ERTH3020 Practical 7:

Slope-Intercept Interpretation of Seismic Refraction

Overview and Purpose

This practical provides an introduction to the interpretation of shallow refraction data, using the *slope-intercept* approach. The real data were recorded during a demonstration on the the 2011 Kilkivan field trip. The results of this practical will be incorporated into your field report. Note that the earth model obtained from the seismic analysis may also assist in reducing the non-uniqueness of the nearby resistivity inversions.

A single demonstration line of length 120m was recorded running parallel to, and approximately 30m south of, the R2 resistivity sounding (see Prac 6 for coordinates of R2). The interpretation process will be interactively demonstrated in class. The approach is summarised below.

1. Background Theory

The *slope-intercept* technique can be easily understood with reference to the classic two-layer refraction time vs distance equations. The direct wave obeys:

$$t_d = \frac{x}{v_1}$$

Note that this is a straight line, slope $1/v_1$ and passing through the origin (zero intercept). The refracted wave obeys:

$$t_r = \frac{x}{v_2} + \frac{2Z \cos i_c}{v_1}$$

This is also a straight line, with a slope $1/v_2$ and intercept $2Z \cos i_c/v_1$. These expressions provide all the tools we need. We will also use a few simple extensions:

- When there are more than two layers, each layer produces an extra line segment.
- The velocity of any layer (v_i) is derived as the reciprocal of slope.
- The thickness (Z_i) of any layer is derived from the intercept.
- When an interface is not planar, the t vs x plot deviates from a straight-line segment.
- When an interface is dipping, a different slope is observed in the up-dip and down-dip directions.

2. Familiarisation with Spread and shot Geometry

The following summarises the recording system, and the geometry assigned in the field:

- 24-channel OYO 1600 refraction seismic system.
- Geophone interval 5m
- Channel 13 on nominal Origin (near recording system(.
- Channel 1 on -60m (towards SE)
- Channel 24 on +55m (towards NW)
- Shots 1-5 at coordinates (-62.5, -32.5, -2.5, 27.5, 57.5m)

3. Familiarisation with Time vs Distance Plots

The arrival time of the first seismic wave at each geophone has been picked and plotted. A convenient presentation for this initial interpretation is to show the arrival times at geophones on either side of each shot point.

Note that the end shots (1 and 5) only have geophones on one side of the shotpoint. Other shots have geophones on both sides.

By examining each plot we can estimate layer parameters in the vicinity of a particular shot. By combining all the observations, we have a means of commenting on lateral changes. The following sections outline the interpretation procedure to be applied at each shotpoint

4. Identification of Number of Layers

Plane-layer refraction theory suggests that on a time vs distance plot, each layer is represented by a different line segment.

For the picks on either side of the shot, fit straight line segments through the points. Note that:

- The number of segments identified is the number of layers.
- If the interface is irregular, the points will not fall exactly on a straight line.
- The direct-wave segment should go through the origin (i.e. the depth to this layer is zero).
- The direct-wave segment should have same slope on forward and reverse picks (because it is not affected by dip of deeper interfaces)

- For the refraction segments, the intercept should be the same for *forward* and *reverse* directions (controlled by the depth to the refracting interface at the shot-point).
- For the refraction segments, the slope can be different for forward and reverse directions (affected by dip on the refracting interface).

5. Estimation of Layer Velocities

The slope of each line segment provides an indication of the seismic velocity in the corresponding layer.

- Estimate the near-surface velocity by calculating the reciprocal of slope for the direct-wave segment. This should be similar for the forward and reverse segments.
- For each of the refracted segments, calculate the reciprocal of slope for the forward and reverse segments. If these are the same, horizontal layering is indicated. Otherwise, the up-dip ray will exhibit a higher *apparent velocity* than the true layer velocity, and the down-dip ray will exhibit a lower *apparent velocity*.
- A reasonable estimate of the true velocity in a layer is the average of the forward and reverse estimates.
- Note that once layer velocities have been estimated, we can calculate the critical angle (i_c) for any interface using (v_{i-1}/v_i).

6. Estimation of Layer Thicknesses

- The thickness of each layer is deduced by measuring intercepts.
- For example, the thickness of Layer 1 (Z_1) is obtained from the intercept of the second segment (T_2) as follows

$$Z_1 = \frac{T_2}{2}\frac{v_1}{\cos i_c}$$

  where i_c is the critical angle for the ray hitting Interface 2.

- For deeper layers, we use differences between interceps. For example, the thickness of Layer 2 (Z_2) is obtained from the intercepts of the second and third segments (T_2, T_3) as follows

$$Z_2 = \frac{T_3 - T_2}{2}\frac{v_2}{\cos i_c}$$

  where i_c is the critical angle for the ray hitting Interface 3.

8. Geological Interpretation

By considering the interpretations at each shotpoint, provide a concise description of the preferred geophysical model for for this location. If possible sketch a simple section indicating layer thicknesses and seismic velocities.

Provide a concise geological interpretation of your geophysical model.

Examine whether the seismic model (in particular layer thicknesses) can help to reduce non-uniqueness in the Kilkivan resistivity inversion.