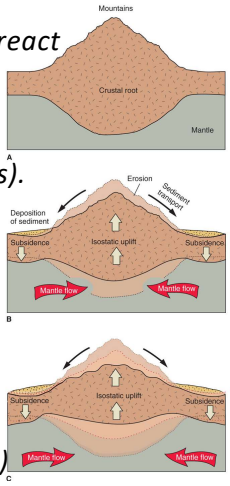
Graph of seismic velocities within Earth

  - The **Core** - is the metallic central zone of the Earth. Specific areas on the opposite side of Earth from large earthquakes do not receive seismic waves, resulting in 'seismic shadow zones'. The **S-wave shadow zone** can be explained by a liquid outer core *(S-wave can't travel through liquid).* Careful observation of P-wave refraction and the **P-wave shadow zone** can be explained by the presence of a solid inner core. Core density can be inferred by:
    - Calculations of mass based on Earth's gravitational pull on other bodies
    - Physical and electro-magnetic properties
    - The composition of iron meteorites. These are thought to remain from the formation of the solar system.



P-wave shadows and S-wave shadow

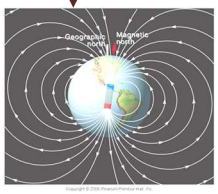
- Core-mantle boundary is marked by great changes in seismic velocity, density, and temperature *(the core being much hotter). The core may melt lowermost mantle or react chemically to form iron silicates in this seismic wave* ***ultralow-velocity zone.***



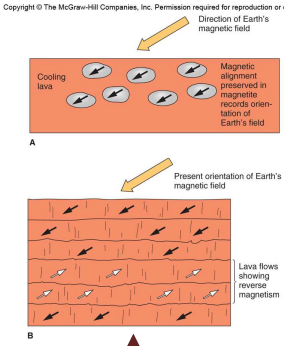
Isostacy - A mountain adjusts vertically as erosion progresses

- **Isostacy** – equilibrium of adjacent blocks of brittle crust 'floating' on upper mantle
  - Thicker blocks of lower density crust have deeper **'roots'** and float higher *(as mountains).*
  - **Isostatic adjustment** – rising or sinking of crustal blocks to achieve **isostatic balance**
    - Crust will rise when large mass is rapidly removed from the surface, as at the end of ice ages. This post-glacial adjustment is called **crustal rebound.**

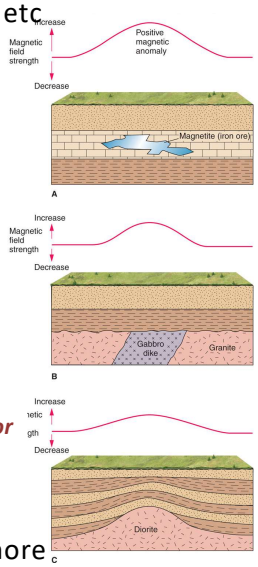
Earth's magnetic field



- **Magnetic Fields** – a magnetic field surrounds Earth.
  - The field has north and south magnetic poles.
  - This field is what a compass detects *(used by sailors for many hundreds of years)*
  - This field is recorded permanently in igneous rock at the moment they cool below the **Curie Point**.
  - **Magnetic reversals** – Earth's north and south poles have switched positions on a regular basis throughout Earth history. The last reversal occurred prior to human understanding of the magnetic field. The next switch could come at any time *(one more thing to worry about?!)*
  - **Paleomagnetism** – the study of ancient magnetic fields, is used for reconstruction of tectonic plate motion over time.
  - **Magnetic anomalies** – sensitive measurement *(measured by a* ***magnetometer****)* of variations in the magnetic field can indicate subsurface metallic ore deposits, etc.



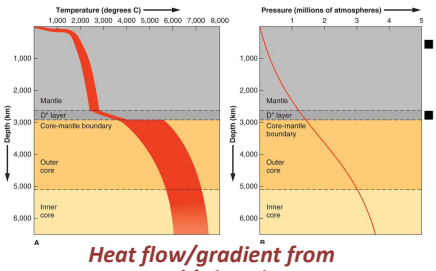
Tiny particles of iron in solidified beds of lava line up with the current (past) magnetic field before solidification



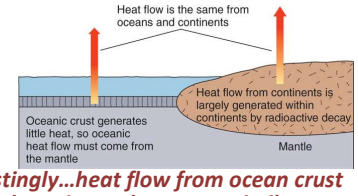
Gravity measurements for underground investigations

- **Gravity** – the force between two objects determined by their masses and the distance between them. Tiny changes in gravity across Earth's surface can be an indication of what lies beneath Earth's surface. These can be measured using a **gravity meter.**
  - **Positive gravity anomaly** *(higher gravity)* – denser materials, metallic ore bodies, mafic rocks.
  - **Negative gravity anomaly** *(lower gravity)* – less dense materials, caves, water, magma, sediments, felsic rocks.

- **Geothermal Gradient** – temperature increases with depth into the Earth.
  - A steep gradient exists from Earth's surface to the asthenosphere, then it is a more gradual gradient. This increase in T° produces little melt except in the outer core - due to the associated steady increase in confining pressure.
  - **Heat flow** is the gradual loss of heat through Earth's surface.
    - **Earth's heat source** is from both the original heat of formation *(accretion and compression)* and ongoing radioactive decay.
    - Outward heat flow through the surface is locally higher where magma is near the surface.
    - Outward heat flow is roughly equal through the thinner oceanic crust and the thicker continental crust. This is likely due to a radioactive decay heat source spread throughout continental rock.



Heat flow/gradient from Earth's interior



Interestingly…heat flow from ocean crust and continental crust are similar