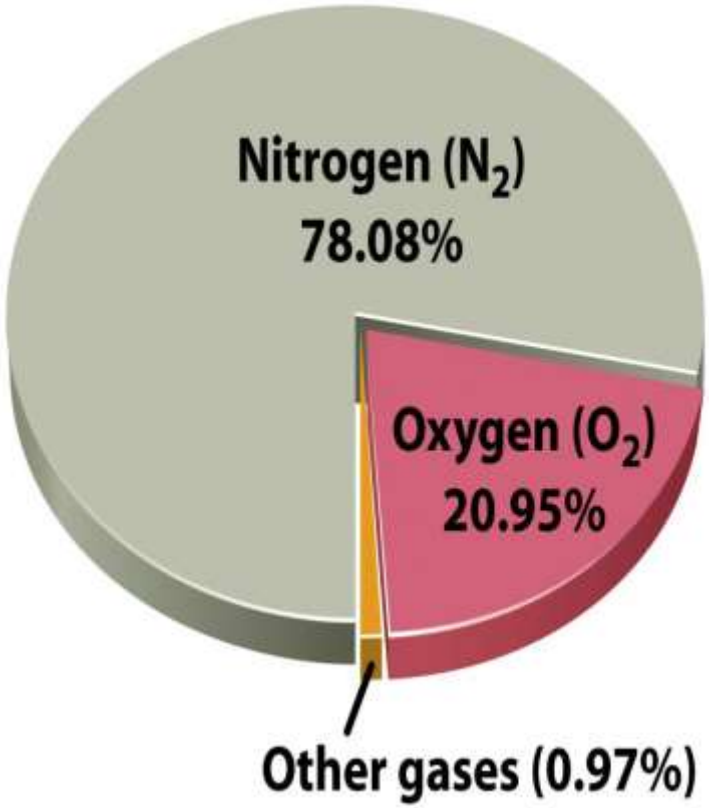
CHAPTER 3:
The Structure & Composition of The Earth

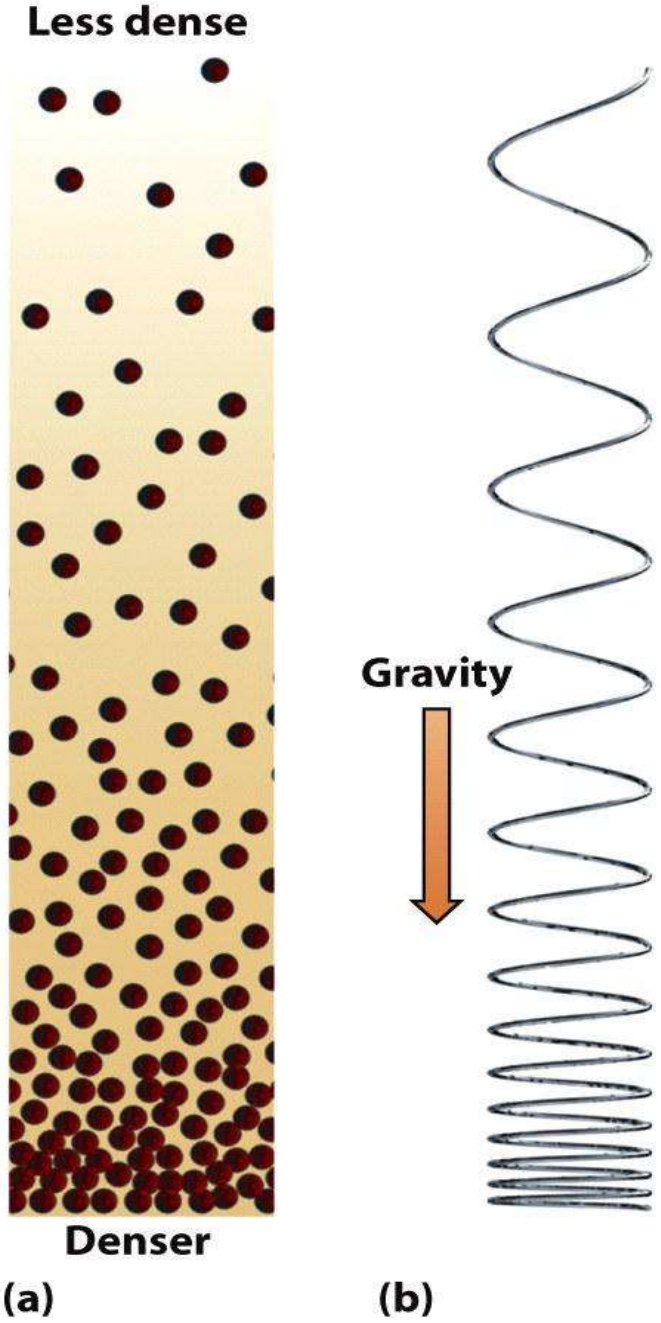
Earth's Atmosphere Distinct layers of gas surround the solid portion of the earth.

- **Composition is ~uniform regardless of altitude**
- 78% N2
- 21% O2
- All others ~1%
- Ar, CO2, CH4, H2O, Ne, CO, SO2
- Some other Planets have atmospheres too!
- None have N2 & O2 as dominant gasses
- Earth was oxygen-free until ~2.5 Ga



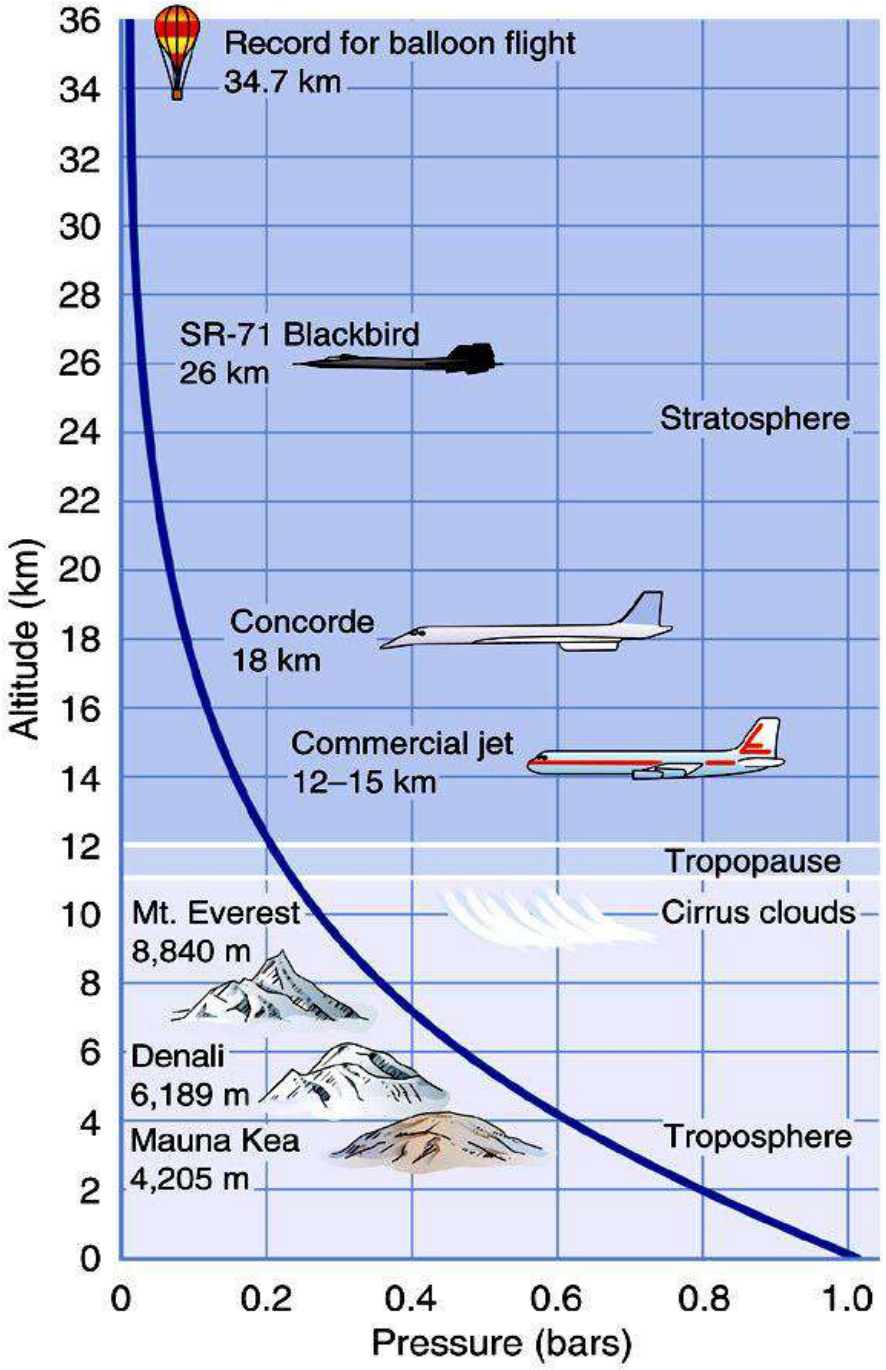
Earth's Atmosphere

- **Pressure decreases with increasing altitude**
- Reflects # of molecules/volume
- Lower pressure = less molecules/volume
- Air pressure @ sea level = 14.7 lb/in2 = 1 bar
- **Pressure is caused by the weight of overlying material**
- Upper atmosphere has less material above it
- Pressure is lower
- 99% of atmosphere is below 50 km, the rest is between 50 and 500 km.



Earth's Atmosphere

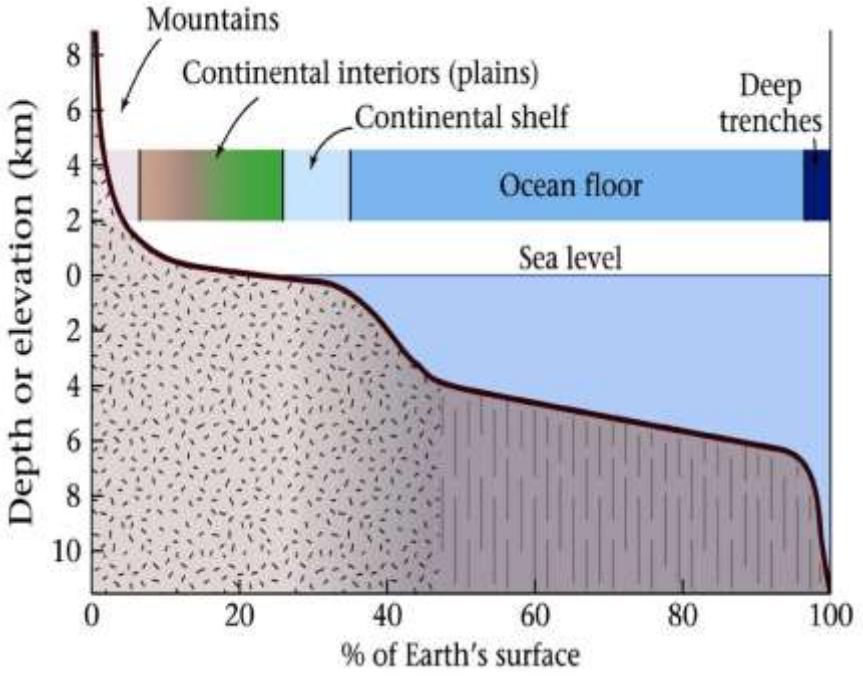
- **Earth's Atmosphere is divided into distinct layers based on altitude**
- Exosphere (very thin ~500 km)
- Atmosphere merges with space
- Thermosphere (>90 km)
- Where space shuttles orbit
- Mesosphere (50-90 km)
- Meteors burn up here
- Stratosphere (12-50 km)
- Stable air; good for jets
- Tropopause (11-12 km)
- Troposphere (0-11 km)
- Mixing layer
- All weather is limited to this layer
- "Tropo" = Greek for "turning"



Earth's Components

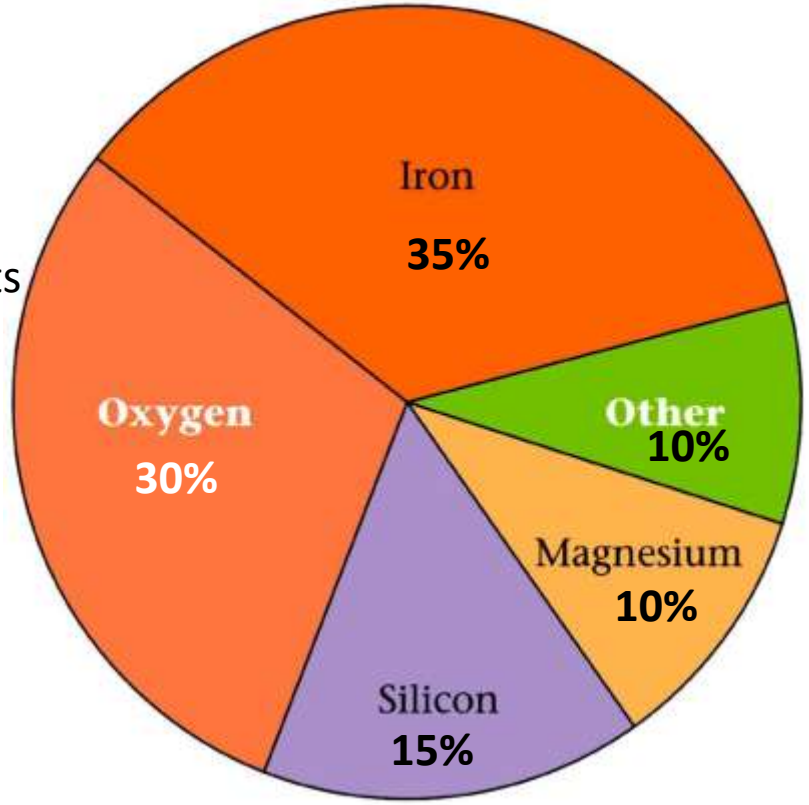
- Earth's surface = ~**30% land, ~70% water**
- unlike any other known planet
- **Hydrosphere = includes oceans, lakes, seas, rivers, & groundwater**
- **Cryosphere = glaciers, snow, and sea ice**

- Earth's surface is not flat; it has **topography**
- Ignoring oceans, Earth's surface is dominated by two distinct elevations:
- Most land is 0-2 km above sea level
- Most of the sea floor is 3-5 km below sea level



Earth's Components

- Earth's elemental composition reflects mostly heavier elements not blown away by solar wind during formation of the solar system
- Most abundant elements
- Fe, O, Si, Mg
- Most common minerals consist of silica (SiO_2) mixed in varying proportions with other elements such as Fe, Mg, Al, Ca, K, Na
- **Felsic = more silica (less Fe/Mg) & less dense**
- E.g. Granite
- **Mafic = less silica (more Fe/Mg)** & more dense
- E.g. Gabbro / Basalt
- Range: **Felsic / Intermediate / Mafic / Ultramafic**



Bulk Earth composition

Earth Materials

- Elements combine in a variety of Earth materials.

–Organic compounds – Carbon-containing compounds.

- Most are residue from once-living creatures.
- Include wood, peat, lignite, coal, and oil.
- Geologically rare (decomposes in contact with oxygen).

Earth Materials

- Elements combine in a variety of Earth materials.

–Minerals – Inorganic crystalline solids.

- Comprise rocks and, hence, most of the Earth.
- Most rocks on Earth are silicates (based on Si and O).

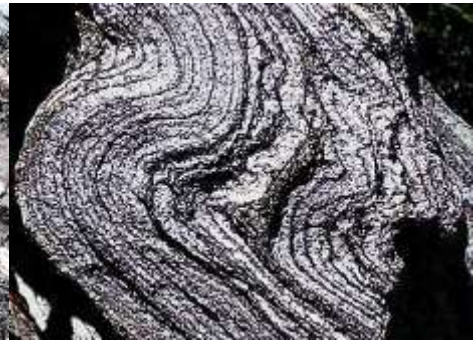
–Glasses – Non-crystalline mineral-like matter.

- Cool too quickly to form structure

–Rocks – Aggregates of minerals. There are many types.

- Igneous – Cooled from a liquid (melt).
- Sedimentary – Debris cemented from pre-existing rock.
- Metamorphic – Rock altered by pressure and temperature.



Earth Materials

- Metals – Solids made of metallic elements.
- Melts – Rocks that have been heated to a liquid.

–Magma – Molten rock beneath the surface.

–Lava – Molten rock at the surface.

- Volatiles – Materials that turn into gas at surface temps.

–H_2O, CO_2, CH_4, and SO_2

–Volatiles are released from volcanic eruption

Earth's Layers

Earth's shape as a clue to the layering of the earth

- If the Earth consisted of a thin solid shell over a thick liquid center, then the surface would rise and fall with tides like the ocean – This does not happen; only the oceans rise and fall.

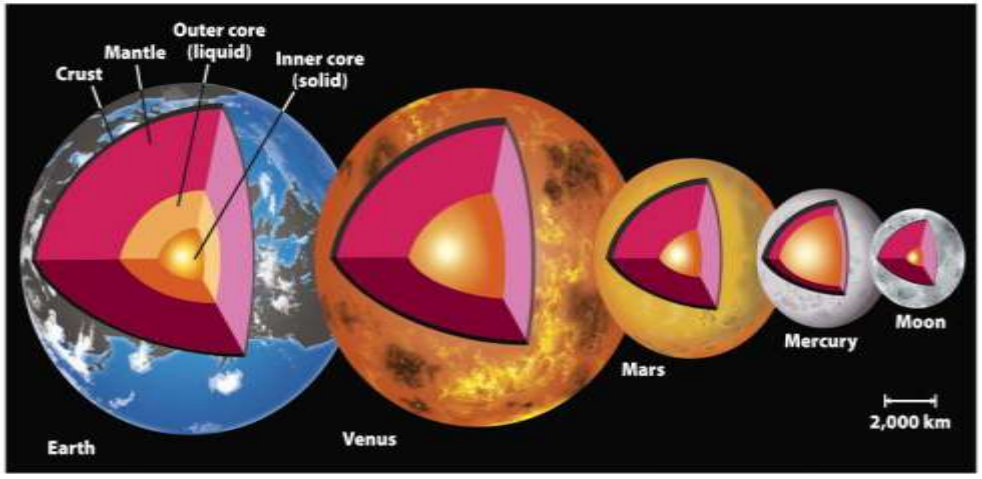
- Thus, the Crust does not float over a liquid interior

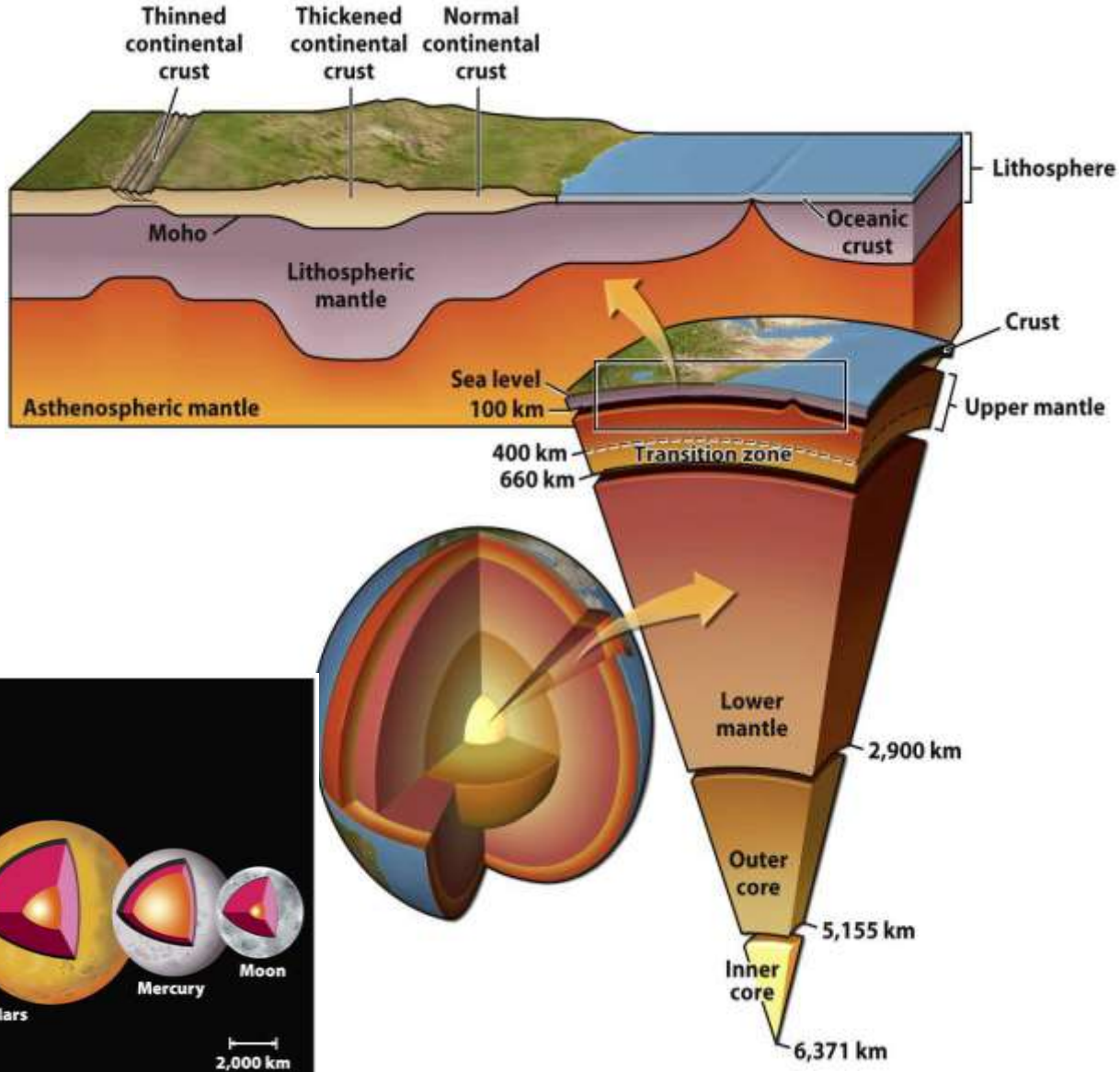
Earth's Interior Layers

–Crust
- Continental
- Oceanic

–Mantle
- Upper
- Lower

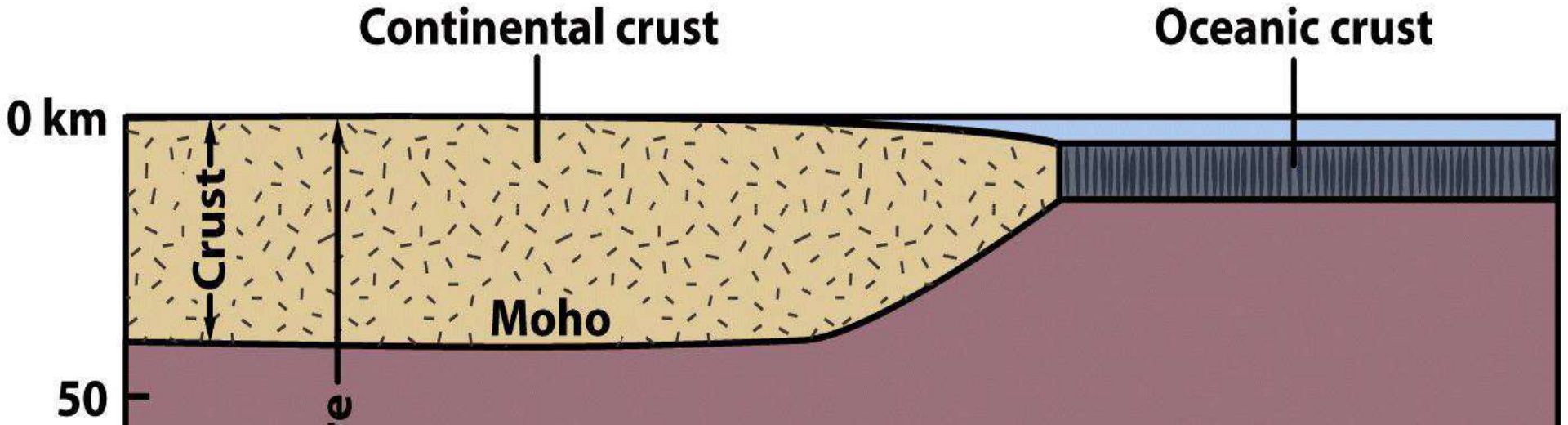
–Core
- Outer – Liquid
- Inner – Solid





The Crust

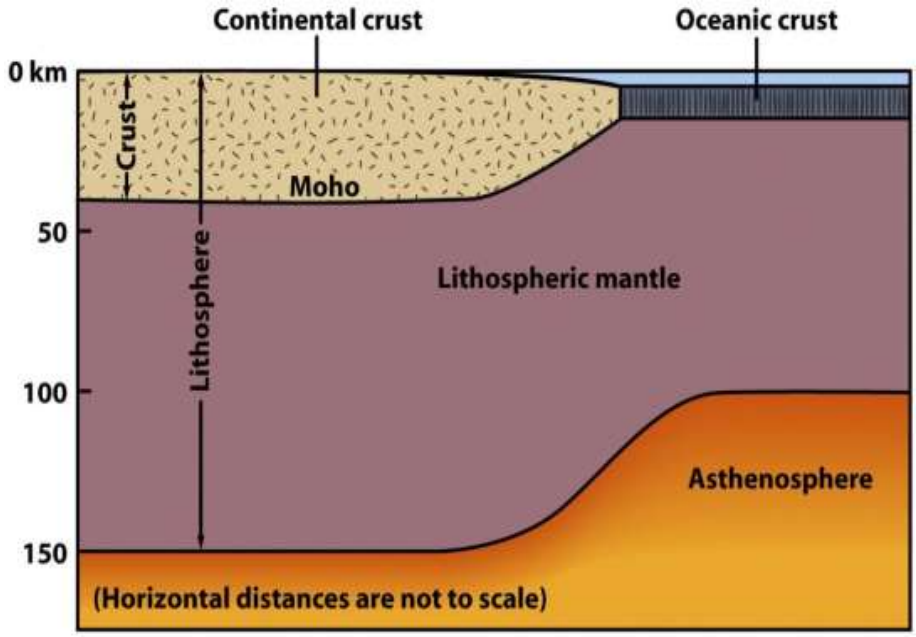
- The outermost "skin" of Earth with variable thickness.
  - Thickest under mountain ranges (70 km – 40 miles).
  - Thinnest under mid-ocean ridges (3 km – 2 miles).
- The Mohorovičić discontinuity or "**Moho" is the lower boundary.**
  - Separates the crust from the upper mantle.
  - Discovered in 1909 by Andrija Mohorovicic.
  - Marked by a change in the velocity of seismic P waves.



Two Types of Crust

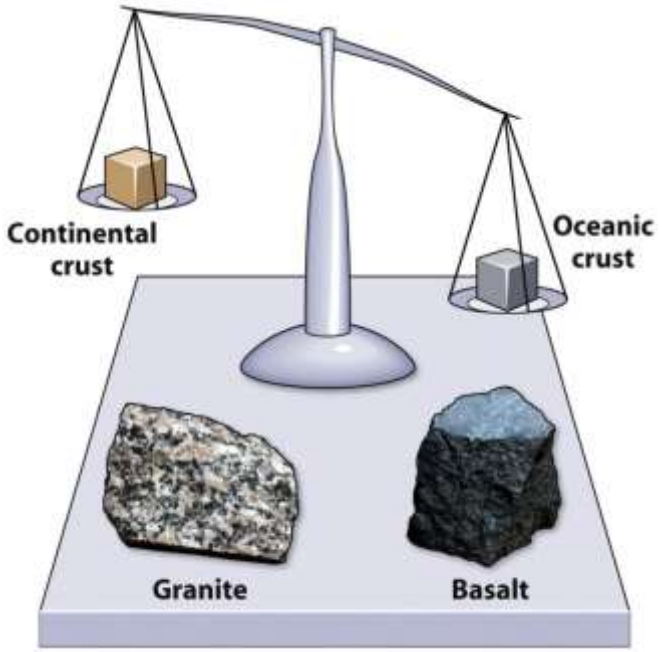
- Continental crust – Underlies the continents.
  - –Avg. rock density about 2.7 g/cm3.
  - –Avg. thickness 35-40 km.
  - –Felsic composition. Avg. rock type = Granite
- Oceanic crust – Underlies the ocean basins.
  - –Density about 3.0 g/cm3.
  - –Avg. thickness 7-10 km.
  - –Mafic composition

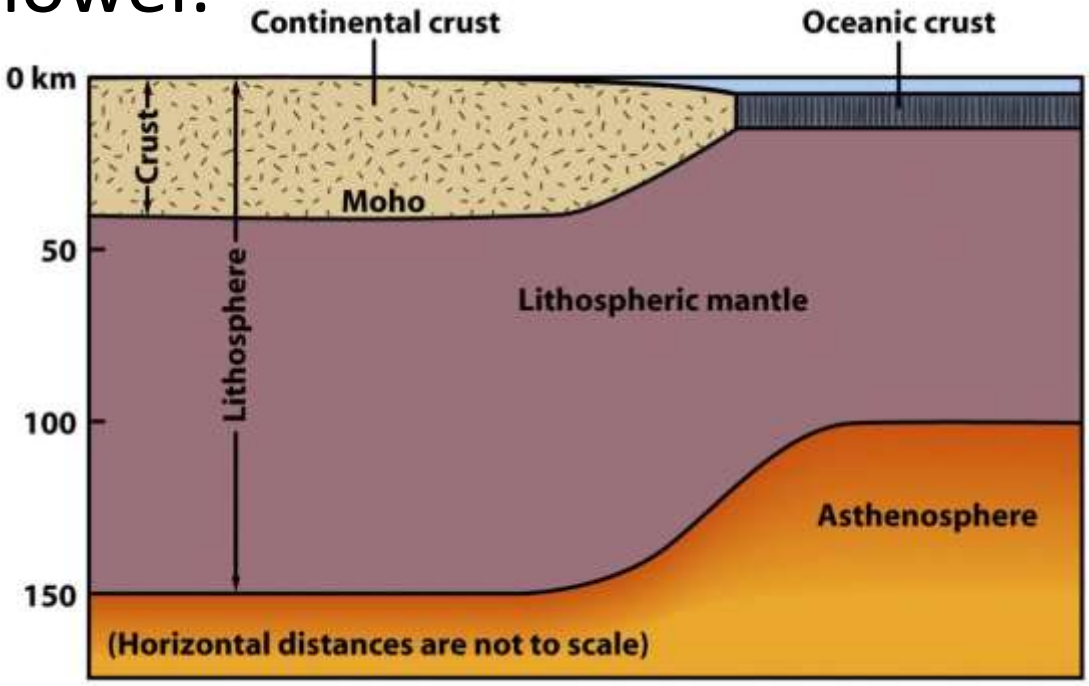
Avg. rock type = Basalt/Gabbro



Two Types of Crust

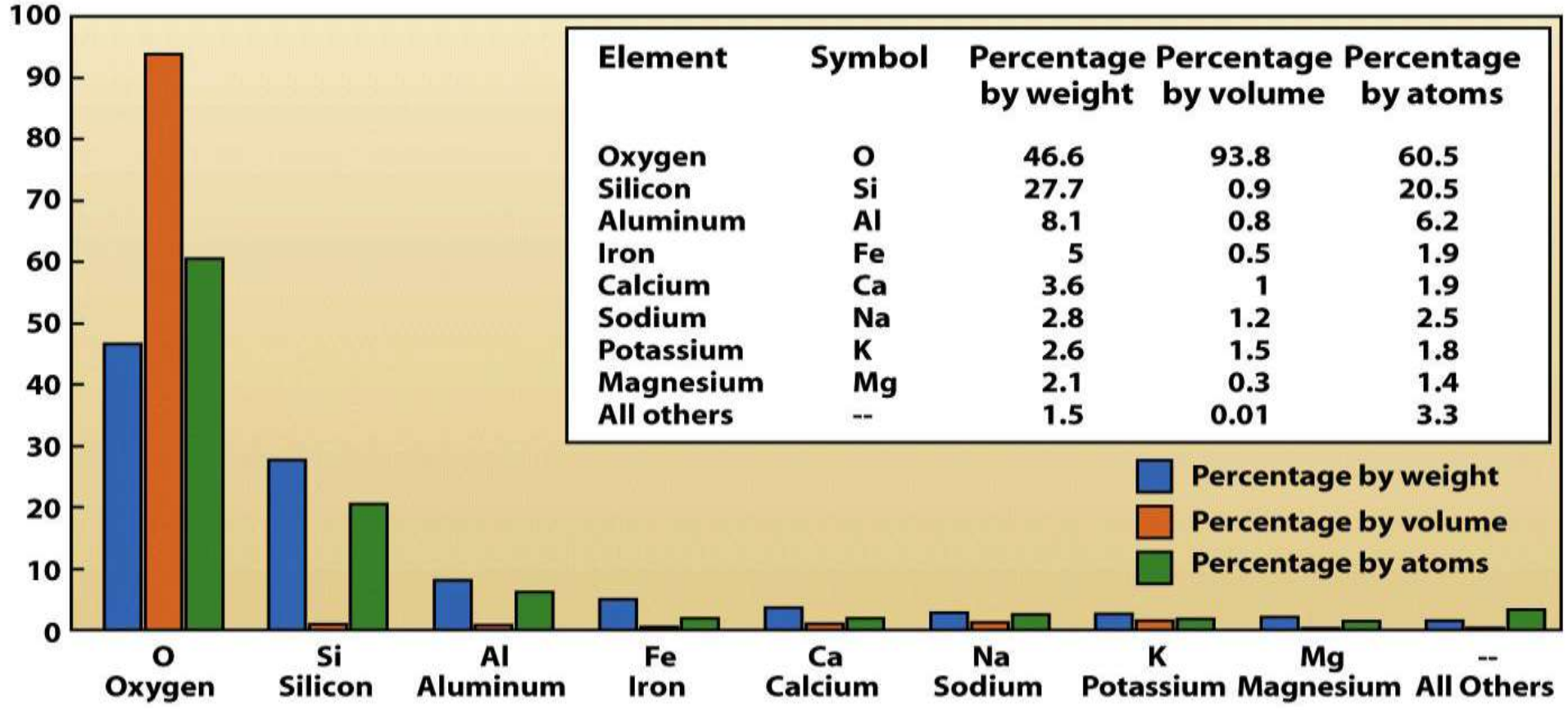
- Crustal density controls surface position.
  - –Continental crust
- Less dense; “floats higher.”
  - –Oceanic crust
- More dense: “floats lower.”





Crustal Composition

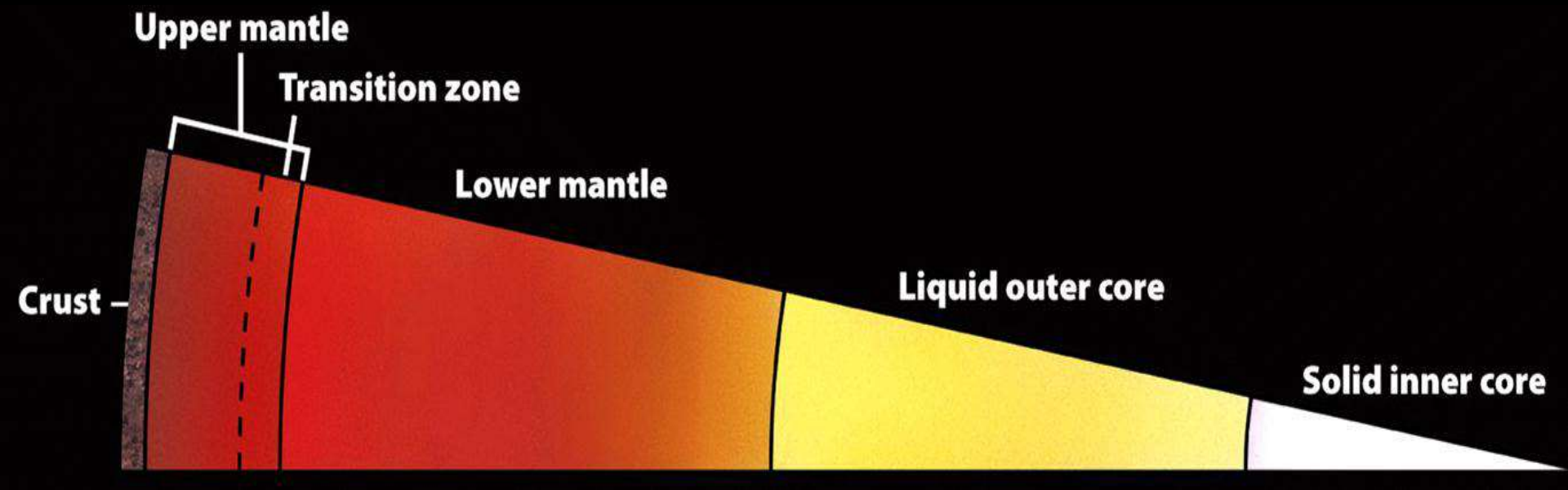
- 98.5% of the crust is comprised of just 8 elements.
- Oxygen is (by far!) the most abundant element in the crust.
  - This reflects the importance of silicate (SiO_2-based) minerals.
  - As a large atom, oxygen occupies ~93% of crustal volume.



Element	Symbol	Percentage by weight	Percentage by volume	Percentage by atoms
Oxygen	O	46.6	93.8	60.5
Silicon	Si	27.7	0.9	20.5
Aluminum	Al	8.1	0.8	6.2
Iron	Fe	5	0.5	1.9
Calcium	Ca	3.6	1	1.9
Sodium	Na	2.8	1.2	2.5
Potassium	K	2.6	1.5	1.8
Magnesium	Mg	2.1	0.3	1.4
All others	--	1.5	0.01	3.3

Earth's Mantle

- **Solid rock layer between the crust and the core.**
- 2,885 km thick, the mantle is 82% of Earth's volume.
- Mantle composition = ultramafic rock called **peridotite.**
- Below ~100-150 km, the rock is hot enough to flow.
- It convects: hot mantle rises, cold mantle sinks.
- Three subdivisions: upper, transitional, and lower.

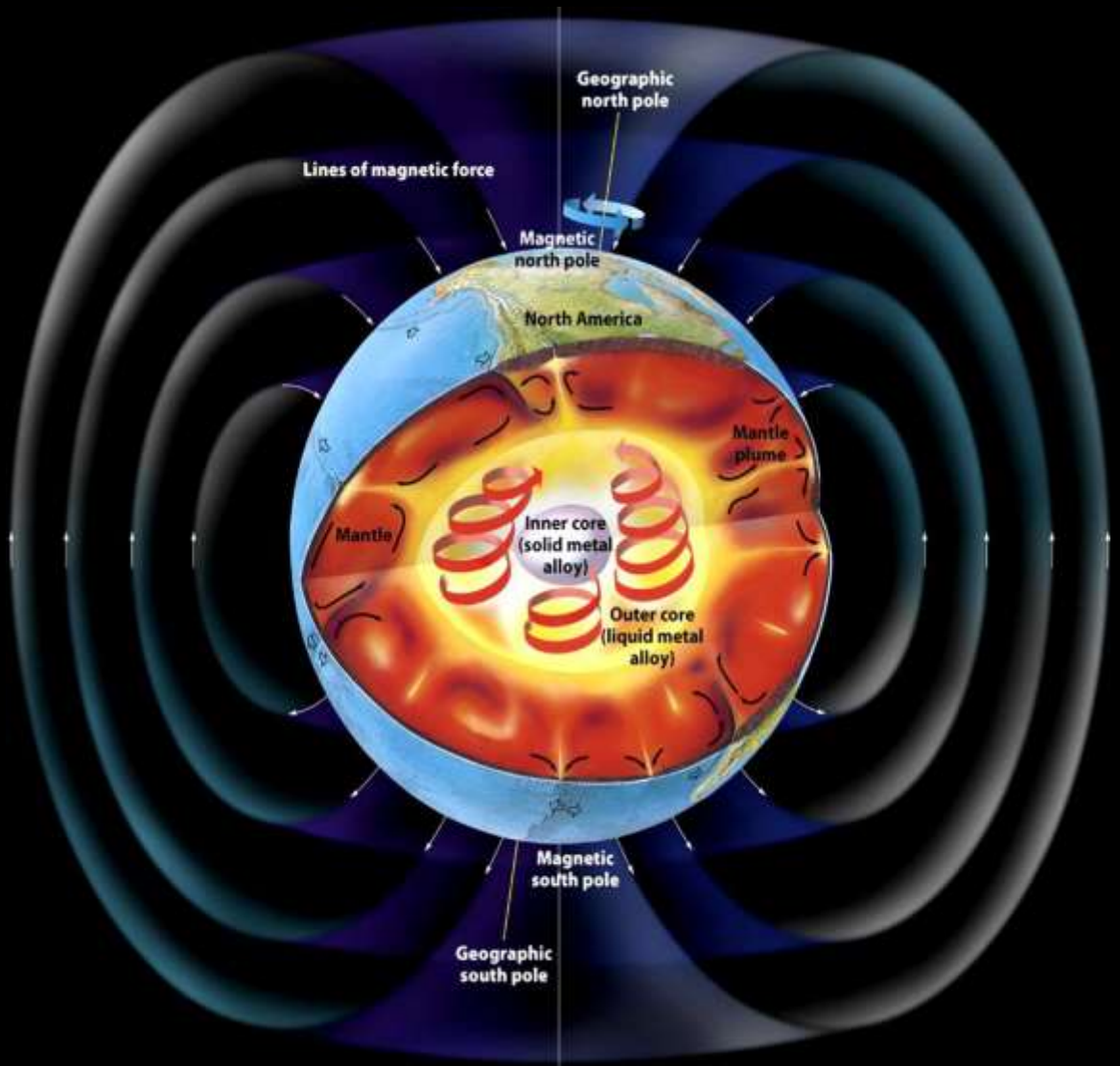


The Core

- An iron-rich sphere with a radius of 3,471 km.
- 2 components with differing seismic wave behavior.
- Flow in the outer core generates the magnetic field.

–Outer core
- Liquid iron-nickel-sulfur
- 2,255 km thick
- Density – 10-12 g/cm3

–Inner core
- Solid iron-nickel alloy
- Radius of 1,220 km.
- Density – 13 g/cm3

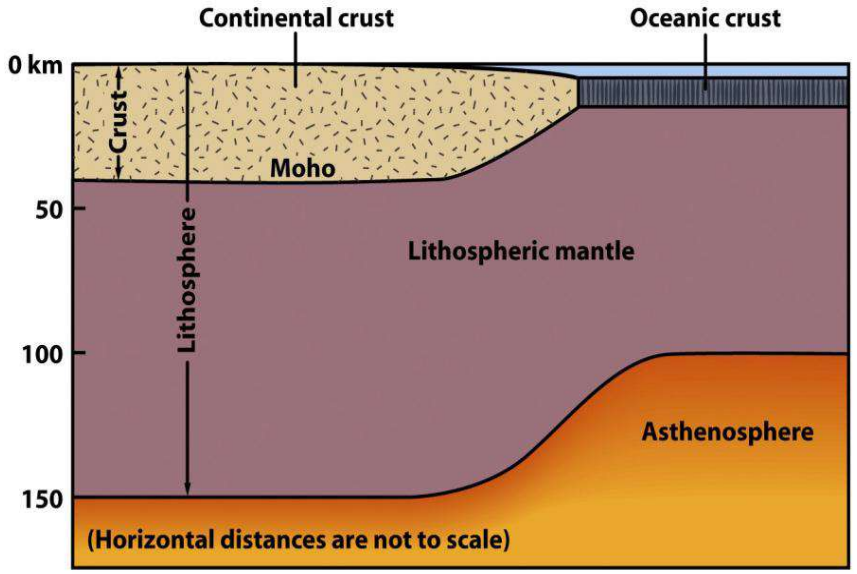


Lithosphere-Asthenosphere

- The Crust, Mantle, Core boundaries
  - –defined by composition

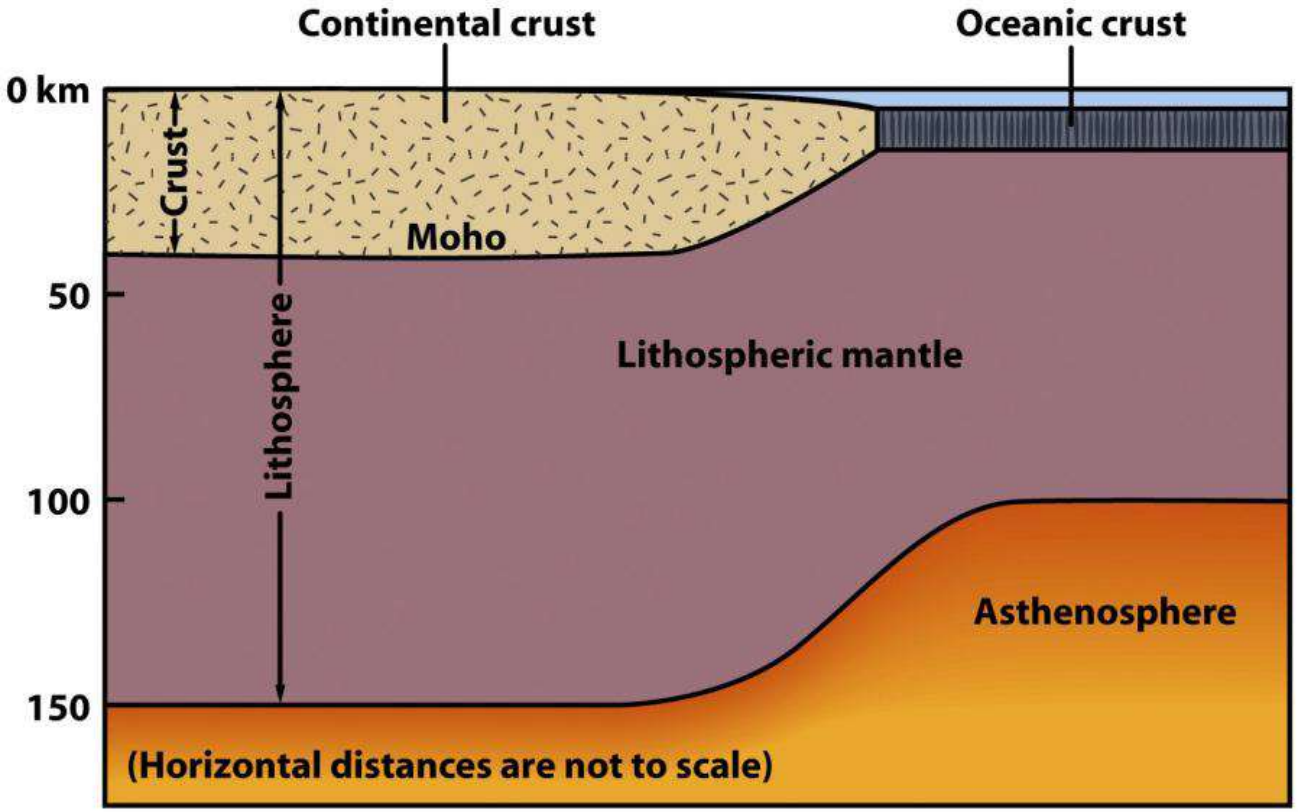
…but sometimes we want to divide the layers of the Earth by their behavior or physical properties

- Lithosphere – The brittle portion of Earth's interior.
  - –Behaves as a non-flowing, rigid material.
  - –The material that moves as tectonic plates.
  - –Made of 2 components: crust and upper mantle.
- Asthenosphere – The ductile portion of Earth's interior.
  - –Shallower under oceanic lithosphere.
  - –Deeper under continental lithosphere.
  - –Flows as a soft **ductile solid.**
  - –Contains a small percentage of melt (< 2%)



Boundaries Between Layers

- The Crust-Mantle boundary = **Moho**
  - –defined by seismic discontinuity indicating significant *change in composition.*
- **Brittle-ductile transition**
  - –Defined by a significant *change in rock physical properties (viscosity)*
  - –Also defined as the depth below which earthquakes do not occur.
- Lithosphere ≠ Crust

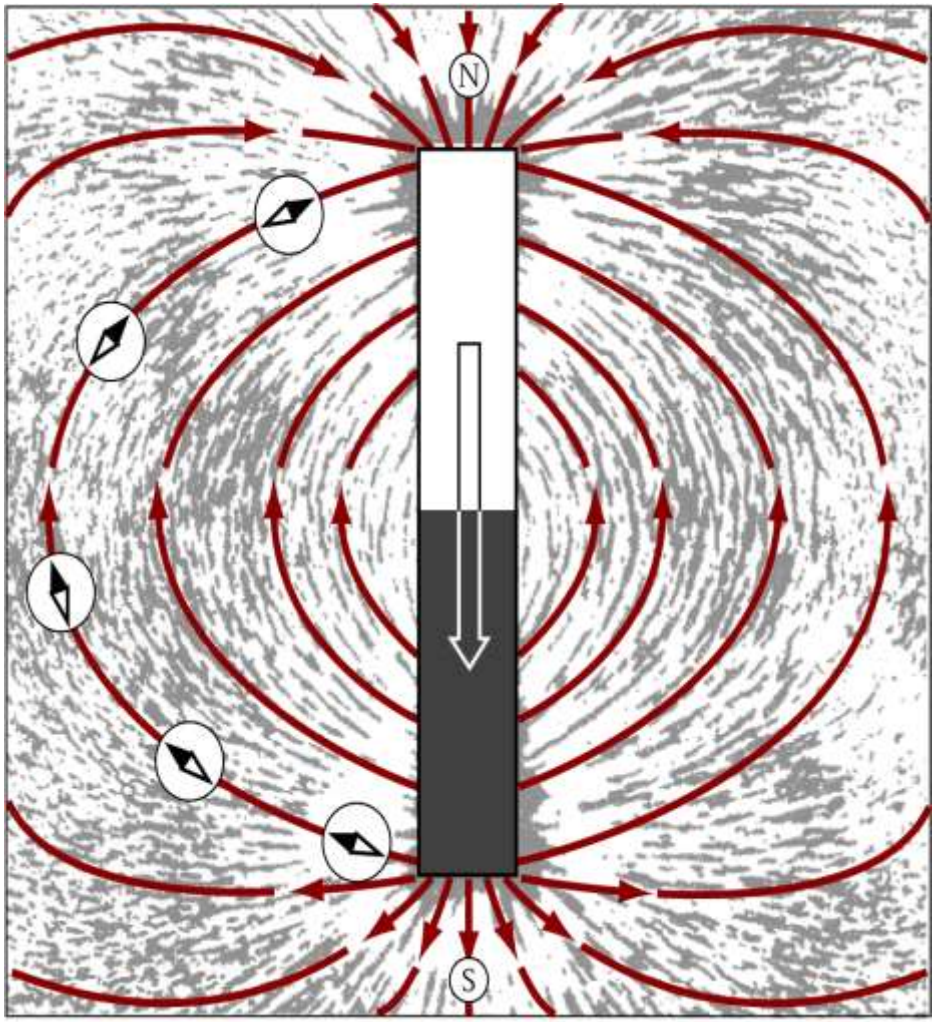


Earth's Magnetic Field

Geodynamo

-The Earth's magnetic field is produced by the ***geodynamo***

-Flow in the liquid iron outer core creates a magnetic field



Magnetic field

- region affected by force emanating from a magnet - grows stronger as separating distance decreases - attracts or repels magnetically charged or moving electrically charged objects - compasses work because Earth is a large magnet

Earth's Magnetic Field

Magnetic field - Like a bar magnet, Earth's magnetic field is a dipole, (has both a N and S pole)

-Solar wind contains electromagnetic particles that are deflected by earth's field. These particles distort the shape of earth's magnetic field in space

-Van Allen belts – two belts in the inner magnetic field where high energy cosmic rays are trapped. Protects us from solar radiation!