Teacher's Guide to

Detecting the Layered Earth
(ver 2, 8/18/03)

OBJECTIVES:

1. The students will be able to create a time-distance graph of P-wave travel-times and predict travel-times and other stations.

2. The students will be able to infer the existence of velocity layering in the Earth from observations of P-wave arrival times.

3. The students will be able to understand the concept of wave refraction.

MATERIALS NEEDED:

Global Earthquake Explorer installed on computers the students can use.
Seismograms from a classic earthquake (available on-line).
Seismic record section of the classic earthquake (available on-line).
Student calculators and rulers.
Data sheet and graph paper.

TEACHER INFORMATION:

1. Some detailed Background Information is available in on-line and print copies to help support teacher preparation for SCEPP exercises. It can be exported in PDF to your disk (along with other student materials) via a button on the Getting Started screen of this module.

2. Students may work alone if sufficient computers are available, but students may be more comfortable working in groups of 2 or 3 at each computer.

3. Prior to this lesson, students should be aware of the basic types of seismic waves, plate tectonics and the nature of the Earth's interior.

4. This module involves the students in making measurements, plotting data on graphs, and making inferences from those graphs.

5. While the Earth science concepts involved may be more appropriate for the middle school level, this module is a good way to help students review basic concepts in

measuring and graphing while still covering some high school level math and physical science standards.

6. Refer to Student Instructional Guide for assistance with the GEE software.

7. Acknowledgement: The first draft of this lab was prepared as a term project for GEOL540 in the Spring 2000 semester by Keith Harris.

ENGAGEMENT

1. Explain: This lesson will involve using earthquake waves as a tool to look into the interior of the Earth. If the earthquake used is a recent, newsworthy event, take a few moments to discuss that earthquake.

EXPLORATION

1. Have the students select and start the module "Detecting the Layered Earth" within the Global Earthquake Explorer. Using GEE, show the students a map of a classic earthquake and station locations. The stations to be used in the analysis will be shown in RED on this map.

2. *Ask*: How would you expect the P-wave arrival time at these stations to vary? Explain: We would expect more distance stations to have later P-wave arrival times because those waves must travel greater distances.

3. Using GEE, show the students a seismic record section for this earthquake. The seismograms for the RED stations on the map are shown in RED on the record section. Have the students examine the seismic record section and confirm that these findings are generally true. Remind the students that the time-distance relationship (T=X/V) can be used to determine the velocity of the Earth with this type of data. [NOTE: Any time you show a seismogram or group of seismographs is a good chance to reinforce identification of the various types of waves.]

4. Have the students use the Global Earthquake Explorer to work their way through several seismograms and construct a table of: Station Name, Distance (km), Origin Time, P-wave Arrival Time, P-wave Travel-Time, using the data sheet provided. Be sure to have them measure the time of the FIRST arriving P-wave energy.

CONCEPT DEVELOPMENT PHASE

1. Have the students construct a time-distance graph using the three closest stations. They should be able to construct a "best-fit" line through these three data points. Best-fit can be done visually or quantitatively, depending on the level of the class.

2. *Ask*: What is the slope of this line?
   Explain: The slope of the line is the velocity of the material that the P-wave is travelling through. Have the students estimate the velocity of the Earth using this method.

APPLICATION PHASE

1. Now that the students have estimated the P-wave velocity, have them PREDICT the arrival time for the next most distant station. Compare this to the observed time. Discuss the differences in the predicted and observed time. Our intention is that the first station used in this prediction exercise will have predicted and observed times that are very close.

2. Once the prediction method is understood, have the students continue their exercise with increasingly distant station. *Ask*: Do the predictions and the observations vary systematically with distance?
   Explain: It appears that the observed arrival time is systematically earlier relative to the prediction with increasing distance.

3. *Ask*: How might we explain this analysis?
   Explain: The P-wave must be traveling through material with a higher velocity. Review the basic travel time equation if necessary to make this point. Explain that there are at least a couple of possibilities. First, that the more distant stations are located on material that is of higher velocity. [Note: Praise students who come up with this scenario. It is quite logical. However, in this case, it is incorrect.] Second, the P-wave may be traveling through faster material at depth in the Earth.

4. *Ask*: How could we tell these possible explanations apart?
   Explain: Using the map, suggest that we could look at an earthquake in the area of suspected higher velocity and see if the travel-times of the closer stations suggest that the velocity is higher in this region.

5. Unfortunately, we cannot guarantee an earthquake in the proper place with respect to the classic earthquake to test this hypothesis. Thus, you must explain that when this test is done, seismologists find that all over the world, the velocity seems to increase at more distant stations. This suggests that the faster material is AT DEPTH.

6. *Ask*: Do you remember from middle school how the structure of the Earth changes with depth?
   Students will probably remember crust, mantle, core. The discussion should lead them to recall that the boundary between the crust and mantle is relatively near the surface.
   Explain: What we are seeing is what happens when the P-wave begins to pass through the mantle, which has a higher velocity than the crust.

7. Conclude the discussion with a sketch of the paths that the P-wave might take through the Earth. This is an example of the *refraction* of a wave as it encounters material of different seismic properties. Drawing on any optics concepts that have been done prior to this exercise may make the discussion more complete.

EXTENSION

1. Challenge the students to find a pair of earthquakes in either the SCEPP or IRIS archives that demonstrate that higher velocities calculated at distant stations cannot be simply a local effect.