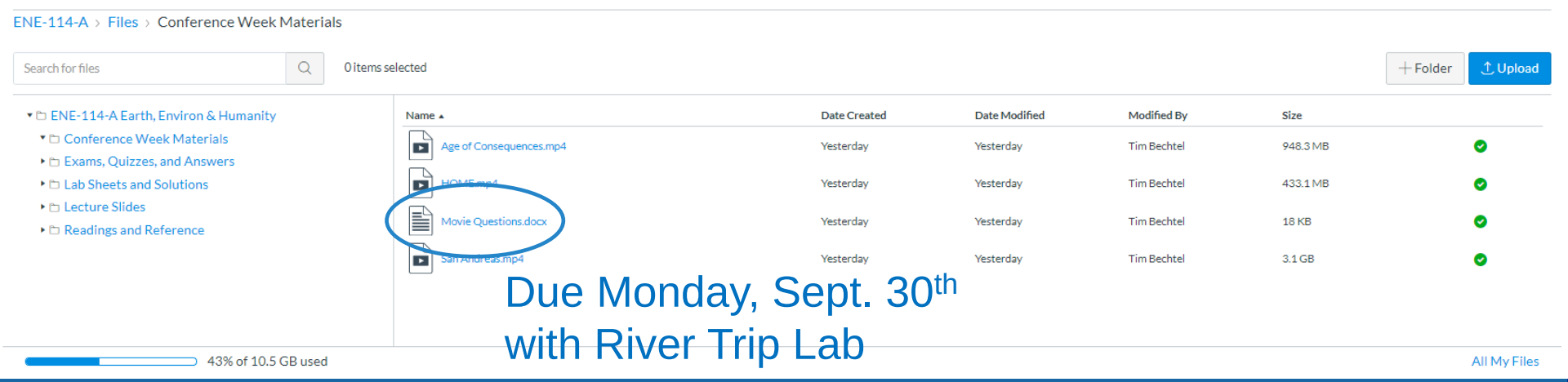
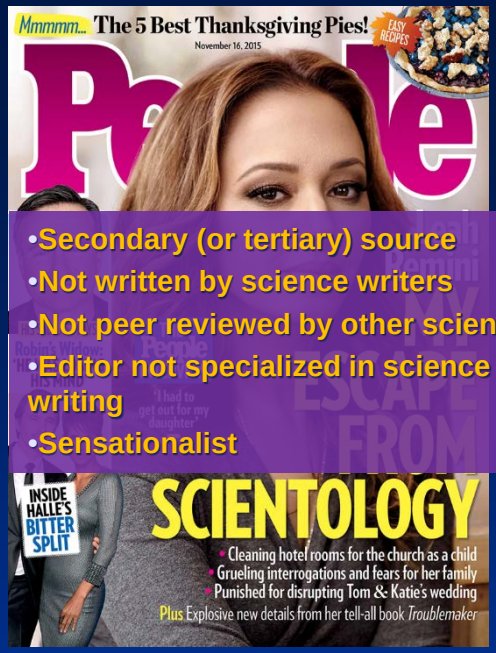
No Class or Lab Next Week

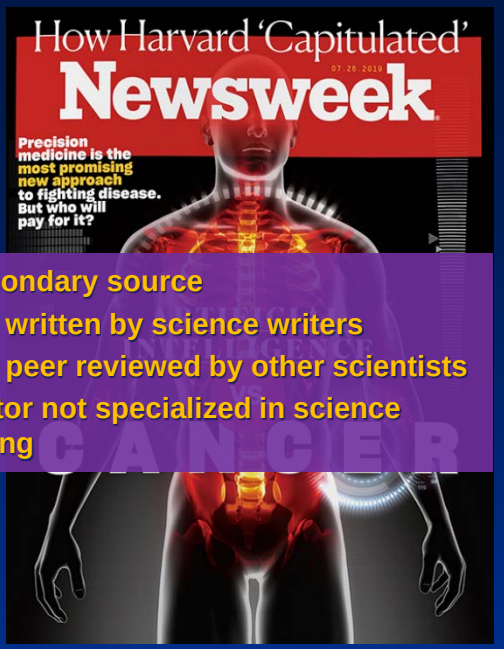


Due Monday, Sept. 30th with River Trip Lab

- Primary source
- Written by scientists
- Not peer reviewed by other scientists
- Editor specializes in science writing



- Secondary (or tertiary) source
- Not written by science writers
- Not peer reviewed by other scientists
- Editor not specialized in science writing
- Sensationalist



- Secondary source
- Not written by science writers
- Not peer reviewed by other scientists
- Editor not specialized in science writing

- Not a source
- Who the F writes this stuff?
- Does anyone review?
- Editor probably just wants sales
- Absurdly sensationalist

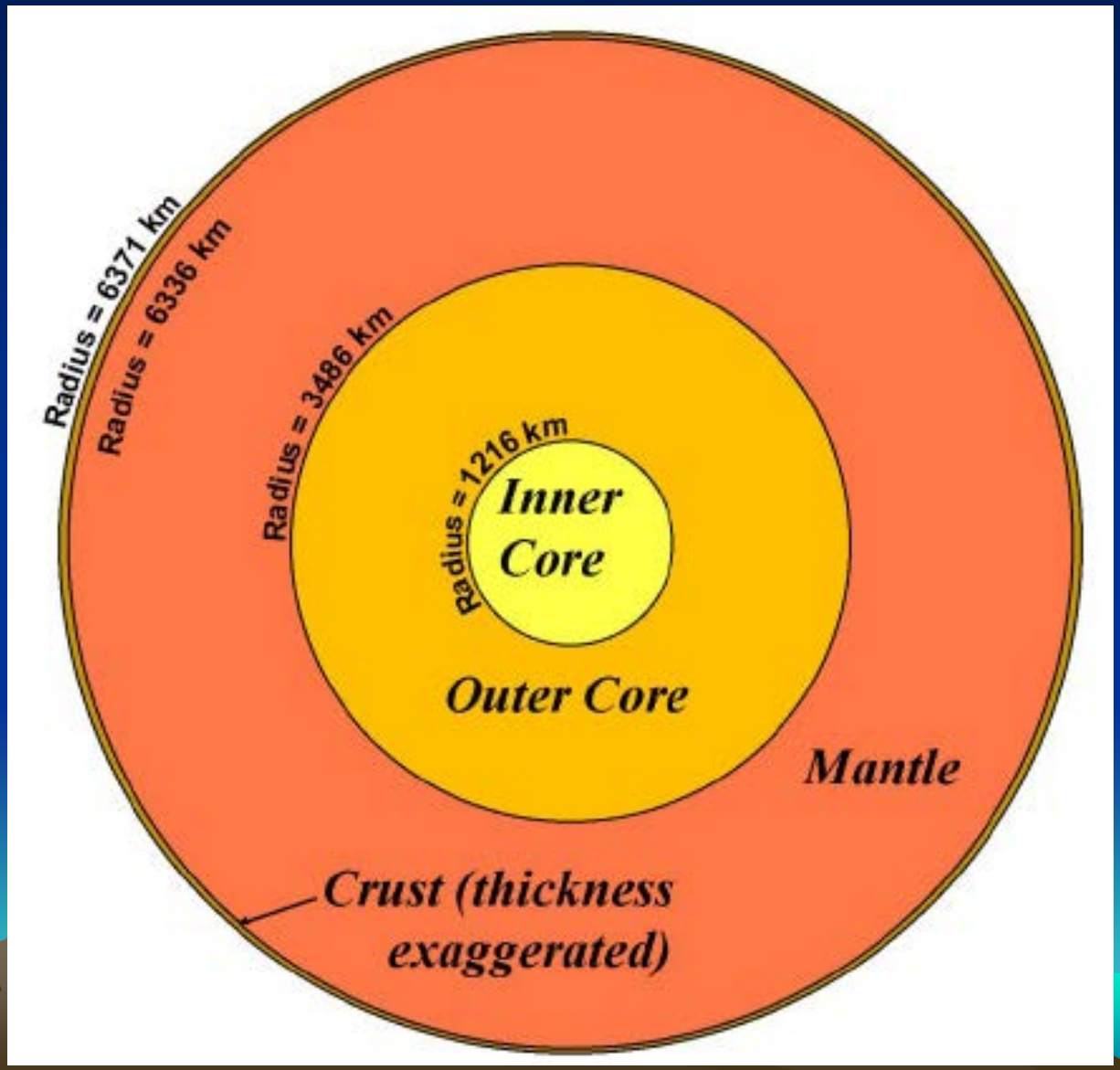
- Primary source
- Written by scientists
- Peer reviewed by other scientists in the field
- Editor is a scientist in the field

- Secondary source
- Written by science writers
- Not peer reviewed by other scientists
- Editor specializes in science writing

Journey to the Center of the Earth

Apologies and/or thanks to Jules Verne, Larry Braile, Mike Wysession, Bruce Bolt, and many others…

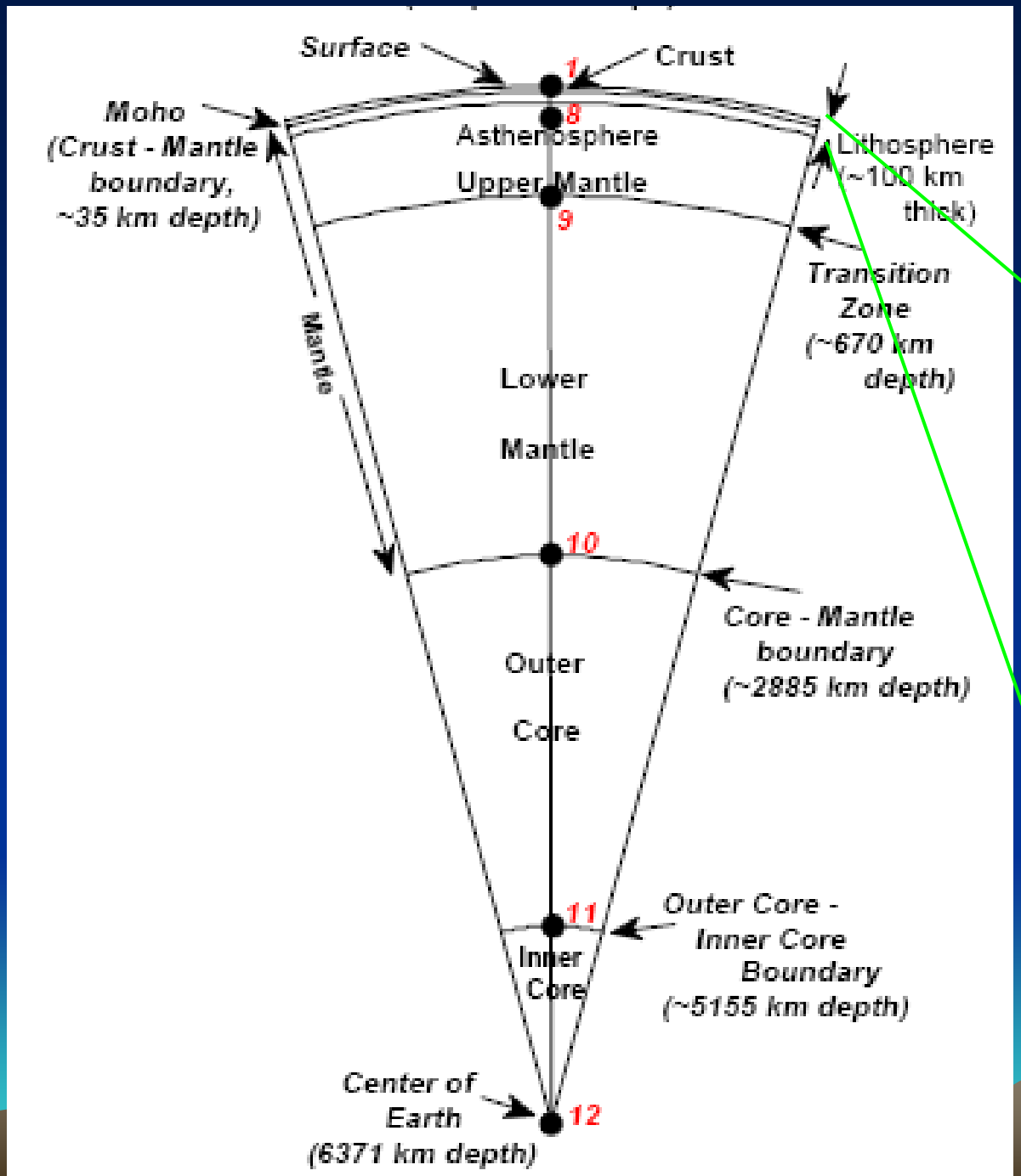
Typical Depiction

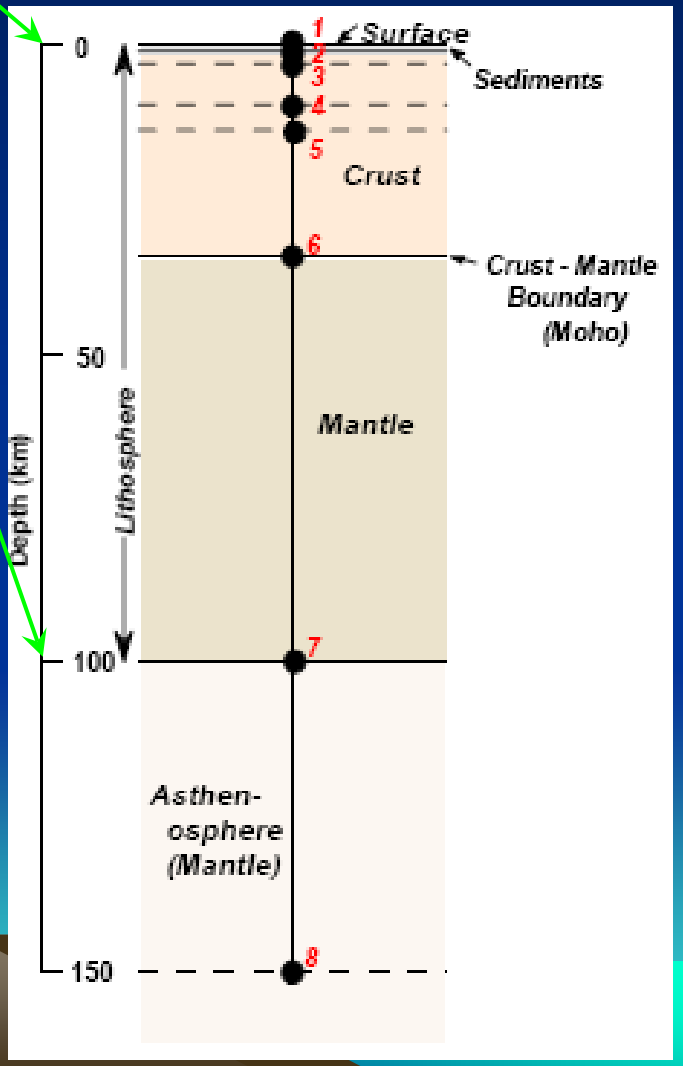


But Let's Start Higher

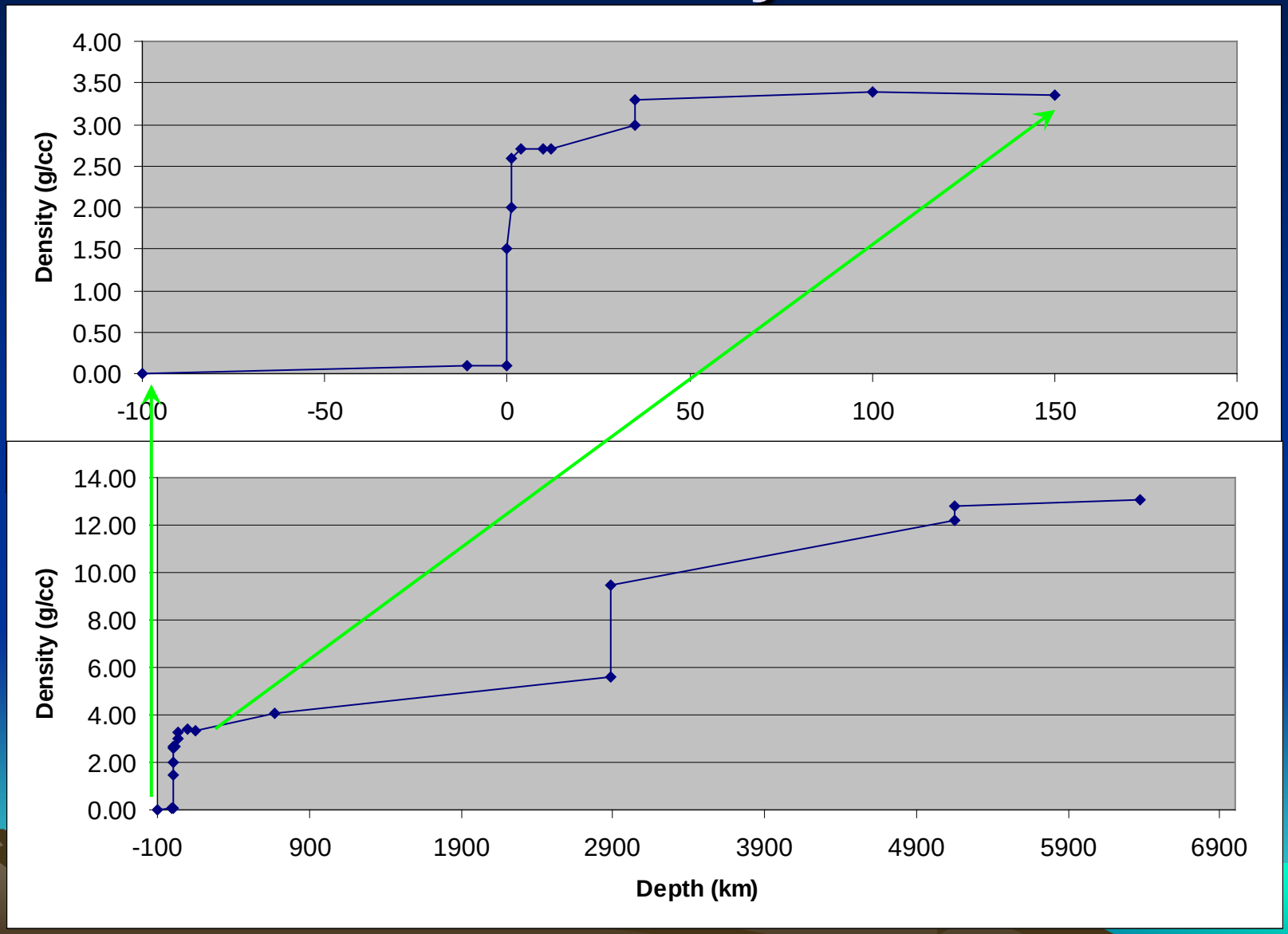
- Atmosphere
  - "Top" is hard to define
  - Karman Line is where re-entry heating is dramatic (100 km)
  - But, 75% of the mass of the atmosphere lies below 11 km
  - "Dry" air is 78% Nitrogen, 21% Oxygen, 1% Argon, 0.04% Carbon Dioxide, and traces of others (methane, nitrous oxide, ozone, sulfur dioxide, etc.)
  - Some of these are "pollutants" (depending on their source, concentration, and height…e.g. CO_2, O_3, etc.)
  - Water vapor is variable, but usually less than 1%

Interesting Spots

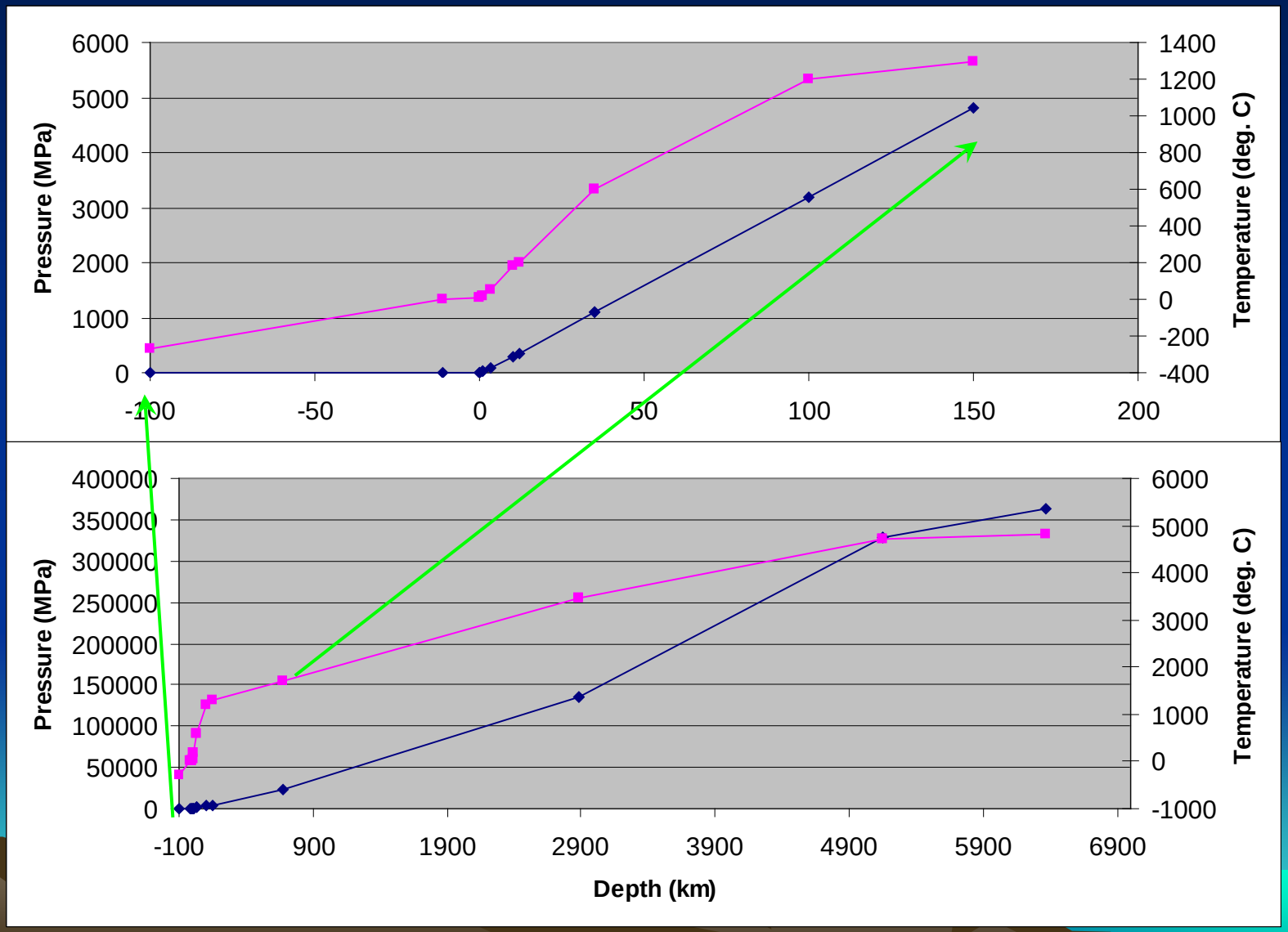




Density


4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Density (g/cc)
-100
-50
0
50
100
150
200
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Density (g/cc)
-100
900
1900
2900
3900
4900
5900
6900
Depth (km)

Pressure and Temperature



Begin Tangent 1

Pressure

- MPa = MegaPascal
  - Mega=$1x10^6$=one million
  - 1 MPa=$10Kg/cm^2$=$140lbs/in^2$ (psi)
  - 14 psi=1 atmospheres (atm)
  - So, 1 atm (***feel it!***) is 0.1 MPa
  - Car tires are usually at about 35 psi

$$35psi * \frac{1atm}{14psi} = 2.5atm$$

$$35psi * \frac{1MPa}{140psi} = 0.25MPa$$

Temperature

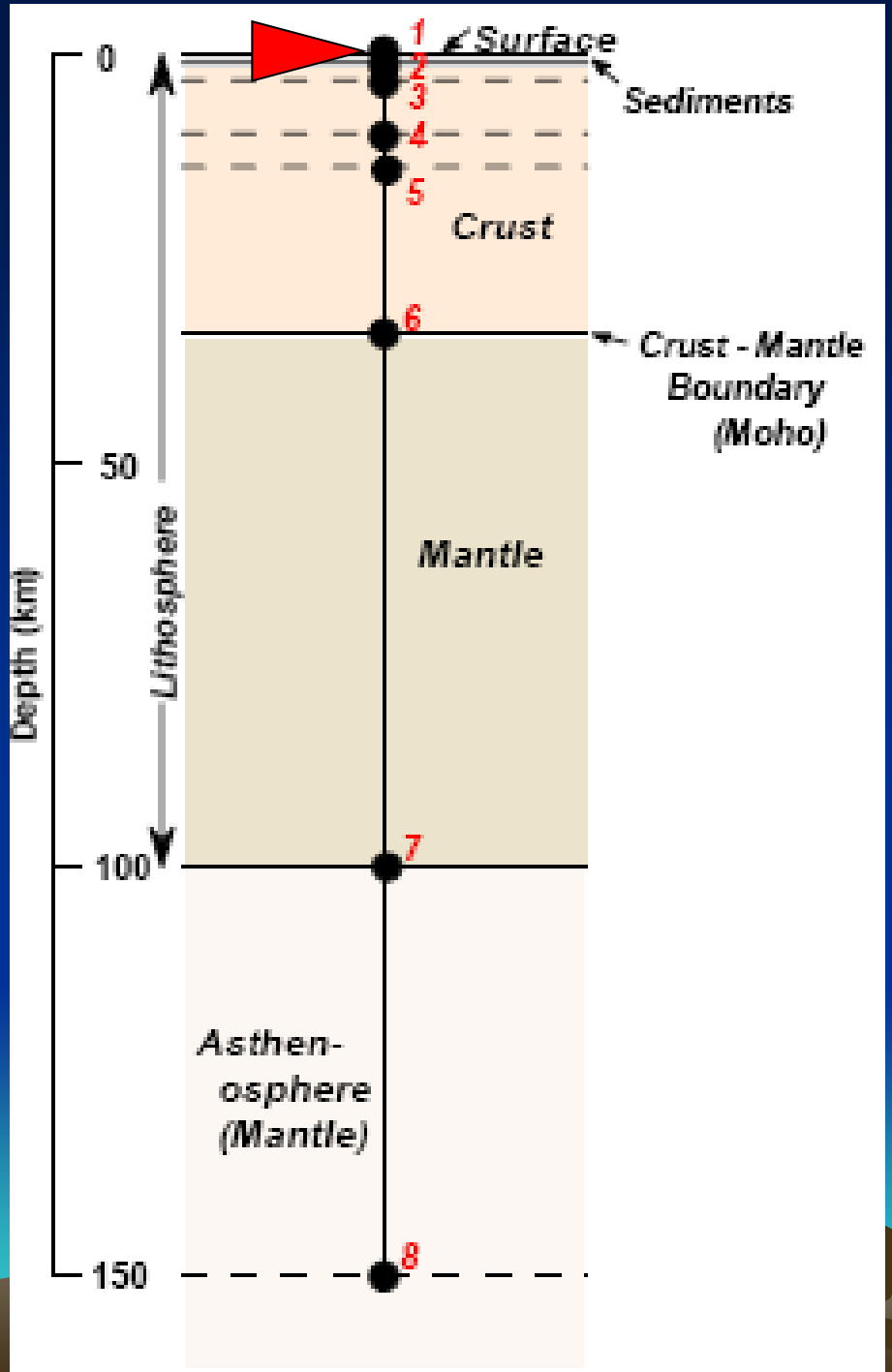
- Heat = amount of energy in a system
  - Produces atomic vibration
- Temperature = average level of atomic vibration
  - Rising heat generally causes rising vibration or T
  - Rising pressure also cause rising T (atomic collisions)
  - For gasses; PV=nRT (Boyle's Law)
- But, the amount of heat (energy) required to raise the temperature of an object by a certain amount is a physical property (like R for gasses)
  - Heat Capacity or Thermal Inertia

Heat Transfer

- Conduction
  - Think frying pan
- Convection
  - Think hair dryer
- Radiation
  - Think sun or heat lamp

Heat vs. Temperature Check for Understanding

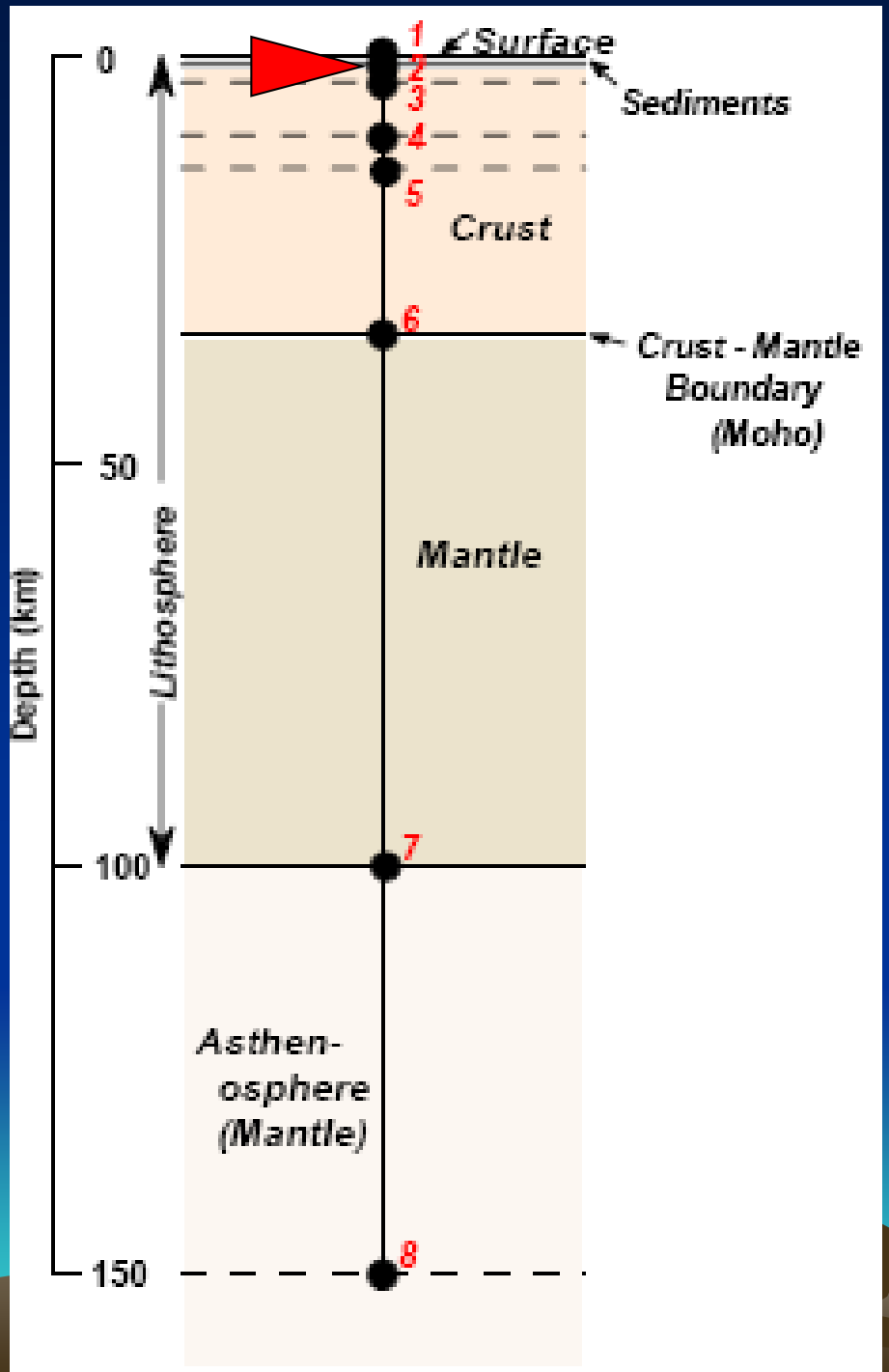
End Tangent 1



Spot 1

The surface (0 km):

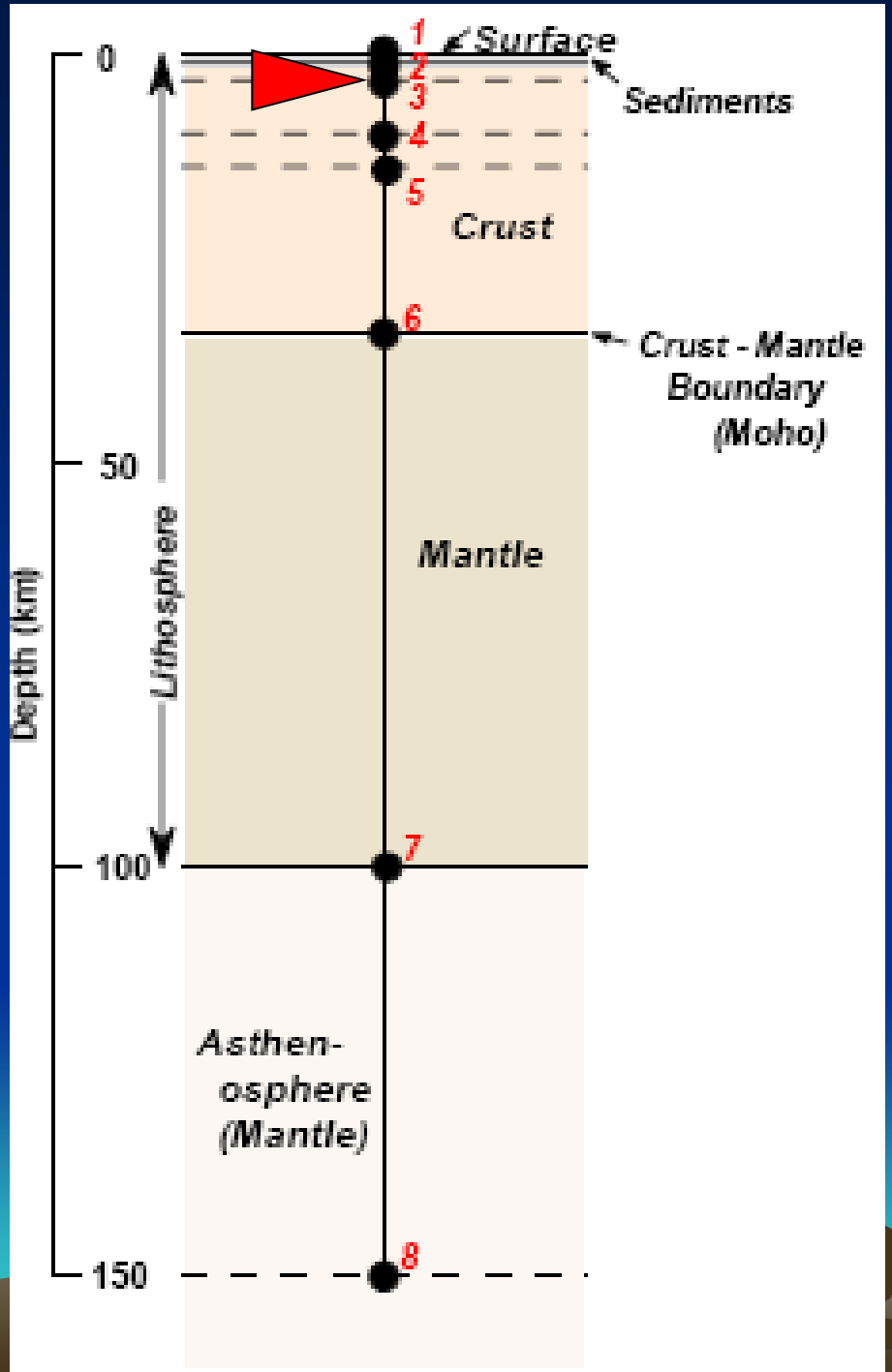
- Different stuff in different places
  - Soil (sand, gravel, muck, etc.)
  - Sedimentary Rock
  - Extrusive Volcanic Rock (lava)
  - Water
- Two types of crust:
  - Oceanic
  - Continental
- For this exercise, we will start on a continent
- Above us is the atmosphere



Spot 2

The Top of “Basement” (~1 km):

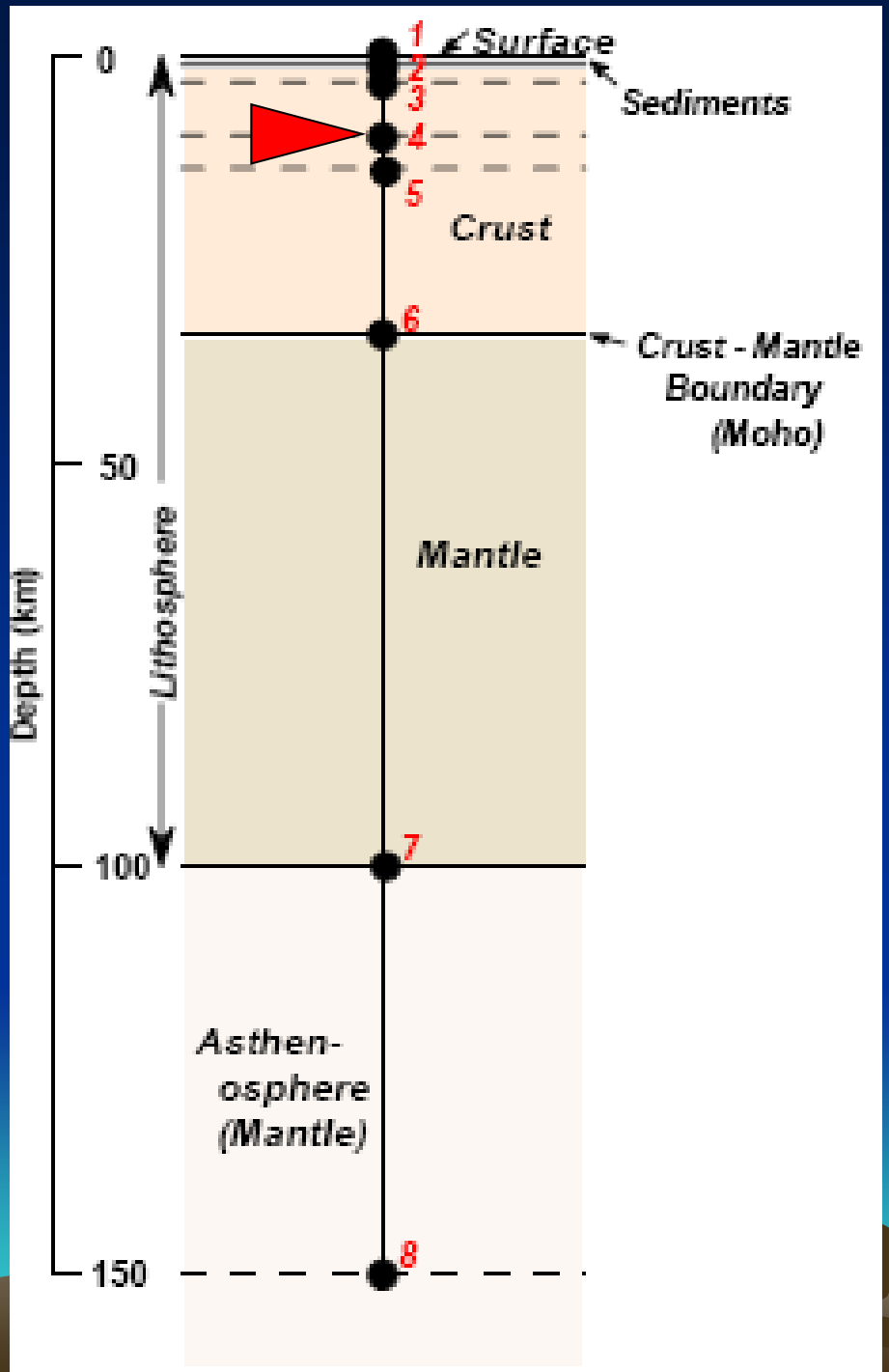
- Below are crystalline rocks
  - Intrusive igneous or highly metamorphosed (cooked)
  - “Granite” beneath continents, “Gabbro” beneath oceans
- Above are sediments or sedimentary rocks
  - Some sedimentary basins go far deeper



Spot 3

Deepest Mine (~3.6 km):

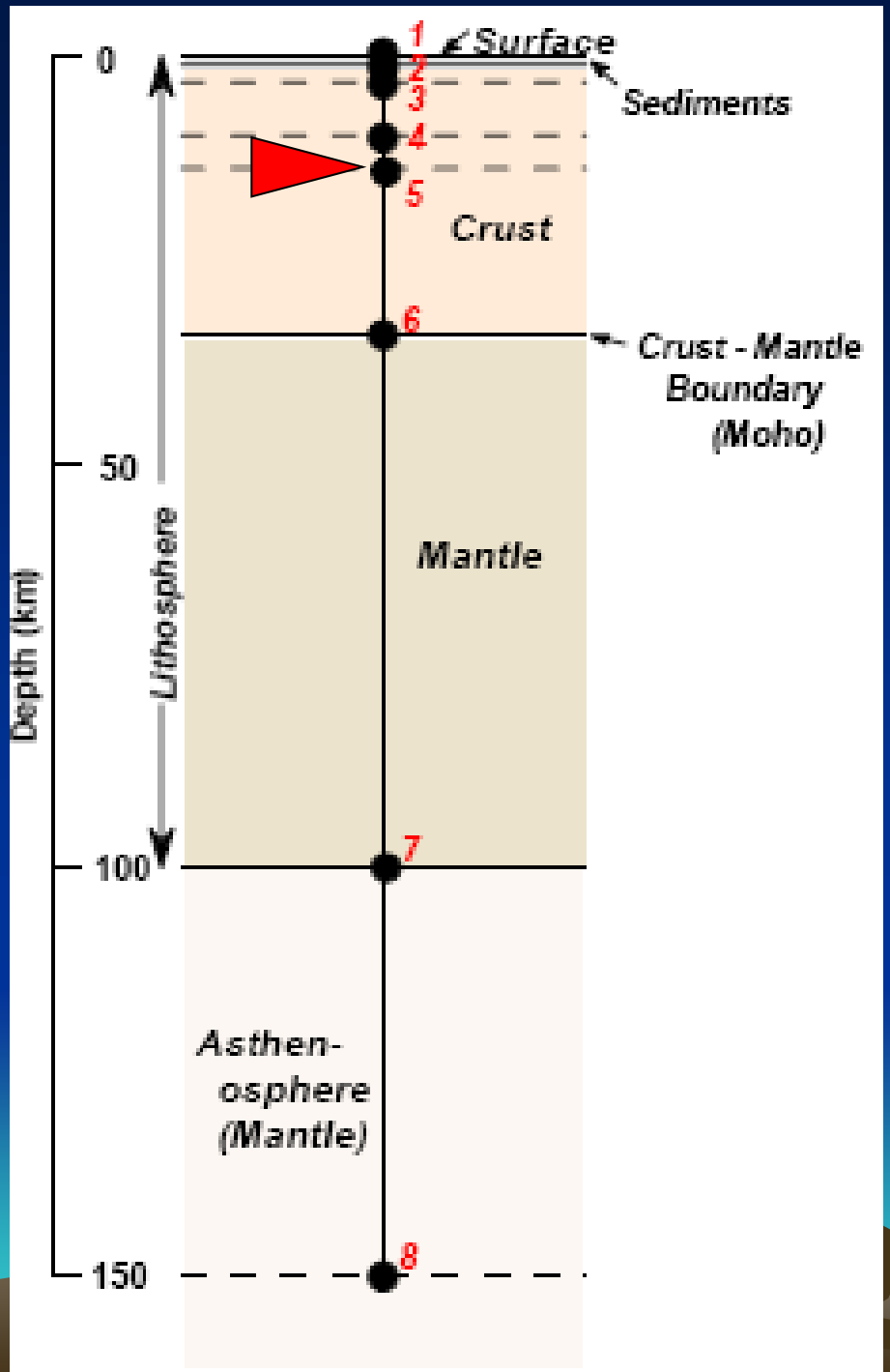
- Gold mine in South Africa
- Temp. is ~50 deg. C
- Chilean miners were at ~1/2 this depth
- Abundant microbes between rock grains (life is everywhere)
- Some natural caves approach this depth



Spot 4

Base of Upper Crust (~10 km):

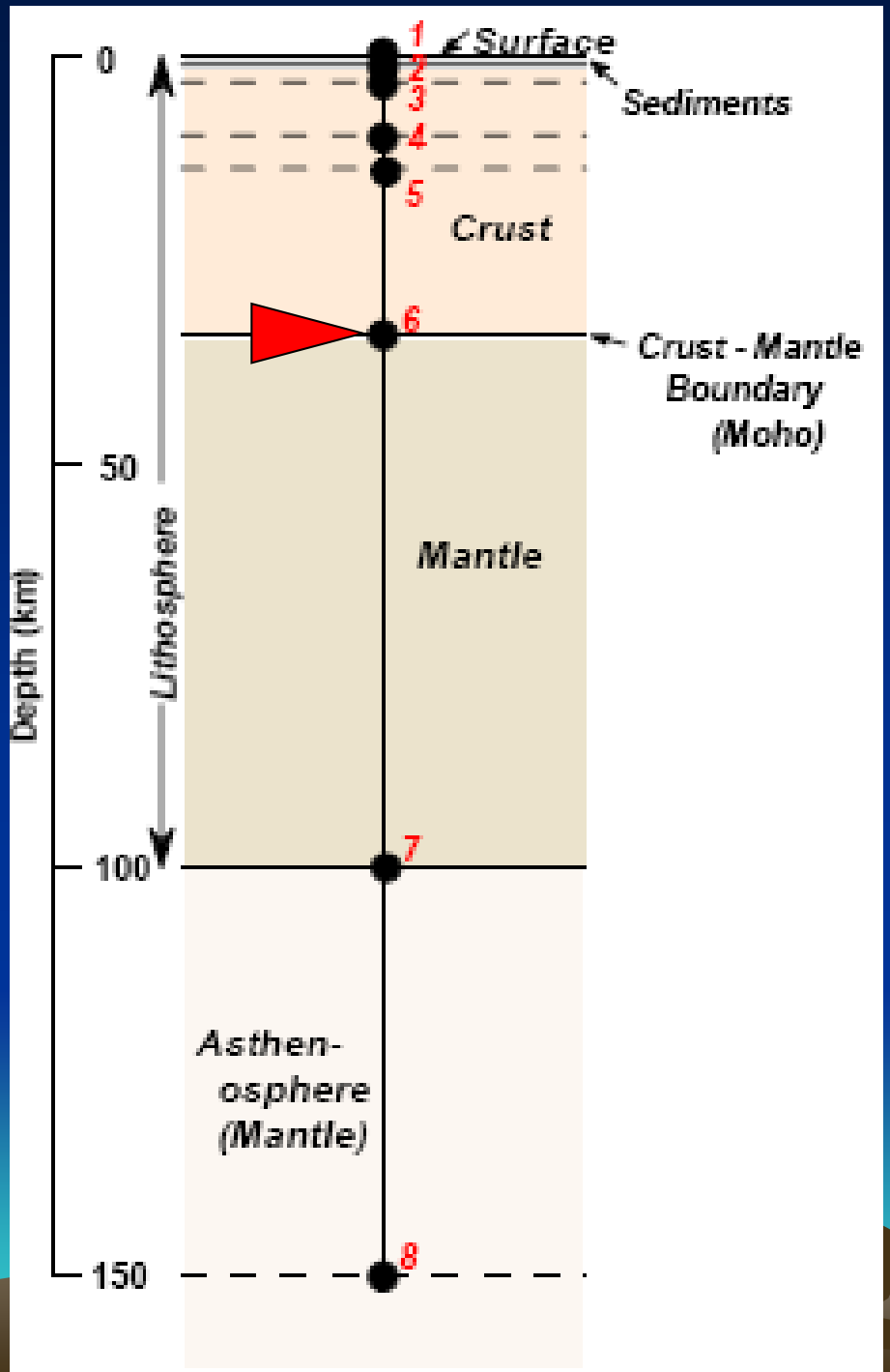
- Rocks here are hot (180 deg. C), but still brittle
- Except in subducting slabs, most earthquakes originate near here



Spot 5

Deepest Drill Hole (~13 km):

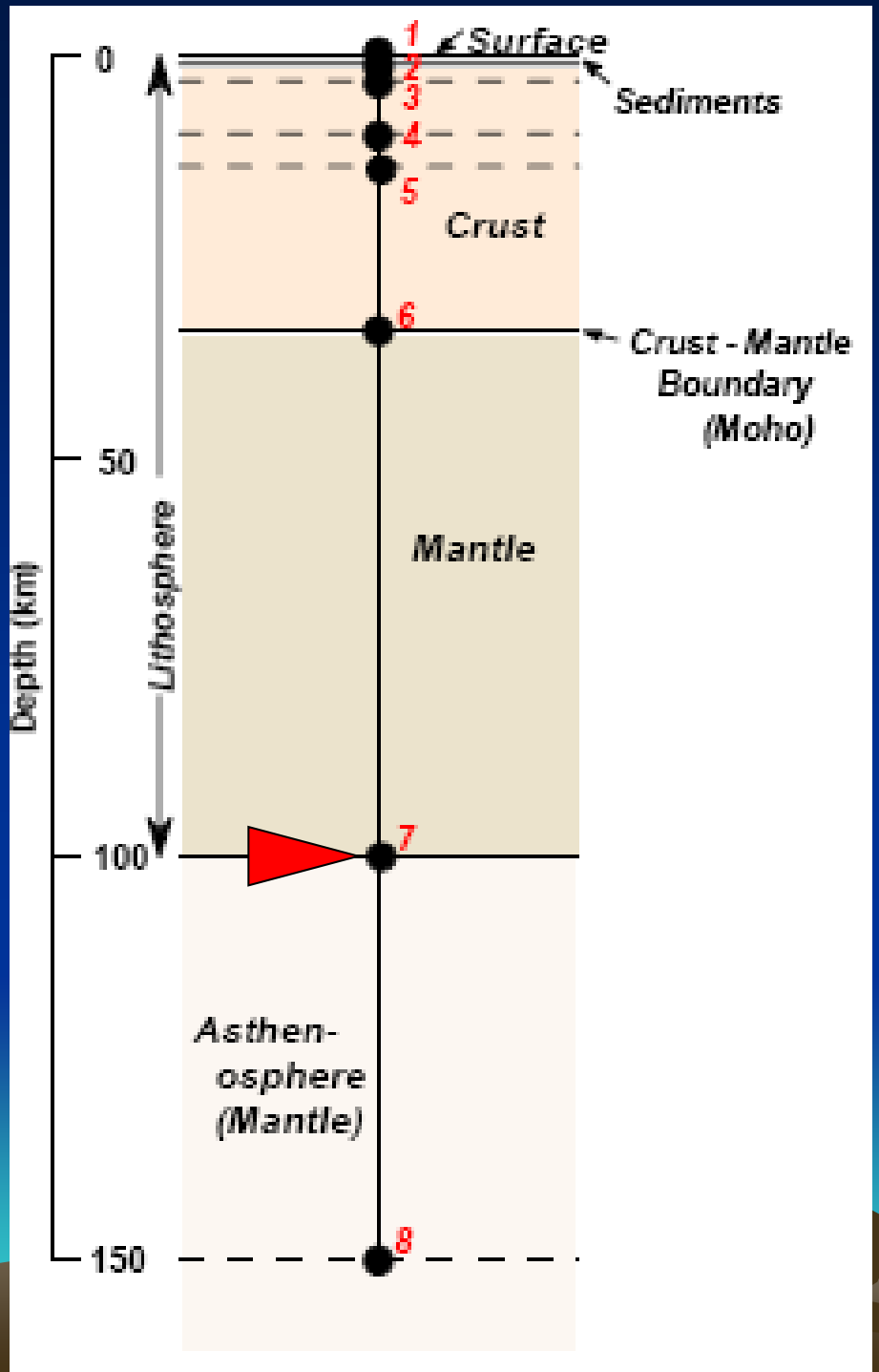
- Kola Peninsula, Russia
- Temp. is ~360 deg. C
- Press. Is ~200 Mpa or 2000 atmospheres
- Drilling has stopped
- Cold War spawned the USA “Mohole” (more later)…



Spot 6

Base of Continental Crust (~35 km):

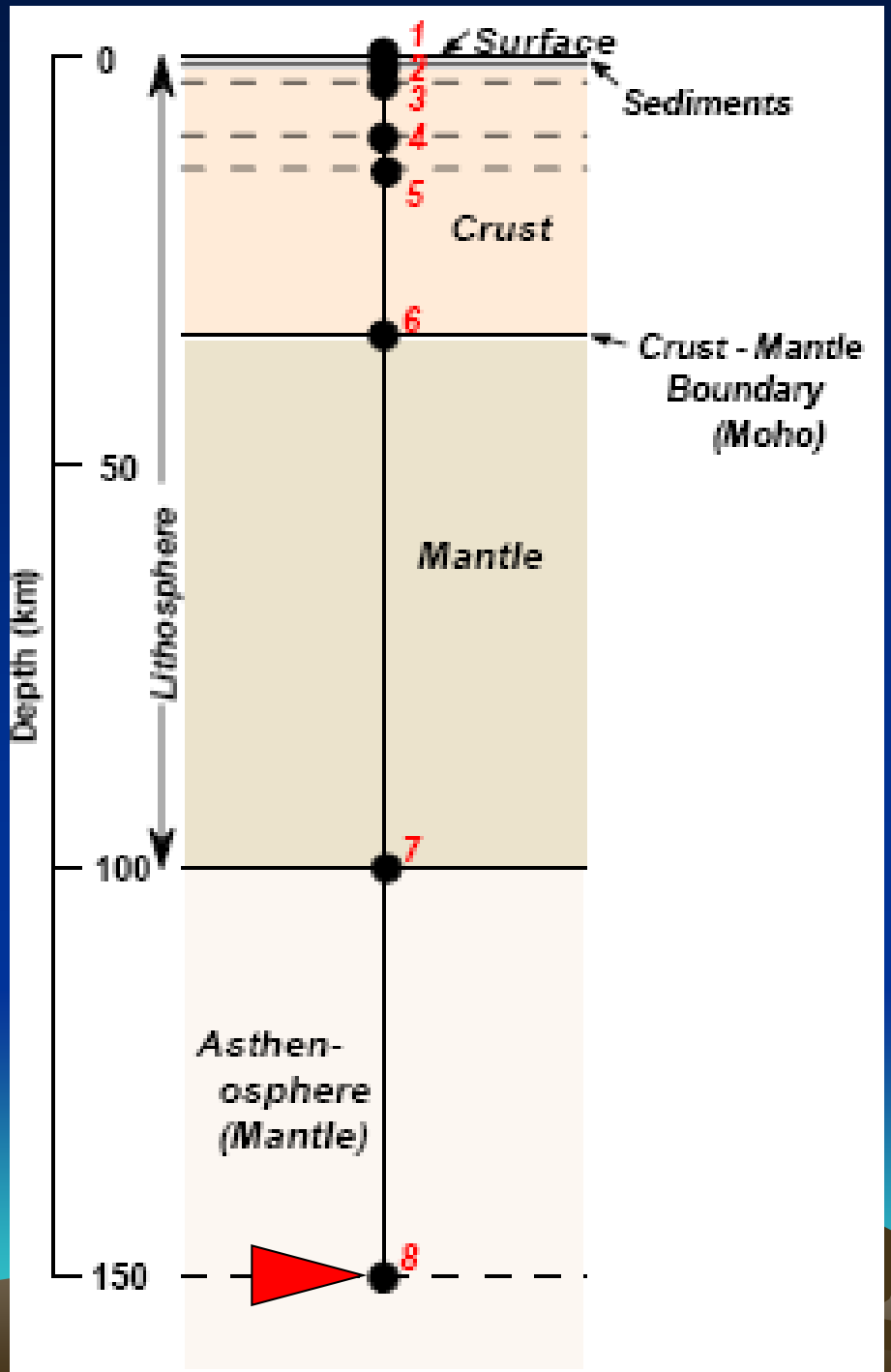
- Base of oceanic crust is ~10 to 15 km
- Big change in seismic velocity noticed by Andrija Mohorovicic
- This is the Moho
- Rocks become dense (high in Fe and Mg)
- Above is Crust (mostly Si and O), below is Mantle (Si and O, but with much Fe and Mg)
- This is a compositional or mineralogical boundary
- Crust is over 90% Oxygen by volume



Spot 7

Base of Lithosphere (~100 km):

- Actually gradational
- Occurs between 50 and 150 km
- Lithosphere is mostly solid (lithos=rock)
- Below is the Asthenosphere (astheno=weak)
- The tectonic plates are made of lithosphere
- Between plates and at Hot Spots, there are windows into the asthenosphere
- This is a mechanical (strength) boundary

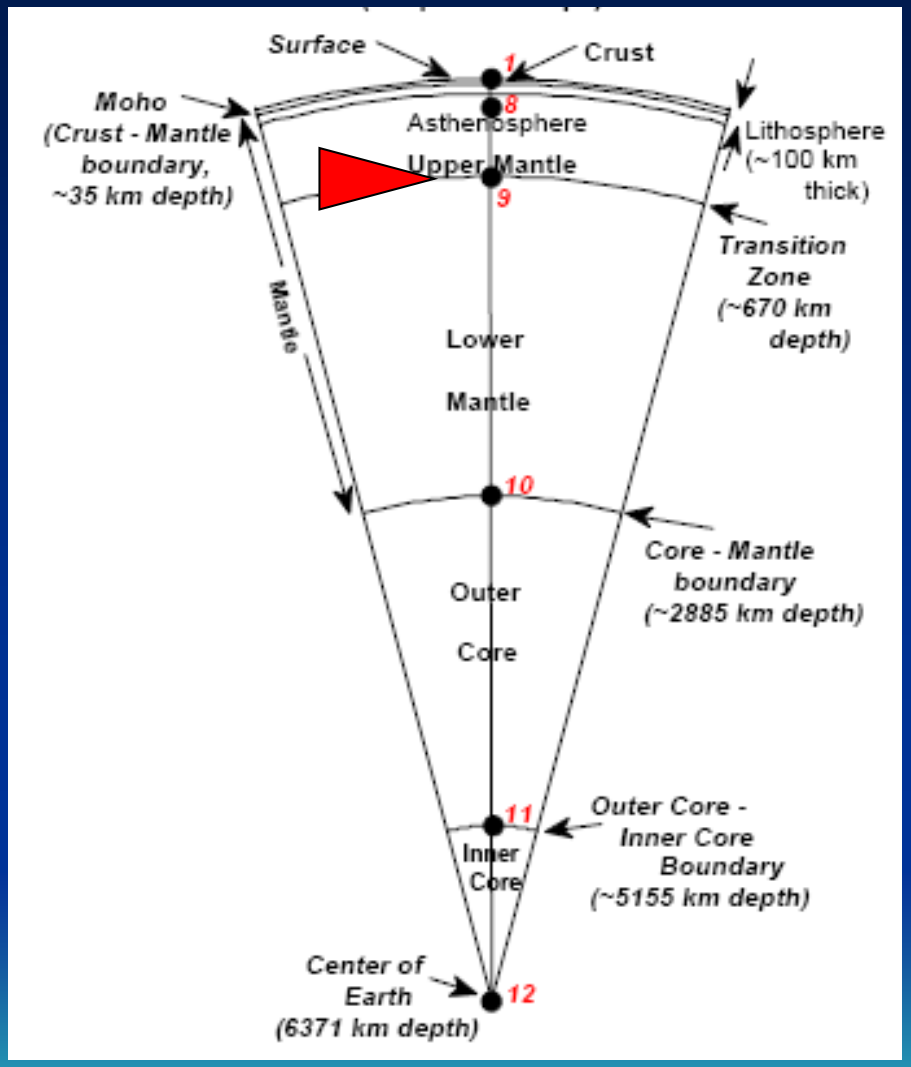


Spot 8

In the Asthenosphere (~150 km):

- Temp. is 1300 deg. C
- Press. Is 480000 atm.
- Material is flowing, and ~2% melted (Earth's heat flows outward by convection in the Mantle)
- This is where magma is generated
- This is where diamonds come from!

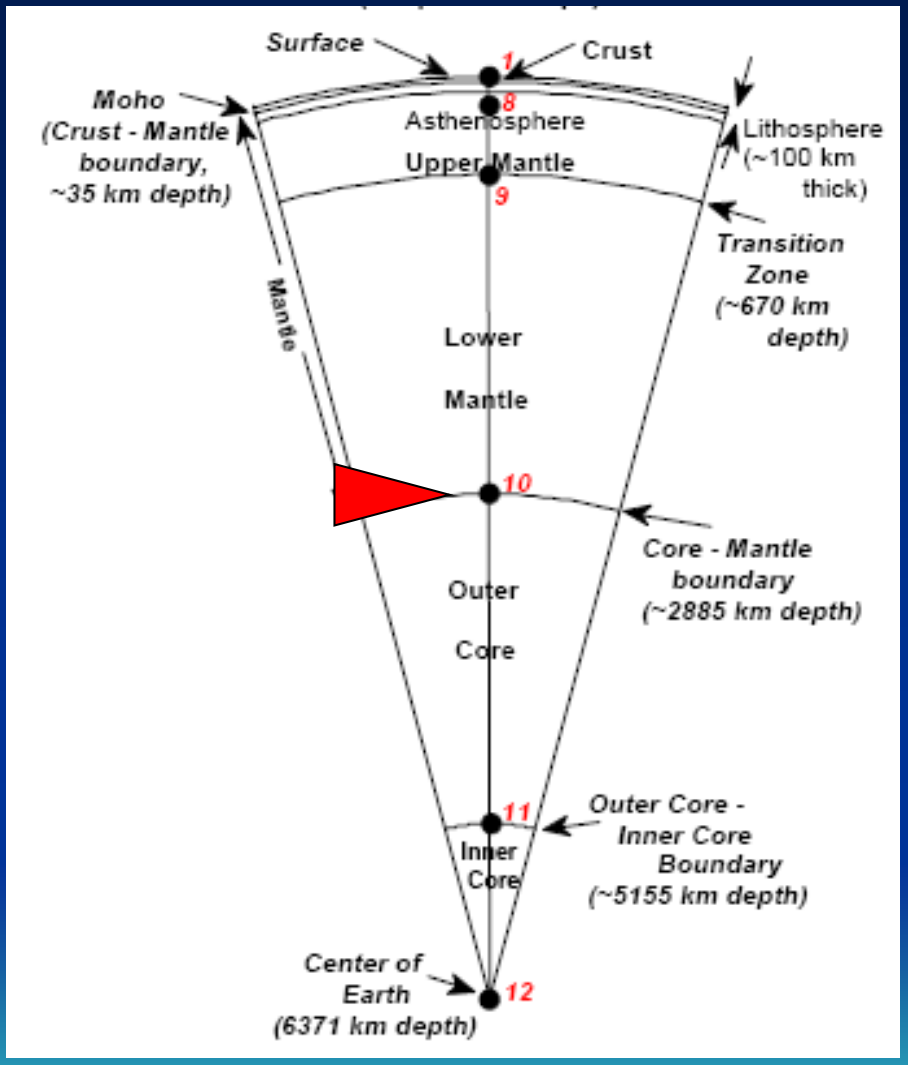
Spot 9



The Transition Zone (~670 km):

- Temp. is increasing, but Press. Is so great that mineral structure changes and becomes even more dense
- Deepest earthquakes occur near here – in subducted slabs that remain cool and brittle until this depth (remember – Earth materials have huge thermal inertia)

Spot 10

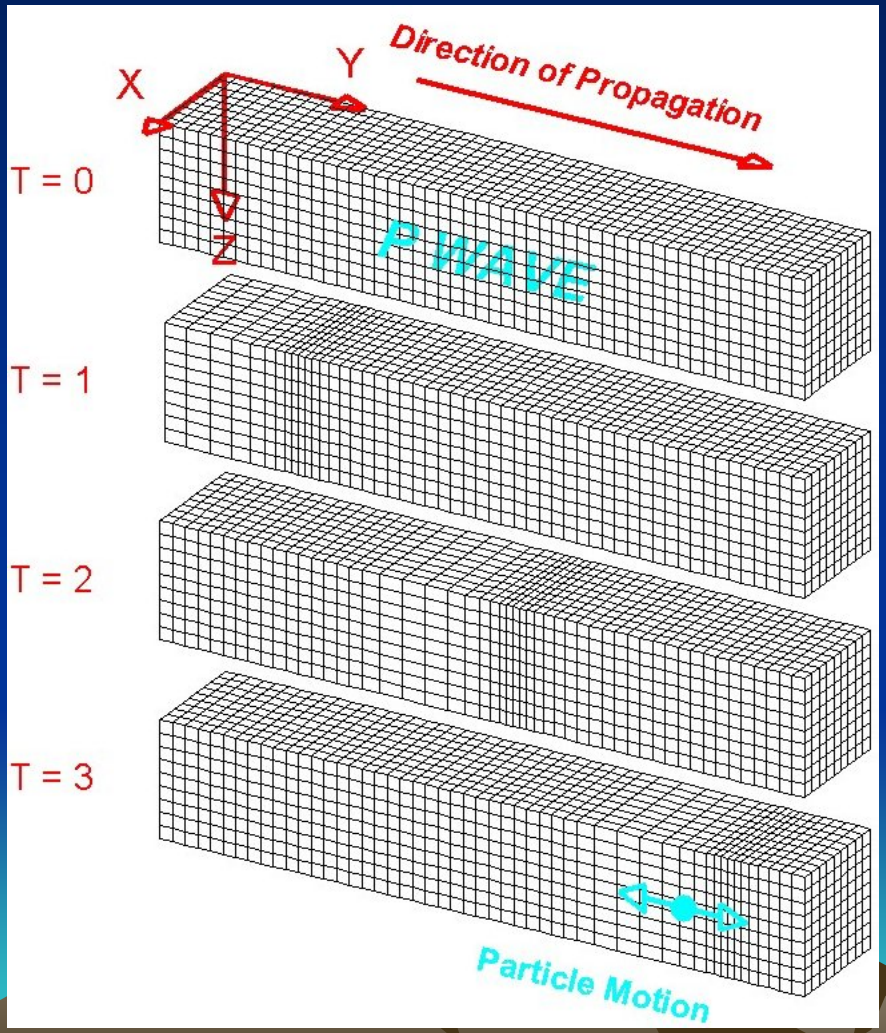


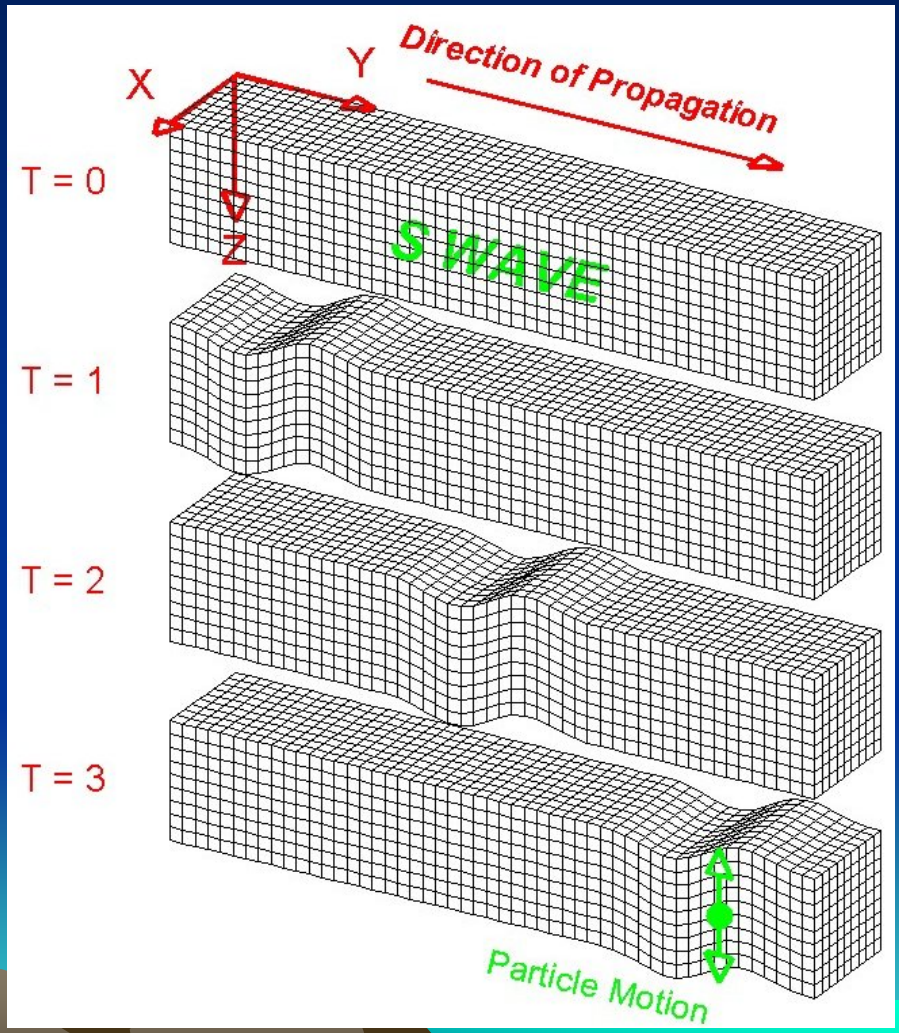
The Core-Mantle Boundary (~2885 km):

- Very prominent boundary
  - Mineralogic/chemical
  - Mechanical
- Above is primarily solid (but flowing), below is true liquid
- Above are silicate rocks (Si and O with some Fe and Mg), below is almost purely Fe, with some Ni and S
- Loss of Si and O means density increases a lot (more than at the Earth's surface!)
- Temp. is 3500 deg. C…three times hotter than an iron blast furnace, so the outer core is liquid
- Liquid creates P-wave and S-wave shadows….

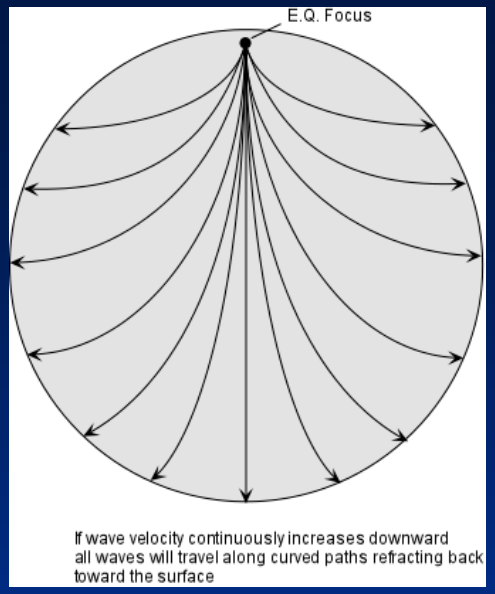
Begin Tangent 2

P versus S Waves

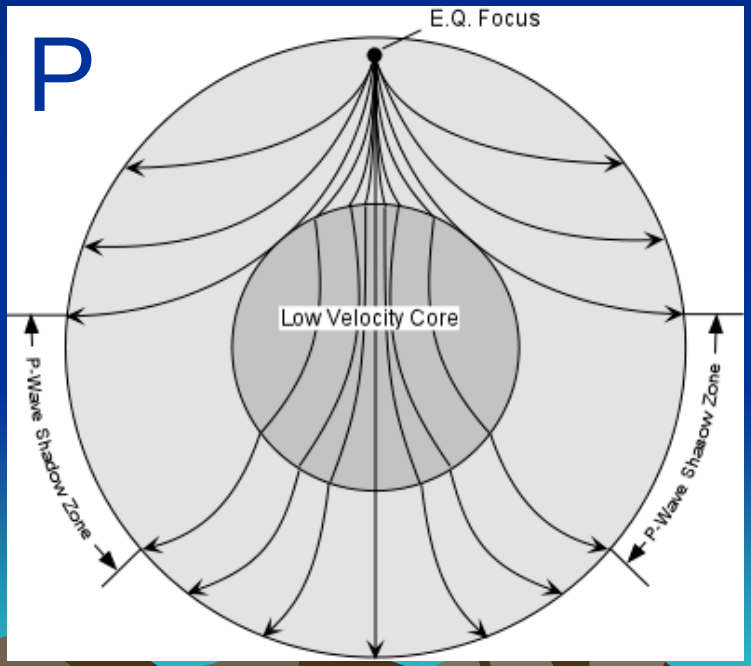


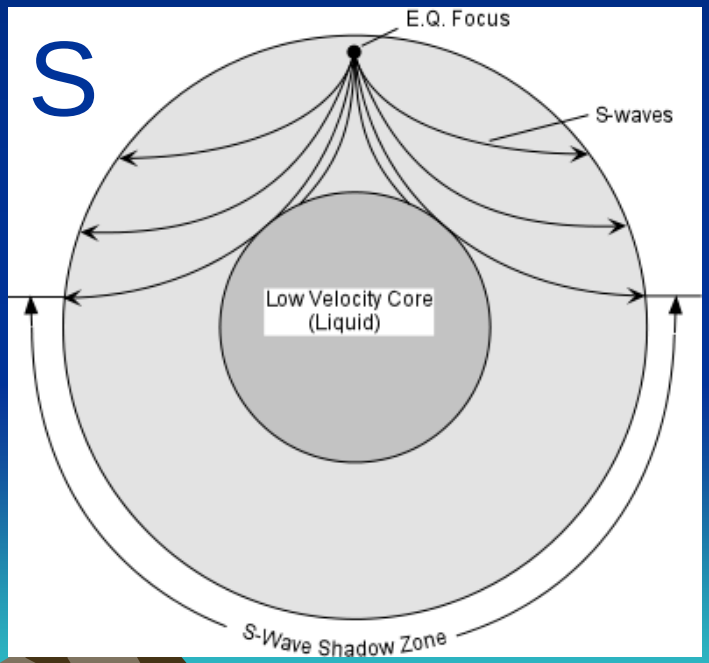


Slinky!



Shadow Zones

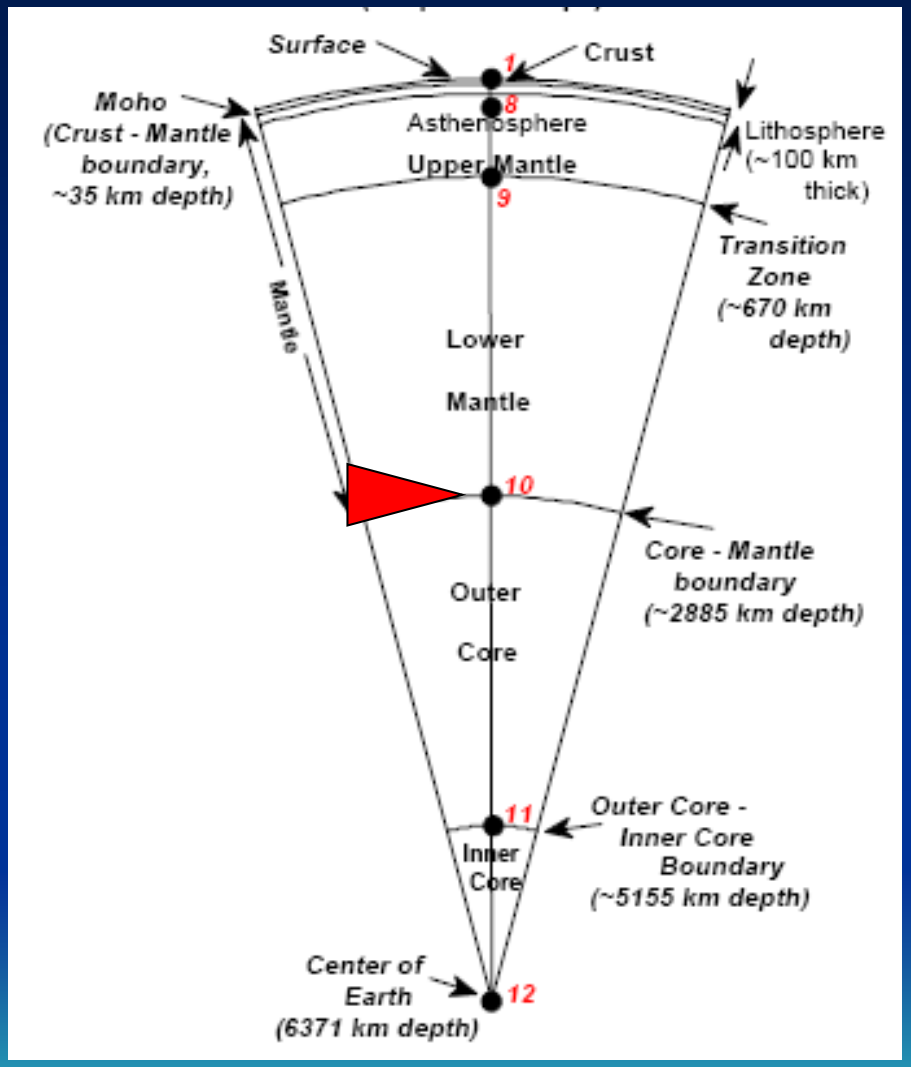




- Note that outer core is very high density, but very low strength
- Low P-wave velocity, No S-wave propagation

End Tangent 2

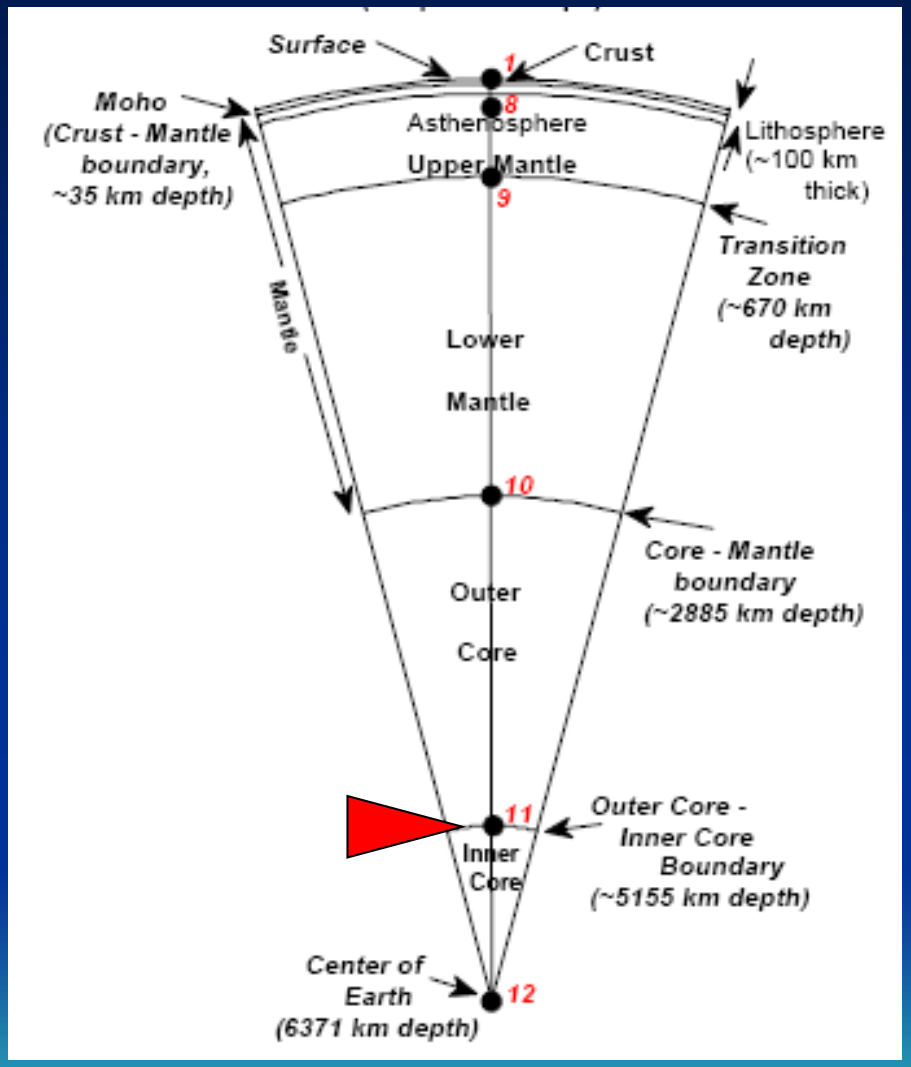
Spot 10



The Core-Mantle Boundary (~2885 km):

- Molten Fe is highly electrically conductive
- Swirling currents produce Earth's magnetic field
- Turbulence and inconstancy cause magnetic field to drift, and sometimes die-out, and periodically reverse! (remember magnetic reversals…very important when we get to plate tectonics)

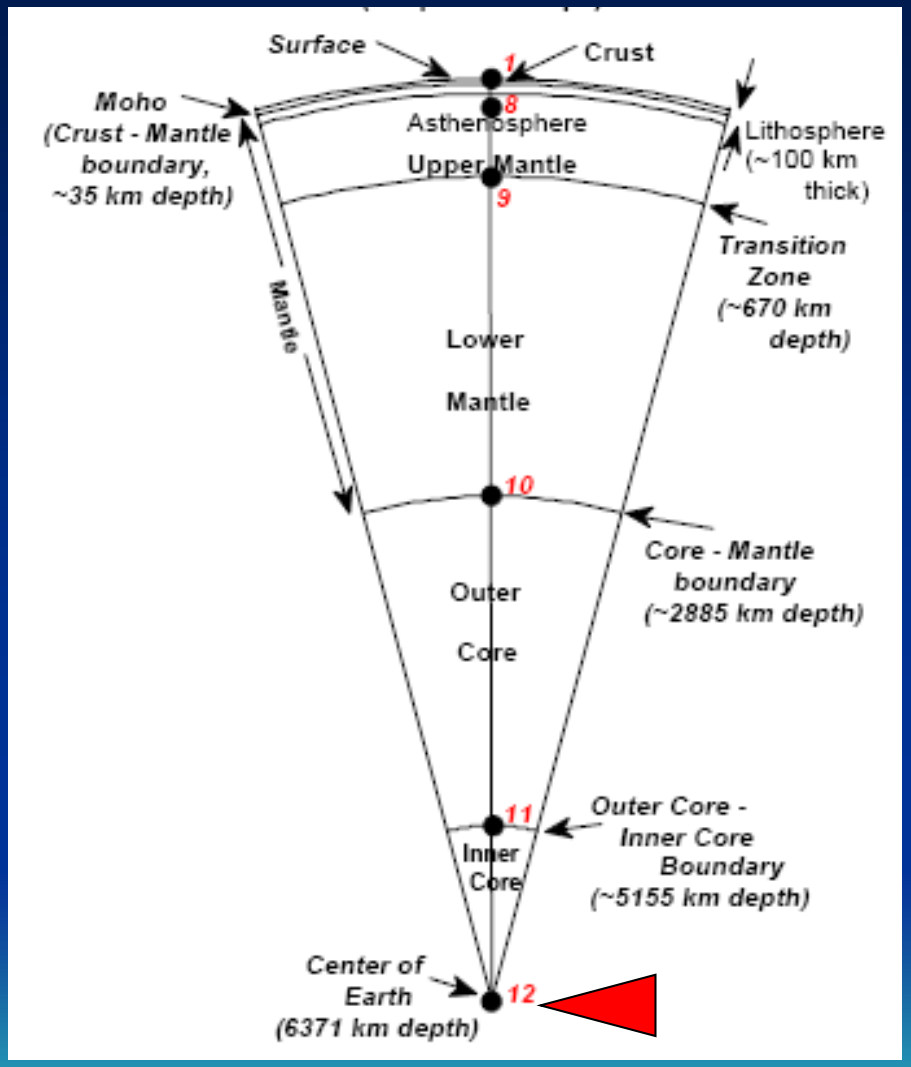
Spot 11



Inner Core-Outer Core (~5155 km):

- Here, Pressure beats Temperature
- No chemical change, but core becomes solid
- De-coupled from the rest of Earth by liquid outer core, so it rotates at slightly different speed – right now it is going faster than Earth

Spot 12



Center of the Earth (~6371 km):

- Temp. is 4800 deg. C
- Press. Is 36.4 million atm.
- Gravity is ZERO!

Why So Hot?

- Latent Heat of Formation
  - Accretion of meteorites, comets, etc.
    - Think of pounding a nail – it heats up (kinetic energy converted to heat)
  - Differentiation
    - Gravitational heating (potential energy converted to heat)
      - "The Iron Catastrophe"
  - Tidal friction: Earth deforms under the influence of Moon and Sun
    - Think of bending a paper clip back and forth (added energy)
  - But most of all: decay of Uranium, Thorium and Potassium
    - Very low concentrations, but Earth materials have huge heat capacity…heat is stored and released only very slowly, so Temp. builds over Deep Time