23. Earth's Interior

Layers in the Earth

We learned earlier in this course that the interior of the Earth consists of several layers, with each layer having different properties to the others.

The thin brittle layer around the outside is called the ______________.

Below this is the ________________, which extends half-way to the center of the Earth.

The upper part of the mantle is brittle, like the crust. Because of their similar behavioral characteristics, they are typically grouped together, referred to as the ________________.

Below the lower portion of the mantle is the ________________, which is liquid.

The center of the Earth is made up of the ________________, which is solid.

So how do we know about these different layers and their properties?

One of the first lines of evidence that the interior of the Earth is different to the rocks at the surface was through calculations of the gravitational attraction between the Earth and the Moon, which can be used to estimate the relative densities of the two bodies.

It was calculated that the Earth must have an average density of about _______ g/cm$^3$.

What is the typical density of rocks near the Earth's surface? ____________ g/cm$^3$.

What do these differences in density tell us about the density of Earth’s interior?

But it doesn't tell us how we know there are distinct layers of different density. That's because we only managed to discover this by analyzing the behavior of seismic waves generated by ________________.

The study of seismic waves to discover information about the interior of the Earth is a branch of geology called ________________.

Seismic Waves and the Earth's Interior

Seismic waves radiate out in all directions away from the focus of an earthquake. We can represent the motion of these waves away from the focus using arrows that we call _________________. They show the directions the waves are moving.

Each of the different types of seismic waves moves at a different speed. This speed is controlled by the properties of the rock that the wave is moving through.

Waves move faster through rocks that are ________________ and ________________.
Based on how fast seismic waves take to travel through the Earth, we have figured out that seismic wave velocities generally _________________ as the waves travel deeper and deeper into the Earth. So this tells us that the rocks must be getting denser and denser with increasing depth.

**Bending the Waves**

When any kind of wave moves from a material of one density into one of a different density, the wave ray becomes bent. So the wave travel direction changes slightly.

This effect is called __________________________.

As P-waves travel through the Earth, they are refracted several times. We can tell this by looking at the locations where the waves reappear at the Earth's surface at different times after an earthquake. Based on how fast waves travel, and how long they took to move through the Earth, they could not have traveled along a straight line from the earthquake focus.

This happens because of the changes in rock density in the different layers, which causes the wave ray paths to be curved through the Earth.

By examining the differences in time it takes P-waves from the same earthquake to reach different seismograph stations all around the world, it is possible to figure out the refracted paths the waves took through the Earth, and therefore the locations of the layer boundaries that separate rocks with different densities.

**Bouncing the Waves**

As waves hit a boundary between two layers with different density, some of the energy gets reflected back up again, just like light being reflected off a mirror.

What is this phenomenon called? __________________________

If we know how fast a wave travels, and how long it takes to move down to the boundary and back up again to a seismograph, what can we calculate?

____________________________________________

This gives us some idea about how we figure out where these different layer boundaries are inside the Earth, and how we know for sure that the inside of the Earth is indeed layered.

**Properties of the Earth's Interior Layers**

**The Core**

There are several boundaries inside the Earth where sudden changes occur in seismic wave velocities, indicating sudden changes in the nature of the Earth’s interior.

What happens to seismic waves at a depth of 2900 km in the Earth?

P-waves: _____________________________________________
S-waves: ____________________________________________

What boundary occurs at this depth? ____________________________________________

P-waves can travel through liquid, solid or gas. S-waves can only travel through solid. We see that S-waves stop dead at the core-mantle boundary.

So what does this tell us about the outer core? __________________________________

Because S-waves stop at the outer core boundary, locations on the other side of the Earth from an earthquake NEVER receive any S-waves! Only P-waves. This will happen at any location that is more than ______ degrees of arc away from the earthquake focus.

What do we call this region where no S-waves are recorded? ________________________

P-waves get refracted as they pass from the mantle into the liquid outer core. This produces a region of the Earth’s surface where no P-waves can be recorded from an earthquake, because the waves get bent away from these areas.

What do we call this region where no P-waves are recorded? ________________________

This shadow zone occurs at any location on Earth that is between _____ and _____ degrees of arc away from the earthquake focus.

So can seismographs located in the overlap of the P-wave shadow zone and the S-wave shadow zone ever know for sure that an earthquake occurred? YES or NO?

BUT, every now and again, a stray P-wave gets recorded inside the P-wave shadow zone. Why does this happen? _________________________________________________________________

How do we know the inner core is denser than the outer core? ________________________

What is the inner core made out of? ________________________

**The Mantle**

Seismic wave velocities increase suddenly at a depth of about 30 km.

What two layers are separated by this boundary? _________________________________

This boundary is called the **Mohorovicic discontinuity**, or more commonly the _________________.

Its depth is actually variable, ranging from 20-90 km below the continents with an average of ____________. Beneath the sea floor, it is 5-10 km deep because oceanic crust is much thinner than continental crust.
At the Moho, there is a change from silica-rich rocks in the crust to mafic rocks in the mantle. A common rock type in the mantle is _________________.

There are other layer boundaries inside the mantle. At a depth of between 100 and 350 km, seismic velocities suddenly decrease.

This portion of the Earth’s interior is called the __________________________. At this depth, rocks are not very elastic- they flow plastically like salt-water taffy. As a result, seismic waves have trouble moving through them. There may even be some melting going on at this depth.

The low-velocity zone marks the boundary between the upper, rigid _________________________ and the underlying ____________________________.

What important geologic process is able to occur on Earth because of the existence of the low-velocity zone?

________________________________

The Crust

The crust is the most complex of the Earth’s layers because it is so variable. The types of rocks change frequently, with a combination of sedimentary, igneous and metamorphic rock types.

The two types of crust are:

______________ - thicker (average of 35 km)
and
______________ - thinner (5-10 km; average of 8 km)

Continental crust gets thinner where the crust is being stretched by tensional tectonic forces, such as in central Nevada (~ 20km thick).

Where is continental crust thickest? (~ 90 km thick) ____________________________

What principle allows continental crust to be thickest here? ____________________________ (i.e., same principle that causes tall icebergs to also extend deepest underwater)

What rock types makes up most of the ocean crust? ___________ and ___________.

Earth’s Magnetic Field

Is Earth’s magnetic field produced by magnetic minerals (e.g. magnetite) inside the Earth? YES or NO?

All magnetic minerals lose their magnetic properties at a certain temperature, called the ______________________ of the mineral.

In fact, the Earth has a magnetic field because: _____________________________
As the liquid moves around, it generates an _______________ field which in turn generates a _______________ field.

This means that the Earth essentially behaves like a giant _______________.

**FINAL QUESTION:**

What other planet has a magnetic field and so also must have a liquid interior?

____________________________