



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

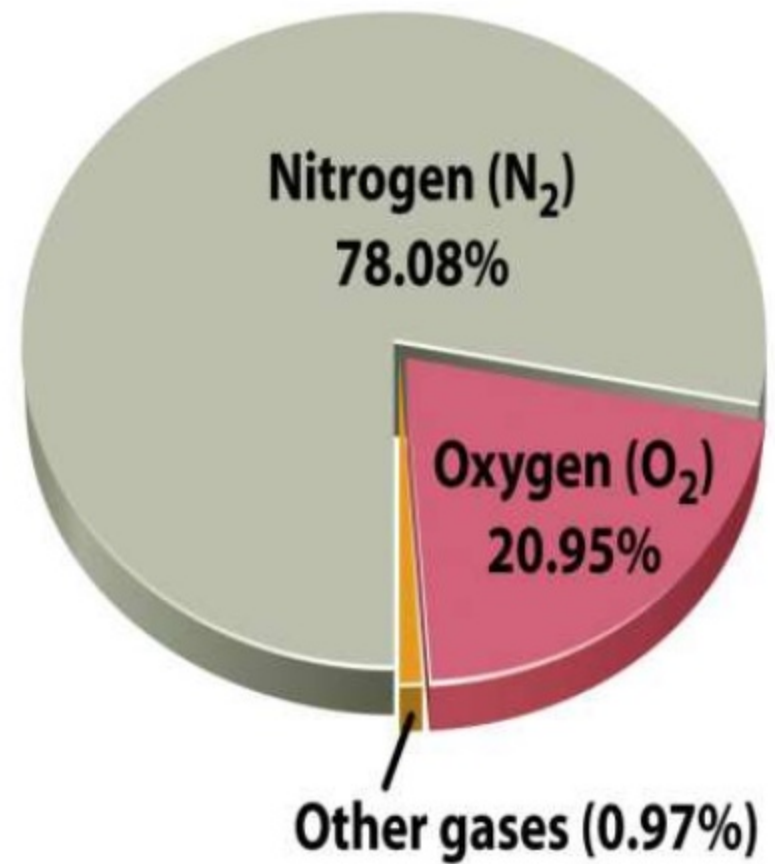
○ All others ~1%

○ Ar, CO₂, CH₄, H₂O, Ne, CO, SO₂

○ Some other Planets have atmospheres too!

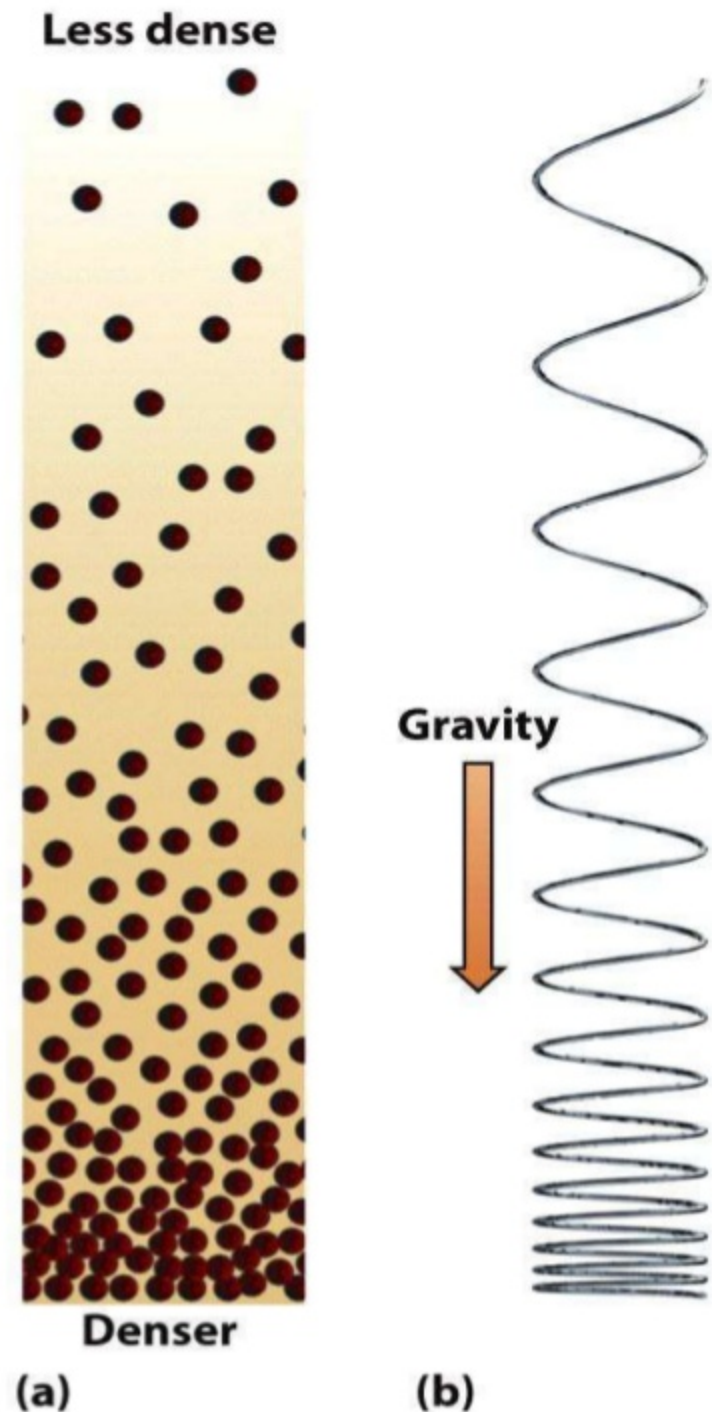
○ None have N₂ & O₂ as dominant gasses

○ 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

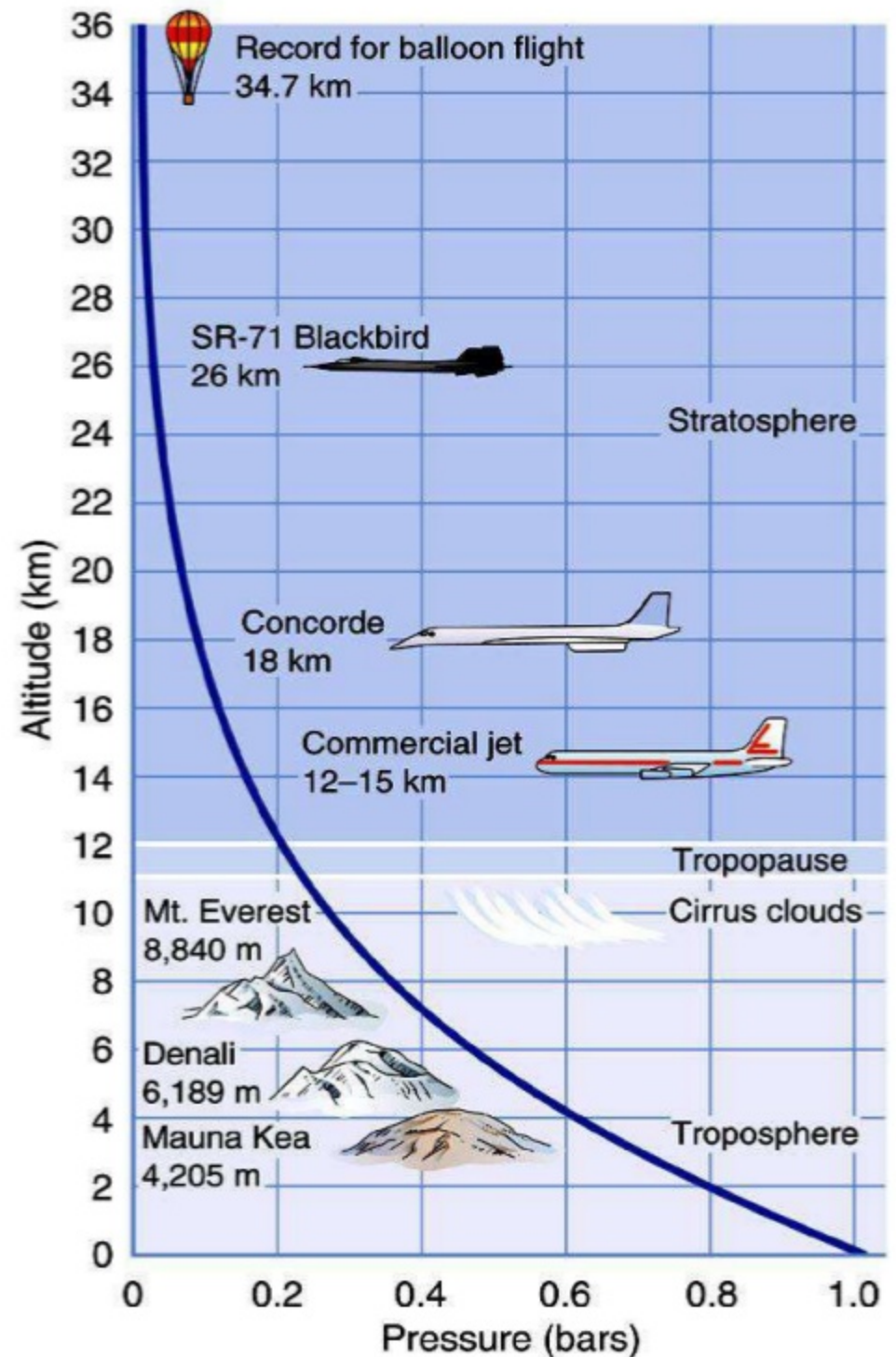
○ Tropopause (11-12 km)

○ Troposphere (0-11 km)

○ Mixing layer

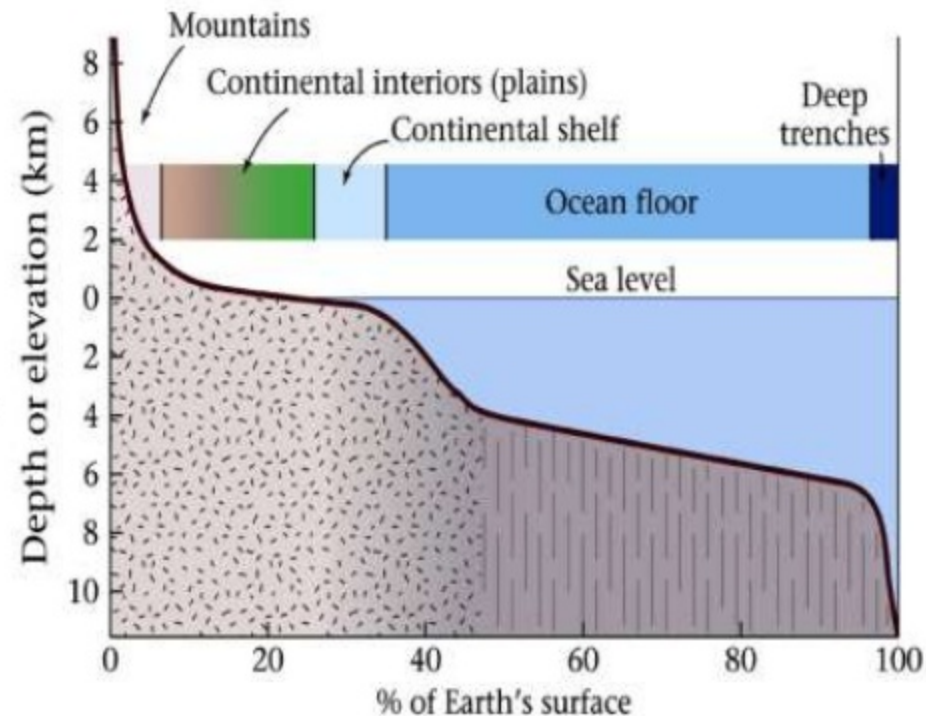
○ All weather is limited to this layer

○ "Tropo" = Greek for "turning"



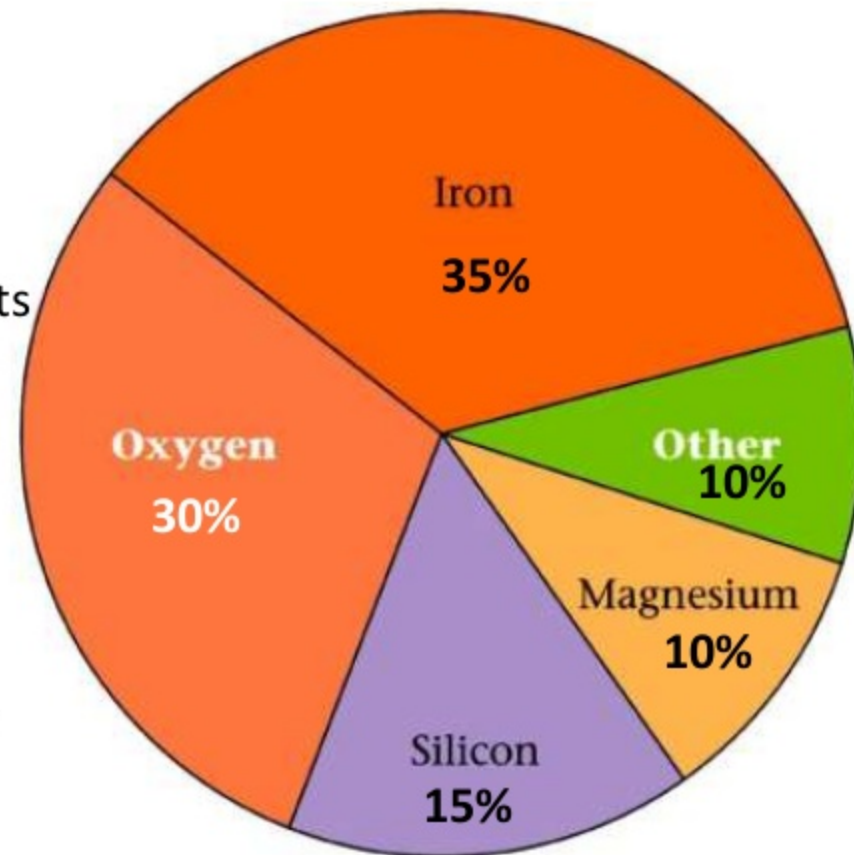
Earth's Components

- 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).



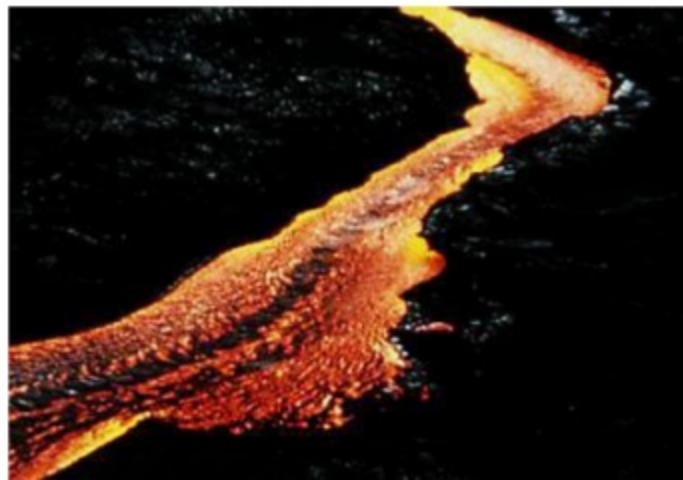
Earth Materials

- 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.
 - H₂O, CO₂, CH₄, and SO₂
 - Volatiles are released from volcanic eruption



Earth's Layers

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

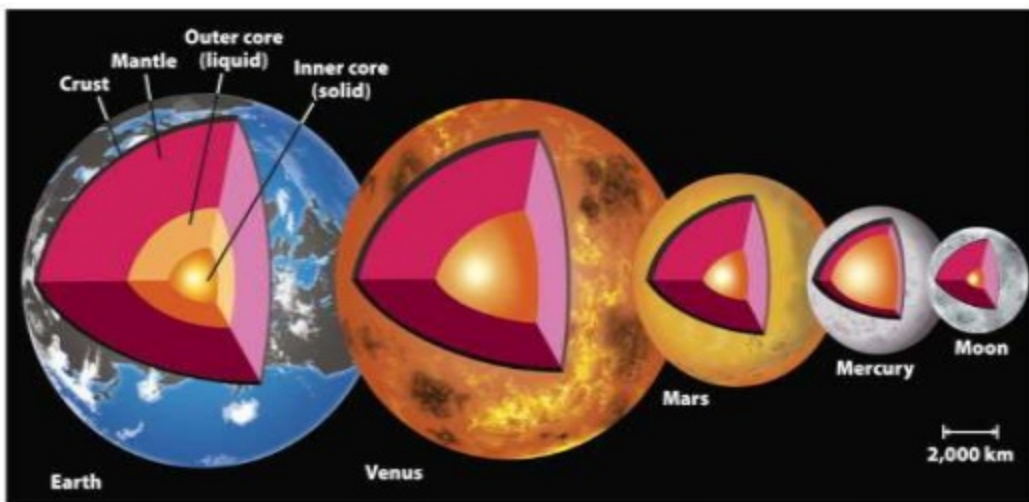
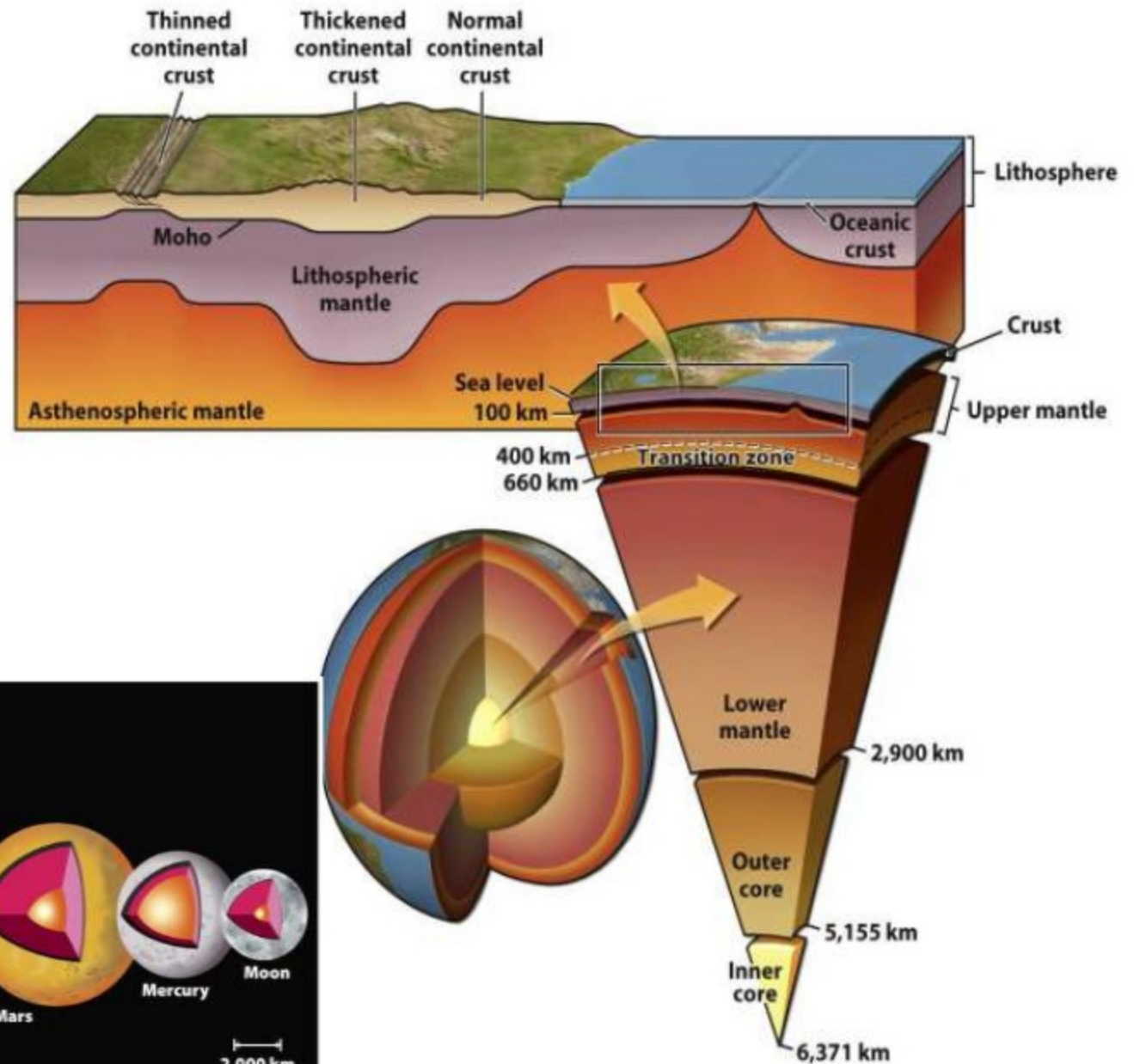
- If the Earth consisted of a thin solid shell over a thick liquid center, then the surface would rise and fall with tides like the ocean – This does not happen; only the oceans rise and fall.



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

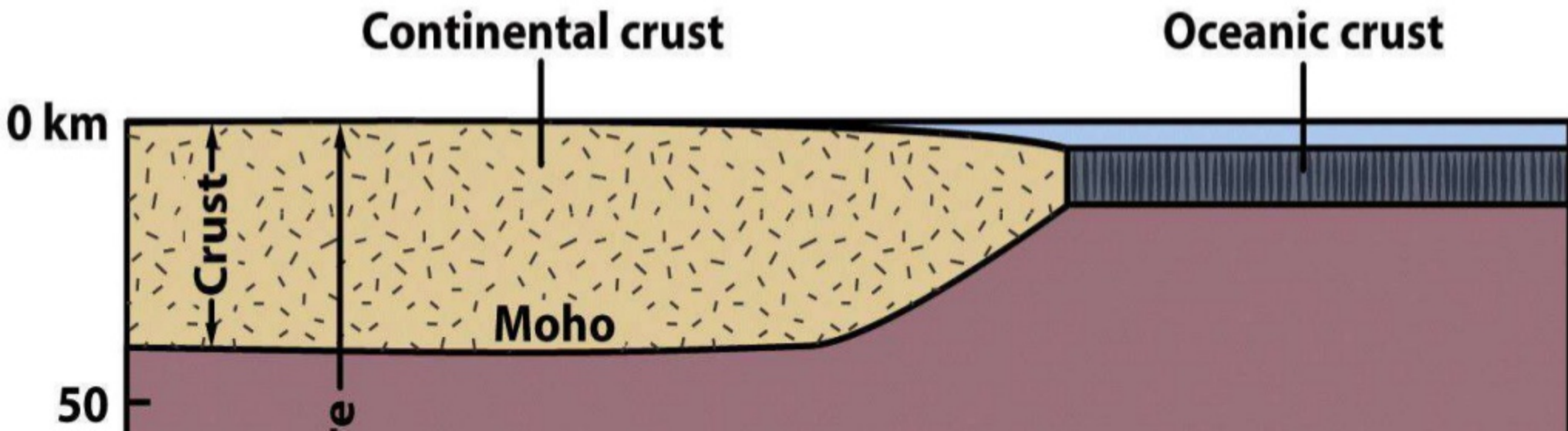
Earth's Interior Layers

- Crust
 - Continental
 - Oceanic
- Mantle
 - Upper
 - Lower
- Core
 - Outer – Liquid
 - Inner – Solid



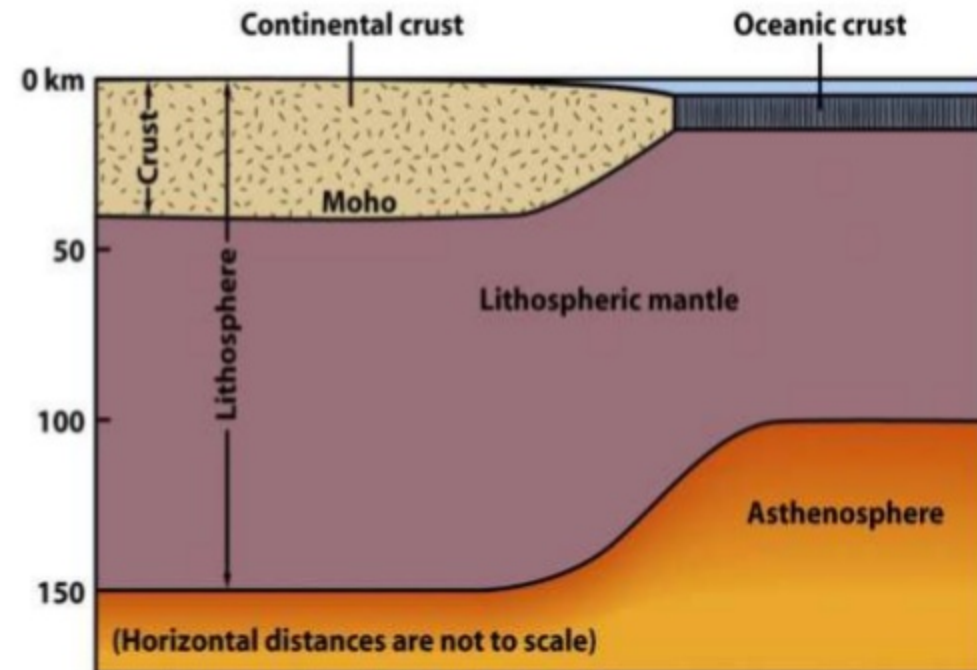
The Crust

- 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.



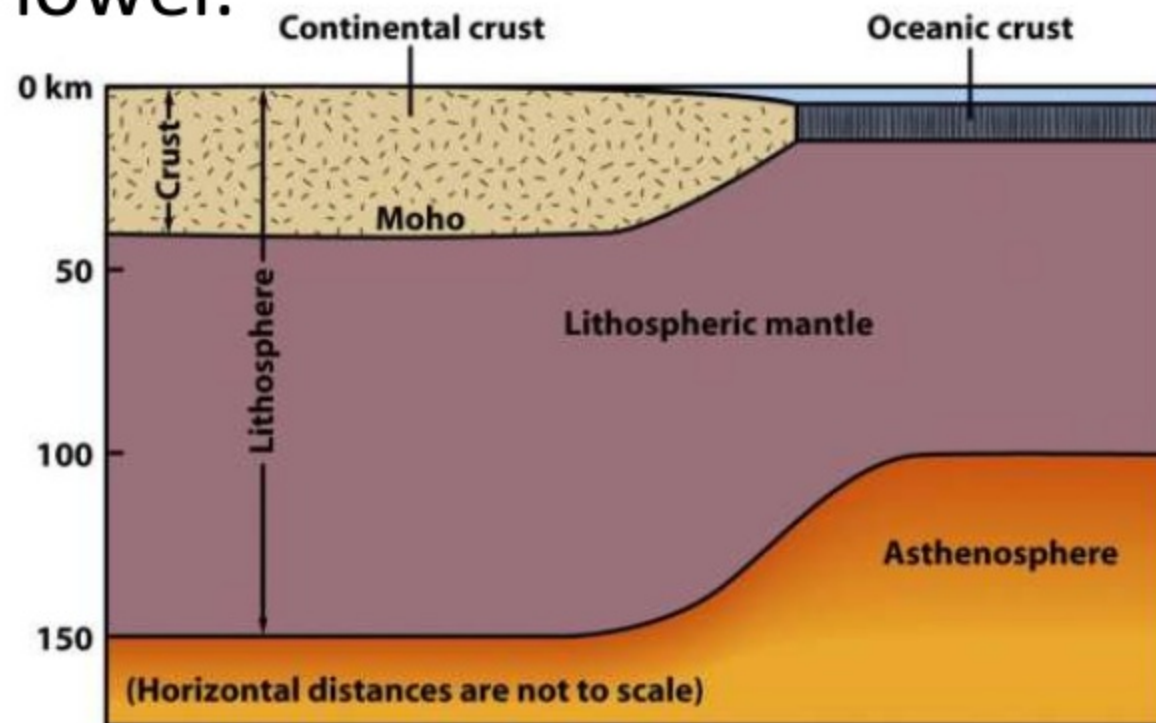
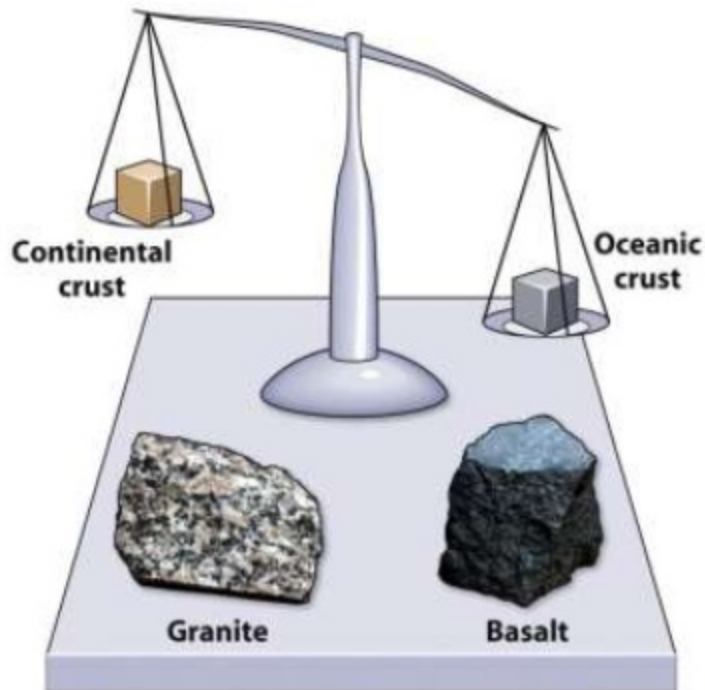
Two Types of Crust

- Continental crust – Underlies the continents.
 - Avg. rock density about 2.7 g/cm^3 .
 - Avg. thickness 35-40 km.
 - Felsic composition. Avg. rock type = Granite
 - Oceanic crust – Underlies the ocean basins.
 - Density about 3.0 g/cm^3 .
 - Avg. thickness 7-10 km.
 - Mafic composition
- Avg. rock type = Basalt/Gabbro



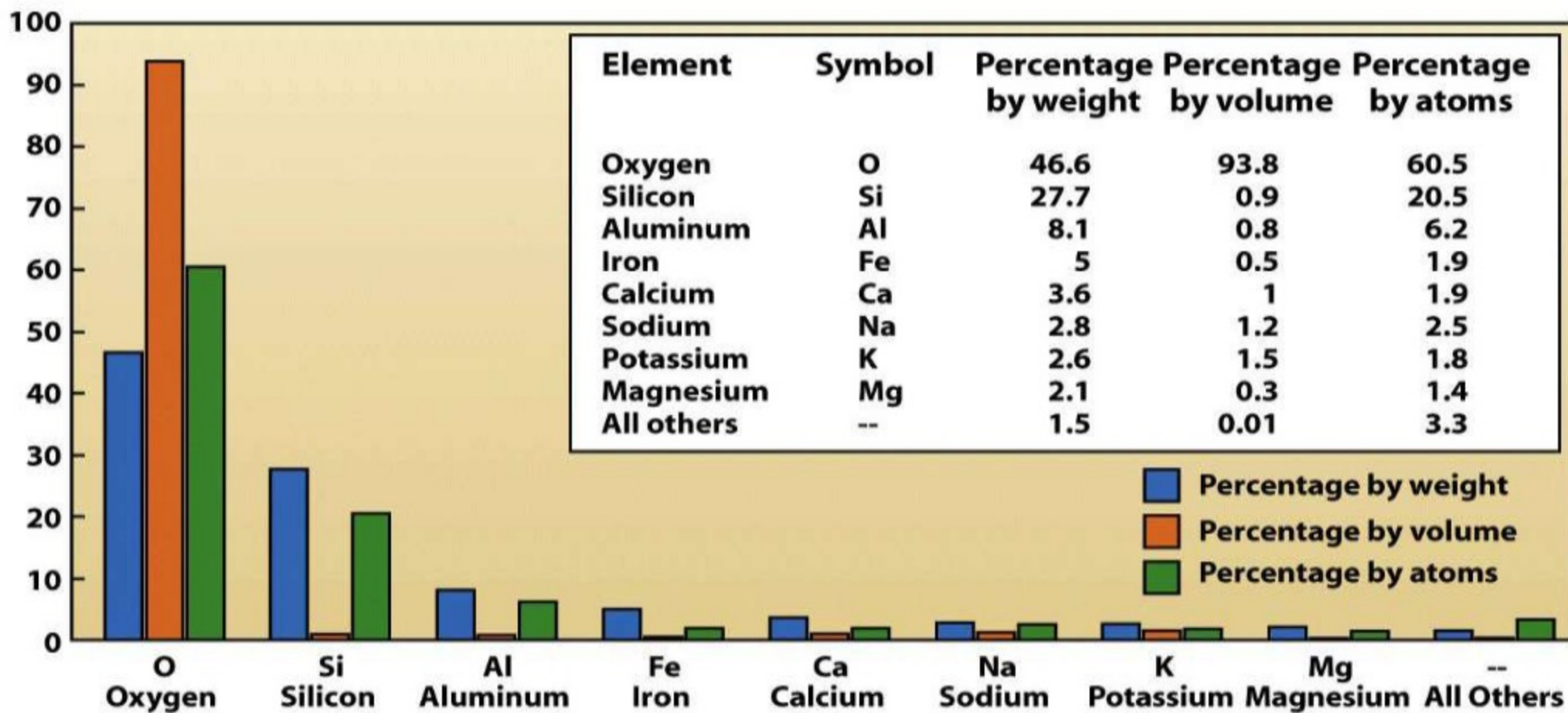
Two Types of Crust

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



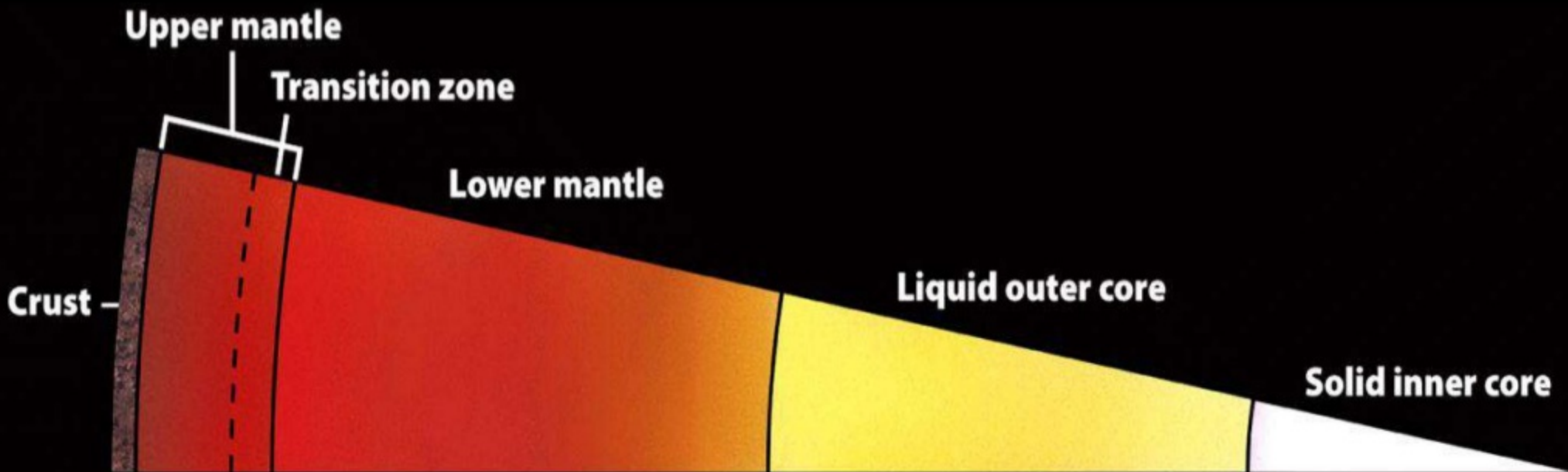
Crustal Composition

- 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.



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

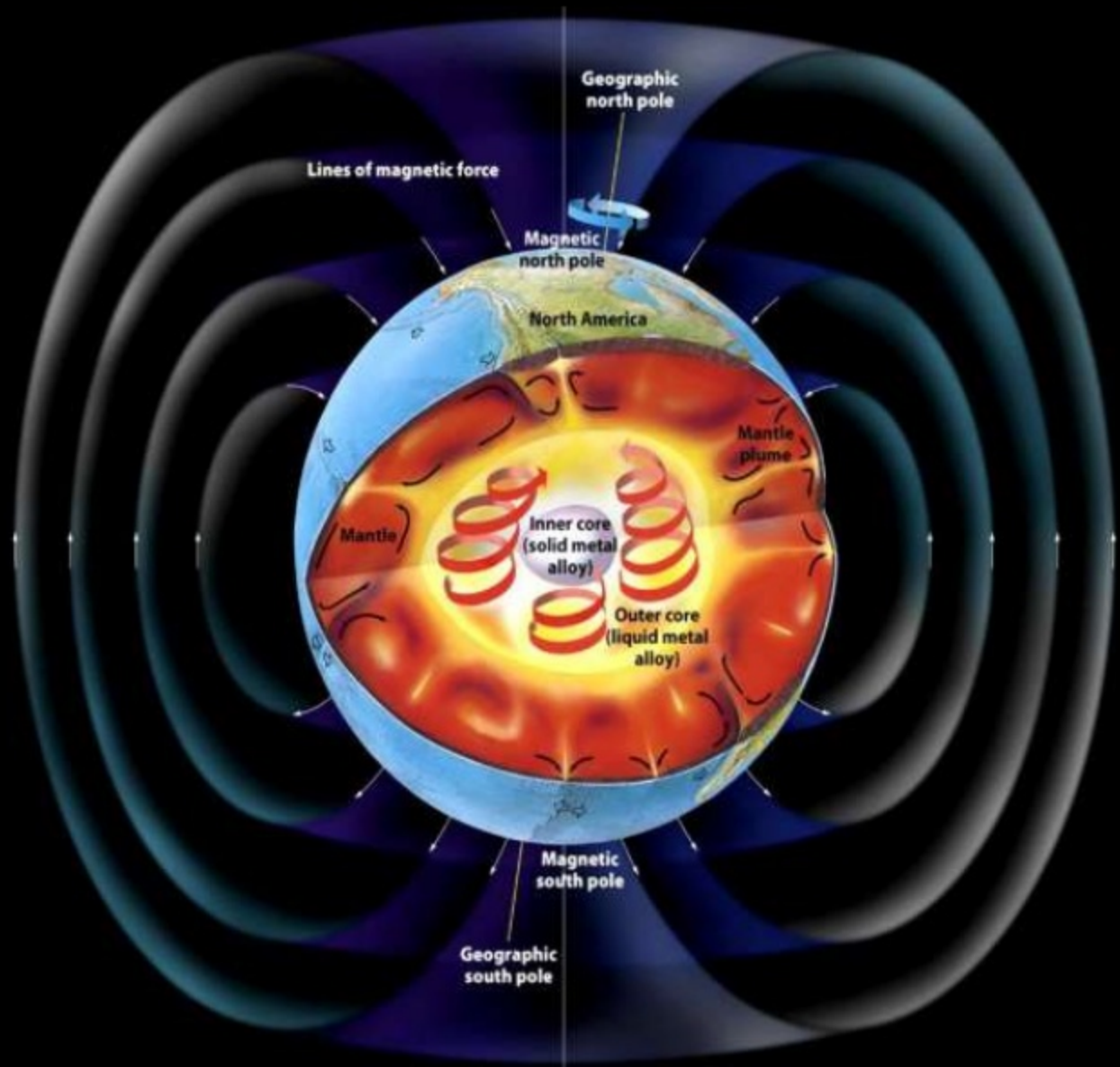
- An iron-rich sphere with a radius of 3,471 km.
- 2 components with differing seismic wave behavior.
- Flow in the outer core generates the magnetic field.

–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

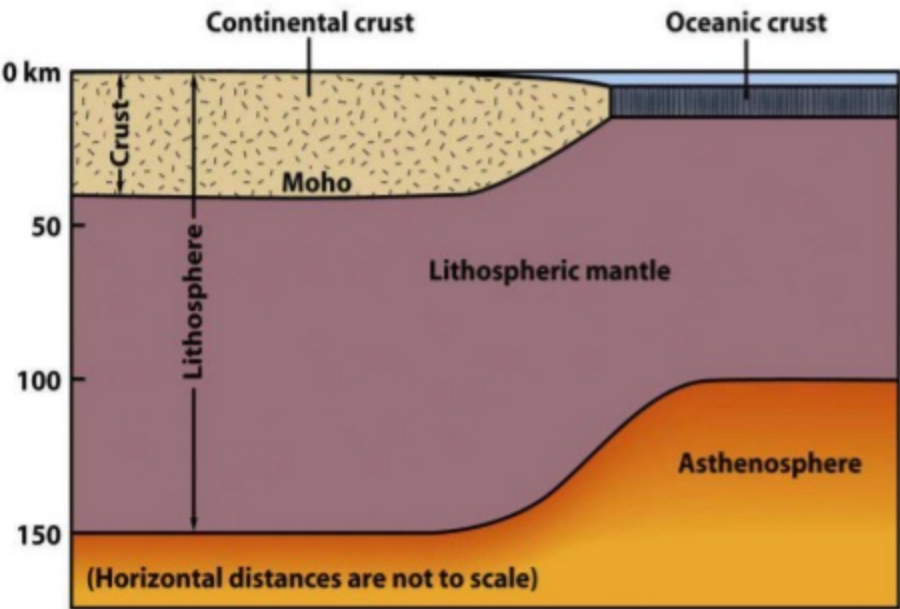


Lithosphere-Asthenosphere

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

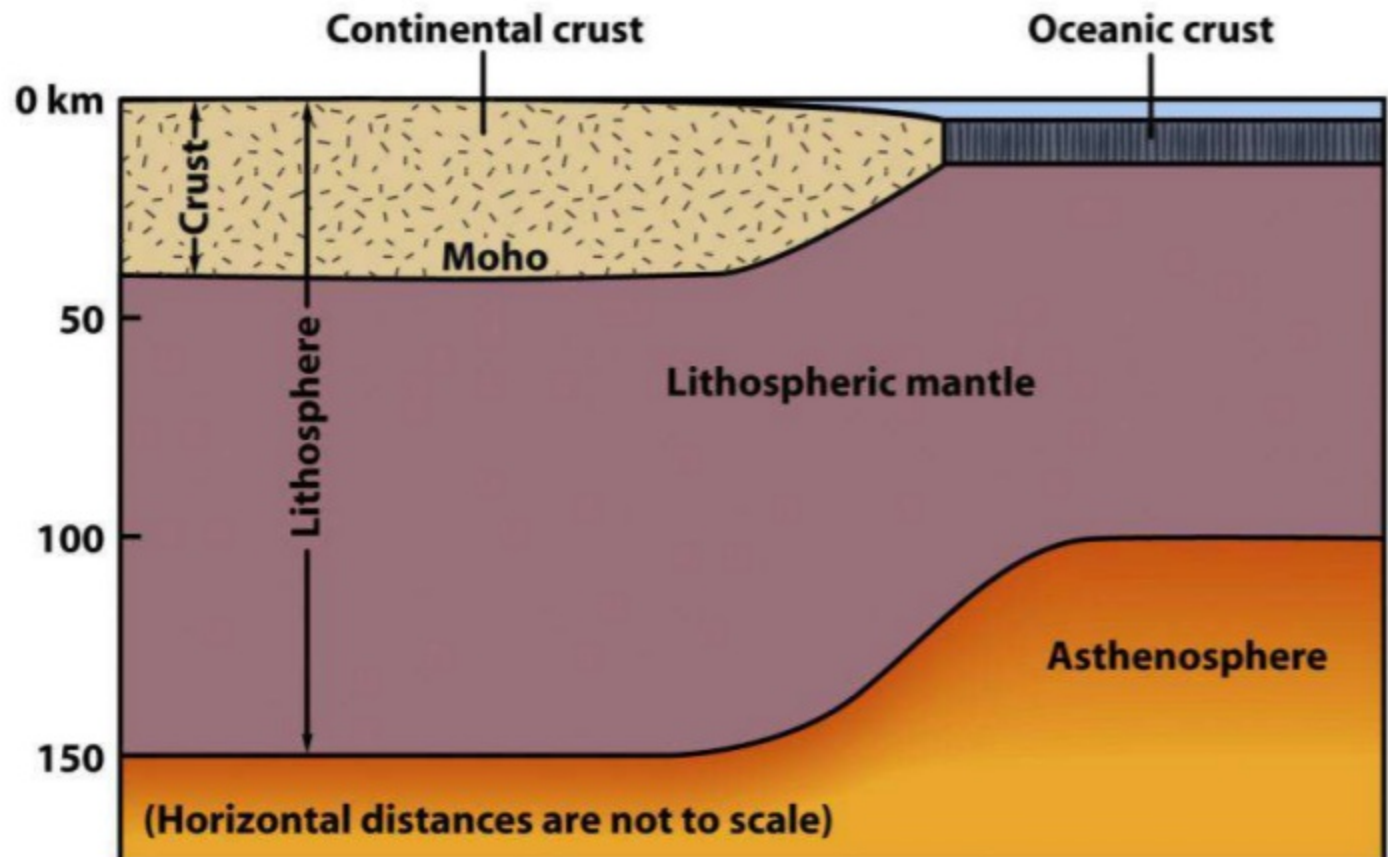
...but sometimes we want to divide the layers of the Earth by their behavior or physical properties

- 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 \neq 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

