SEISMIC WAVES AND THE EARTH'S INTERIOR

As we discussed in class, earthquakes occur when two portions of Earth crust move with respect to each other. On opposite sides of a fault line, forces in the Earth attempt to move different portions of the crust in opposite directions. Normally, there is some amount of friction locking the two regions of the crust together. Over time, the stress builds until at some point, the amount of accumulated stress becomes too great, and the two portions of crust move past each other. Once the stress is released, the crust has been permanently offset. There is a wonderful animation of this earthquake mechanism that shows nicely how earthquakes occur across fault lines. This model for explaining earthquakes is called the **elastic rebound** theory of earthquakes. The Earth is elastic, meaning, the Earth deforms without rupture during the period of gradually building stress. However, when the stress is released, the crust rebounds to its original state of stress.

When earthquakes occur, energy is released that generates a series of waves that travel through the Earth. When these seismic waves reach a certain location, they cause the surface of the Earth to vibrate. Much of what we have learned about the interior of the Earth comes from studying seismic waves.

Seismic Waves

We can recall our slinky demonstrations to describe how a wave occurs. When the slinky is disturbed, we see a pattern move from one end of the slinky to the other. This propagating pattern is the wave. Waves are caused whenever a certain medium (that is, the material through which the wave will travel) is disturbed, **and** if the medium resists that kind of disturbance. You can show your class this with a series of rubber bands. Get some rubber band and hold them very taut, and use a student volunter to "twang" the rubber band. Notice how rapidly the rubber band vibrates. Now, try this with a much more loosely held rubber band, perhaps a very long rubber band that has barely any tension in it. You will see that the rubber band barely vibrates. The difference in these two results derives from the greater tension in the former case, underscoring that the speed of waves in a medium depends on the amount of resistance to deformation that medium possesses.

Yesterday we discussed that there are two basic types of seismic waves that travel through the Earth. The first of these is the **P wave**, and the other is the **S wave**. P waves are referred to both as *primary waves* or *pressure waves*; S waves as *secondary waves* or *shear waves*.

The diagram below shows the differences between P and S waves:

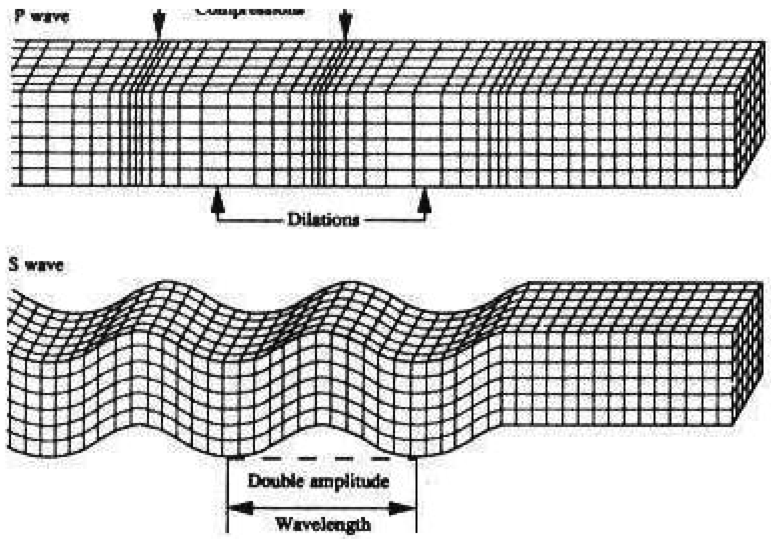

image courtesy U. Michigan

This diagram shows that P waves are caused by exerting a compressional force on an object. When we exerted such a force on the slinky, the slinky resisted being compressed, and propagated a P wave in response. S waves arise from forces trying to change the shape of of an object. As the diagram shows, shear waves are the result of the medium's resistance to this sort of deformation.

There are some important concept to keep in mind when we use seismic waves to investigate the structure of the interior of the Earth. The first is that **P waves travel faster than S waves**. This is the reason they are referred to as primary waves, as they are the first seismic waves to arrive at a seismic station. The second is that **seismic waves travel faster through media which offer more resistance to that type of deformation**. Thus, P waves travel faster through solids than through gases (do you or your students have any experience consistent with this? ever heard of the phrase 'keep your ear to the ground'?). More importantly for our purposes, P waves travel faster through denser rock, slower through less dense rock. You may see some diagrams of the interior of the Earth that labels the asthenosphere the *low velocity layer*. This means that seismic waves travel more slowly through this layer, because the region is less rigid than the mantle above or below it.

Let's think about the properties of liquids and how they might effect the propagation of seismic waves. Do liquids resist being compressed? In other words, would water (or any other liquid) resist having its *volume* changed? Of course they do, and liquids do propagate P waves. Do liquids resist changes to their shape? How much force do you have to exert to pour liquid from one container to a differently shaped one, or how much resistance do you encounter when drinking then swallowing liquid? The very definition of a liquid as a substance 'with definite volume but taking the shape of its container' indicates that liquids readily, and without resistance, change their shape. Thus, **S waves**

do not propagate through liquids. **Describing the Size of Earthquakes** There are three standard ways of describing earthquakes. The first of these is the **Modified Mercalli Index** which classifies earthquakes on the basis of the destruction caused in a location. This is useful for describing the societal impact of an earthquake, but not useful in telling us about the underlying mechanisms of earthquakes, since many factors contribute to the amount of damage caused, such as distance from earthquake, density of buildings, type of soil, type of construction of buildings. Perhaps the best known scale is the **Ricther Scale**, first introduced in the 1930s by CalTech geologist Charles Richter. His scale is based on the amplitude (amount of) ground vibration caused by the earthquake waves. His scale is **logarithmic**. This means that an earthquake of Richter magnitude 5 has 10 times the magnitude of ground vibration as an earthquake of magnitude 4. LArge earthquakes, of Richter magnitude 7 or 8, are extremely destructive; an earthquake of magnitude 8 has 1000 times the ground vibration as an earthquake of magnitude 5.

The Richter scale is the one most people know, and it is still reported in the press. However, in the last few years, geologists have begun using the **moment magnitude** scale to describe earthquakes. This scale most accurately measures the total force applied to crustal rocks during an earthquake. The moment magnitude is determined by how much slip (offset) occurred as a result of the earthquake, along with how much area was affected by the slippage. The product of these two is the moment magnitude, and these are especially accurate for larger (and more potentially destructive) earthquakes.