University of Manitoba
2015 Geophysics Field School

Birds Hill Project: Data Analysis
Seismic Refraction Survey

Groups:

- Question 1 should be completed by the data acquisition group
- Questions 2-3 should be completed with your partner(s)
- Questions 4-6 should be completed individually.

This work should be completed in 90 minutes. All work is due at 10 PM.

- The data archiving must be submitted *electronically* on a jump drive to an instructor, in a folder with project name and group number in the name, and subfolders indicating the particular survey.
- Data reduction and analysis answers should be submitted in hard-copy, with one copy submitted for each data analysis pair or trio. The results can be submitted in hand-written form.
- The interpretation answers should be submitted in hard-copy, with one copy submitted for each person. The results can be submitted in hand-written form.

An instructor will provide each member of the group with hard copies showing plots of the reflection data as well as electronic copies of the data files.

Data Archiving:

1. Data files should be carefully archived on an appropriately labelled directly on a jump-drive with a README file explaining the data format, date and place of collection, the group who collected it, the group who archived it, and any other pertinent details (*i.e.* survey configuration). Submit an electronic copy of the data and the README file.

Data Reduction and Analysis:

2. Using the hard copies of the results provided by the instructor, fit straight lines to the direct and refraction arrivals. Tabulate the velocity and intercept for each of the arrivals. Include the diagrams showing the line fits in your submitted answer.

3. Fit the data with a simple, horizontally-layered, seismic model, with at most three layers (you can either chose the highest-quality line, or average the slopes/intercepts from multiple lines). The theory is listed in the Appendix.

Interpretation:

4. Describe the different signals that can be discerned in the data (e.g. direct arrival, refracted arrival, reflected arrival, air wave, ground roll) – how visible are they, where do they show up, and how coherent are they between instruments?

5. Discuss the evidence for dipping interfaces or local velocity heterogeneities in the data.

6. Interpret the overall results in terms of the surficial geology of the area using the map provided in the Birds Hill background document, and published values for seismic velocity (e.g., Table 1, Figure 1).

Table 1. Seismic velocity in near-surface materials (**Knight & Endres 2005**)

Material	V_p (m/s)
Soil	180–450
Sand, gravel	500–1000
Clay	500–2200
Till	1500–2200
Sandstone	1450–1650
Shale	2200–4000
Limestone	3600–6000

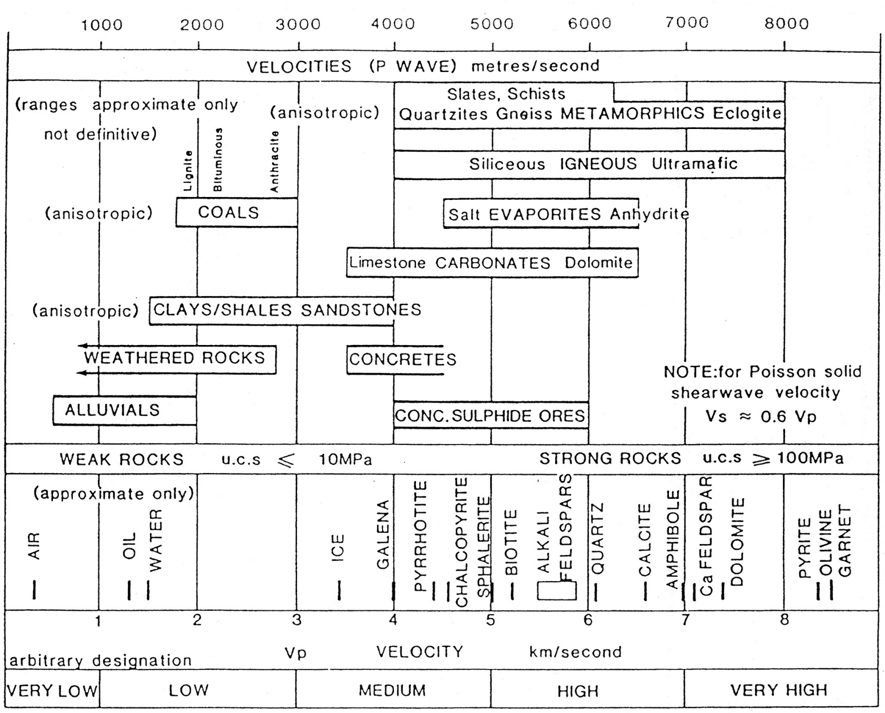

Figure 2. Typical P-wave velocity range for different rocks and earth materials (**from Emerson 1990**).

References

Emerson, D.W., 1990. Notes on mass properties of rocks; density, porosity, and permeability. *Explor. Geophys.*, **21,** 209-216.

Knight, R.J., & Endres, A.,L., 2005. An Introduction to Rock Physics Principles for Near Surface Geophysics. Chapter 3 in *Near-Surface Geophysics,* ed. Butler, D.K., Society of Exploration Geophysicists, Tulsa, Okla. p. 31-70.

Appendix: Multiple-Layer Seismic Refraction

Seismic refraction can be used in a multi-layered environment in which the velocity increases with depth to determine the thicknesses and velocities of the layers. The formula for the travel time t_n for the wave refracted along the top of the n'th layer (Figure 1) is:

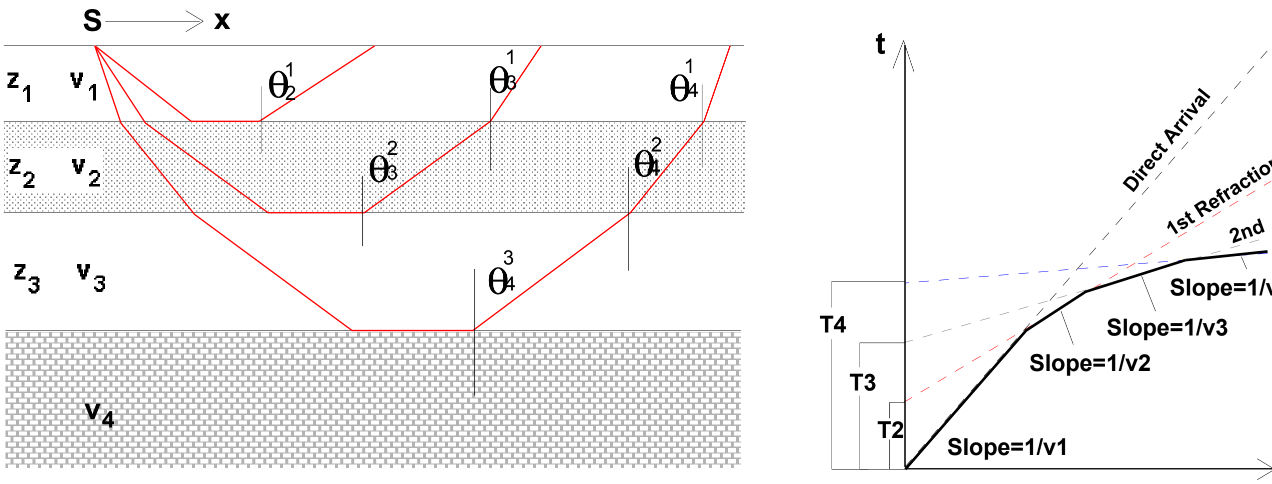

Figure 1: Refraction in multiple layers

$$t_n = \frac{x}{v_n} + \frac{2z_1}{v_1}\cos\theta_n^1 + \frac{2z_2}{v_2}\cos\theta_n^2 + \frac{2z_3}{v_3}\cos\theta_n^3 + \ldots + \frac{2z_{n-1}}{v_{n-1}}\cos\theta_n^{n-1} = \frac{x}{v_n} + T_n \qquad \text{Eq. 1}$$

where θ_j^i is the angle the ray that is critically refracted off the top of the j'th layer makes with the vertical in the i'th layer and is given by

$$\sin\theta_i^j = \frac{v_i}{v_j} \qquad \text{Eq. 2}$$

Note that z_i is thickness not depth of the i'th layer. For a three-layer case we can expand equation 2 to get

$$t_1 = \frac{x}{v_1} + T_1 \qquad T_1 = 0 \qquad \text{Eq. 3}$$

$$t_2 = \frac{x}{v_2} + T_2 \qquad T_2 = \frac{2z_1}{v_1}\cos\theta_2^1 \qquad \text{Eq. 4}$$

$$t_3 = \frac{x}{v_3} + T_3 \qquad T_2 = \frac{2z_1}{v_1}\cos\theta_3^1 + \frac{2z_2}{v_2}\cos\theta_3^2 \qquad \text{Eq. 5}$$

On the arrival time plot (Figure 1) note that

(**a**) the slope of the arrival critically refracted along the top of the nth layer is $1/v_n$
(**b**) the intercept of the arrival critically refracted along the top of the nth layer is T_n and
(**c**) the intercept depends on the velocity and thicknesses of all of the overlying layers.

To analyze a seismic refraction record from a multiple layered region we would proceed as follows:

i. Measure off the intercepts T_2,T_3,... and slopes of the observed first arrivals
ii. Convert all of the slopes into the velocities of the layers v_1,v_2,v_3,....
iii. Use the intercept of the 1st refracted arrival T_2 with v_1, v_2 to estimate z_1.
iv. Use the intercept of the 2nd refracted arrival T_3 with v_1, v_2, z_1 to estimate z_2.