Geol 335.3

Lab 3 – Interpretation of refraction seismic data using the PLUS-MINUS method

The data for this lab represents a shallow seismic investigation for groundwater exploration. The problem is to find the deepest point of a buried valley that might contain a gravel aquifer. 24 geophones were placed at 12m intervals in a fixed spread. Four shots were fired at locations along the spread. Each shot was fired at the depth of 1m.

You may use Matlab or Excel, or do all plotting and calculations by hand.

Distance (m)	Elevation (m)	Shot A	Shot b	Shot C	Shot D
0	101.0	Shot position	.068	.144	.196
12	101.0	.015	.059	.135	.187
24	100.9	.024	.051	.127	.179
36	100.9	.033	.042	.118	.170
48	100.9	.042	.034	.110	.162
60	100.8	.050	.025	.102	.153
72	100.7	.059	.015	.093	.145
84	100.6	.068	Shot position	.085	.136
96	100.4	.077	.015	.076	.128
108	100.2	.086	.026	.068	.120
120	100.2	.095	.035	.060	.112
132	100.5	.104	.045	.052	.104
144	101.2	.114	.054	.045	.097
156	102.0	.124	.064	.030	.090
168	102.5	.134	.074	.015	.083
180	103.0	.144	.085	Shot position	.075
192	103.3	.154	.095	.015	.068
204	103.6	.163	.104	.030	.062
216	103.9	.168	.109	.045	.053
228	104.2	.173	.114	.053	.044
240	104.5	.179	.119	.058	.035
252	104.7	.184	.124	.063	.026
264	104.8	.190	.130	.069	.015
276	105.0	.196	.137	.076	Shot position

This table is also provided in Excel format from which you can extract columns for loading into Matlab (or even process it in Excel? This is possible but not encouraged.)

1) [10%] On the same sheet of paper, plot the refraction time/distance graphs and the surface elevations.

2) [5%] Compare the near-offset (direct wave) moveouts from all four shots. Estimate V_1 from shot C. Note that in other shots, the direct-wave branches are poorly sampled by geophones. What does this mean in terms of the thickness of the first layer?

3) [5%] Identify the head wave travel-time segments that you will use in the plus-minus inversion. Note the change in the moveouts from shots A and B near x = 200–220 m. Consider two ways to interpret these changes: (i) as caused by a change in refractor dip (in which direction?), and (ii) as an emergence of another, deeper refractor. For the moment, stay with option (i).

4) [25%] Calculate the MINUS times for all pairs of reversed head wave segments:

$$t_{MINUS} = T_{\mathrm{ax}} - T_{\mathrm{bx}}.$$

   T_{ax} is the time from shot A to receiver x. Use only the head wave segments that have opposite slopes on the time/distance graphs. Plot the MINUS times vs. offset for ALL shot pairs on the same graph and interpret the refractor velocity (V_2). The slope of the MINUS graph is $2/V_2$. Where does the change in velocity occur on the profile?

5) [25%] Calculate the PLUS times for all pairs of shots. Use only the head wave segments that have opposite slopes:

$$t_{PLUS} = 0.5(T_{\mathrm{ax}} + T_{\mathrm{bx}} - T_{\mathrm{ab}}).$$

   The PLUS theory is valid for shots on the surface. If the shots are buried, travel times are smaller than they would be if the shot were on the surface, so a correction should be made. The correction is the DELAY time associated with the shot depth. Therefore, the delay time associated with the shot depth (D_{ad}, D_{bd}, D_{cd}, D_{dd}) should be added to all times. In this exercise, we will use 1ms for all shot delay times since all shot depths are 1m and all picks are rounded to the nearest millisecond:

$$t_{PLUS} = 0.5(T_{\mathrm{ax}} + T_{\mathrm{bx}} - T_{\mathrm{ab}} + 0.001\ \mathrm{s})$$

6) [15%] Determine the depth below the shot points to the first interface using the following equation:

$$t_{PLUS} = 2T_{delay} = \frac{2Z_1 \cos\vartheta}{V_1},$$

   where Z_1 is the depth to the first interface, V_1 is the first layer velocity at offset x, and ϑ is obtained through the Snell's law. Plot your depth estimates on your elevation plot.

7) [10%] Now return to the uncertainty of the change refractor slopes in question 3). How would the model change if we now assume that the travel-time branches at x > 200-220 m from shots A and B come from a deeper refractor? Can you offer further arguments in favor or against such a model?

8) [5%] Rounding the times to 1ms implies a time error of $\delta t \approx 0.5$ ms. How large depth error does this amount to? For a comparison, how much depth uncertainty would be caused by a 0.5-ms normal-incidence reflection time error?

Turn in:

Plots and write-ups in a zipped directory.