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Models of the interior of the Earth

The first thing we will do is look at the model of the interior of the Earth that is homogeneous with a P wave seismic velocity of 11 km/s.

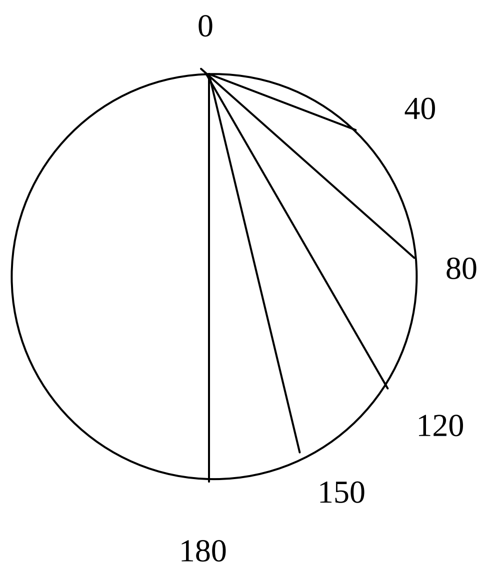

TABLE 1. Model of the interior of the Earth with constant seismic velocity 11 km/sec

Geocentric Angle Δ (degrees)	raypath length (km)	Travel Time (s)	Travel Time (min)
0			
40			
80			
120			
150			
180			

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1. Plot the calculated travel times at the five distances (place a dot at the distance and location given by the data in columns 1 and 3 of Table 1 on the graph shown in Figure 1. Draw a smooth curved line through the calculated travel times beginning at zero distance (Delta) and zero time. Observed travel times for the compressional wave are plotted as solid lines. . Do the observed and calculated times differ significantly? What does this imply about our assumption that the Earth's interior can be modeled using a P wave with a constant velocity of 11 km/s?

2. If the Earth is homogeneous and we selected a different velocity than 11 km/s, could we obtain an adequate fit between the observed and calculated travel times? Why or why not?

3. Which of the raypaths you looked at tell us about the shallow Earth? Which tells you about the deep Earth? Which tell you about both? (This is a slightly tricky question)

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4. Now that we know that the Earth's interior cannot consist of a constant velocity, we use the travel time information to make additional inferences about the velocity structure of the interior. Compare your answers to the measured P-wave velocities. In shallow areas do you need the velocity to be greater or smaller? How about deeper? How do you know this?

PART 2: a 2 layered Earth

5. You will now attempt a 2-velocity model of the Earth. You can do this with math, but to make it simpler we will just use a 1:25,000,000 scale model of the Earth (Figure 2, the big handout). You can measure ray-paths to determine their lengths. We will make an Earth that has a seismic wave velocity of 9 km/sec for the upper 1000 km and 12 km/sec for the rest of the Earth.
   a. Draw 5 wave paths at 20, 60, 100, 140 and 180 degrees from the origin using a protractor.
   b. Any wavepaths that hit the higher velocity interior will refract. You will have to measure the angle that it hits at and use Snell's law to calculate the angle that it leaves the interface at. Then use a protractor to draw in the new ray path that travels through the higher velocity zone.
   c. When the wavepath emerges from the high velocity zone it will refract again (you don't need to calculate the angle of refraction here – it is the same as your incoming wave was in part 5b). Draw the wavepath to the surface.
   d. Measure the TOTAL distance the wave travels in the low velocity zone with a ruler. Enter in Column 1 and multiply by 25,000,000 to get the equivalent distance in the Earth (enter in column 2). Be careful – the wave may travel through the low velocity zone twice!
   e. Measure the distance the wave travels in the high velocity zone with a ruler. Enter in Column 3. Multiply by 25,000,000 to get the equivalent distance in the Earth. Enter in column 4.

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f. Convert distances from centimeters to kilometers. 100 cm = 1 m ; 1000 m = 1 km. Enter in Columns 5 and 6
g. Calculate, given the velocity and the distance traveled, the time the wave needs to traverse the high and low seismic velocity zones (columns 7 and 8); add these two to get the total travel time of the seismic wave. Enter in Column 9
h. Measure the angle formed by the radii for each point where your raypath emerges from the interior of the Earth. Enter in column 10.
i. On <u>**figure 1**</u> Draw a smooth curved line through the calculated travel times beginning at zero distance (Delta) and zero time.

j. Answer the following questions:
    i. Does your new model match the observed P wave travel times better than your first model?

    ii. Where does it work better and where worse?

    iii. If you were to do a 3 layer Earth, what three layers might you do? Why?

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Table 2: Two velocity model of the Earth

Angle of beginning ray	Measured distance through low velocity seismic zone (cm)	Equivalent distance for Earth (cm)	Measured distance through high velocity seismic zone (cm)	Equivalent distance for Earth (cm)	Converted distance in low velocity zone (km)	Converted distance in high velocity zone (km)	Time in low velocity zone (sec)	Time in high velocity zone (sec)	Total time (travel time)	Angular distance between origin and the point that the wave strikes surface (deg)
20										
60										
100										
140										
180										

6. From the simple analysis that we have performed, we can infer that Earth's interior has a velocity structure in which the velocity varies with depth. How could we determine if the velocity also varies laterally (with location)?

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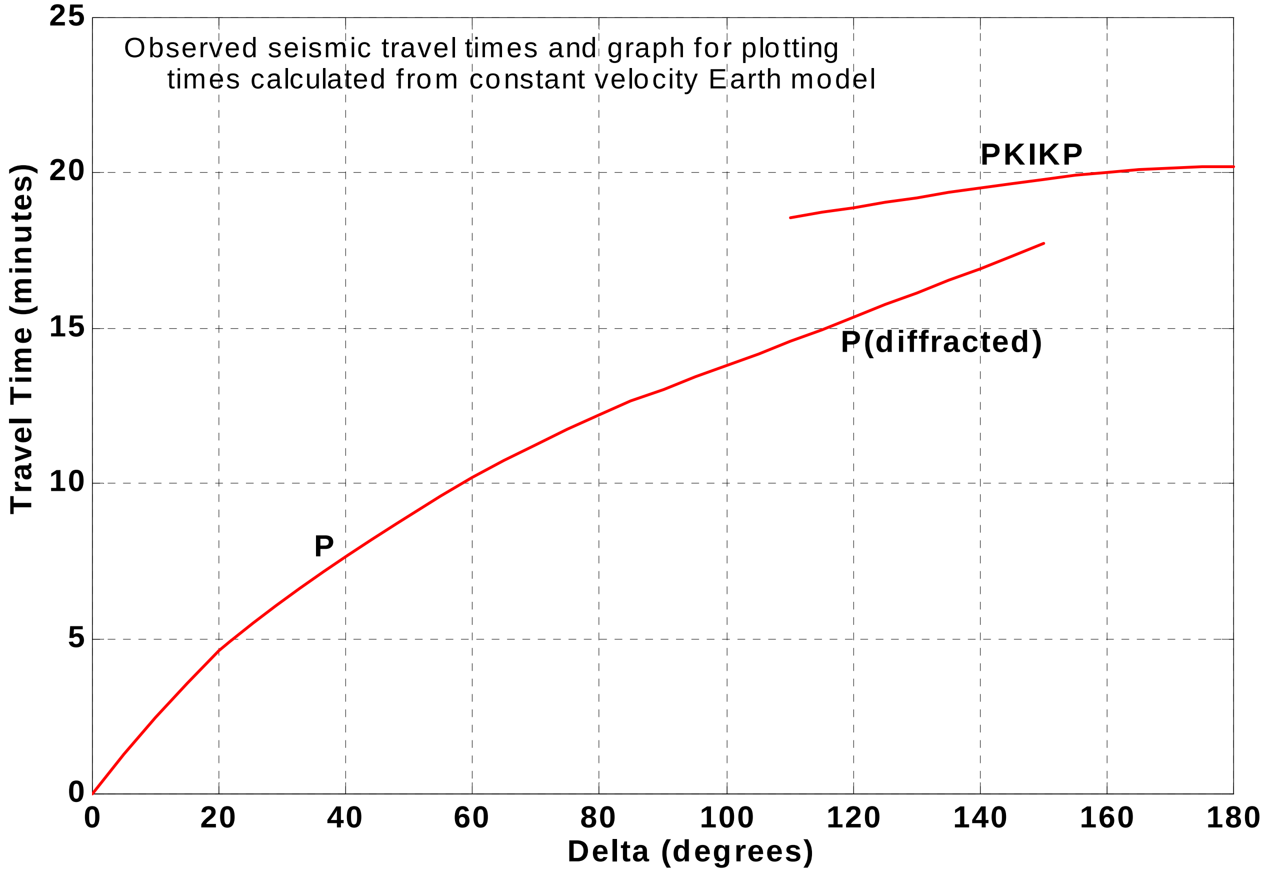

Figure 1 . Observed time travel curve for a compressional wave through the Earth. From Braile (2000)

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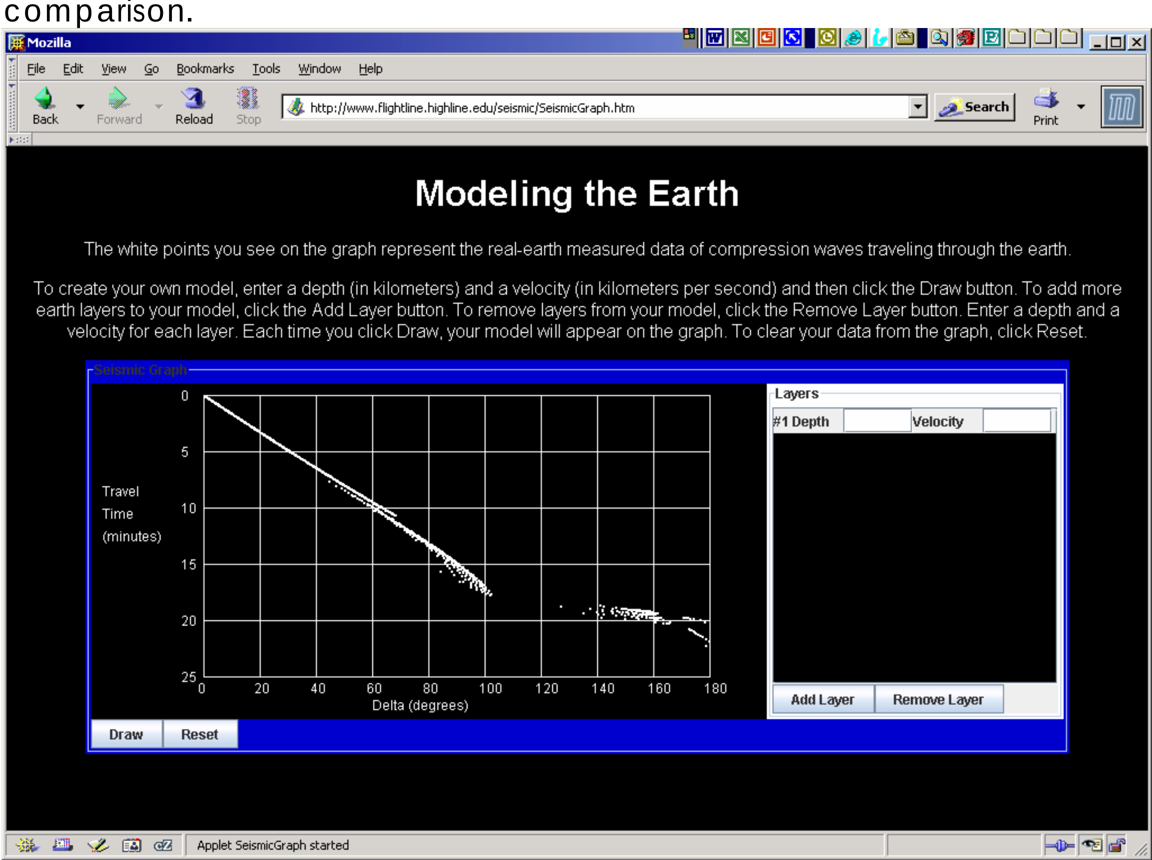
Part 3: As many layers as you want

Now that you have completed modules 1 and 2, you will use the power of a computer to try out more complicated models of the Earth. You will go to a website at http://www.flightline.highline.edu/seismic/SeismicGraph.htm.

This web-based program (shown below) will allow you to model as many layers of the Earth as you wish. For each layer, you will enter a velocity (in kilometers per second) and a depth (in kilometers). The program will then show a graph of distance in degrees and travel time in minutes. It will also show you the graph of the measured values of the Earth (in white dots) for comparison.



To begin with, see how your module 2 looks on this graph. Enter your first layer's data, click add a layer, and then enter your second layer's data. Press "draw." Then, enter the two velocities and depths you used in module 2. Click OK. Does it look like the graph you made? What does

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Keeping the number of layers at 2, try altering either the depth numbers or the velocity numbers to see if you can get a model that better matches the real Earth data. On a piece of paper, keep track of the values you enter each time.

7. What velocities and depths did you find worked best?

Now, you get to explore. You can add as many layers as you want, with any depth that you choose. Remember that the distance to the center of the Earth is 6370 kilometers. You can choose any velocity between 0 and 100 for each of these layers.

When you have gotten as close as you can to the real Earth data, write the layer depths and velocities that you used and take a screen shot by pressing Alt-Print Screen and pasting the image into a Word document. Print the document and turn it in with this lab.

8. How good is your model? Do you think there might be any other models that would be closer? How would they be different?

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9. Do you think that two different models could produce the same time-travel curve? If so, would there be any way to determine which one is the correct model?

10. Finally, write at least a paragraph explaining to your grandmother how we know what the interior of the Earth is like.