I. Objectives

1. Investigate the internal structure of the Earth from the perspective of an observational seismologist and/or a theoretical seismologist.
2. Determine whether the Earth can be considered as homogeneous based on an average seismic velocity.
3. Analyze and describe lab procedures that could produce possible errors.

II. Introduction

How do we know that the Earth's internal structure is layered? This lab will introduce you to some of the evidence that indicate that it is.

Note: diagrams and original lab from IRIS, Determining Earth's Internal Structure, www.iris.edu/hq/resource/determining_internal_structure

III. Materials

Record section, ruler, meter stick, protractor, left and right halves of Earth Scale Model, tape

IV. Prelab Definitions

1. record section

2. geocentric angle

3. homogeneous

4. epicenter

V. Lab Procedure

Break into groups of 4 and then into pairs. One group pair will play the role of an observational seismologist; the other pair will play the role of a theoretical seismologist. Follow the directions below and make careful measurements. Once you have completed your data table and compared it with at least one other group, work through the discussion questions for your section.

VI. Observational Seismologists Worksheet

Background
The simplest solution to the question "What is beneath our feet?" is a homogeneous Earth, or one comprised entirely of the rock we see at the surface. Since seismic waves travel through Earth, they make a useful tool to "probe" the inside of Earth to discover what might actually be inside.

Task
Your task is to help test if Earth is homogeneous by analyzing a set of seismograms from a single earthquake to determine how long it *actually* takes for the seismic waves released from an earthquake to arrive at various points on Earth's surface.

Implications
If your findings match the findings of the theoreticians, then Earth is homogeneous or all rock throughout. However, if your observations do not match the theoreticians' findings, than we can reasonably assume that the Earth is not homogenous or made entirely of rock and will need to develop a new model.

Diagrams

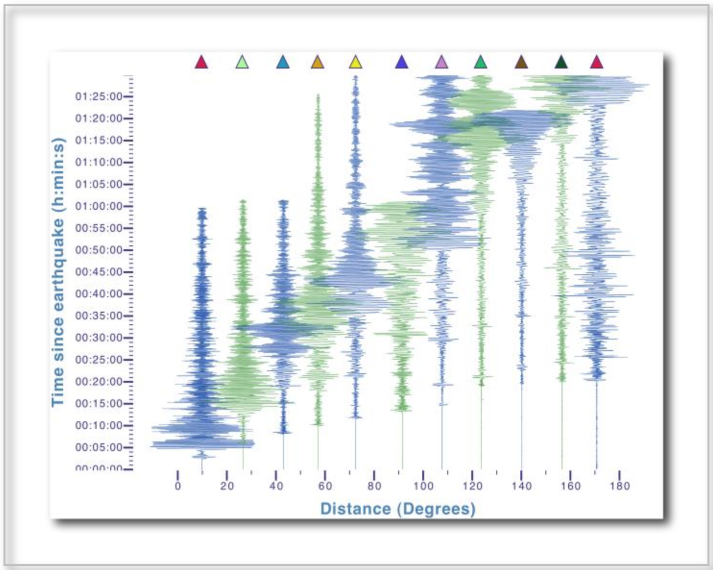

Figure 1: A record section is a special way of displaying a collection of seismograms from an earthquake.

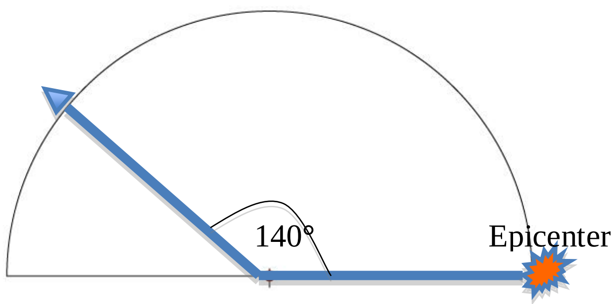

Figure 2: The geocentric angle is measured from the focus of the earthquake, through the center of Earth to the station location at the surface

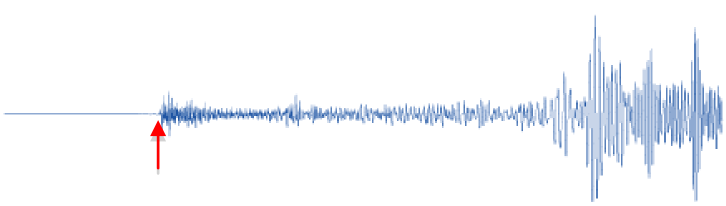

Figure 3. The arrival of seismic energy is indicated on the seismogram by a change from the background or previous signal

<u>Procedure to Determine Travel Time for Waves</u>
A record section, shown in Figure 1, is a special way of displaying a collection of seismograms from a single earthquake recorded at different points on Earth. Each seismogram is plotted according to its distance from the epicenter on the x-axis (the distance from the seismograph to the epicenter is provided in degrees as measured by the geocentric angle shown in Figure 2) and the time since the earthquake on the y-axis.

Step 1: Record the distance of each seismograph from the earthquake, represented by its seismogram in the record section, in terms of geocentric angle in Table 1.

Step 2: Examine each seismogram in Figure 3 and identify the first arrival of energy at that station. Using a ruler read the scale on the y-axis to determine how long it took the energy to travel to that station. Record this information in Table 1.

Step 3: Compare your results with another group of seismologists who used the same earthquakes and stations.

Step 4: Hand in your group's final data or enter the data from your table into the spreadsheet or graph provided by your instructor.

Table 1: Observational Seismologists' Data		
Station number	Station distance in degrees	Travel time in minutes

VII. Observational Seismologists' Discussion

1. Describe any difficulties you and your team had generating your data.

2. Describe any areas where error might have been introduced into your data.

3. Describe any trends and oddities you notice in your data.

4. Compare the arrival times the theoreticians found with what the seismologists observed in Earth. Describe how they are like and unlike one another.

5. What does this imply about our hypothesis that the Earth's interior is homogeneous Earth, or comprised entirely of the rock we see at the surface? How do we know?

VIII. Theoretical Seismologists' Worksheet

Background
The simplest solution to the question "What is beneath our feet" is a homogeneous Earth, or one comprised entirely of the rock we see at the surface. Since seismic waves travel through Earth, they make a useful tool to "probe" the inside of Earth to discover what might actually be inside.

Task
Your task is to help test this hypothesis by creating a model of a homogeneous Earth, using the known velocity of seismic waves in rock ~ 11 km/s. From this model you will predict how long it *should* take seismic waves to reach various distances around Earth.

Implications
If your findings match the findings of the seismologists then Earth is homogeneous or all rock throughout. However, if your observations do not match the seismologists' findings, than we can reasonably assume that the Earth is not homogenous or made entirely of rock and will need to develop a new model.

Model Scale
What is the radius of the model (Figure 4)? _________cm

What is the scale of this model? 1cm: _______________________cm

Assume that the mean radius of the Earth is 6,371 km and that 1 km = 100,000 cm

Diagrams

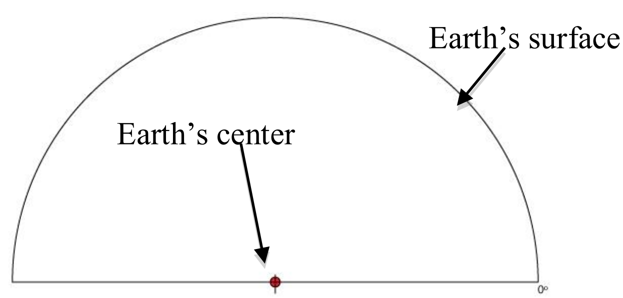

Figure 4: Scale, cross-section model of one of Earth's hemispheres

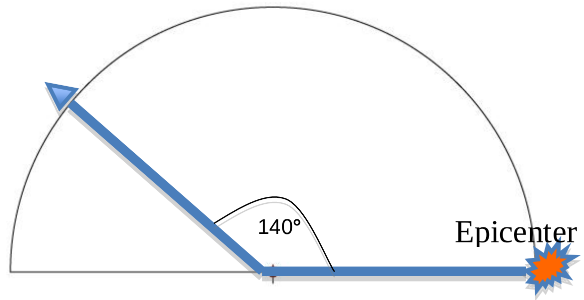

Figure 5: A **geocentric angle** is measured from the focus of the earthquake, through the center of Earth to the station location at the surface

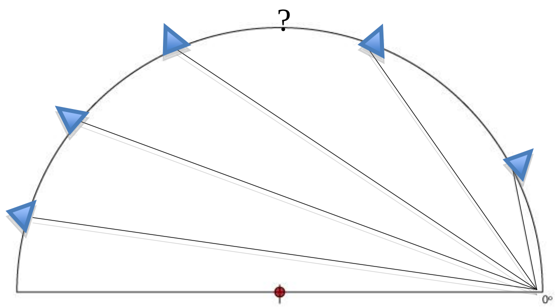

Figure 6: An earthquake occurs at 0° and seismic energy radiates out in all directions and arrives at seismic stations at the surface

Procedure to Develop Predictions

Step 1: Draw a star as indicated to mark the epicenter of the earthquake.

Step 2: Draw triangles on the surface of the model to indicate seismometers to record the arrival of the seismic waves. Assign each triangle a number and record that in Column A of Table 2. Unless instructed otherwise, you may place them anywhere you want but consider the following: What range of angles do you want the model to cover? What would be "enough" data?

Step 3: Determine the location of the stations you added, with your protractor by measuring the *geocentric angle* in Figure 5. Record the geocentric angle for each station in Column B of Table 2. Remember: One degree of geocentric angle corresponds to an arc of ~111km on the surface!

Step 4: *Earthquake!* Draw straight lines representing seismic waves in Figure 6 from the epicenter to the seismograph. Measure the length of these paths in cm and record this distance in Column C of Table 2.

Step 5: Convert the model distances to real Earth distances by converting cm in Column C to km in Column D of Table 2. You will need the scale of the model you calculated previously.

Step 6: Calculate the time it takes the seismic waves to travel to each station using the constant velocity of the seismic waves in our model, 11 km/s. Record this time in Column E of Table 2, below. Convert the seconds to decimal minutes in Column F of Table 2.

Step 7: Compare your results with another group of seismologists who used the same earthquakes and stations.

Step 8: Provide your teacher with your group's final data or enter the data from your table into the spreadsheet or graph provided by your instructor.

Table 2: Theoretical Seismologists' Data					
A	B	C	D = C x 320 km/cm	E = D/11 km/s	F = E/60 s
Station Number	Station Location Δ (degrees)	Distance seismic waves travel in model (cm)	Distance seismic waves travel in Earth in km	Travel time in s	Travel time in min

Conversion notes:

*model distance (cm) scaled to distance at Earth's scale (km): 1cm = ~32,000,000 cm or 1cm on the model = 320 km

****** speed of seismic waves in constant velocity Earth of 11 km/s

IX. Theoretical Seismologists' Discussion

1. Describe any difficulties you and your team had generating your data.

2. Describe any areas where error might have been introduced into your data.

3. Describe any trends and oddities you notice in your data.

4. Compare the arrival times the theoreticians found with what the seismologists observed in Earth. Describe how they are like and unlike one another.

5. What does this imply about our hypothesis that the Earth's interior is homogeneous Earth, or comprised entirely of the rock we see at the surface? How do we know?

Lab courtesy of Dr. Jim Washburne