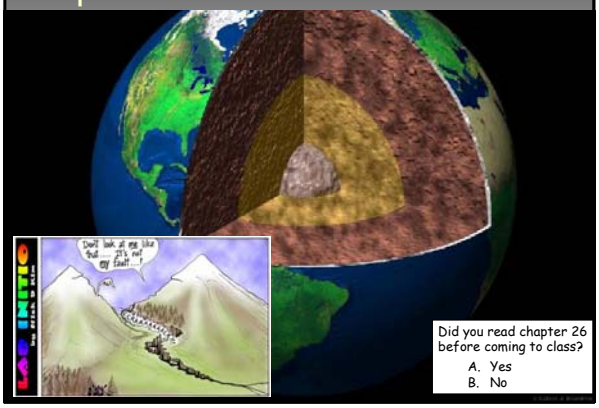
Chapter 26: Earth's Interior



The Interior of the Earth

- The main features of the earth's surface are continents and ocean basins.
- What are the main features of the earth's interior?
- How did we find out what these features are?

The difference between science and "not science"

How do we know anything about the Earth's Interior?

- Direct Observations
- Inferences from Meteorites
- Evidences from Earth's Mass & Density
- Evidences from Seismology
- Evidences from Earth's Magnetic Field

Digging a hole where people can go: a mine

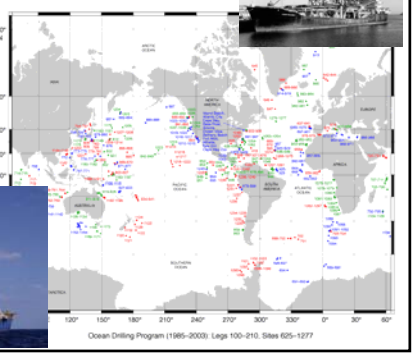
- The East Rand Mine is the world's deepest mine, 3585m (2.2 miles) below surface

1933, ½ mile

2005, ~2 miles

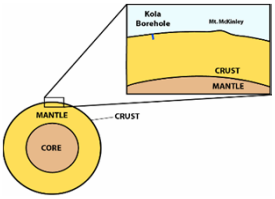
Drilling a Hole

Ocean Drilling Program
- Deepest hole penetrated
  - 2,111 m (1.31 mi)
  - E Pacific Ocean
- Shallowest water depth
  - 37.5 m (123 ft)
  - NW Pacific Ocean
- Greatest water depth
  - 5,980 m (3.72 mi)
  - W Pacific Ocean

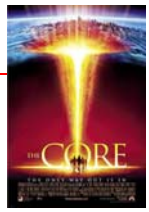


Drilling a hole

- The deepest hole drilled was in the Kola Peninsula in Russia, with a total depth of 12.26 km.



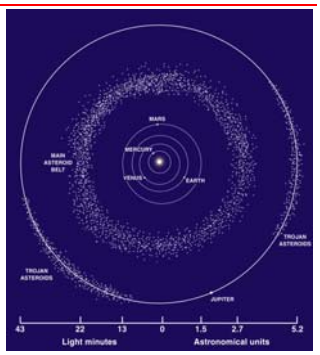
Direct Observations



- Inclusions in Volcanic Eruptions
  - Pieces of rock from deep in the Earth are brought up in magma as it rises to the surface

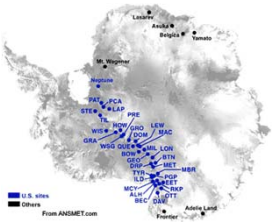
What is a Meteorite?

- **Meteorite:** - chunk of rock from space that lands on earth. ("shooting star")
- Many are from the asteroid belt, which is thought to be composed of the same material that the rocky planets are made of.



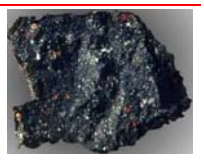
Where do you go to find meteorite?

- Antarctica



Types of Meteorites

- Stony Chondrite
  - From undifferentiated bodies

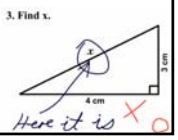


- Iron
  - From differentiated bodies

- Stony Achondrite
  - From differentiated bodies

Weighing the earth

- **Determining the mass of the Earth**
  - $F = GmM/d^2$
    - What is this equation?
    - What do 'm' and 'M' represent?
  - $F = ma$
    - How could we use these two equations to determine the mass of the Earth?
- The force accelerating objects in freefall (e.g. the Moon) is gravity!



Weighing the earth

$F = GmM/d^2$

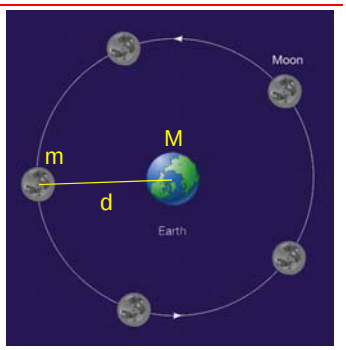
$F = ma$

$F = F$, so

$M_{Earth} = ad^2/G$

Since we know how the moon accelerates and how far away it is, we can find the mass of the earth

$M_{Earth} = 6 \times 10^{24}$ kg

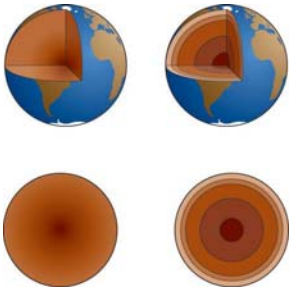


Evidences from Earth's Mass & Density

- **The mass of the earth is $6x10^{24}$ kg**
- **The volume of the earth is $1.1x10^{21}$ m^3**
- **Density of overall Earth is 5.5 g/cm^3**
  - Granite has a density of ~2.7 g/cm^3
    - Continental Crust
  - Basalt has a density of ~3.0 g/cm^3
    - Oceanic Crust
  - Peridotite has a density of ~3.3 g/cm^3
    - This represents the rocks from the Upper Mantle
- **So, what does this tell us about the Earth's Interior?**

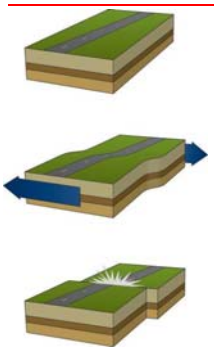
From density alone can we tell which of the models below is correct?

Gradually increasing density model



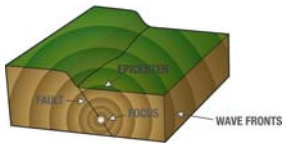
Layered density model

Evidences from Seismology

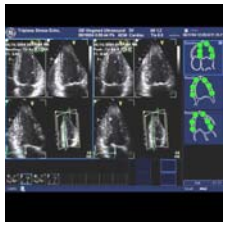


Elastic Rebound

Earthquakes produce waves, called seismic waves

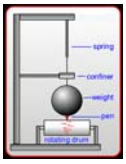


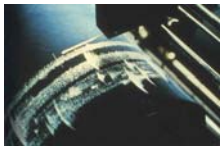
How can listening to vibrations tell us about interior of an object?



Listening to the earth

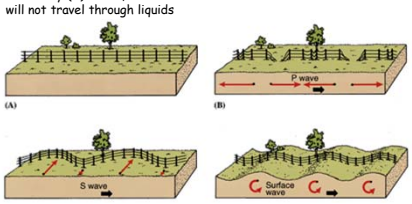
- In the early 1950's sensitive devices were developed to monitor nuclear bomb testing and stations were set up around the world to detect explosions.
- The devices also monitor earthquakes and have given us a great deal of information about the earth's interior.



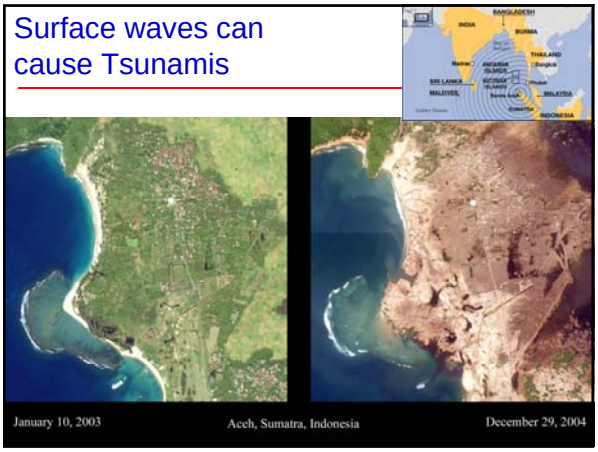


Types of Waves

- Surface waves
  - cause most of the damage and destruction
- Volume waves
  - compression waves
    - primary (P) waves, arrive first
    - travel through solids and liquids
  - shear waves
    - secondary (S) waves, arrive second
    - will not travel through liquids



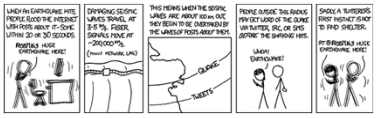
Surface waves can cause Tsunamis



Japan 2011

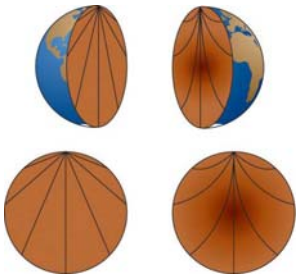
Speed of Seismic Waves

- P faster than S
- Speed generally increases with depth, except
  - Mohorovicic discontinuity (~30 km)
  - Mantle / core boundary
- Speed constant in inner core



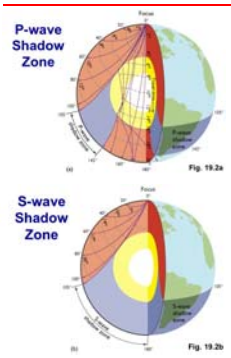
How would seismic waves travel through the different Earth density models?

Uniform density model



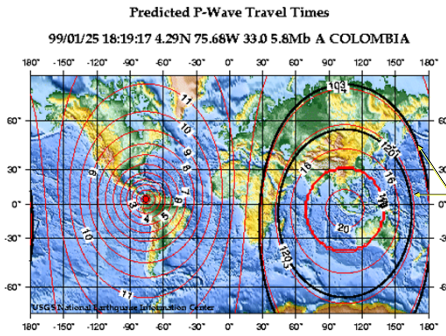
Gradually increasing density model

Shadow Zones



- **P Waves**
  - Waves change speed abruptly when they transition from solid to liquid
  - This causes bending (refraction)
  - Refraction makes it impossible for waves to arrive in the shadow zone
  - Resulting shadow zone is doughnut-shaped
- **S Waves**
  - S waves cannot travel through the core
  - Resulting shadow zone is bowl-shaped
  - Implies core is liquid

A Real Shadow Zone



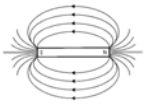
Shadow zone between the dark ovals

Evidences from Earth's Magnetic Field

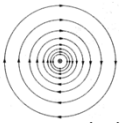
- Earth has a strong magnetic field
  - Problem: Solid Iron loses its magnetism at ~770°C
  - Interior reaches that temperature at a depth of only 25-50 km
  - The iron core starts at a depth of ~2900 km and the temperature ~4000°C
- Is it likely that the Earth has a solid, magnetized core?
- How else can the magnetism be produced?

Ways to make a magnet

1. Iron and nickel atoms in certain arrangements

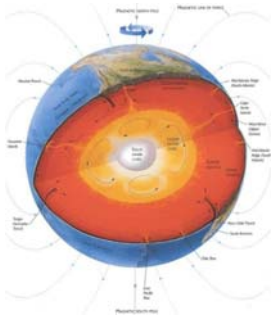


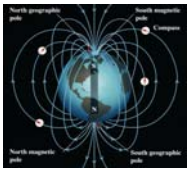
2. Electric currents



3. Move a neutral metal in a pre-existing magnetic field. This creates a current, and this electric current creates the magnetic field

Earth as a magnet: A self exciting dynamo

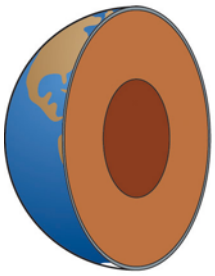


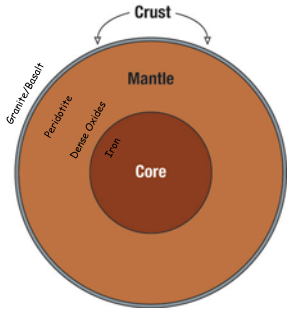


So what do we conclude?

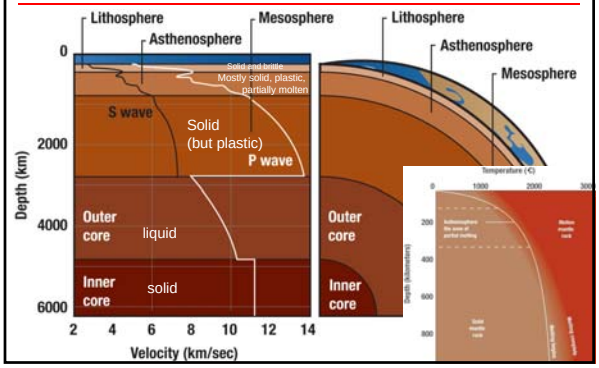
- Earth is Layered
  - Compositional Layers
    - Core – made of Iron
    - Mantle – made of Peridotite
    - Crust – made of granite & basalt
  - Mechanical Layers
    - Inner Core – Solid
    - Outer Core – Liquid
    - Mesosphere – Solid, but plastic
    - Asthenosphere – Mostly solid, plastic, 1-6% liquid
    - Lithosphere – Solid, brittle

Compositional Layers





Mechanical Layers



Secondary (shear) seismic waves will not propagate through the outer core. This is convincing evidence that the outer core is

a) Molten or liquid
b) Metallic
c) Composed primarily of oxides, silicates, and other minerals
d) Exactly located at the center of the earth
e) Very dense

Seismic wave speeds generally increase with depth, but at a specific depth called the Mohorovicic discontinuity there is a sharp drop in speed. This is evidence that:

a) The chemical composition of the crust changes at this depth
b) The density of the crust changes sharply at this depth
c) The pressure changes sharply at this depth
d) The temperature and pressure at this depth allows partial melting of the minerals