Earthquake P-Wave and S-Wave Travel Time

Overview:

When the Earth’s crust quickly moves or snaps it produces an earthquake, releasing energy in the form of seismic waves that radiate out from the focus. The focus is where the crust broke. Seismic waves have different properties. The P-wave is the fastest wave, reaching distance seismographs first. Because it can travel through all phases of matter, it can travel completely through the Earth’s interior reaching the other side of the Earth. The arrival of the P-wave causes little damage, but it is a warning sign that the slower, more destructive S-wave is on its way. The S-wave causes much destruction due to its shearing action. The S-wave can only travel through solids, thus it is stopped by the liquid outer core.

Due to the differences in the speed of the P and S-waves, a separation time of these waves occurs. The farther a seismograph is from the epicenter of an earthquake, the greater the separation time will be for the arrival of the P and S-wave. Using the known speeds of the P and S-waves and the arrival time of these waves as recorded on a seismogram, a seismologist can determine the distance to the epicenter. Using seismograms from three seismographs from different locations, the location of the epicenter can be determined.

The Graph:

The Axis – The x-axis is the Epicenter Distance scale. The bold dark lines represent increments of 1000 km ($1 \times 10^3$ km). The lighter lines represent intervals of 200 km. The y-axis is the Travel Time scale. The bold dark lines represent intervals of a minute, while the lighter lines represent intervals of 20 seconds.

The Graph – The bold graph lines represent the speed of the P and S seismic waves. When an earthquake occurs, the P and S-waves are generated at the same time. This is shown on the graph at minute 0. These waves immediately start to separate since the P-wave is faster. Thus, the two lines become farther apart as distance increases producing a separation time. To get the travel time for either wave for a certain distance, move upward from the given distance until it intersects the correct seismic line. At this intersection point, read over to the Travel Time axis. For example, a P-wave traveling 7200 km would take a travel time of 10:40 (10 min. 40 sec.) to go this distance. The slower S-wave would take 19:20 (19 min. 20 sec.) to go the same distance. Given the travel time of a seismic wave, the distance from the epicenter can be determined. For example, how far would a P-wave travel in 8:20? Locate this time on the Travel Time axis and move across to the P-wave line. At the intersection point, move directly down to the Epicenter Distance axis. The answer is 5000 km. For the same travel time, the slower S-wave would have only traveled 2400 km. So as you can see, these problems are “up and over” or “over and down” problems.

Epicenter Distance – If we know the arrival time of both waves, the distance to the epicenter can be determined. The arrival time of the P-wave and the S-wave may be given to you, or you may have to interpret them from a seismogram. Once you have determined the arrival time of both waves, subtract the P arrival time from the S arrival time. This is the separation time. Using the edge of a piece of paper, mark off this separation time using the Travel Time axis. You should have two marks representing the separation time. Take this paper with these marks to the graph, position it until the marks fit vertically between the P and S lines. Reading directly down from this “fitted” position to the x-axis will give you the epicenter distance.