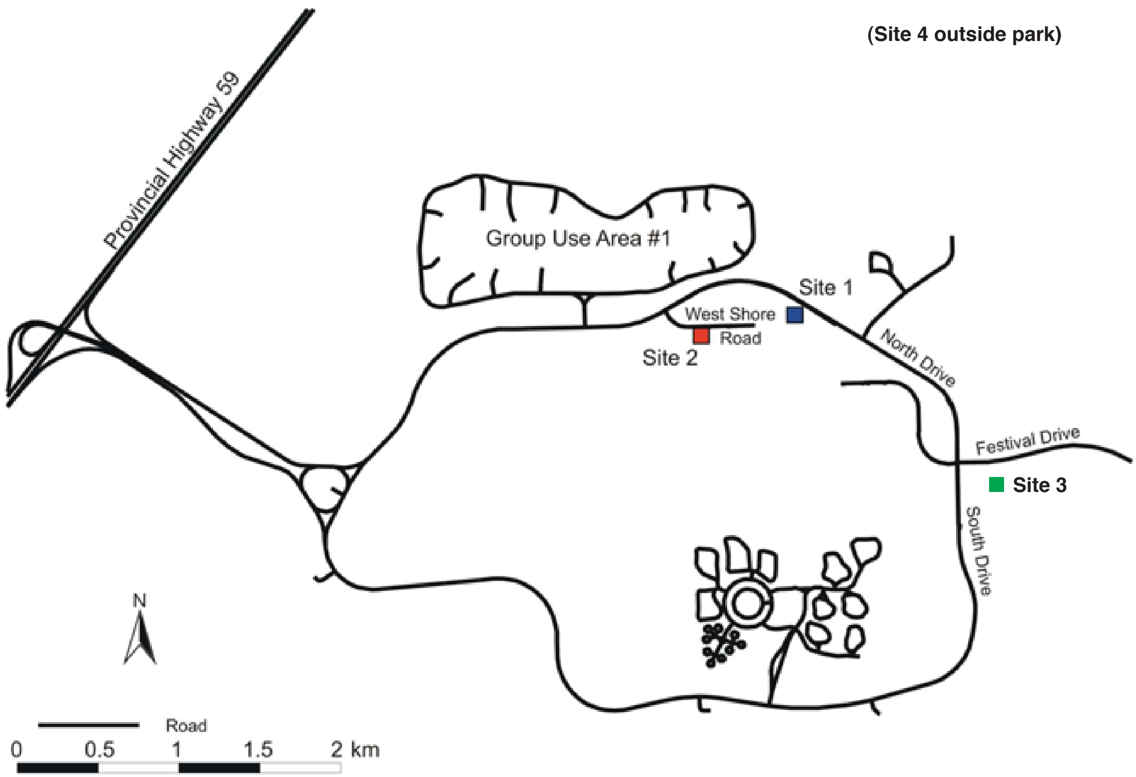
University of Manitoba
2015 Geophysics Field School

Birds Hill Project: Day 1 or 2 (April 28 or 29)
Seismic Refraction Survey



Schedule: Group 1 (Site 1), 28th, morning; group 2 (Site 2), 28th, afternoon; group 3 (site 3), 29th, morning. Allow about 2.5 hours for data collection.

Goals: Birds Hill is an esker complex, with a sandy composition very different from the rest of the Red River valley. Today you will characterize its seismic velocity and near-surface layering, and familiarize yourself with a modern small-scale refraction system.

Table 1. Equipment required for Birds Hill seismic surveys		
No.	Item	Specific components
1	Geometrics geode seismic system	Geode instrument including 24 geophones, cabling (spread cable, data cable, power cable), and laptop connector box.
		Manual
		12 V battery
		Metal hammer plate
		Hammer, trigger, and tape to attach trigger
		Field computer
		Inverter
		Ear protectors
		Safety glasses
3	Surveying	4 x 50 m tapes
		1 Brunton compass
		2 wooden stakes or pin flags
		GPS

PRE-SURVEY INSTRUCTIONS

1. Read the project instruction sheets in full prior to commencing the survey.
2. Review the instrument components and connection of the cabling.
3. Using the appropriate seismic refraction equations (Appendix 1), calculate the crossover distance for a two-layer velocity structure consisting of an upper layer with velocity 300 $m.s^{-1}$ and thickness 4.0 m overlying a layer with velocity 1400 $m.s^{-1}$. Approximately how long should the survey line be to observe the cross-over?
4. Check that your GPS unit is switched to UTM coordinates.
5. Use the Geological Survey of Canada Geomagnetic Laboratory declination calculator to estimate the present declination for Birds Hill (50° N, 97° E). Set the declination of the compass to the correct value for Birds Hill. The declination calculator is at http://geomag.nrcan.gc.ca/calc/mdcal-eng.php.
6. Pack all necessary equipment carefully into one vehicle.

FIELD INSTRUCTIONS

The aim of our measurements is to become familiar with the seismic system and to perform one or two reversed seismic refraction soundings at a specified location at Bird's Hill. Please pay attention to environmental concerns and try and minimize any long-term impact on the ground -- fix any large holes that develop during hammering. Consolidate data recording in a small number of log books.

1. In association with the instructor, set up the seismograph at the first sounding location.

2. Carefully sketch the location and azimuth of each profile including the proximity of any cultural features. Record sufficient details to enable the site to be reoccupied. Record the seismometer details including the instrument model. Record all other equipment needed for the survey. Sketch the configuration of the survey.

3. Complete a forward sounding using 1 m geophone spacing and then using 3 m geophone spacing. For each spread record the file name, geophone configuration, number of hammer stacks (fold), operator names and any other comments. Lay out a table in the logbook to record this information.

4. Complete a reverse sounding using the two geophone spacings. Record the time-averaged GPS location of the zero offset point for the reversed profile.

5. As time permits, complete a second sounding at a location of your choice.

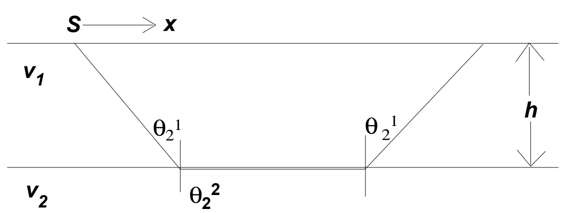
APPENDIX 1 - SEISMIC REFRACTION THEORY

Figure 1 shows the geometry of seismic refraction for a two-layer structure. As rays enter a medium of increased velocity they are refracted towards the horizontal and are **critically refracted** when $\theta_2^2 = 90^\circ$. Here θ_i^j refers to the incidence angle in the i'th layer of a ray that is critically refracted at the top of the j'th layer. From Snell's Law, we have for critical refraction:

$$\theta_2^1 = \sin^{-1}\left(\frac{v_1}{v_2}\right)$$

The critically refracted ray forms a **head-wave** propagating along the top of layer 2 at the faster velocity of this layer. The head wave acts as a source of new waves (Huygen's Principle) which travel back to the surface. The corresponding seismic rays have an incidence angle of θ_2^1. These refracted arrivals will be recorded by surface geophones and on arrival time plots will form straight lines with a smaller slope (*i.e.*, faster velocity) than the direct arrivals.

Close to the seismic source, the first signal to arrive is the direct arrival. At greater distance from the source the refracted arrival will arrive first. The crossover of the direct and refracted arrival is called the **crossover point** and the closest point to the source that a refraction arrival can occur is called the **critical point.** When plotting seismic arrival time curves you should not show a refracted arrival at offsets less than the critical point.



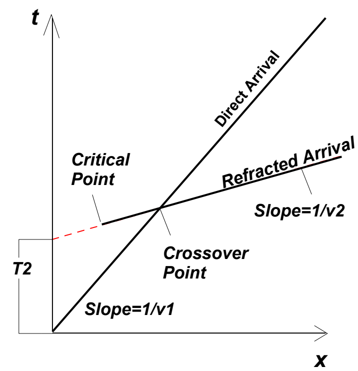


Figure 1: Seismic refraction for two layers

The formulae for the direct and refracted arrivals for a two-layer structure are respectively:

$$t = \frac{x}{v_1} \quad \text{and} \quad t = \frac{x}{v_2} + \frac{2h}{v_1}\cos\theta_2^1 = \frac{x}{v_2} + T_2$$

We can use the slope of the direct and refracted arrivals to determine the velocity of the two layers (and thus the angle for critical refraction). We can use the observed intercept T_2 of the refracted arrival with the x=0 axis to determine the thickness of the top layer. The formula for the cross-over point is:

$$x_{cross} = \frac{2h\cos\theta_2^1\, v_2}{(v_2 - v_1)} = 2h\sqrt{\frac{v_2 + v_1}{v_2 - v_1}}$$

and this formula can also be used to determine the thickness of the top layer.