OTHER INDIRECT EVIDENCE FOR THE EARTH'S STRUCTURE

Meteorites that fall to earth are relics left over from the origin of the solar system.

Most were formed 4.6 billion years ago, the age of the earth

The composition of these meteorites probably says a great deal about the composition of the earth

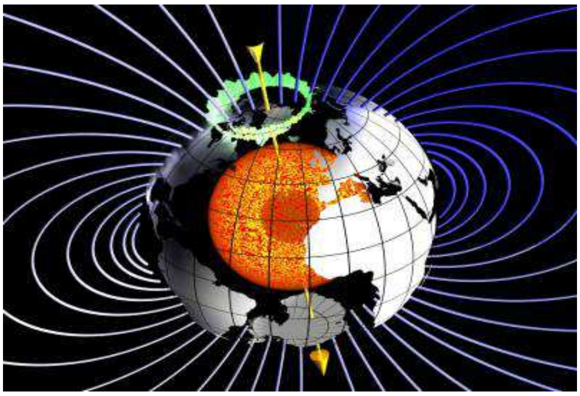
THERE ARE 3 MAIN TYPES OF METEORITES

Iron meteorites are the same composition as the core

Carbonaceous Chondrites are the same composition as the whole earth

Stoney meteorites are the same composition as the mantle

The presence of the earth's magnetic field is evidence for an iron rich outer core that is in motion and is therefore fluid



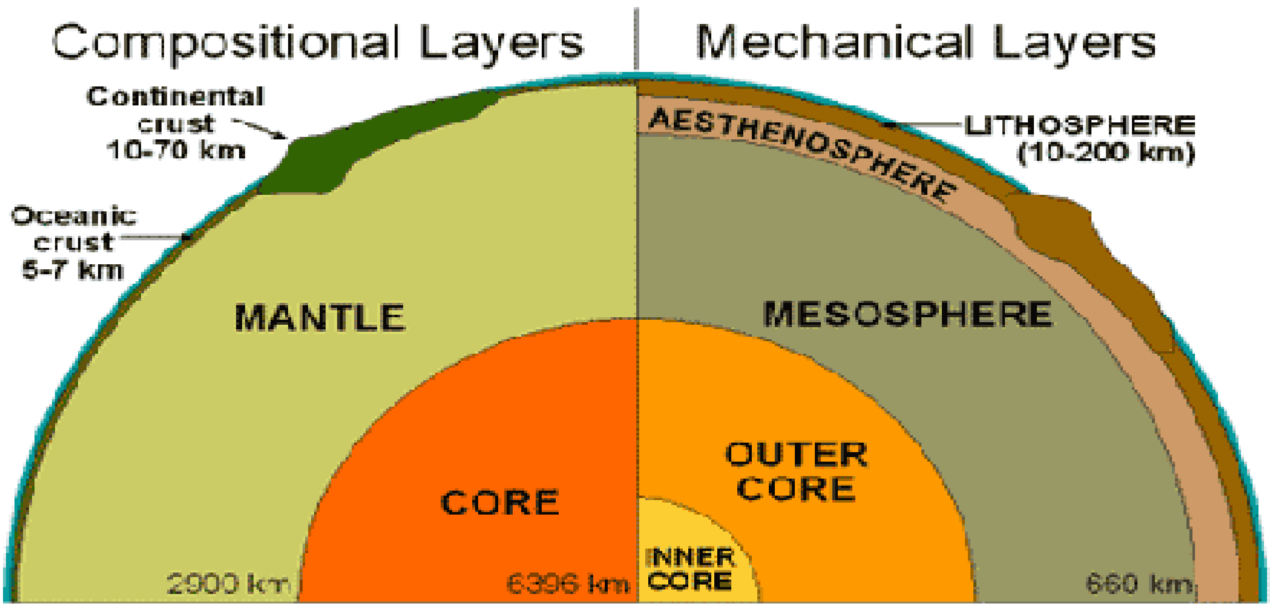
The density of the whole earth is 5.5 g/cm3

We know the density of the crustal rocks is only 2.7 – 2.9 g/cm3

Therefore densities inside the earth must be much higher than that on the surface

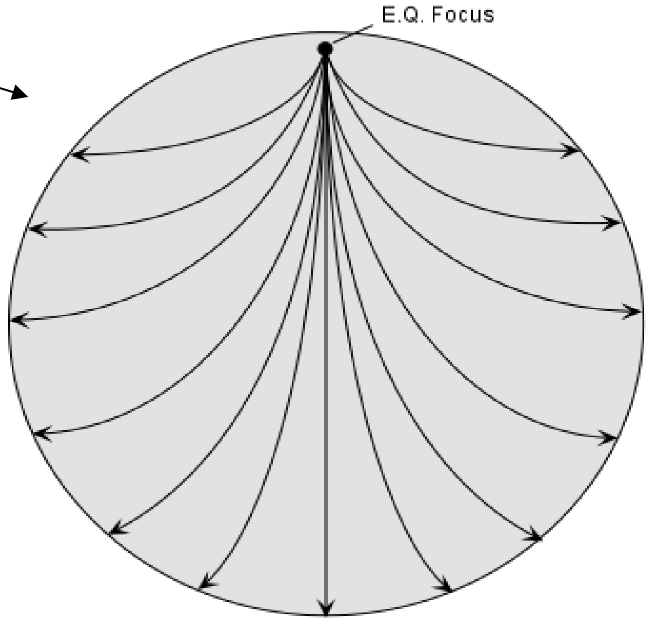
The density of the core is over 11 g/cm3

Density changes suddenly at the earths boundaries / discontinuities

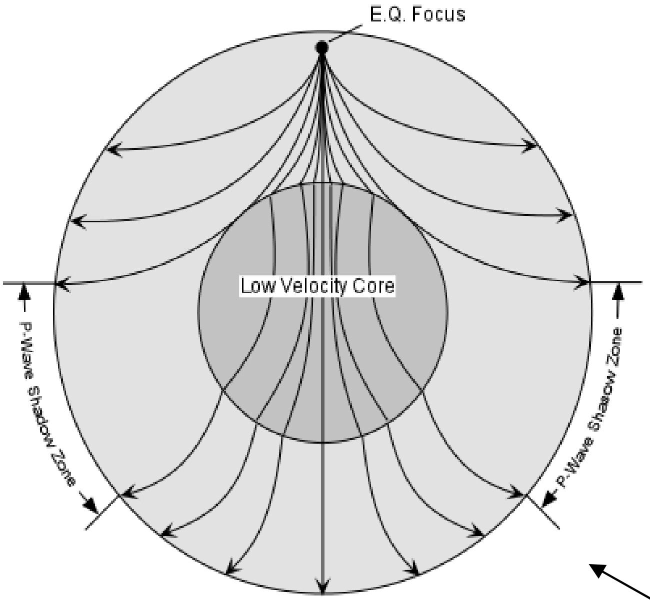


PASSAGE OF SEISMIC WAVES THROUGH THE EARTH

If the seismic wave velocities gradually increase with depth in the Earth, the waves will continually be refracted along curved paths that curve back toward the Earth's surface

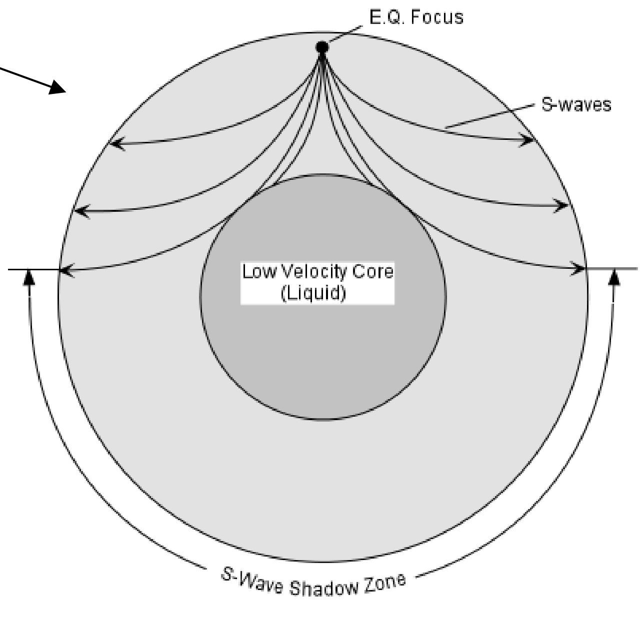


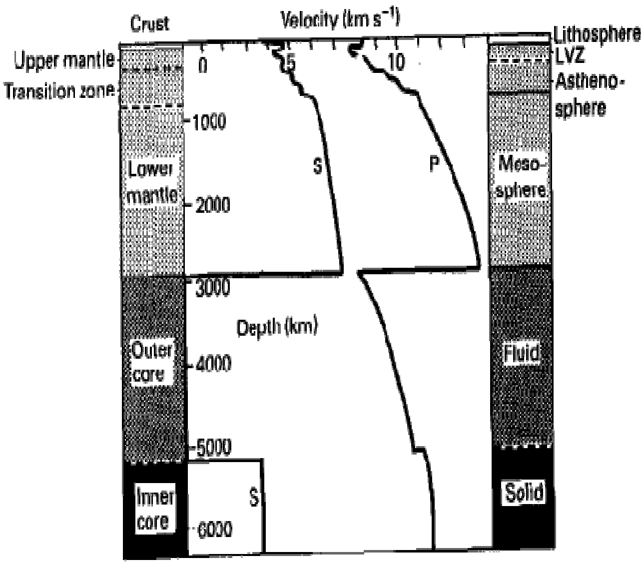
If wave velocity continuously increases downward all waves will travel along curved paths refracting back toward the surface



One of the earliest discoveries of seismology was a discontinuity at a depth of 2900 km where the velocity of P-waves suddenly decreases. This boundary is the boundary between the mantle and the core and was discovered because of a zone on the opposite side of the Earth from an Earthquake focus receives no direct P-waves because the P-waves are refracted inward as a result of the sudden decrease in velocity at the boundary. This zone is called a P-wave shadow zone.

This discovery was followed by the discovery of an S-wave shadow zone. The S-wave shadow zone occurs because no S-waves reach the area on the opposite side of the Earth from the focus. Since no direct S-waves arrive in this zone, it implies that no S-waves pass through the core. This further implies the velocity of S-wave in the core is 0. In liquids rigidity = 0, so S-wave velocity is also equal to 0. From this it is deduced that the core, or at least part of the core is in the liquid state, since no S-waves are transmitted through liquids. Thus, the S-wave shadow zone is best explained by a liquid outer core.





PROPERTIES IF THE EARTHS LAYERS AND BOUNDARIES/DISCONTINUITIES

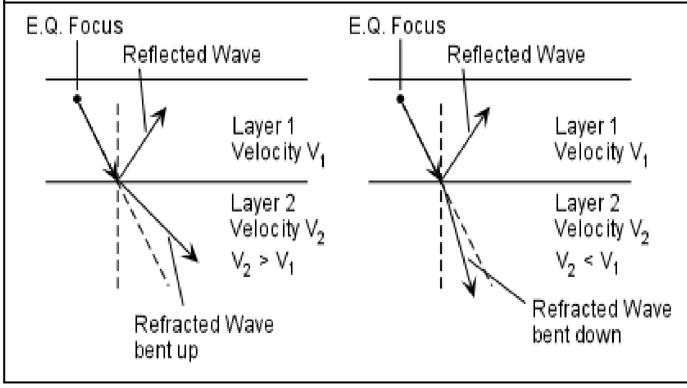
Layers of Different Physical Properties

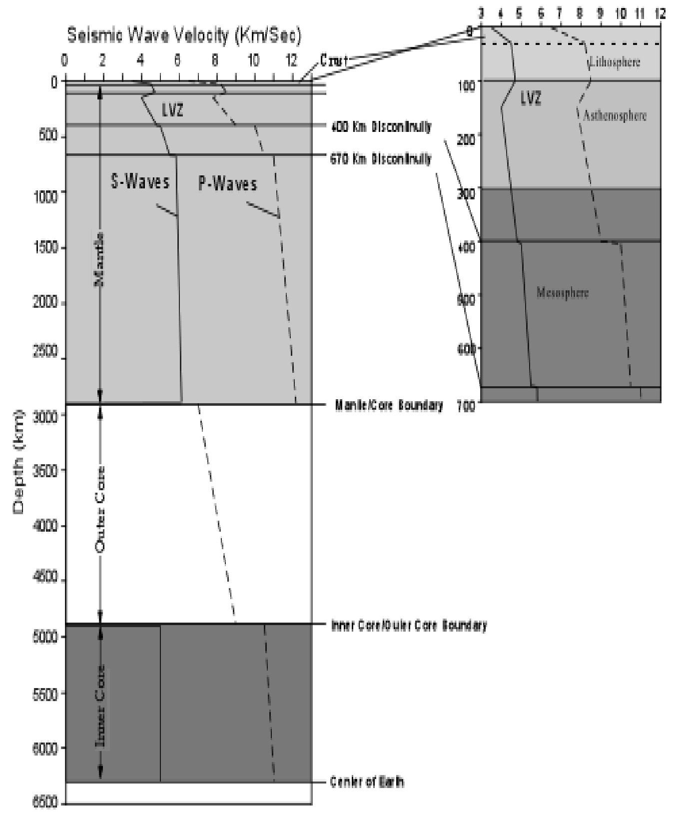
- At a depth of about 100 km there is a sudden decrease in both P and S-wave velocities. This boundary marks the base of the lithosphere and the top of the asthenosphere. The lithosphere is composed of both crust and part of the upper mantle. It is a brittle layer that makes up the plates in plate tectonics, and appears to float and move around on top of the more ductile asthenosphere.
- At the top of the asthenosphere is a zone where both P- and S-wave velocities are low. This zone is called the ***Low-Velocity Zone*** (LVZ). It is thought that the low velocities of seismic waves in this zone are caused by temperatures approaching the partial melting temperature of the mantle, causing the mantle in this zone to behave in a very ductile manner.
- At a depth of 400 km there is an abrupt increase in the velocities of seismic waves, thus this boundary is known as the ***400 - Km Discontinuity***. Experiments on mantle rocks indicate that this represents a temperature and pressure where there is a polymorphic phase transition, involving a change in the crystal structure of Olivine, one of the most abundant minerals in the mantle.
- Another abrupt increase in seismic wave velocities occurs at a depth of 670 km. It is uncertain whether this discontinuity, known as the ***670 Km Discontinuity***, is the result of a polymorphic phase transition involving other mantle minerals or a compositional change in the mantle, or both.

Reflection and Refraction of Seismic Waves.

If composition (or physical properties) change abruptly at some interface, then seismic wave will both reflect off the interface and refract (or bend) as they pass through the interface. Two cases of wave refraction can be recognized.

1. If the seismic wave velocity in the rock above an interface is less than the seismic wave velocity in the rock below the *interface, the waves will be refracted or* bent upward relative to their original path.
2. If the seismic wave velocity decreases when passing into the rock below the interface, the waves will be refracted down relative to their original path.





- **Layers of Differing Composition**

  The Crust - Mohorovicic discovered boundary the boundary between crust and mantle, thus it is named the ***Mohorovicic Discontinuity*** or ***Moho***, for short. The composition of the crust can be determined from seismic waves by comparing seismic wave velocities measured on rocks in the laboratory with seismic wave velocities observed in the crust. Then from travel times of waves on many earthquakes and from many seismic stations, the thickness and composition of the crust can be inferred.
- In the ocean basins crust is about 8 to 10 km thick, and has a composition that is basaltic.
- Continental crust varies between 20 and 60 km thick. The thickest continental crust occurs beneath mountain ranges and the thinnest beneath lowlands. The composition of continental crust varies from granitic near the top to gabbroic near the Moho.
- The Mantle - Seismic wave velocities increase abruptly at the Moho. In the mantle wave velocities are consistent with a rock composition of peridotite which consists of olivine, pyroxene, and garnet.
- The Core - At a depth of 2900 Km P-wave velocities suddenly decrease and S-wave velocities go to zero. This is the top of the outer core. As discussed above, the outer core must be liquid since S-wave velocities are 0. At a depth of about 4800 km the sudden increase in P-wave velocities indicate a solid inner core. The core appears to have a composition consistent with mostly Iron with small amounts of Nickel.

geographyjohn

AS GEOLOGY

CASE STUDY REVISION BOOKLET

STRUCTURE OF THE EARTH

Inner core: depth of 5,150-6,370 kilometres
The inner core is made of solid iron and nickel and is unattached to the mantle, suspended in the molten outer core. It is believed to have solidified as a result of pressure-freezing which occurs to most liquids under extreme pressure.

Outer core: depth of 2,900-5,150 kilometres
The outer core is a hot, electrically conducting liquid (mainly Iron and Nickel). This conductive layer combines with Earth's rotation to create a dynamo effect that maintains a system of electrical currents creating the Earth's magnetic field. It is also responsible for the subtle jerking of Earth's rotation. This layer is not as dense as pure molten iron, which indicates the presence of lighter elements. Scientists suspect that about 10% of the layer is composed of sulphur and oxygen because these elements are abundant in the cosmos and dissolve readily in molten iron.

D" layer: depth of 2,700-2,900 kilometres
This layer is 200 to 300 kilometres thick. Although it is often identified as part of the lower mantle, seismic evidence suggests the D" layer might differ chemically from the lower mantle lying above it. Scientists think that the material either dissolved in the core, or was able to sink through the mantle but not into the core because of its density.

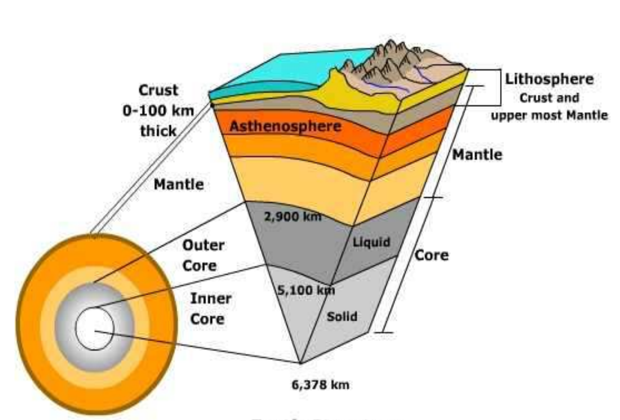
Lower mantle: depth of 650-2,900 kilometres
The lower mantle is probably composed mainly of silicon, magnesium, and oxygen. It probably also contains some iron, calcium, and aluminium. Scientists make these deductions by assuming the Earth has a similar abundance and proportion of cosmic elements as found in the Sun and primitive meteorites.

Transition region: depth of 400-650 kilometres
The transition region or mesosphere (for middle mantle), sometimes called the fertile layer and is the source of basaltic magmas. It also contains calcium, aluminium, and garnet, which is a complex aluminium-bearing silicate mineral. This layer is dense when cold because of the garnet. It is buoyant when hot because these minerals melt easily to form basalt which can then rise through the upper layers as magma.

Upper mantle: depth of 10-400 kilometres
Solid fragments of the upper mantle have been found in eroded mountain belts and volcanic eruptions. Olivine $(Mg,Fe)_2SiO_4$ and pyroxene $(Mg,Fe)SiO_3$ have been found. These and other minerals are crystalline at high temperatures. Part of the upper mantle called the asthenosphere might be partially molten.

Oceanic crust: depth of 0-10 kilometres
The majority of the Earth's crust was made through volcanic activity. The oceanic ridge system, a 40,000 kilometre network of volcanoes, generates new oceanic crust at the rate of 17 km^3 per year, covering the ocean floor with an igneous rock called basalt. Hawaii and Iceland are two examples of the accumulation of basalt islands.

Continental crust: depth of 0-75 kilometres
This is the outer part of the Earth composed essentially of crystalline rocks. These are low-density buoyant minerals dominated mostly by quartz (SiO_2) and feldspars (metal-poor silicates). The crust is the surface of the Earth. Because cold rocks deform slowly, we refer to this rigid outer shell as the lithosphere (the rocky or strong layer).



Earth Structure
(Not to Scale)