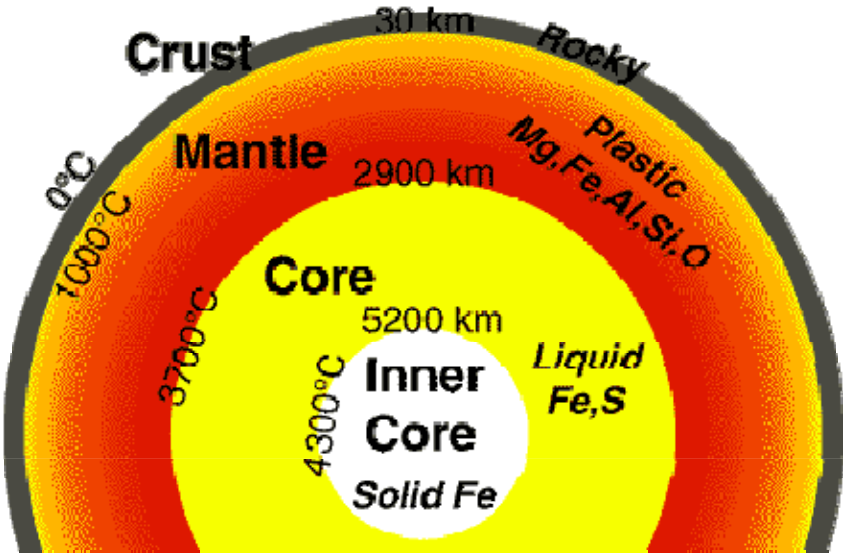
Earth's Interior

The Earth, the Sun, and the rest of the solar system, was formed 4.54 billion years ago by accretion from a rotating disk of dust and gas. The immense amount of heat energy released from gravitational energy and from the decay of radioactive elements melted the entire planet, and it is still cooling off today. Denser materials like iron (Fe) sank into the core of the Earth, while lighter **silicates** (Si), other oxygen (O) compounds, and water rose near the surface.



(J. Louie)

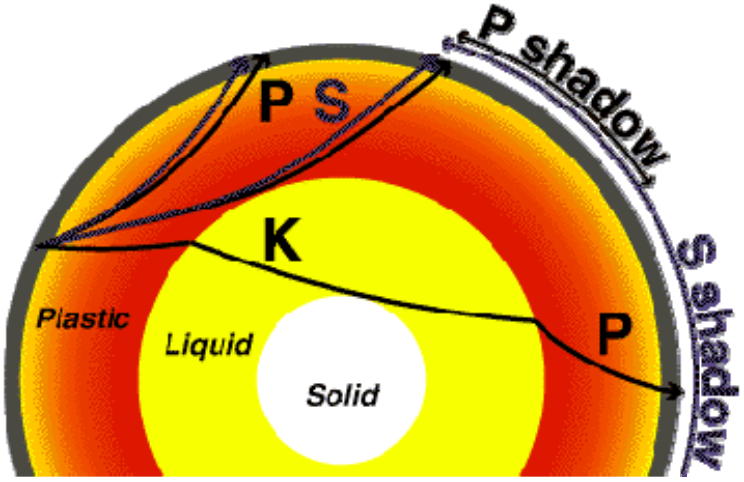
The earth is divided into four main layers: the **inner core, outer core, mantle**, and **crust**. The core is composed mostly of iron (Fe) and is so hot that the outer core is **molten**, with about 10% sulphur (S). The inner core is under such extreme **pressure** that it remains solid. Most of the Earth's mass is in the mantle, which is composed of iron (Fe), magnesium (Mg), aluminum (Al), silicon (Si), and oxygen (O) **silicate** compounds. At over 1000 degrees C, the mantle is solid but can deform slowly in a **plastic** manner. The crust is much thinner than any of the other layers, and is composed of the least dense calcium (Ca) and sodium (Na) aluminum-silicate minerals. Being relatively cold, the crust is rocky and **brittle**, so it can fracture in **earthquakes**.

Exploring the Earth's Core

How was the Earth's core discovered? Recordings of seismic waves from earthquakes gave the first clue. Seismic waves will bend and reflect at the interfaces between different materials, just like the prism below **refracts** and scatters light waves at its faces.

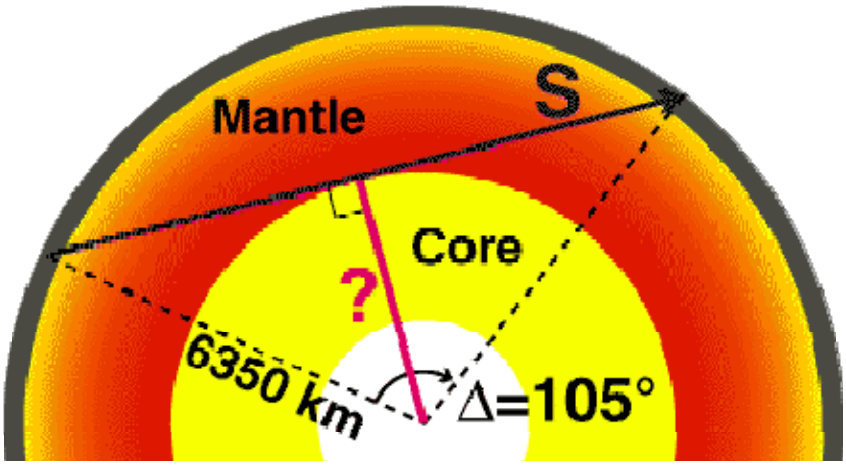
(original image from the Exploratorium; used by permission)

In addition, the two types of seismic wave behave differently, depending on the material. Compressional **P waves** will travel and refract through both **fluid** and solid materials. Shear **S waves**, however, cannot travel through fluids like air or water. Fluids cannot support the side-to-side particle motion that makes S waves.



(J. Louie)

Seismologists noticed that records from an earthquake made around the world changed radically once the event was more than a certain distance away, about 105 degrees in terms of the angle between the earthquake and the seismograph as measured at the center of the earth. After 105 degrees the direct P- and S- waves disappeared almost completely, but slow **surface waves** and waves taking other paths would arrive from over the horizon. The area beyond 105 degrees distance forms a **shadow zone**. At larger distances, some P waves that travel through the liquid core (path K on the figure above) would arrive, but still no S waves. The Earth has to have a molten, fluid core to explain the lack of S waves in the shadow zone, and the bending of P waves to form their shadow zone.



(J. Louie)

You can get a rough estimate of the size of the Earth's core by simply assuming that the last S wave, before the shadow zone starts at 105 degrees, travels in a straight line. Knowing that the Earth has a radius of about 6370 km, you have a right triangle where the cosine of half of 105 degrees equals the radius of the core divided by the radius of the earth.

The fact that the Earth has a **magnetic field** is an independent piece of evidence for a molten, liquid core. A compass magnet aligns with the magnetic field anywhere on the Earth. The earth cannot be a large **permanent magnet**, since magnetic minerals lose their magnetism when they are hotter than about 500 degrees C. Almost all of the earth is hotter, and the only other way to make a magnetic field is with a circulating **electric current**. Circulation and **convection** of **electrically conductive** molten iron in the Earth's outer core produces the

magnetic field. To make the magnetic field, the convection must be relatively rapid (much faster than it is in the plastic mantle), so the core must be fluid. Much of the energy to drive this convection comes from growth of the solid inner core, with the release of energy as the iron changes from solid to liquid.