OLLI SG 492
Plate Tectonics

Session 2 - September 26, 2022

Today’s Meeting

- Formation of the Earth - Runaway Accretion.
- Layered Earth.
- Earth’s Magnetic Field.
- Formation of the Moon.

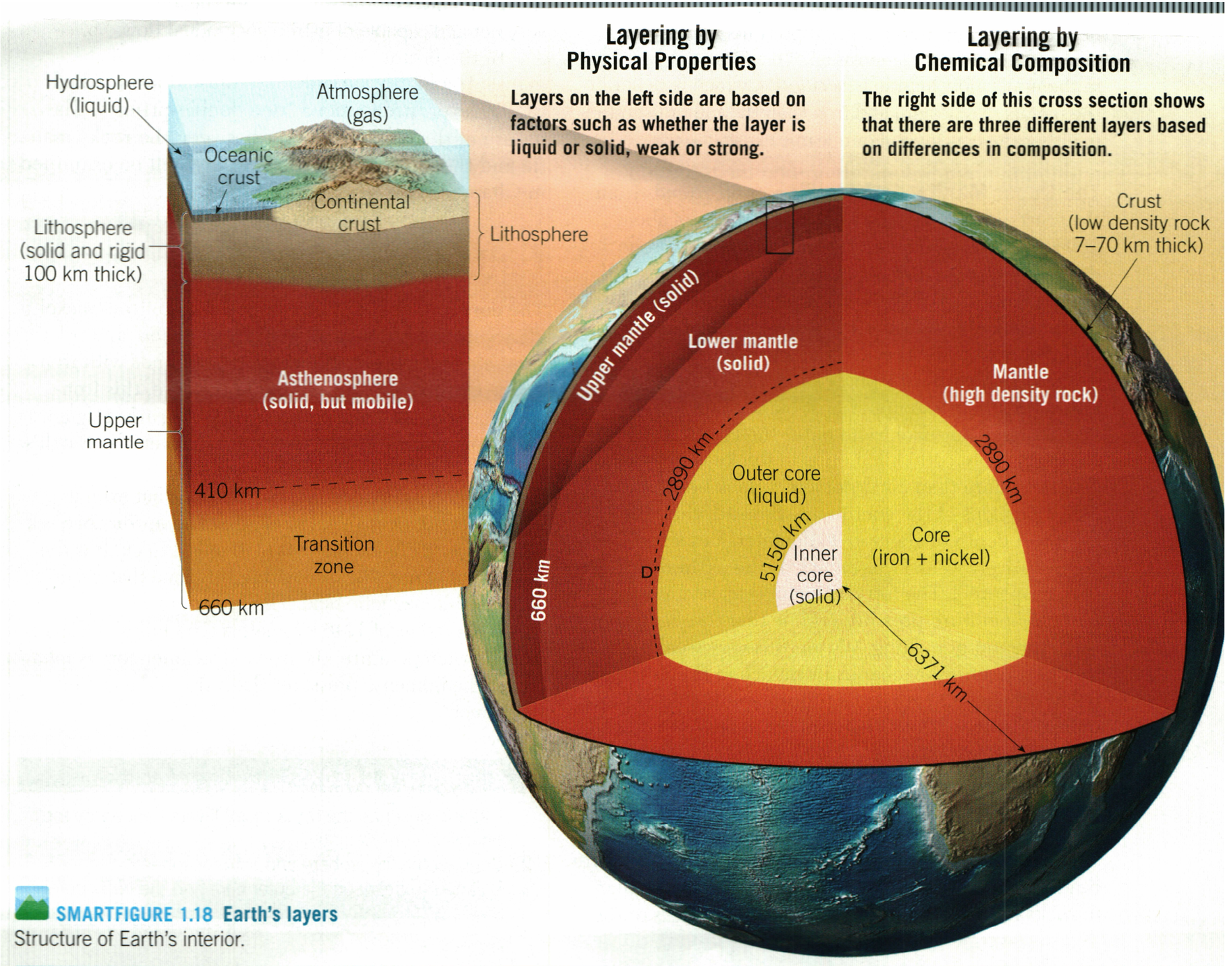
Chemical and Physical Differentiation of the Earth

- The collisions that created Earth through accretion, resulted in a molten planet. Kinetic energy of collisions was converted to thermal energy. Earth was hot enough to melt iron and nickel.
- Chemical differentiation - Based on their chemical binding preferences, elements began forming molecules and minerals.
- Physical differentiation:
  - Some molten iron and nickel formed blobs and sank toward the center of the Earth, forming the core.
  - Lighter elements separated out from the molten Earth and rose to form the mantle and the crust.
- Eventually, as Earth cooled, a semi-solid crust formed.

Chemical and Physical Differentiation of the Earth

- Hazen on chemical and physical differentiation:
  - Video 14.3 - from 13:40 to 14:16 (differentiation)
  - Video 14.4 - from 16:42 to 18:10 (physical differentiation)

Earth's Layers



SMARTFIGURE 1.18 Earth's layers
Structure of Earth's interior.

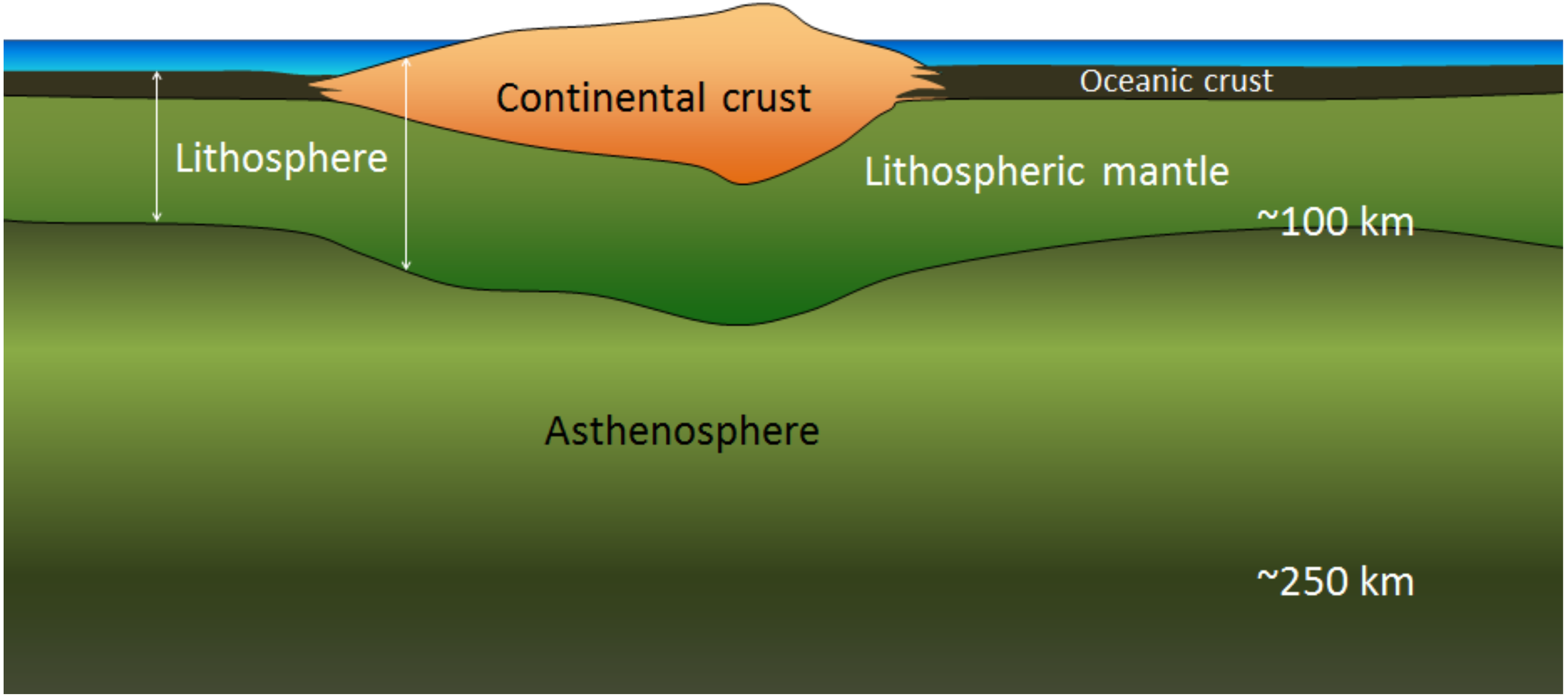
Layered Earth - Crust

- Two types of crust:
  - Oceanic Crust - Density of 3.0 gm/c^3; average thickness of 7 km. (4.5 mi.)
  - Continental Crust - Density of 2.7 gm/c^3; average thickness of 40 km. (25 mi.)
    - Range of thickness of continental crust - 70 km. (45 mi.) under mountain ranges, 20 km (12 mi.) under the Basin and Range.
  - The boundary layer between the crust and the mantle is the Moho, named after the Serbian seismologist Andrija Mohorovicic.

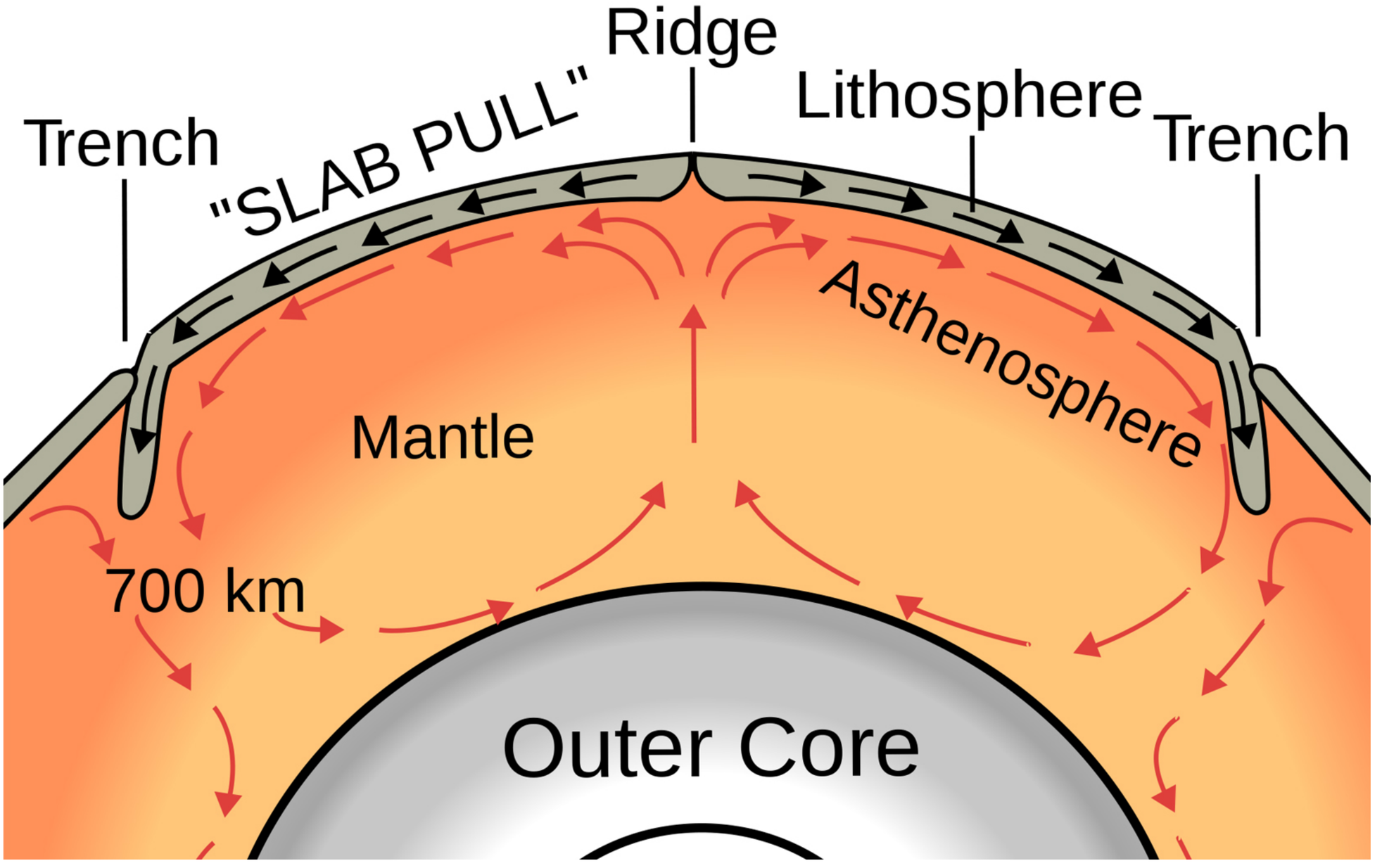
Layered Earth - Mantle

- Contains 82% of Earth's volume; 2900 km. thick (from the Moho to the outer liquid core); average density of 3.3 gm/c^3. Solid, but hot and capable of flowing (ductile). Consists of three shells:
  - Upper mantle, 660 km. deep; consists of:
    - Lithospheric mantle - ranges in depth from a few km. under oceanic ridges, to 200 km. under continental interiors. Rigid, and combined with crust it forms the Lithosphere.
    - Asthenosphere - ranges from 200 to 300 km. deep. Weaker than lithospheric mantle due to Earth's heat.
    - Transition Zone - ranges between 400 and 660 km. deep. Marks the transition between the upper and lower mantle.

Lithospheric Mantle



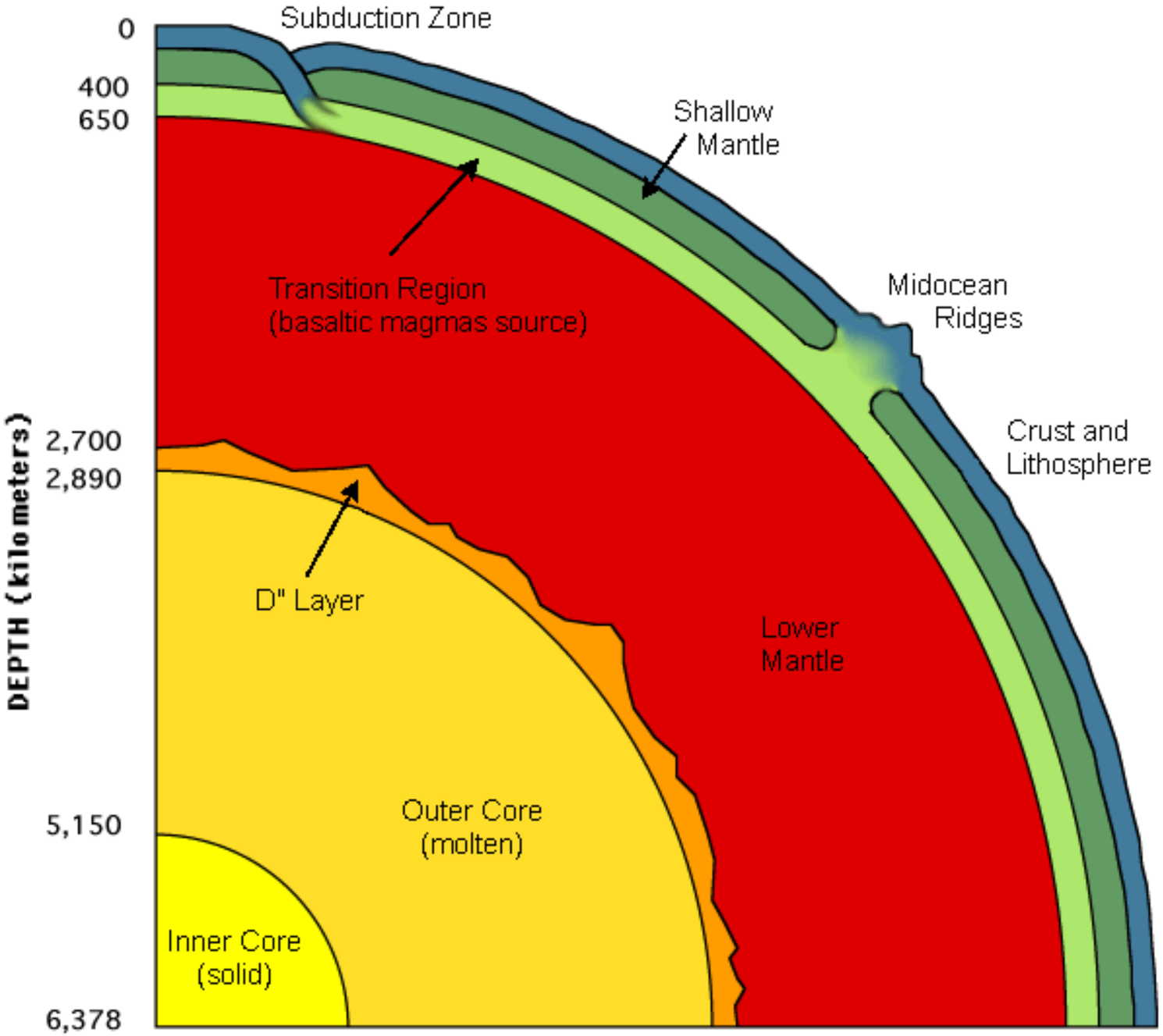
Asthenosphere



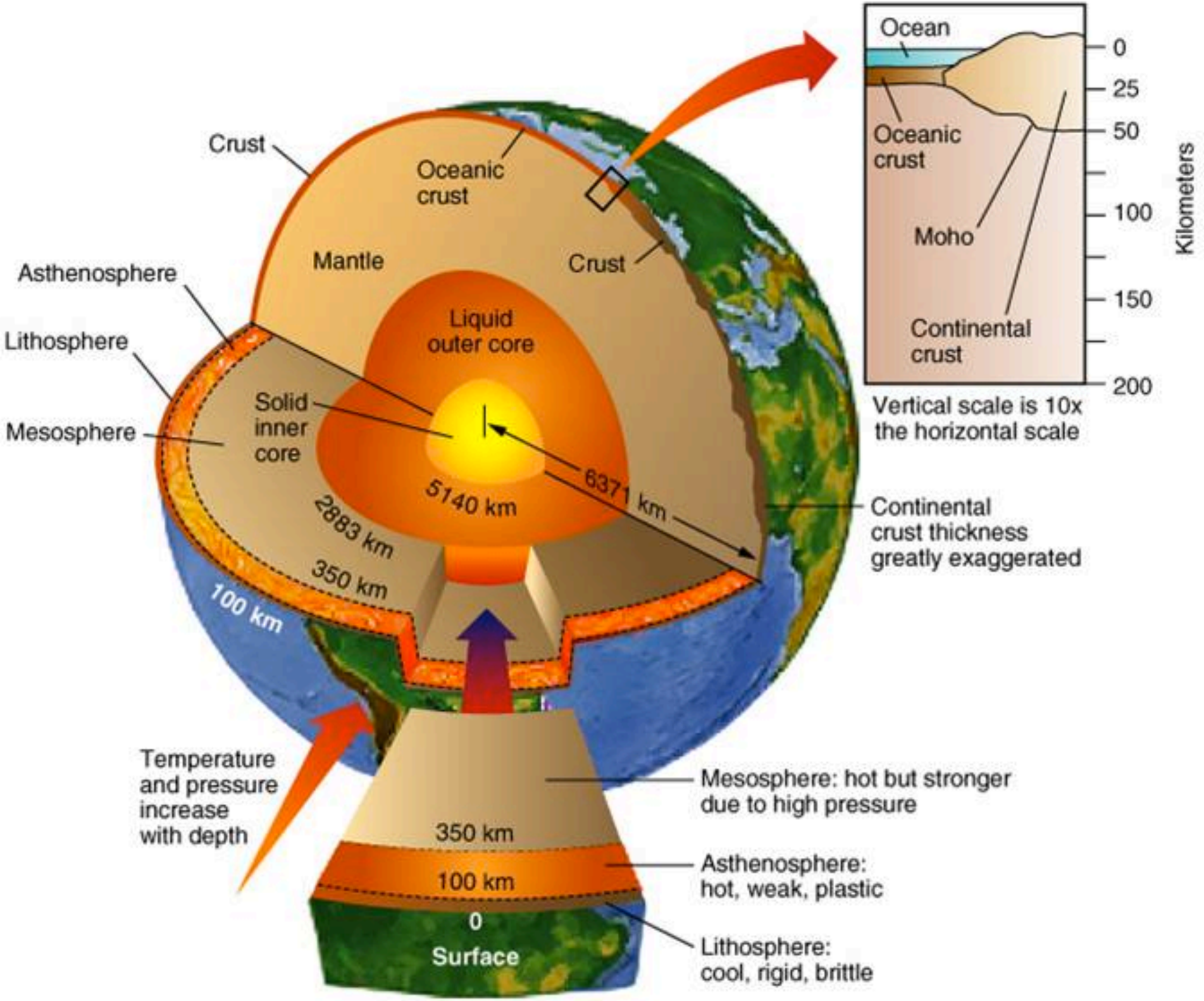
Layered Earth - Mantle

- Mantle (cont'd.)
  - Lower Mantle - Contains 56% of Earth's volume. From 660 km. to 2900 km. deep. Extends from the Transition Zone to the Outer Liquid Core.
  - The D" Layer (Dee Double Prime) - Boundary layer between the Lower Mantle and the Outer Liquid Core. Graveyard of subducted oceanic Lithosphere, birthplace of deep, hot mantle plumes. A few hundred km. in thickness.

D” Layer


Subduction Zone
0
400
650
2,700
2,890
5,150
6,378
DEPTH (kilometers)
Shallow Mantle
Transition Region
(basaltic magmas source)
Midocean Ridges
Crust and Lithosphere
D" Layer
Lower Mantle
Outer Core
(molten)
Inner Core
(solid)

Earth's Layers



Layered Earth - Core

- Contains about 18% of Earth's volume, but 1/3rd of it's mass. Composed of two layers:
  - Liquid Outer Core - composed mostly of iron and nickel, with 15% other lighter elements.
    - Density increases at mantle-core boundary from 5.6 gm/c^3 to 9.9 gm/c^3.
    - Responsible for Earth's magnetic field - convection in liquid outer core creates spiral flows of iron-rich fluids, creating a geodynamo.
    - A remnant of Earth's intensely hot formation; will eventually become solid.

Layered Earth - Core

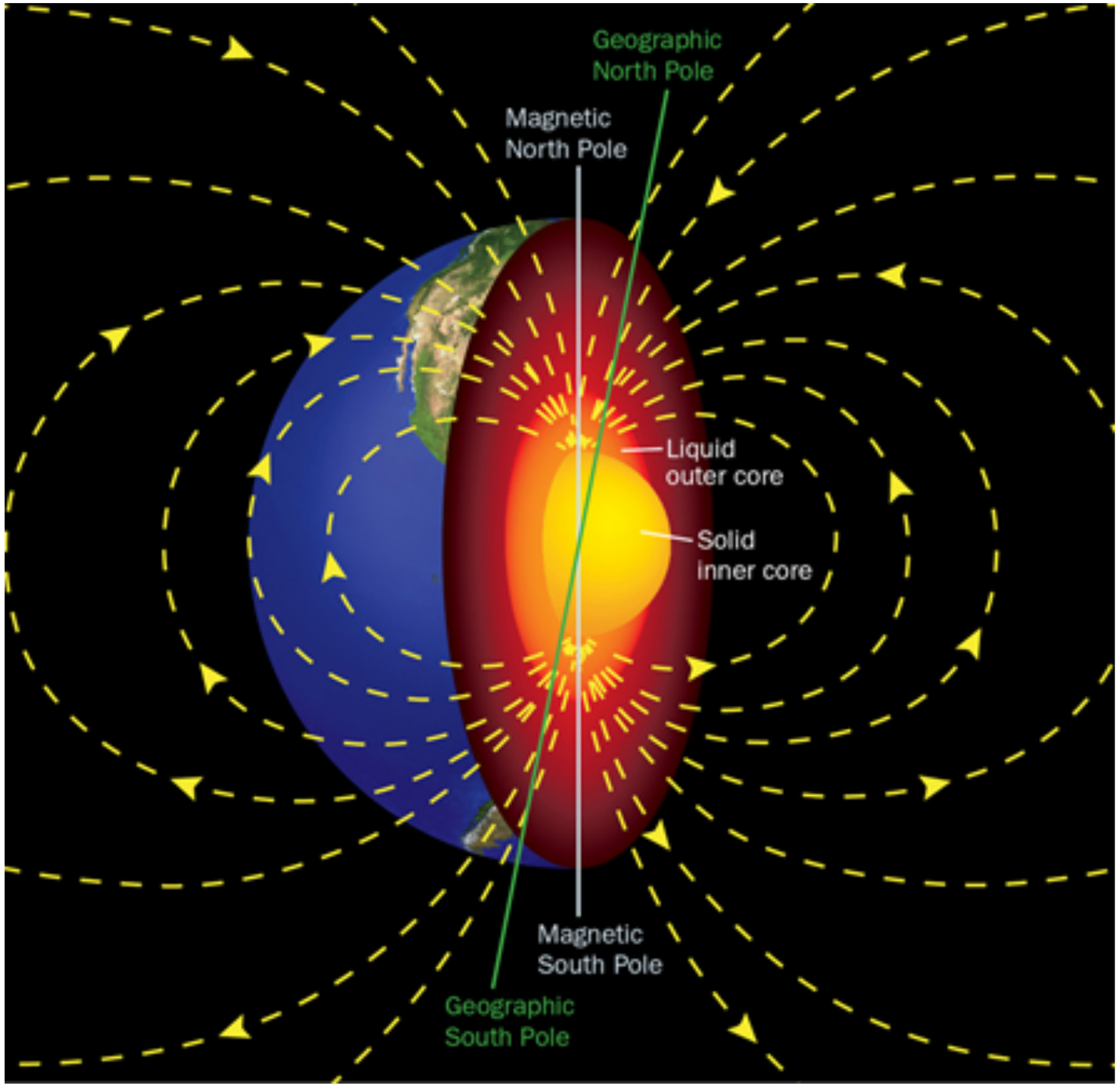
- Core (cont'd.)
  - Solid Inner Core - comprised mostly of iron, with trace amounts of other elements. Density of 13 gm/c^3.
    - As Earth cooled, iron in the core crystallized, becoming solid. Continues to grow.
    - Rotates independently of, and faster then, Earth's other layers.

Earth’s Core

Geodynamo

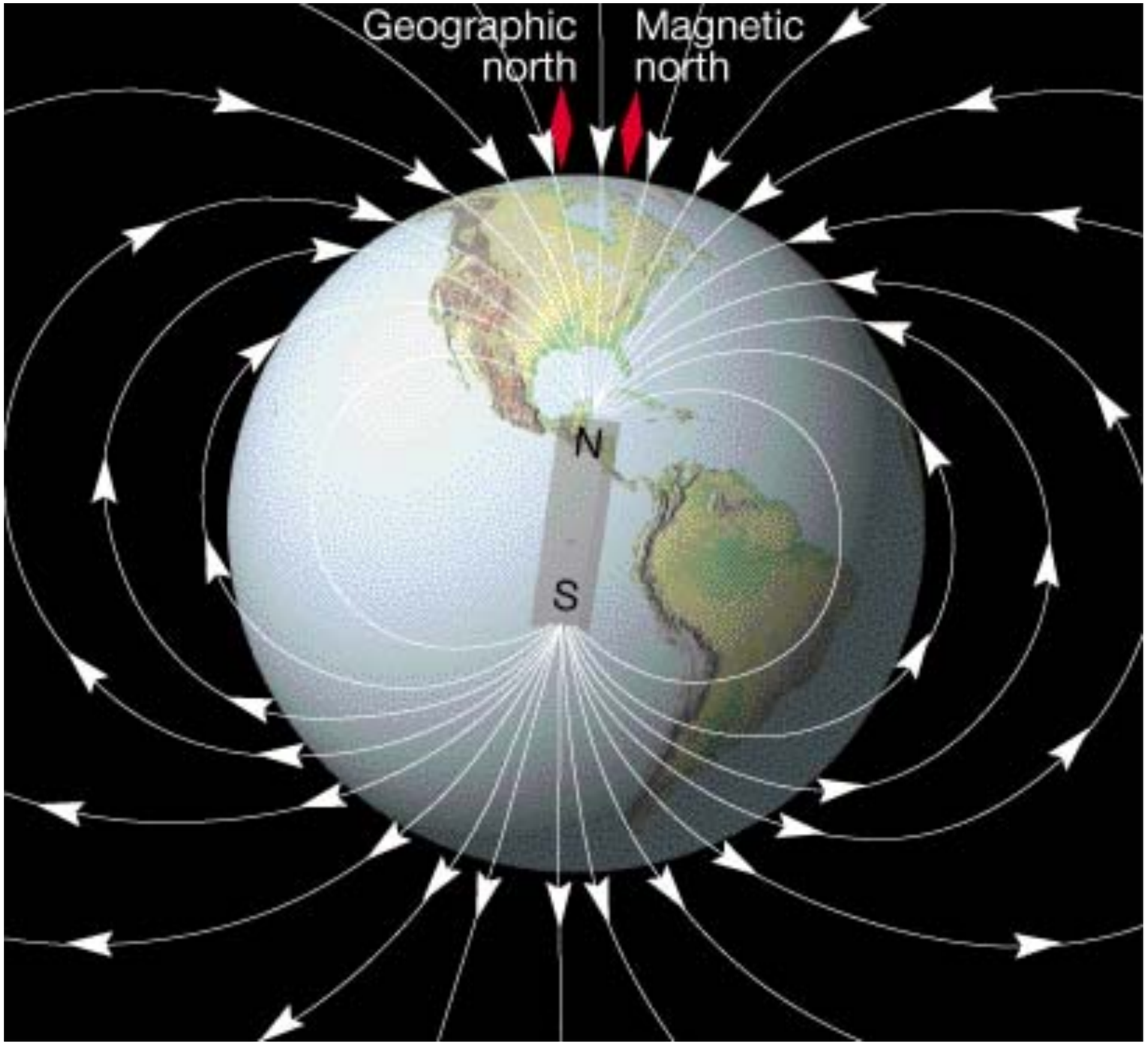
Earth’s Core

Earth’s Magnetic Field



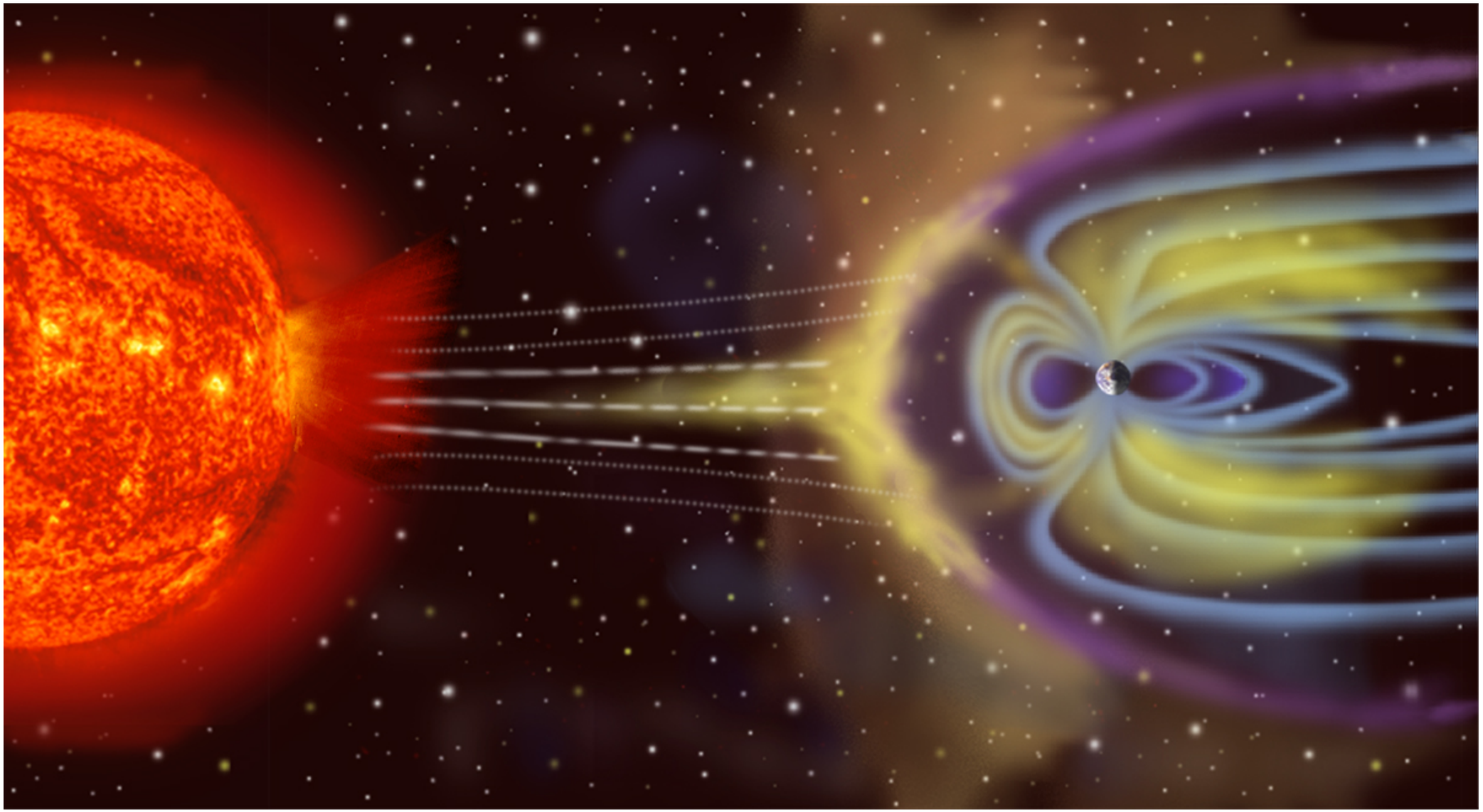
Earth's Magnetic Field

Inclination of the Field



Earth's Magnetic Field

Protection from Solar Wind



The composition of the Earth

(including crust, mantle and core) in terms of major chemical elements

1. Iron (Fe) - 35%
2. Oxygen (O) - 28%
3. Magnesium (Mg) - 17%
4. Silicon (Si) - 14.3%
5. Sulfur (S) - 2.7%
6. Nickel (Ni) - 2.7%
7. Calcium (Ca) - 0.6%
8. Aluminum (Al) - 0.4%
9. Other elements - 0.6%

Crust:
Oxygen, Silicon,Aluminum

Mantle:
Olivine, Pyroxenes

Core:
Iron, Nickel

Possibly:
Oxygen, Silicon, Sulfur

Formation of the Moon

- The Big Thwack - Proto-Earth collided with a planetesimal about the size of Mars, called Theia.
- Debris from proto-Earth and Theia encircled proto-Earth and coalesced into the Moon.
- A remanent of Theia was consolidated into proto-Earth increasing it’s mass.
- Hazen on The Big Thwack:
  - Video 16.1

Up Next

- Early Earth
  - Formation of the crust.
  - Hadean and Arcaean Periods.
- Fundamentals of plates.
- History of the theory and evidence.

Next Time - Plates!