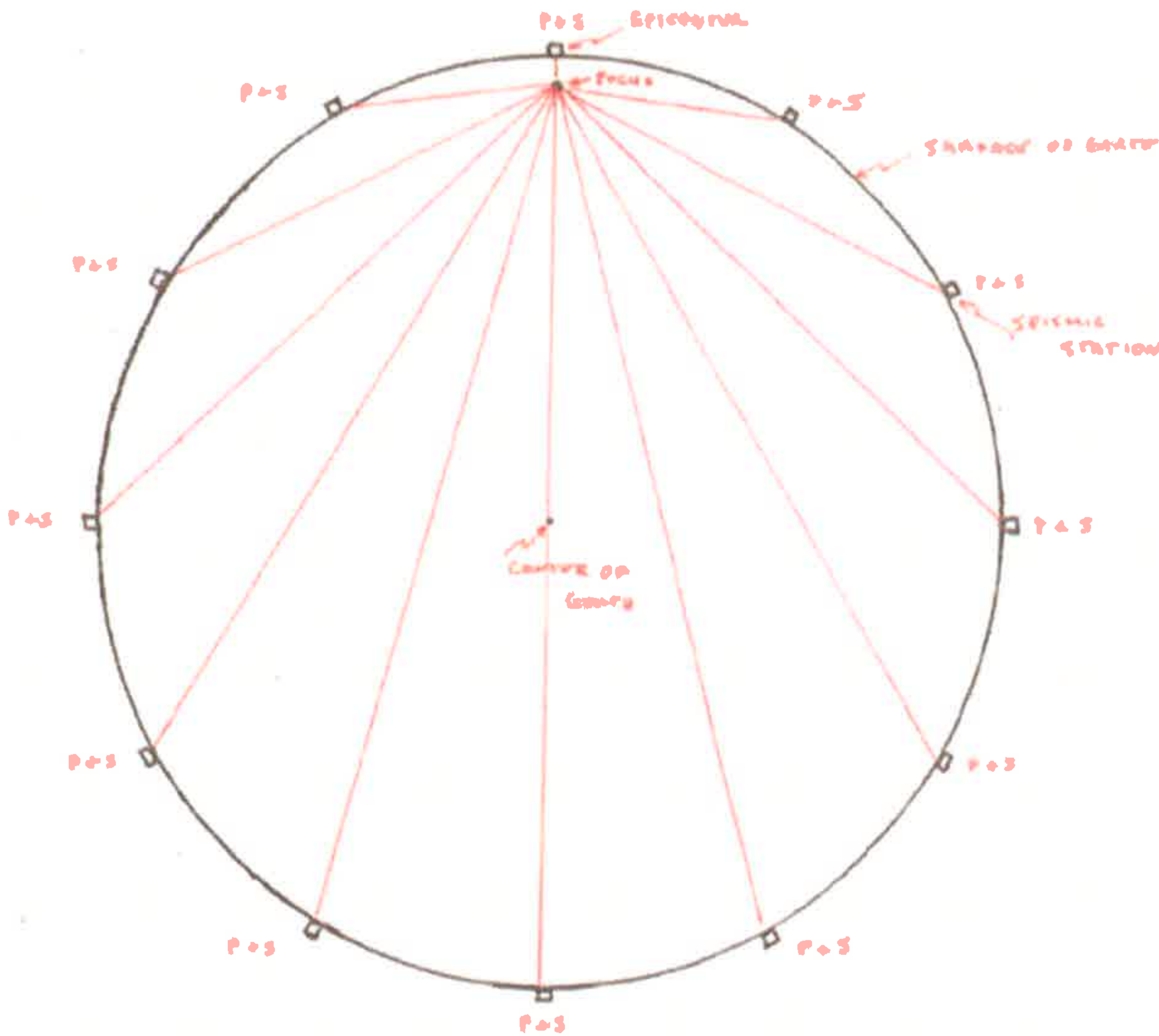
The deepest mine in the world is the Mponeng Gold Mine in South Africa (4.0km, 2.5 miles, 13,200 feet). The deepest hole that has been drilled is the Kola Superdeep Borehole along the Russia-Finland border (12.262km, 7.619 miles, 40,230 feet). Yet, just about every geology textbook in the first or second chapter has either a piece of pie shaped diagram or a diagram of concentric spheres showing the interior of the Earth and introducing the terms crust, mantle, outer core, and inner core. Since we have not seen first hand the mantle, outer core, and inner core by digging or drilling, how do we know this?

The Answer (in two words):

SEISMIC WAVES

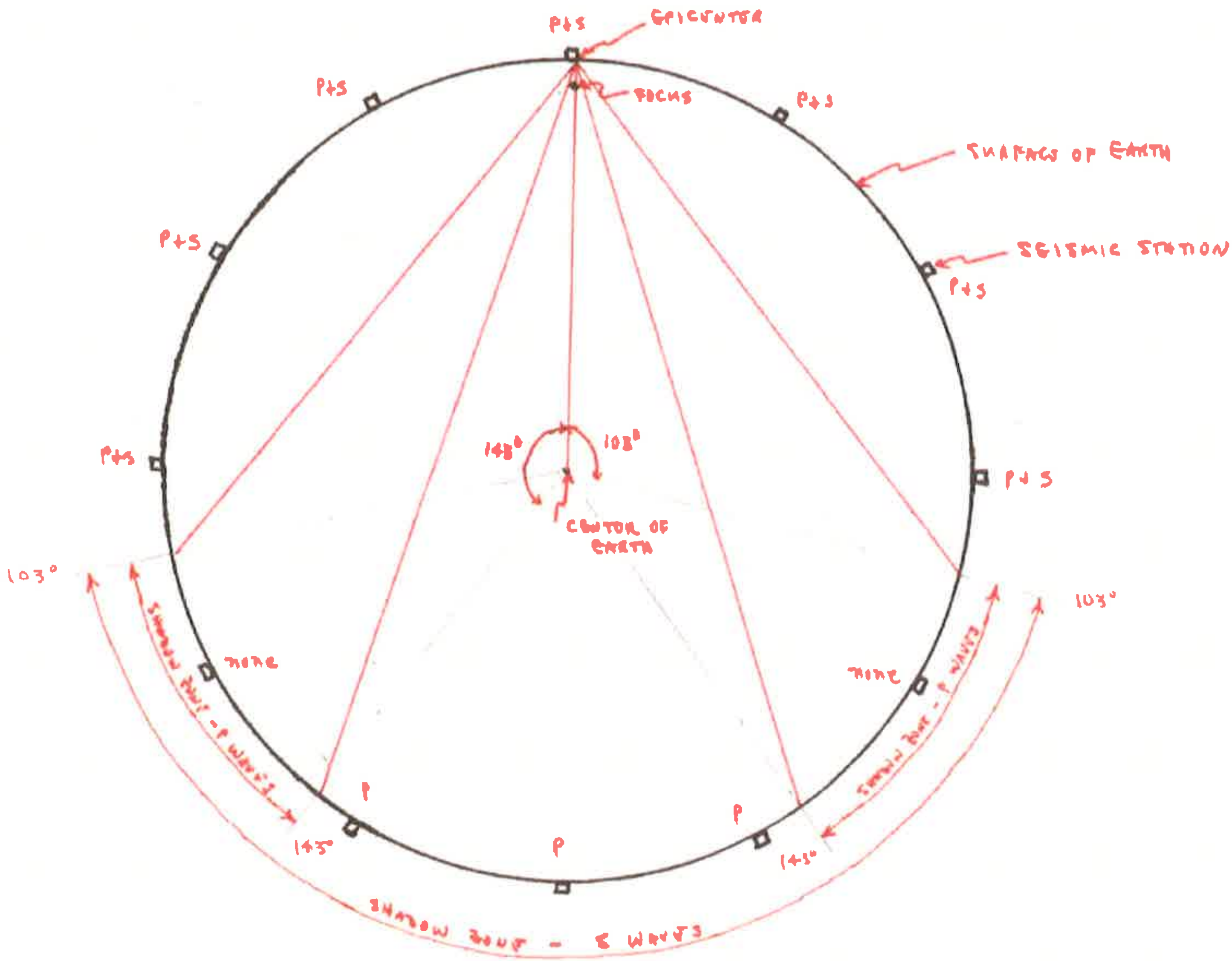
Since all, some, or none of the seismic waves arrive at seismic stations throughout the world at different times, the interior of the Earth is determined. We will examine the evidence.

If the Earth was homogeneous, here is the way earthquake data would look.



All seismic stations would receive both P and S waves just at different times. The greater the distance from the focus, the greater the time lag. The shorter the distance from the focus, the shorter the time lag.

However, here is what we see.



From the top, go 130 degrees to the right and 130 degrees to the left. In this area, all seismic stations receive both P and S waves. From 130 degrees on

the left all around the bottom to 130 degrees on the other side, no S waves are recorded. This is called the Shadow zone of the S waves. If we could cut the Earth, this zone would look like a bowl.

From 130 degrees to 143 degrees on the left around to the 130 degrees to 143 degrees on the right, no P waves are detected. This is called the Shadow zone of the P waves. If we could cut the Earth, this zone would look like a donut.

From 143 degrees on the left around the bottom to 143 degrees on the right, the P waves arrive but at a time later than expected.

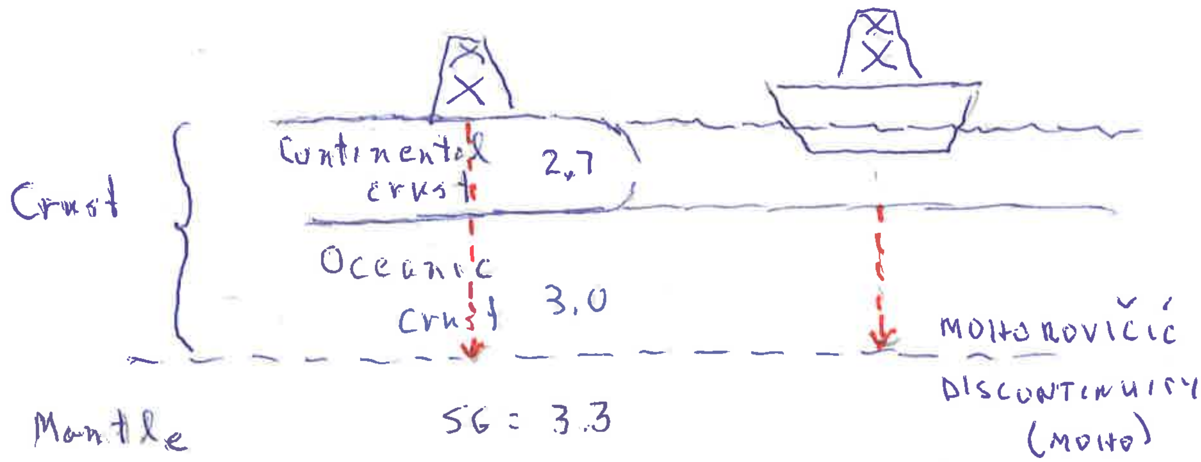
From this we can conclude that the Earth is <u>not</u> homogeneous.

Transmittal of earthquake waves depend upon:

1. **Changes in rock type (granite vs gabbro)**
2. **Changes in crystal structure (polymorphs)**
3. **Changes in physical state (solid, liquid, or gas)**

Let's look at the characteristics of each layer.

A. The crust



The crust is made up of 2 parts. The continental crust has a specific gravity of around 2.7 (feldspars, quartz, calcite, etc.). The oceanic crust has a specific gravity of around 3.0 (mafic igneous rocks like basalt). Thus the continents 'float' on the oceanic crust. The boundary between the crust and the mantle is called the Mohorovičić discontinuity or Moho for short. There is a change in the velocity of the P and S waves at this boundary. As you go from the less dense crust to the more dense mantle, the velocities of the P and S waves increase. Conversely, as you go from the more dense mantle to the less dense crust, the velocities of the P and S waves decrease. It

depends on whether the focus is in the mantle or in the crust.

At one time geologists decide to drill a deep hole to the mantle to collect mantle material and observe it firsthand. This was called Project Mohole.

Where to drill?? On land you had a stable platform but had to drill through more rock. In the ocean you had less rock to drill but the platform was unstable. This is where Howard Hughes came into the picture. Hughes essentially put propellers on all sides of a ship and tied them to stationary beacons via computers. When the ship veered, the propellers would either speed up or slow down to keep the ship in one position. Hughes developed 2 ships, one called the Glomar Challenger and the other called the Glomar Explorer.

One question that arose was if the material sampled at depth would change before it reached the surface because the environment from where it was sampled (high temperature and pressure) had changed.

The project was never funded properly thus set aside. The Glomar Challenger was used in the

Deep Sea Drilling Project (DSDP) to obtain sample from the ocean floor. These samples were used in age dating and paleomagnetic date to support the theory of continental drift.

As a side note, the Glomar Explorer was involved in raising parts of a sunken Russian submarine from a depth of 3 miles.

B. The mantle

The mantle is composed of ultramafic rocks (peridotite and dunite). It is solid but plastic. Remember that the deepest focus of earthquakes is about 700km.

C. The outer and inner core

The boundary between the mantle and the outer core is called the Guttenberg Discontinuity. S waves do not pass through this boundary because there is a change in physical state---from solid to liquid. The boundary between the outer core and the inner core is called the Lehmann Discontinuity. This is a change from liquid back

to solid because of the intense pressure at this depth.

What is the composition of the core? Three hypotheses have been suggested.

1. Data from meteorites

    Iron meteorites—native iron and iron sulfides

    Stony meteorites---iron and nickel silicates

    Stony-iron meteorites---both native iron and iron silicates

Since meteorites are supposed left over material from when the solar system formed, could the core be metallic iron?

2. Specific gravity of the Earth

Astronomers have determined the specific gravity of the Earth is 5.5. The four inner planets (Mercury, Venus, Earth, and Mars) are called the "rocky planets" and have specific gravities of 5.0 to 5.5. The outer planets (Jupiter, Saturn, Uranus, and Neptune) have specific gravities that range from 0.9 to around 1.5. If we had a big

enough bathtub filled with water, the planet Saturn would float.

Use the formula of Density = Mass/volume

From the density of the whole Earth we subtract the mass/volume of the crust and the mass/volume of the mantle and knowing the volume of the core we can determine that the core should have a specific gravity of 10.5. That is very close to what native iron would have.

Maybe it is possibly native iron.

3. The Earth's magnetic field

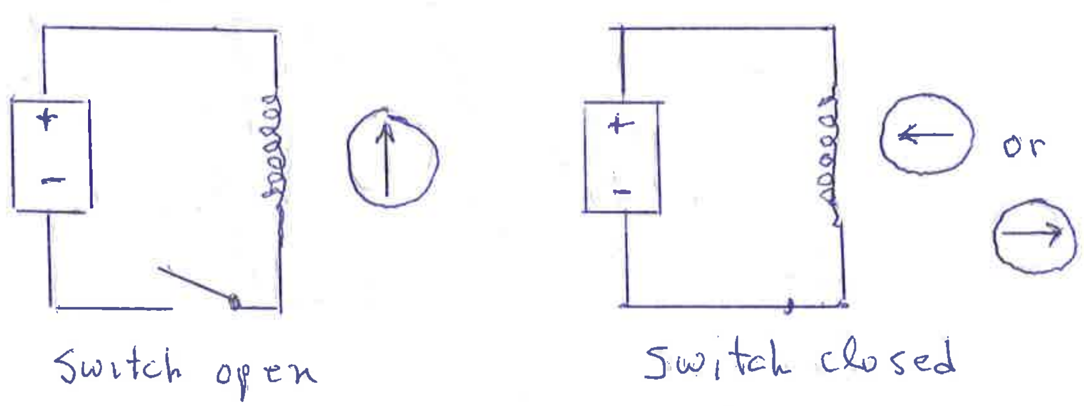
Why does the Earth have a magnetic field? Three hypotheses have been suggested.

a. The core is a big blob of permanent magnetized material. The problem with that is it is too hot. There is a characteristic called the Curie temperature. That is the temperature at which a magnetic material loses it magnetism. We know that a magnet 'sticks' to the mineral magnetite. If we heat the sample up, once we reach the Curie temperature, the magnet no longer is attracted to the sample.

b. Maybe there is enough iron in the crust. The fourth most abundant element in the Earth's crust is iron at 5.0%. Using a formula similar to that of gravity, we can plug in that amount of iron to see how much magnetism would be generated and compare it to what is actually seen. <u>They don't match</u>.

c. Elasser's dynamo hypothesis

In the diagram below you see a switch, a battery, a coil of wire, and a magnetic compass. With the switch open, the compass points toward the magnetic north pole. When the switch is closed, the compass needle swings either toward or away from the coil. Electrons flowing generate a magnetic field.



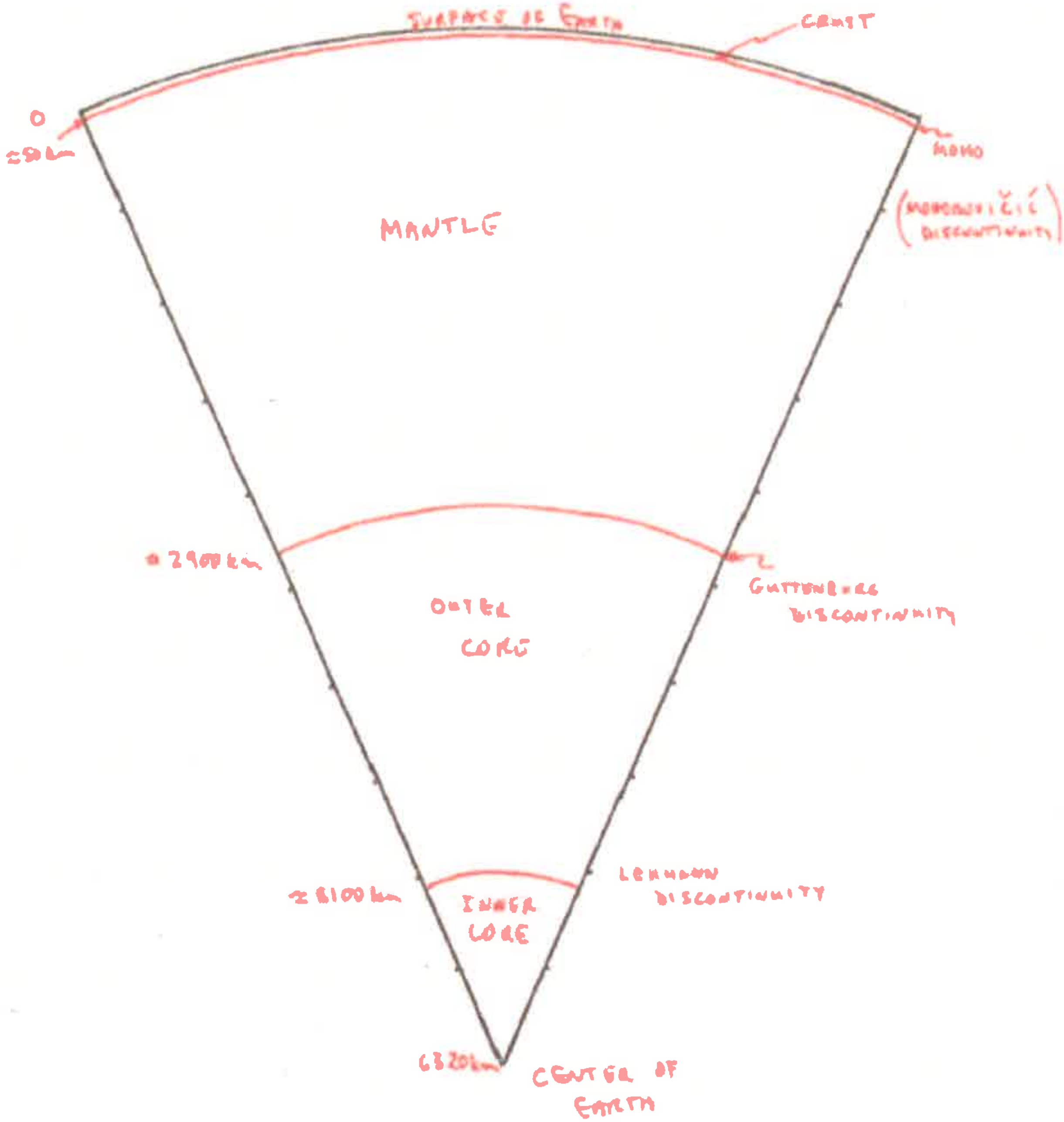
In ionic bonding, there is a transfer of electrons from one element to another. These electrons are not free to move.

In covalent bonding, there is a sharing of electrons between two elements. These electrons are not free to move.

In metallic bonding, the electrons are not tied to any particular nucleus and are thus free to move.

Therefore, if the core was metallically bonded material which was moving because the Earth is rotating, a magnetic field would be generated. Perhaps it should be called Elasser's dynamo theory.

This is diagram of the interior of the Earth drawn to scale. Notice how thin the crust is in relation to the rest. That is where we live.



2.4% volume of earth is crust
81.8% volume of earth is mantle
15.8% volume of Earth is core

If it wasn't for seismic waves, we would not have any idea about the makeup of the interior of the Earth.