Amherst College
Geology 41: Environmental & Solid Earth Geophysics
Seismic Refraction Survey

The purpose of this lab is to demonstrate how subsurface geology can be investigated through shallow refraction seismology. During this lab, we will conduct a seismic refraction survey in the sandbox in the basement. After conducting our survey will dig down through the sediment in the sandbox and directly observe the materials through which we shot our refraction survey.

For our survey, seismic waves will be generated with a relatively low energy seismic source (weight drop). The arrivals of these waves will be recorded by a digital seismograph at a linear array of 12 geophones. As you saw in class, it is difficult to determine the path or phase of most seismic waves that arrive after the first arrival. However the phase of the first arrival is easy to determine as it must be a P-wave. For this reason, we are going to analyze only the first arrivals at each geophone, these are often referred to as *first breaks*.

Successful analysis of the subsurface geology by refraction seismology depends on a relatively simple geometry to the subsurface geology. An ideal geometry would be to have a series of layers (either horizontal or inclined) each of which has a higher P-wave velocity than the overlying layer. In the Amherst area a possible subsurface geometry that would meet this requirement could have some or all of the following layers:

organic rich-soil	V_P =	<0.5 km/sec
unsaturated glacial sediment		0.5-1.5 km/sec
water saturated glacial sediment		1.0-2.5 km/sec
Mesozoic sedimentary rock		2.5-4.5 km/sec
Paleozoic metamorphic rock		4.0-6.5 km/sec

Our sandbox contains a layer of sand that is above a reinforced concrete floor. Although we do not initially know the seismic wave velocities of either of these 2 materials

DATA ACQUISITION

In the sandbox, set up a geophone array with the geophones spaced 15 cm apart. Data will be acquired by placing the source at each end of the array (in seismo-jargon, both forward and reversed lines will be shot). The shot points will be placed near the first geophone (15 cm offset) and at some distance from the first geophone (30 and 50 cm offsets). We will collect data for a total of 6 shots. Be sure to save the data as the computer AND print out paper copies. Be sure to take notes to identify all of the files generated by your study.

After you have completed this survey dig through the sand and see determine the depth to the concrete interface. Remove the geophones and all of the cords from the sandbox and grade the sand so that there is a difference in sand thickness of ~30 across the sand box. Replace the geophones with a 15 cm spacing and repeat the survey with an offset of ~15 cm. Move to the far end of your array and perform a reverse shot. Be sure to save the data

as the computer AND print out paper copies. Be sure to take notes to identify all of the files generated by your study.

DATA REDUCTION

1) For each of the 8 shots, determine the travel time for the first break.
2) For each of the 8 shots, plot the travel time (y-axis) against distance (x-axis).
3) Examine each distance travel-time graph:

Does the travel time increase linearly with distance from the shotpoint (i.e., do you have a straight line that passes through the shotpoint at travel time = 0)? If so, then the subsurface geology is homogeneous, the materials that we see at the surface are the same as those at some depth. From the slope of your travel-time graph, determine the seismic velocity of this material.

Alternatively, does the travel time graph seem to be composed of a series of linear segments each with a progressively shallower slope? If so, then the subsurface geology is composed of a series of layers with progressively higher seismic velocities. From the slopes of each segment on your travel-time graph, determine the *apparent seismic velocities* of each layer.

Or, does the travel time graph have a different shape to it? If it does, describe the shape. The subsurface geology is complicated and not easy to interpret from refraction seismology.

4) Interpret the results from all of the lines in each of the two surveys:
*Are the reciprocal times (time to a hypothetical 13th geophone) of the forward (geophone 13 located at the reverse shot point) and reversed (geophone 13 located at the forward shot point) lines the same for each of the 4 different array geometries? If so, then you have probably done a good job picking first arrivals. If not, look carefully at the original seismograms.
*Are the apparent velocities of each layer in the forward and reversed lines the same? If so, then the layers are horizontal and the apparent velocities calculated above are the true seismic velocities.
*Are the forward and reversed lines different? If so, this suggests that the interface is inclined. For an inclined interface, the up-dip velocity is greater than the down-dip velocity. Which direction is the interface dipping? Determine the true velocity of the lower layer and the dip of the interface.

$$\text{dip} = \frac{1}{2}\left[\arcsin\left(\frac{V_1}{V_{slow}}\right) - \arcsin\left(\frac{V_1}{V_{fast}}\right)\right]$$

$$V_2 = \frac{V_1}{\sin\left\{\frac{1}{2}\left[\arcsin\left(\frac{V_1}{V_{slow}}\right) + \arcsin\left(\frac{V_1}{V_{fast}}\right)\right]\right\}}$$

for shallow dips in which sin (dip) ≈ dip this equation reduces to:

$$\frac{1}{V_2} = \frac{1}{2}\left(\frac{1}{V_{slow}} + \frac{1}{V_{fast}}\right)$$

V_1- velocity above the interface
V_2- velocity below the interface

What are the depths to the interfaces at the top of each of your layers?

$$X_{co} = 2z\,\frac{\sqrt{V_2 + V_1}}{\sqrt{V_2 - V_1}}$$

X_{co}- distance to slope change on the travel-time graph
z- upper layer thickness

5) How does the refraction structure of the sandbox compare with the structure determined by shovel? Nature of layers? Thickness of layers? Dip of layers?