

The Anatomy of the Earth



Some basic Earth facts

Radius	6,378 km
Surface Area	510,900,000 sq Km
Equatorial Circumference	4



Early Studies

- Isaac Newton calculated, from his studies of planets and the force of gravity, that the average density of the Earth is twice that of surface rocks and therefore that the Earth's interior must be composed of much denser material.
- Based on the cooling rate of iron cannonballs Georges Leclerc calculated that the age of the earth was 75,000 years

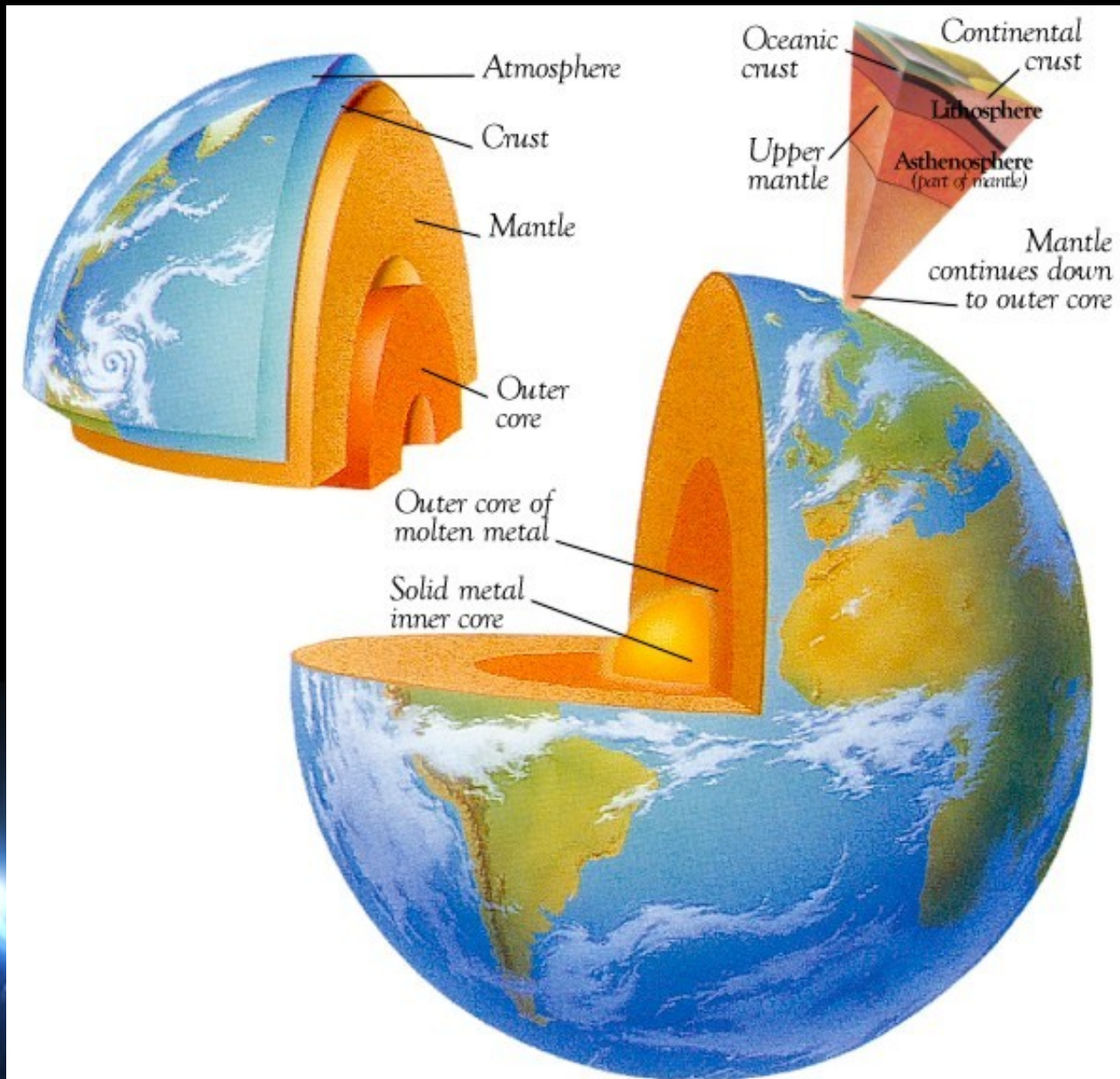


1643-1727



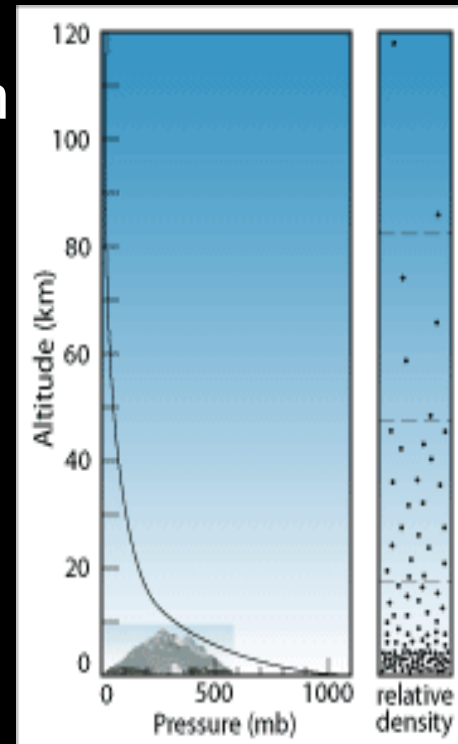
1707-1788

So what is the Earth made of?



Atmosphere

- Mass of the atmosphere is about 5 quadrillion (5×10^{15}) tonnes or 0.0000008 of Earth's mass
- Atmosphere extends about 100km above the Earth
 - 50% of atmosphere mass is below 5.6km
 - 90% of atmosphere mass is below 16km
- Pressure at the surface ~ 1 bar

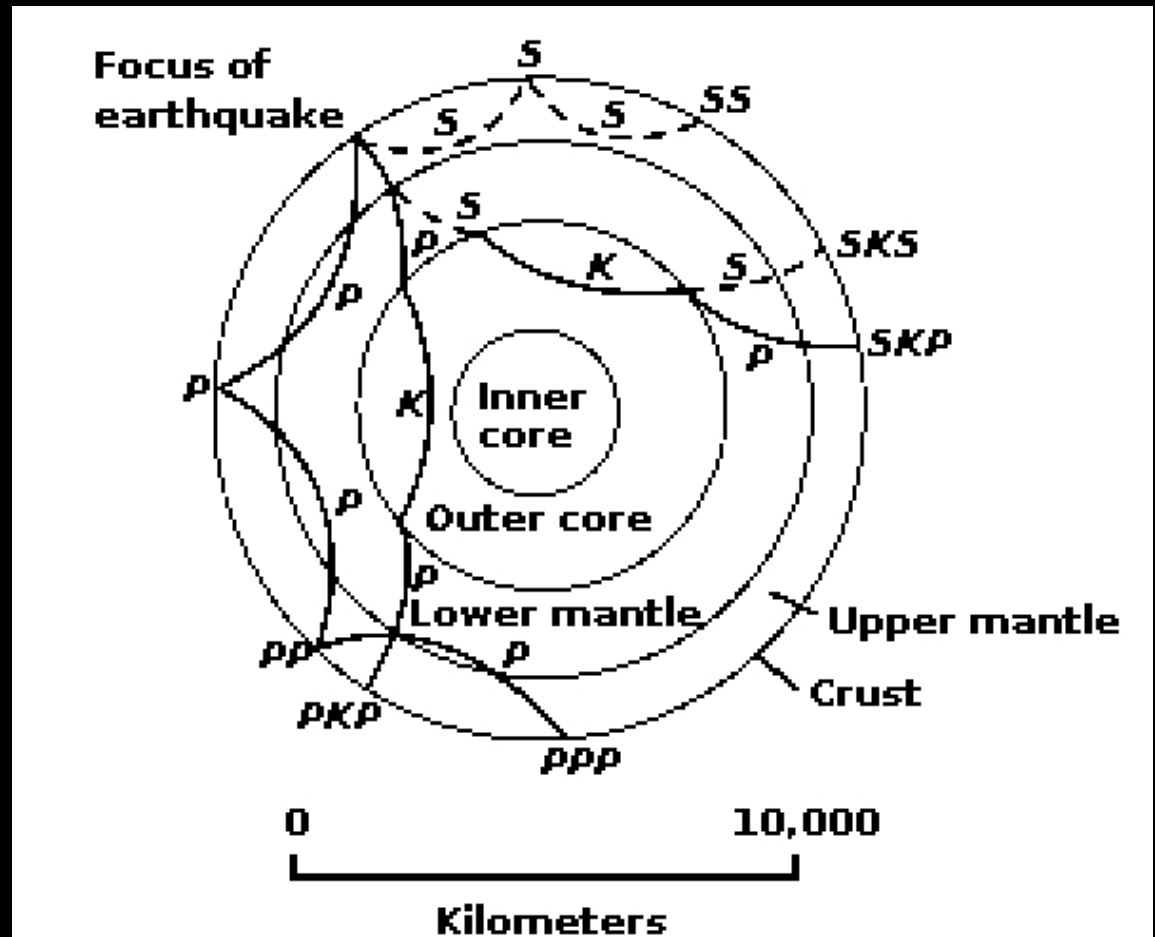


Atmosphere Composition

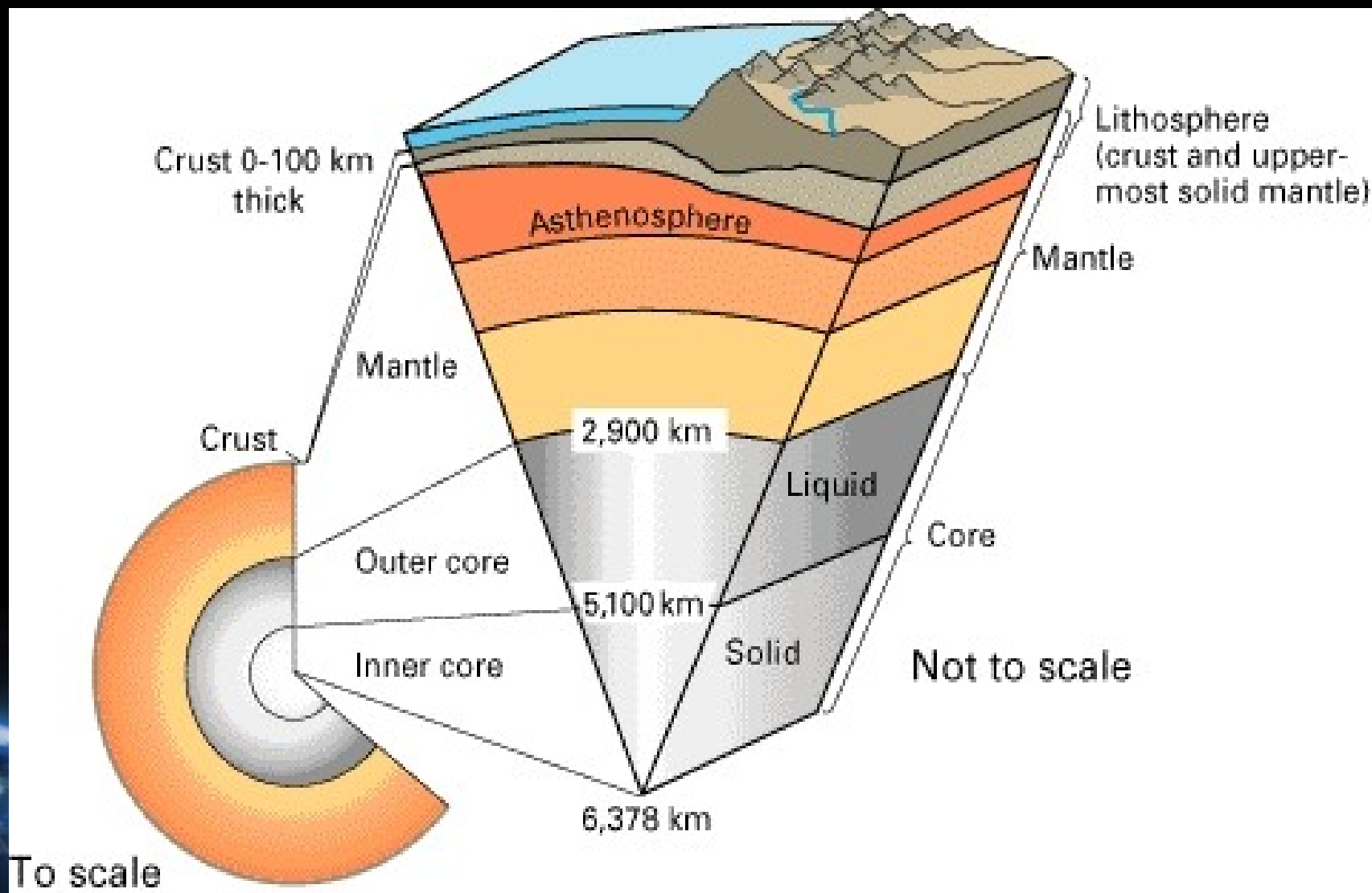
Nitrogen (N ₂)	78.08%
Oxygen (O ₂)	20.95%
Argon (Ar)	0.93%
Carbon Dioxide (CO ₂)	0.039%
Neon, Helium, Methane, Krypton, Hydrogen	<0.001%

How do we know what's inside?

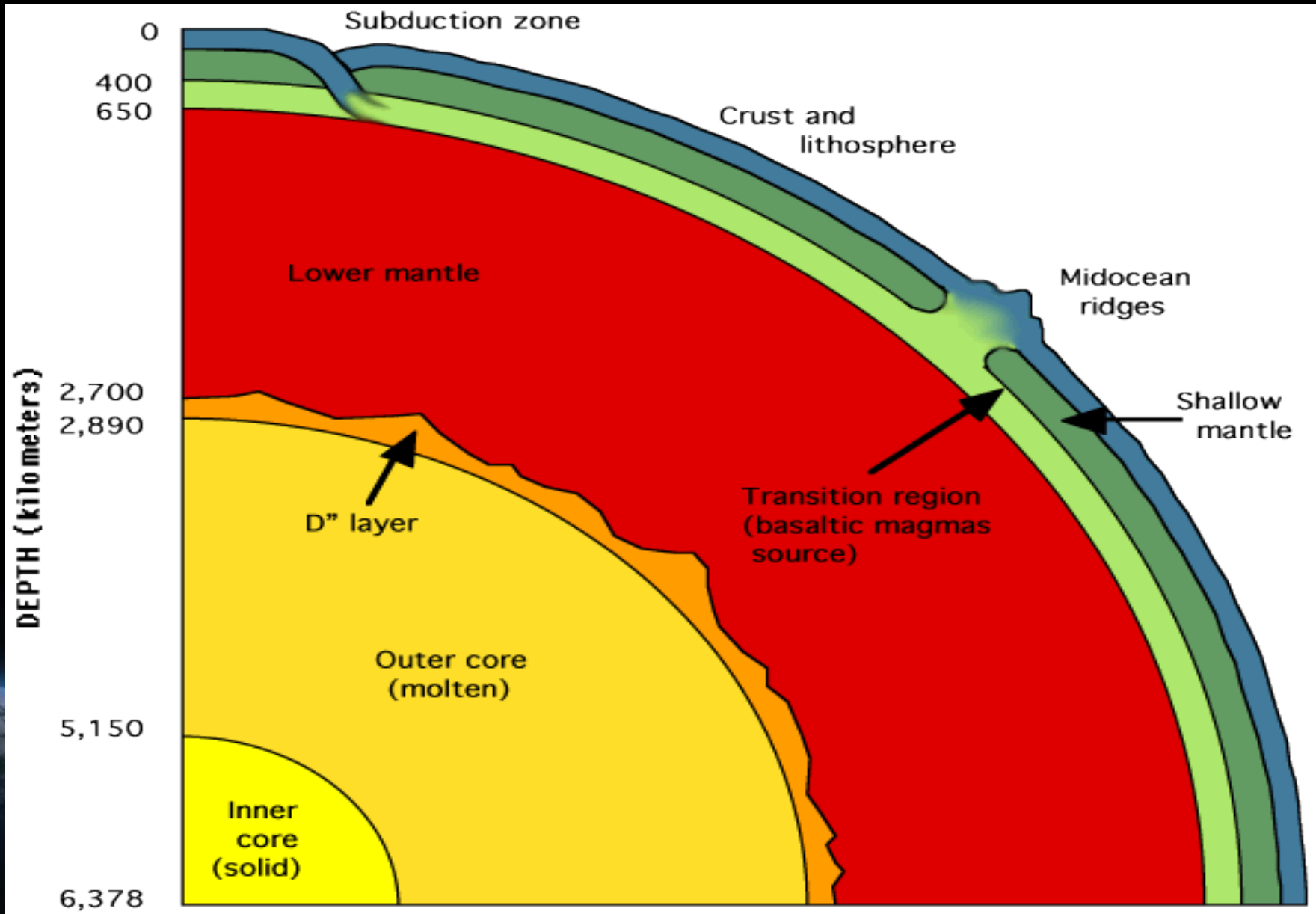
Measurement of seismic waves following earthquakes or large explosions



So what is inside the Earth?



So what is inside the Earth?



Deepest holes

- Mines - The TauTona Mine or Western Deep No.3 Shaft, is a gold mine in South Africa. It is 3.9 km deep:
 - >5,600 miners operate the mine
 - 800 km of tunnels
 - Ambient temperature 55°C
 - Rock face temperature 60°C
 - Time to the face ~ 1 hr
 - Cage stages travel at
58 km/hr



Deepest Holes

- Today, the deepest hole ever created is on the Kola peninsular. The “SG-3,” hole is about nine inches wide and reaches over 12.3 kilometers into the Earth’s crust.
 - Drilling took twenty-four years. Progress was finally halted in 1994, about 2.7 kilometers short of its 15 km goal.
 - 0.2% of the way to the Earth centre



What did Kola tell us?

- No transition from granite to basalt at 3-6km predicted by seismology
- Core samples taken for full length of the hole – oldest rock is 2.7 billion years old
- Rocks saturated with water at this depth
- Microscopic fossils at 6.7km
- Crust is hotter than expected – estimated to be 300°C at 15km



The Crust

- Less than 1% of Earth's volume
- Continental Crust 20-80 km thick
- Oceanic Crust 5-10 km thick



Crust Rocks

- The Crust is composed mainly of silicate rich igneous rock.
- The Continental Crust is composed of the lighter granitic igneous rock, higher in aluminium, sodium, and potassium
- The Oceanic Crust is composed of the heavier, darker, igneous rock largely basalt which is higher in iron and magnesium than the continental crust.

Chemical Composition

Component	Volume
Oxygen	46.6%
Silicon	27.8%
Aluminum	8.1%
Iron	5.0%
Calcium	3.6%
Sodium	2.8%
Potassium	2.6%
Magnesium	2.0%
others	1.6%

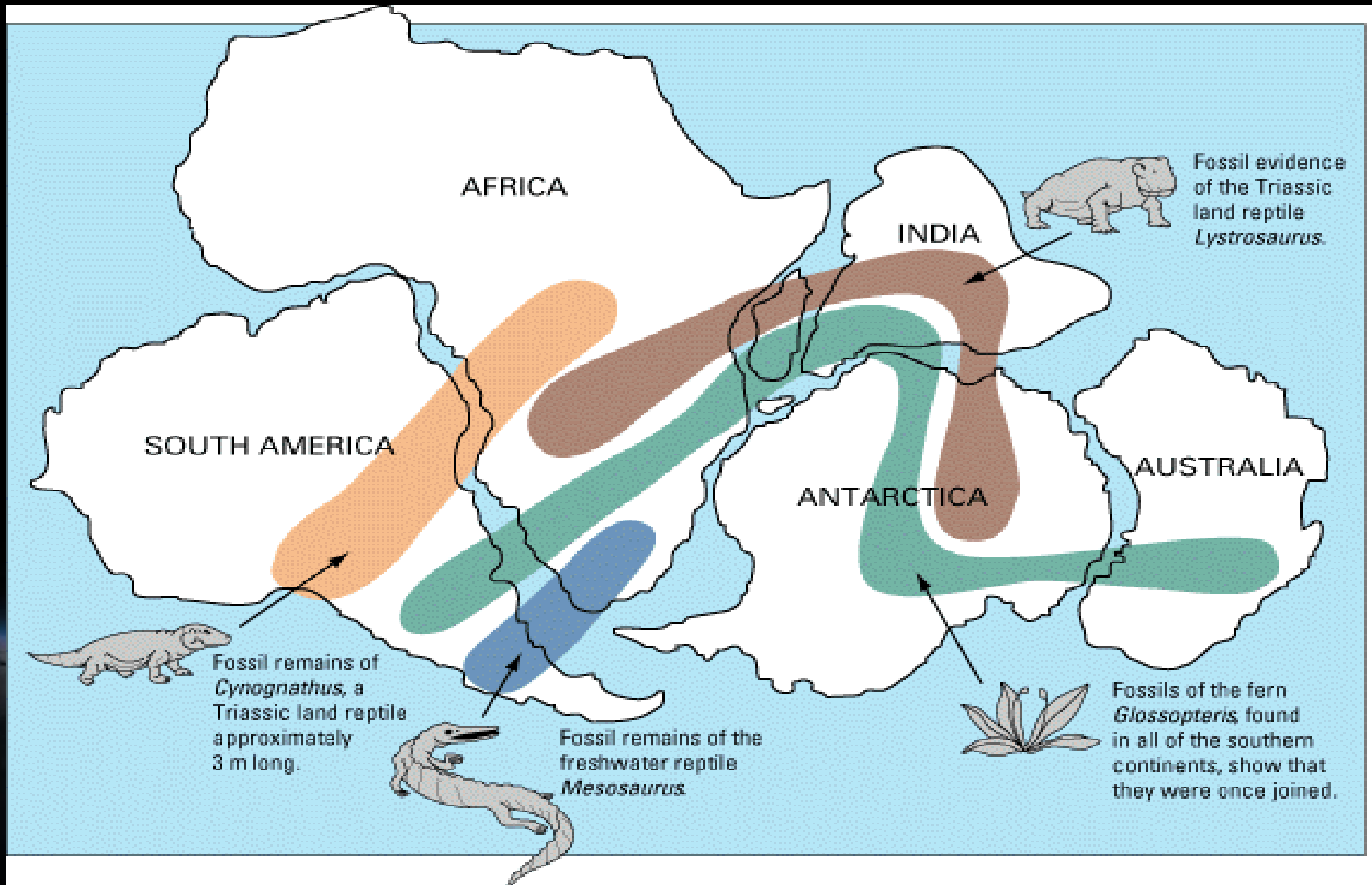


Continental Drift

- A theory that continents are not static was proposed by Alfred Wegener (1880-1930) in 1912
- Received with scepticism by the established Scientific community
- Wegener went to great length to provide evidence for his theory
- Finally accepted in 1960s



Pangea

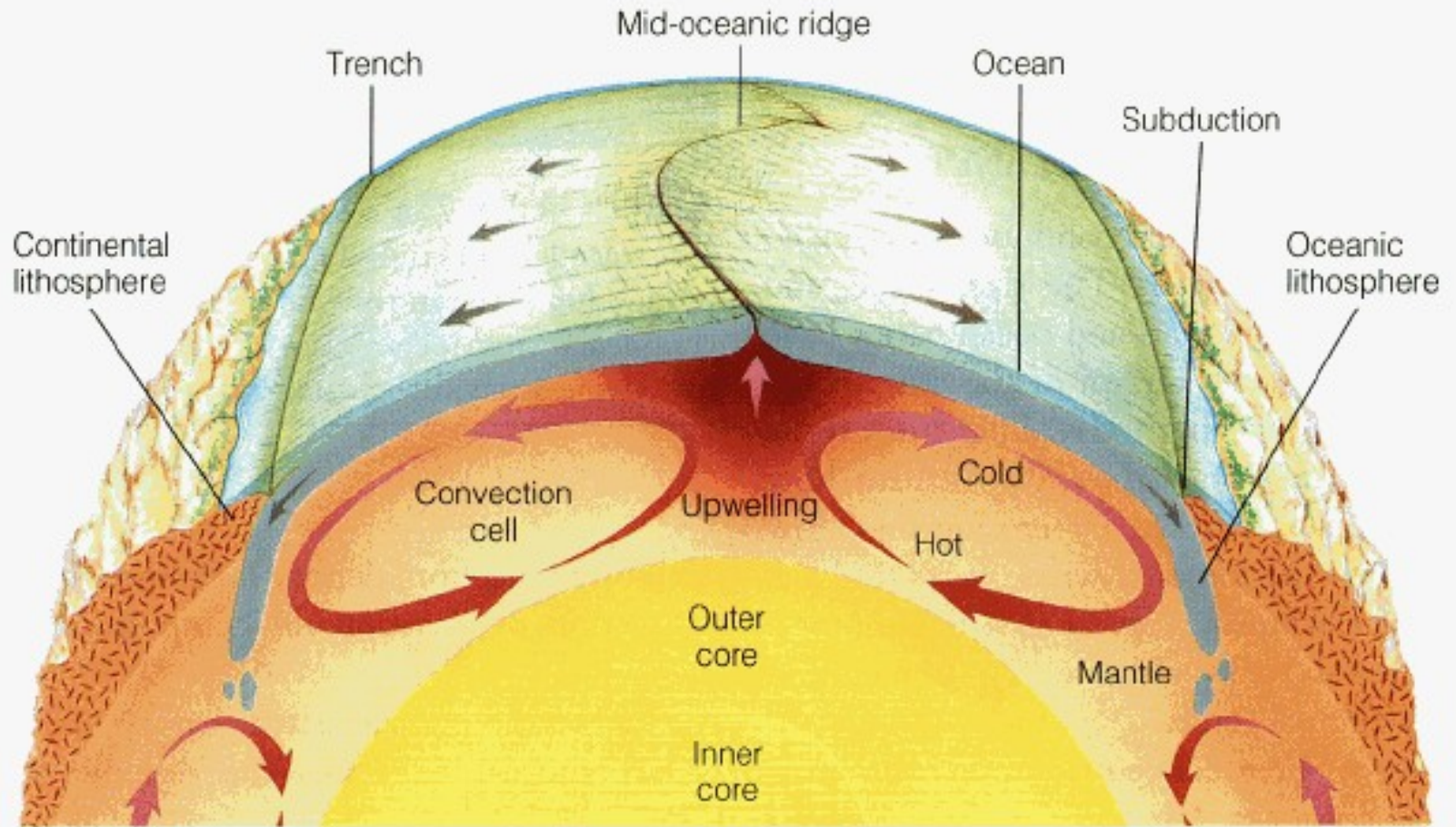


Continental Drift & Plate Tectonics

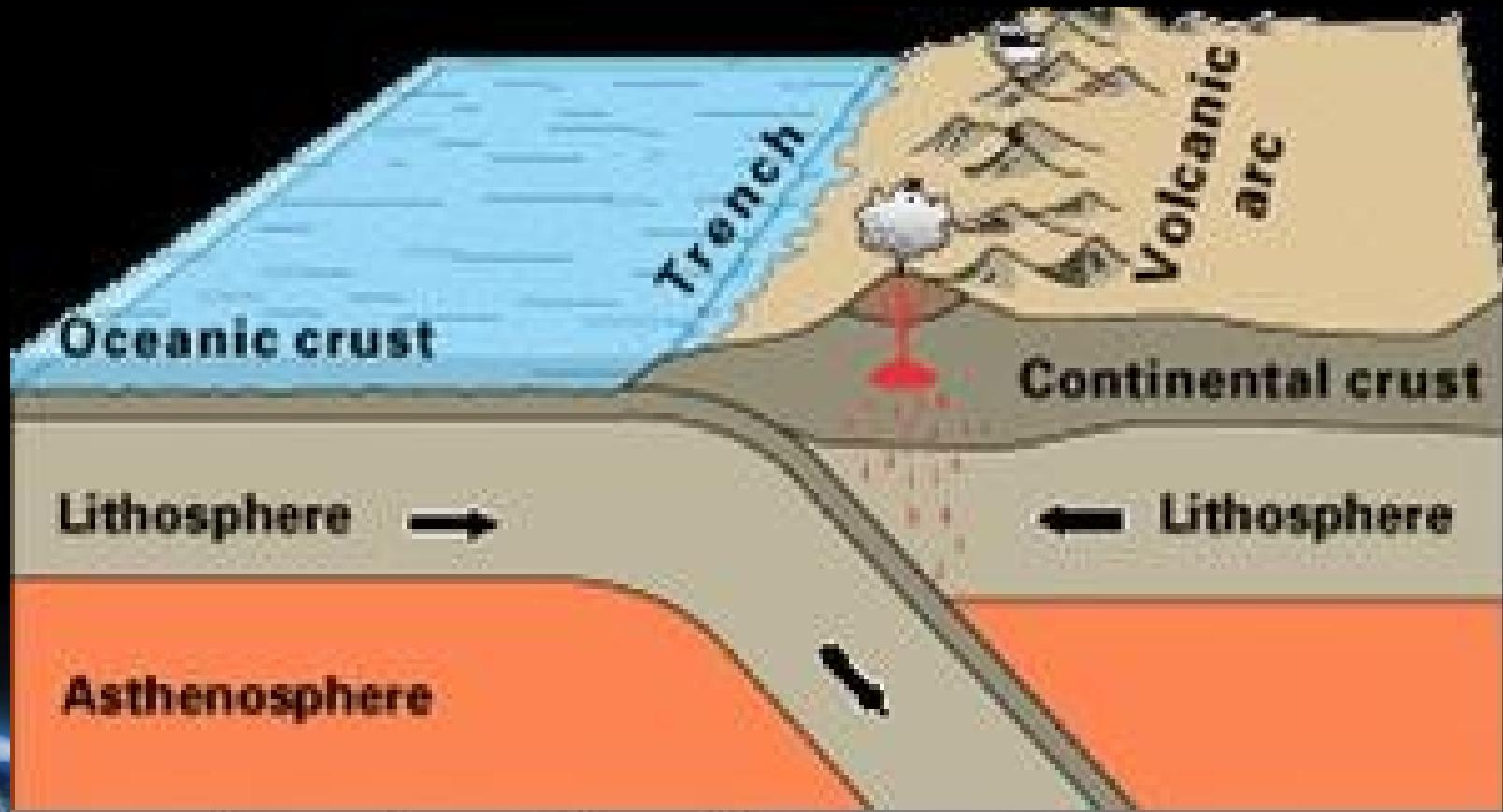
- The Crust comprises a number of plates
- These plates “float” on the denser mantle material in the Asthenosphere
- Convection currents in the mantle cause the plates to move
- Movement changes the location of the plates and hence the continents on the surface of the earth



The Mantle

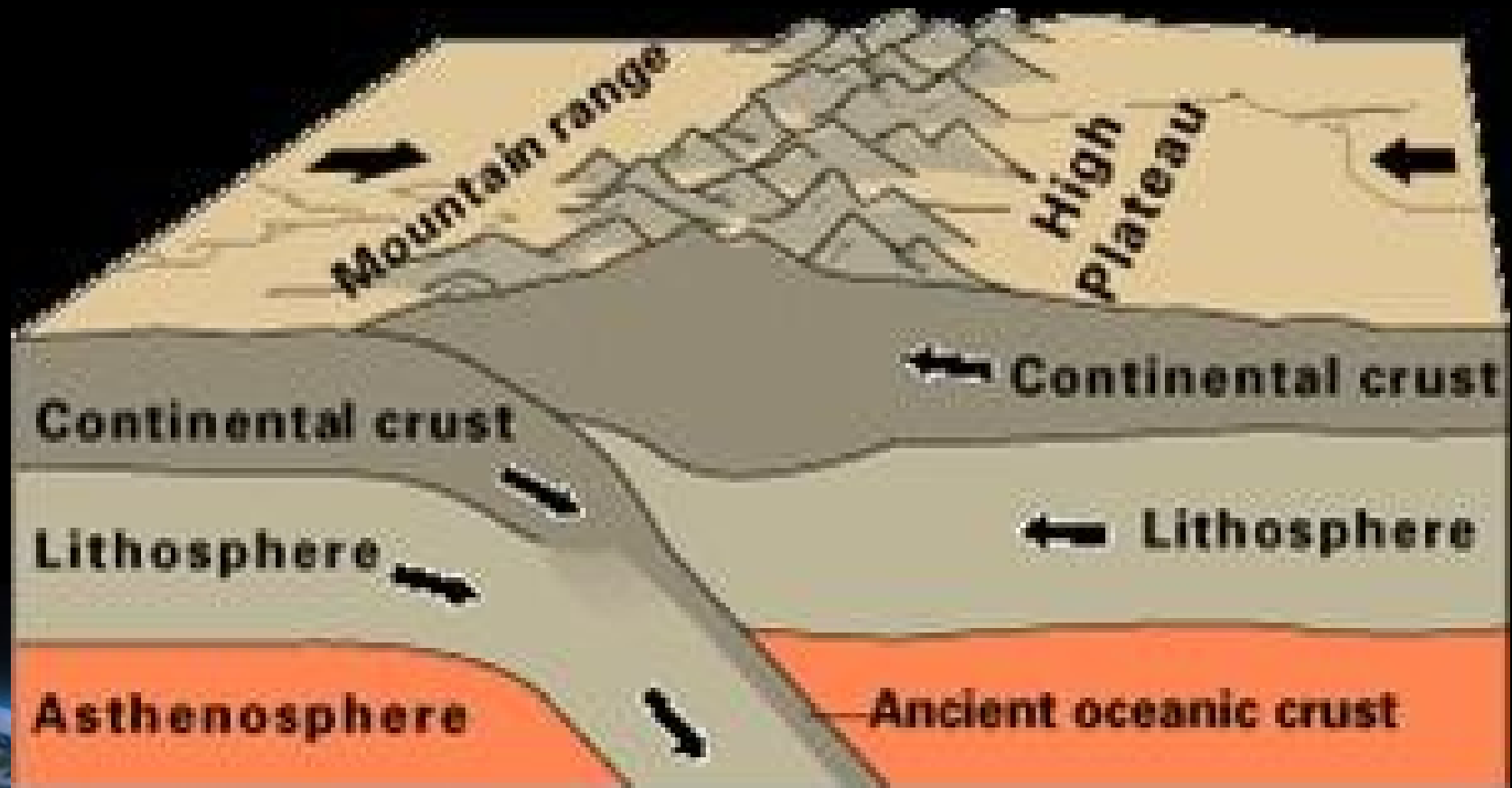


Oceanic Plate – Continental Plate



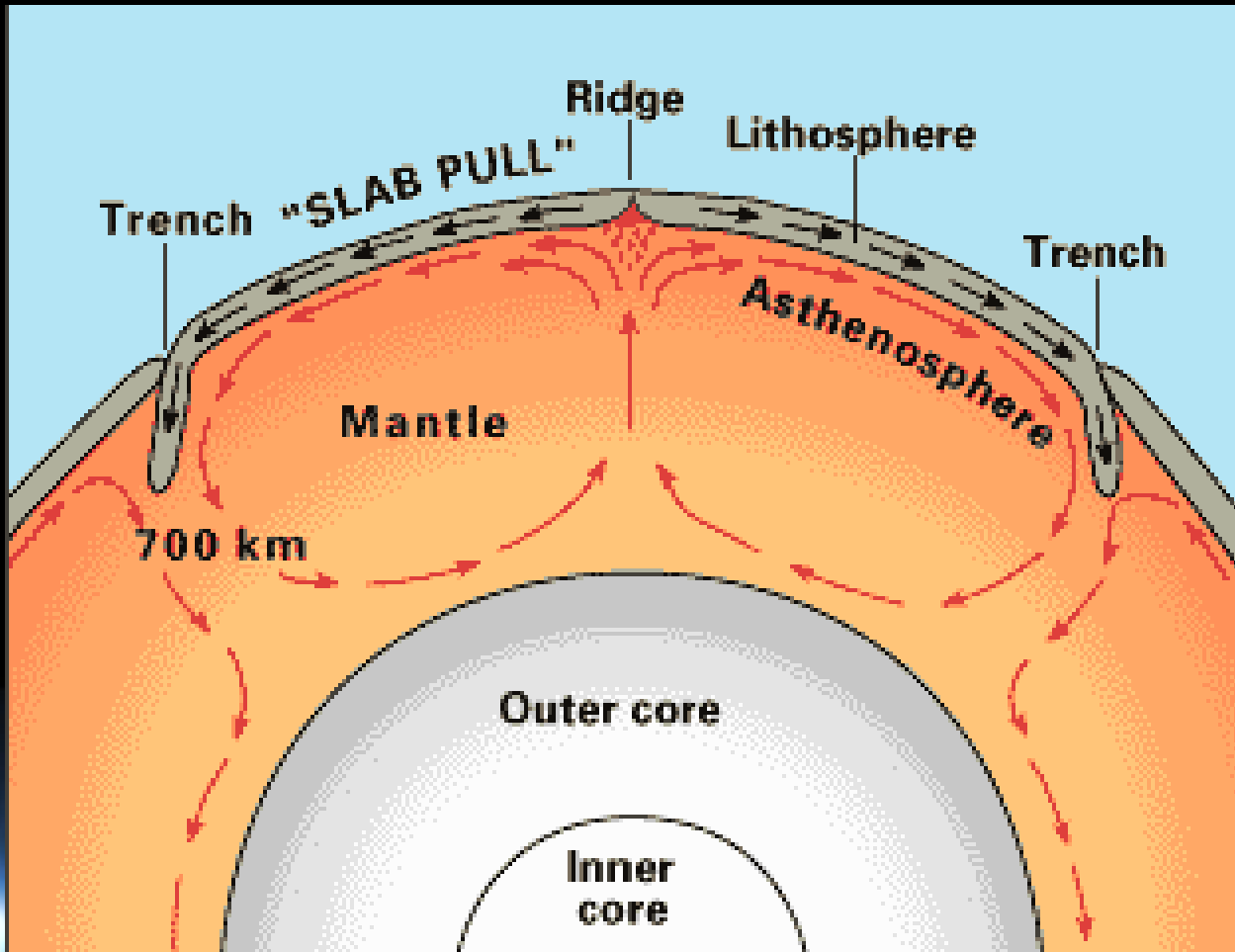
Oceanic-continental convergent boundary

Continental Plate - Continental Plate



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The Mantle



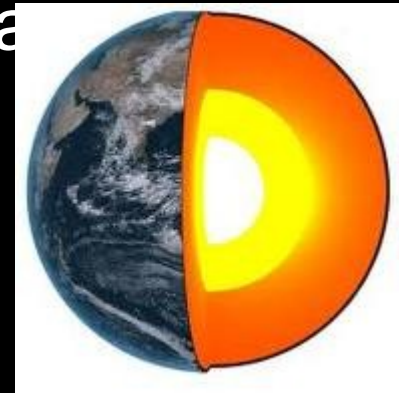
The Mantle

- 84% of the Earth volume
- Temperature
 - 500 °C to 900 °C close to crust
 - 4000 °C close to the core
- Almost exclusively solid – despite temperature
 - enormous pressure prevents melting



The Core

- Outer core and Inner Core
 - Liquid outer Core (approx diameter of Mars)
 - Solid inner core (approx diameter of moon)
 - 15% of Earth's volume
- Temperature at the core around 6000°C
 - Hotter than the surface of the Sun
- Pressure at the core around 3,600,000 ba



Core Composition

- Outer and Inner core are composed mainly of iron (80%) and nickel plus some lighter elements - sulphur and oxygen?
- Inner core may be made of giant iron crystals running north-south – perhaps as large as 10km



Magnetism

- Inner Core may rotate at a different speed to the mantle and crust due to the liquid nature of the Outer Core.
- Differing rotation rates are thought to be the source of the Earth's magnetic field.



Why is the earth still hot?

- Residual heat
- Mechanical heat
 - gravity
- Latent heat
 - Core cooling and solidifying
- Radioactive decay
 - Potassium 40, Uranium 238, 235, and Thorium 232



Earth Heat Output

- Earth's total heat output is estimated at 44 Terawatts
(World consumption around 15 Terawatts)
- Approx 29 Terawatts from radioactive decay
- The Earth will remain hot longer than the lifetime of the sun.

