

**NJCU Field Geophysics Seismic Refraction Exercise –
Create a Geologic Cross-Section from First Arrivals** *Fall 2008*

Expected Student Outcomes

- Learn / reinforce skills at laying out and staking a survey line
- Use GPS to accurately locate survey points every 3m (10 feet) (optional)
- Become familiar with Seismic refraction data collection techniques
- Interpret seismic refraction data to create a simple geologic cross-section, including:
 - Estimation of number of layers
 - Calculation of layer velocities
 - Hypothesized lithologies based upon layer velocities
 - Calculation of depth to bedrock

Introduction – This exercise builds upon what you learned in Assignment 03, and uses field data collected from Turtle Back Park in S. Orange, NJ in Fall 2008 with the help of Rutgers – Newark personnel. Your goal is to produce a scaled geologic cross-section along a survey line. The general geologic setting of this area includes mapped glacial (moraine) deposits on top of basalt.

Two seismic lines are provided. In the future, this exercise will be extended to include the creation of a “dipping layer” case, where first breaks from both lines are plotted on one travel-time vs distance plot. For the first iteration of this exercise, however, you may use just one line.

Procedure

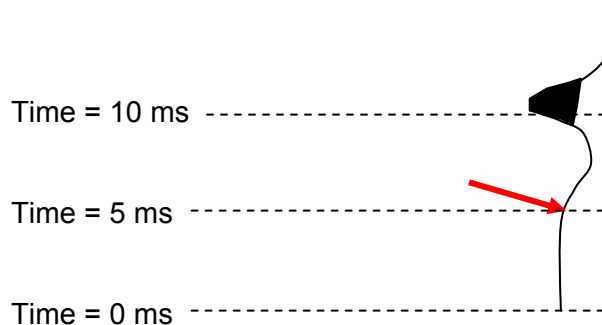
Step 1 – Pick first breaks

Two lines are shown below. The only difference is the location of the seismic source (in this case, a series of stacked hammer blows on a steel plate). Line 1 has the source on the northern (left) end of the line, while Line 2 has the source at the southern (right) end of the line. The seismic trace from each geophone is positioned at the interval (in meters) from the beginning of the line (X=0). The trace at each geophone is recorded in milliseconds.

Nomenclature is as follows: 1 millisecond (aka 1 msec) = $\frac{1}{1000}$ sec = 0.001 sec

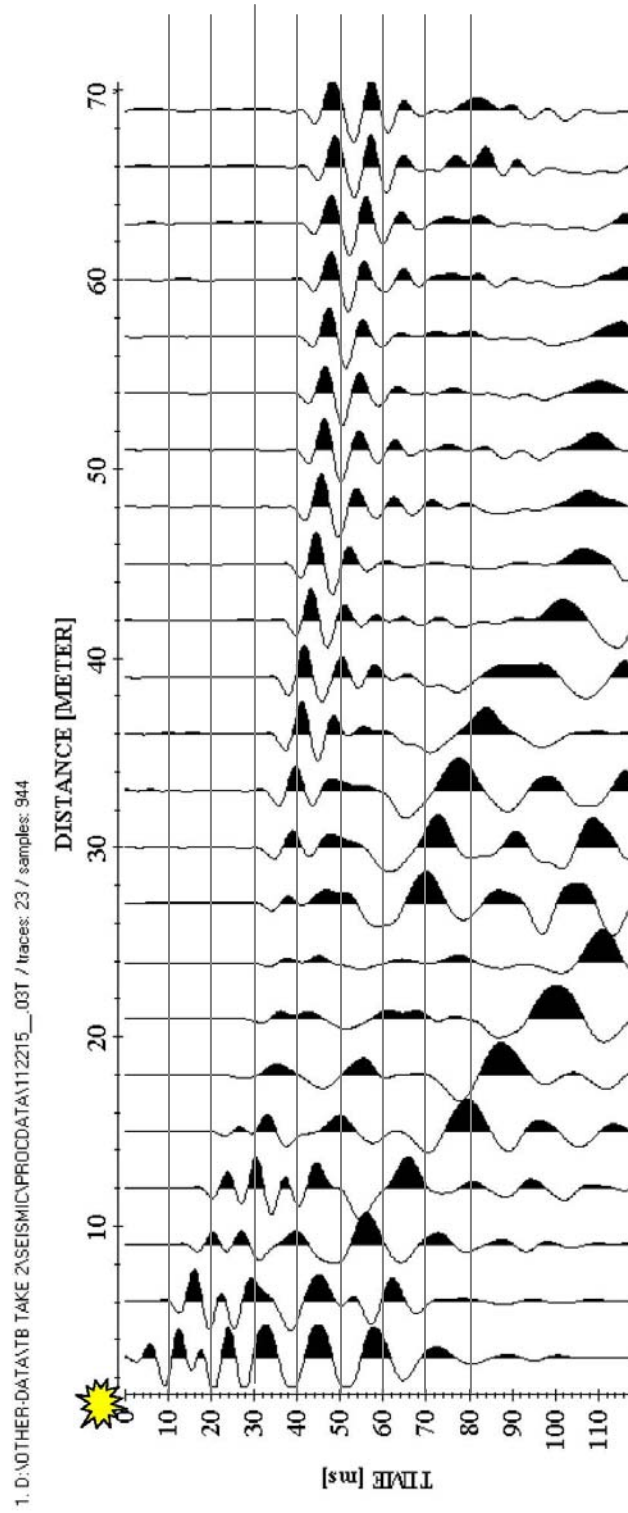
Your first task is to note the time that it takes for the seismic source to reach each geophone. This is a procedure that is also known as picking the “first break”, and involves the interpreter making a judgment as to when the seismic wave first arrives at the geophone. Depending upon a geophone’s distance from the seismic source, the first arrival of the seismic wave may come through surficial deposits, or perhaps through a deeper, faster layer.

With refraction data, you are only concerned with the first “arrival” at each geophone. For this exercise, it is suggested that you make the “pick” of the first arrival when the line begins to bend away from a straight line. The first arrival is at 5 milliseconds in the example below:



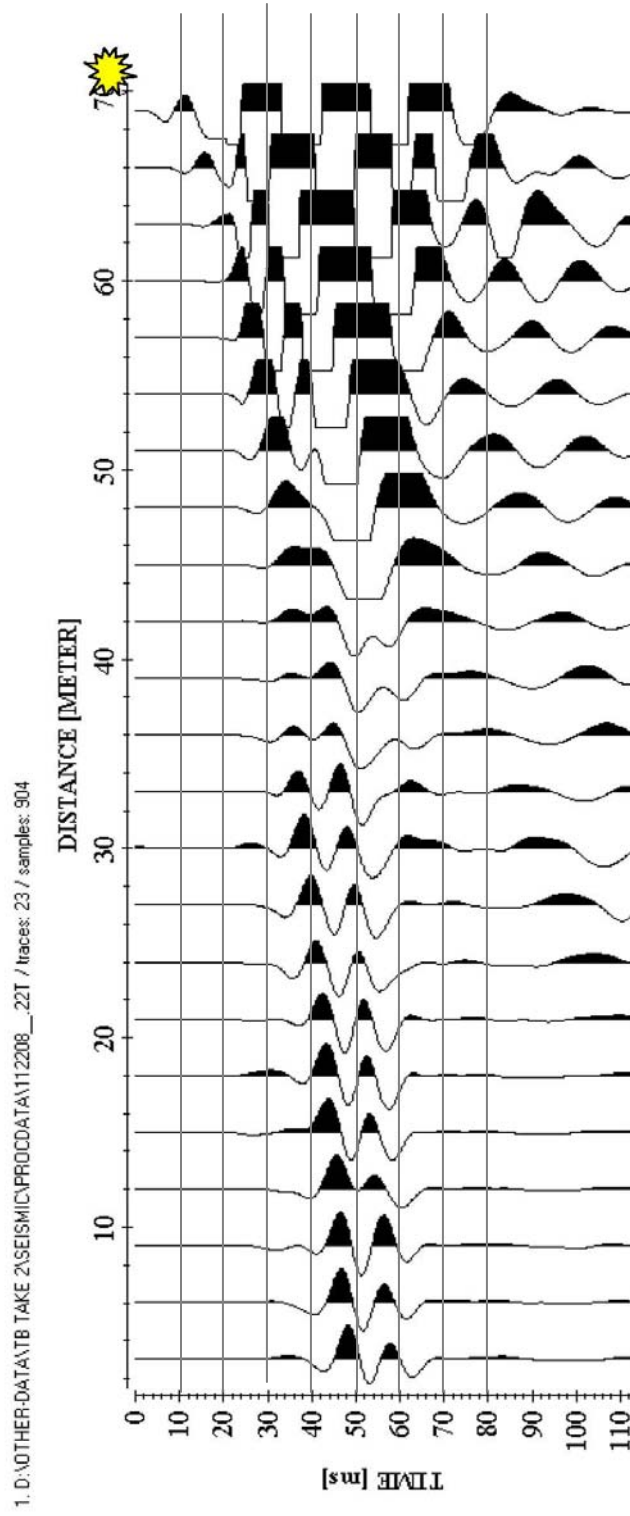
Line 1 is shown below:

Shot at Parking Lot, towards the woods



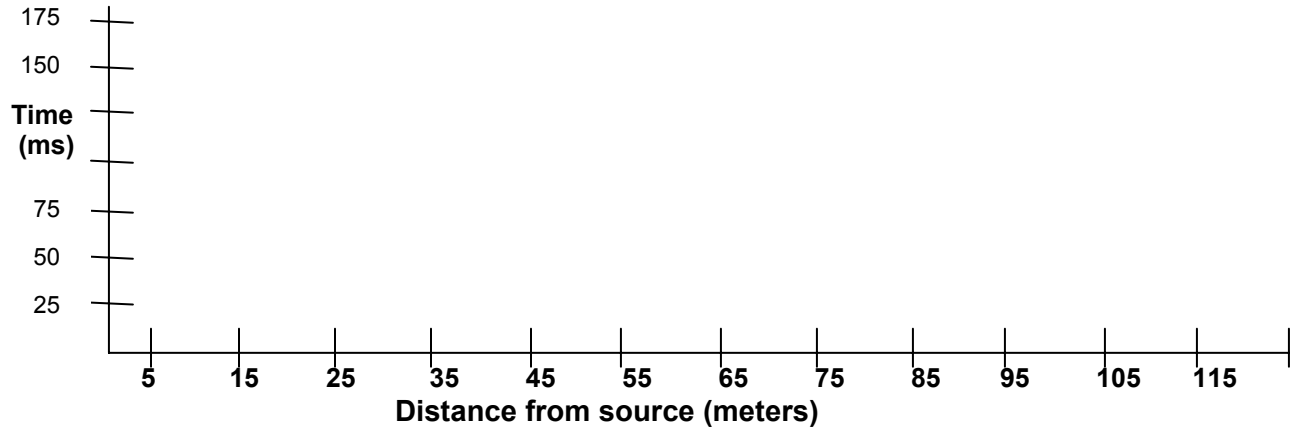
Line 2 is shown below:

Shot in middle of field, shooting towards parking lot

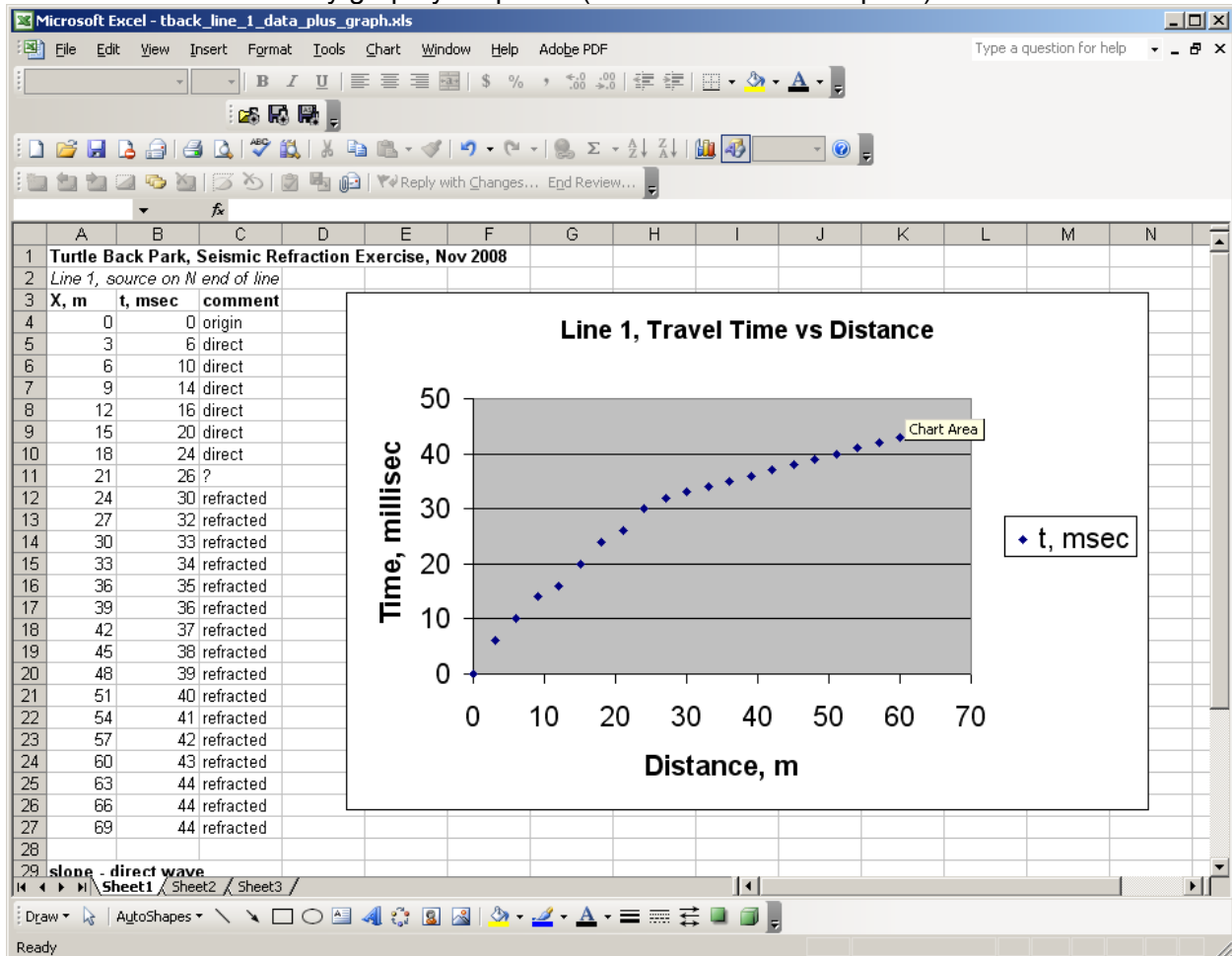


Step 2 – Plot the first breaks on a travel-time vs distance graph

In this step, you will create a travel-time vs distance graph based upon your first arrival picks. Convention dictates that TIME is plotted on the Y axis and DISTANCE is plotted on the X axis, as shown below. If desired, feel free to use this graph to plot your points.



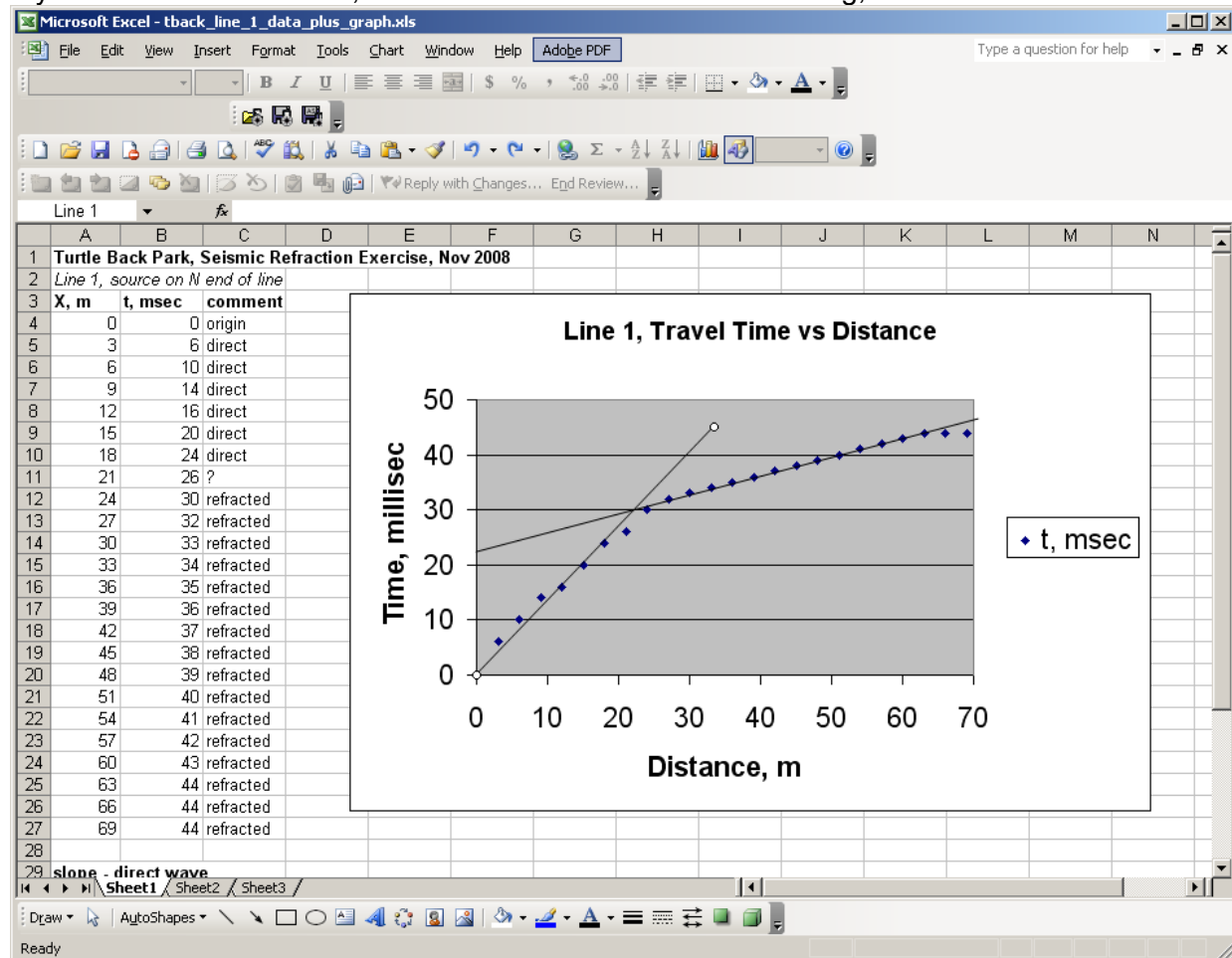
Alternatively, you can use MS Excel to store the points in 2 columns (X and t). You can then use Excel to automatically graph your points (use the X-Y scatter option):



Step 3 – Create “best fit” line segments through your points

In this step, you want to create as many straight-line segments as are necessary to “fit” the data points (I used only 2 lines for the sake of simplicity). You can draw each straight line segment from your points if you plotted them by hand (above) by sighting along your graph at a shallow angle. If you follow this approach, it is suggested that you “ink” your points first, then use pencil to draw your line segments, since you may draw several line segments before you achieve a “best fit”. Make sure you project your line segment(s) all the way back to the “Y” axis of your graph. IMPORTANT – recognize that the straight-line segment representing the surface layer will intersect the y axis at $t=0$, but the rest of the line segments will intersect the Y-axis higher up (t_i in the equation later on).

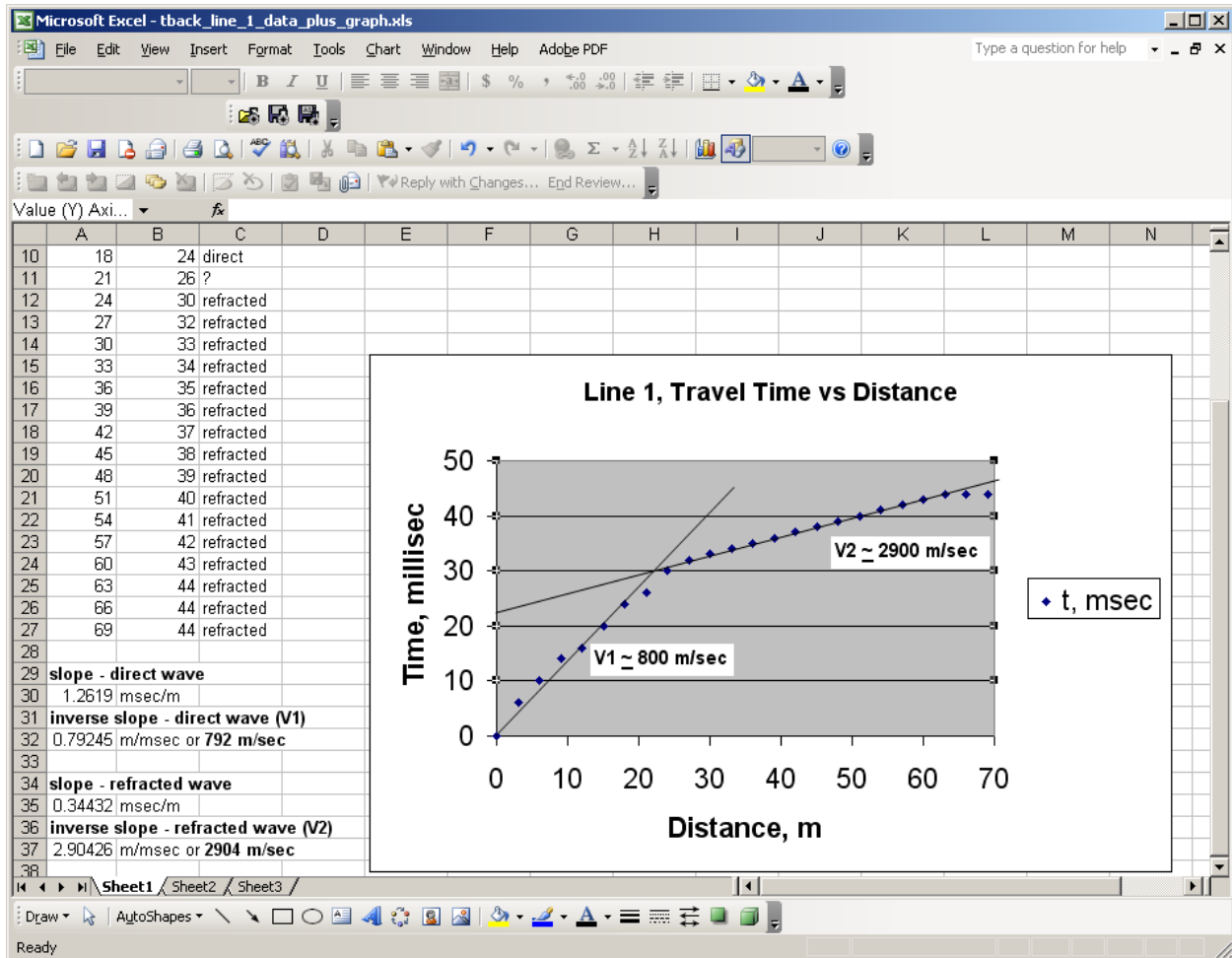
If you choose to use Excel, use View > Toolbars > check Drawing, and draw lines:



Step 4 – Determine slopes and inverse slopes of line segments to determine velocities

The slope (defined as $\Delta y/\Delta x$) of each straight-line segment plotted on the current graph is not your end product. What you need is the INVERSE of that slope, which will be the velocity ($\Delta d/\Delta t$) of the subsurface layer represented by that particular line segment. However, it is easiest to first determine the slope of each of your lines in the current graph (i.e., Δ time / Δ distance), then simply calculate the inverse of the slope to produce velocity. You will finally need to multiply your inverse slope value by 1000 in order to convert units of measurement from meters per millisecond (m/ms) to meters per second (m/sec), which is a much more standard measurement format. You can either do this by hand or can use Excel to determine the slope of each line segment (see Help in Excel, then type in Slope as a keyword).

My calculations produced the following data:



Step 5 – Create a simple geologic cross-section along the seismic survey line

Your final task is to prepare a simple cross-section of the subsurface. You first need to calculate the depth to each interface (just one in this case). You can do this because 1) you know the **velocity** of each layer through which seismic energy is passing, and 2) you have an estimate of the **time** that it would take for that interface to be reached directly below the source at the position of the Y-axis. You will use the following equation to calculate h_1 :

$$h_1 = \frac{t_1}{2} \frac{(V_2 V_1)}{\sqrt{(V_2^2 - V_1^2)}}, \quad \text{where } h_1 \text{ is the thickness of layer 1}$$

Remember to convert all of your distance units to METERS and your time units to SECONDS **BEFORE** you start your calculations! This will yield a value for h_1 in units of meters. What is your value of h_1 ? My calculations reduced to the following:

$$h_1 = .011 \text{ sec} \times \frac{823 \text{ m}}{\text{sec}} = 9.05 \text{ m}$$

Consult a geoscience reference (e.g., geophysics textbook, the Web, etc.) to link your calculated velocities with possible sediment or rock types (e.g., soil, granite). Label your cross section layers with both velocities and the possible sediment or rock type of each layer: