Geol 335.3
Lab 2 – Interpretation of Seismic Data

The purpose of this exercise is to identify events and provide an interpretation of seismic shot records. You were given two plots of the same seismic reflection record from one shot: unscaled and with exponential scaling applied to compensate the geometrical spreading. Also, a plot of band-pass filtered records with 200-ms Automatic Gain Control (AGC) is provided. The data set was acquired using a symmetric split-spread geometry. The offset is in meters, and the trace spacings are 20m.

Note that display is the key component of seismic processing – even with a simple change in scaling, the records reveal different aspects of the data.

In the following, indicate all the events using colored pencils or highlighters.

1. [5%] Determine near which channel shot 163 was fired. Mark the shot location with a flag on the top margin of the plot.
2. [10%] Identify all linear events:
    a. Refractions; note any changes in moveouts;
    b. Ground roll
3. [5%] Locate the cross-over points if they exist (the distances where one refractions overtakes other refractions or direct wave).
4. [10%] Pick the first breaks from the plots. Plot them on a *T-X* diagram (time vs. offset plot). Use Matlab for plotting.
5. [10%] Calculate the apparent velocity of each linear event, including the ground roll. The apparent velocity equals 1/(slope on the *T-X* diagram).
6. [5%] Identify two reflection hyperbolas.
7. [10%] Pick the arrival times of these reflections and compute their stacking velocities using the $X^2 – T^2$ analysis (for explanations of the method, see below). (Use Matlab)
8. [40%] Determine the velocity model. Comment on the agreement between refraction and reflection travel-time data.
9. [5%] What is the frequency of the noisy trace on channel 96? What is this noise most likely caused by?
10. **Bonus 5%**: Comment on the dispersive character of the ground roll. Dispersion describes the type of wave propagation in which the wavelet is continuously changing its shape. For a dispersive wave, its different frequency components propagate at different velocities. These velocities are called *phase velocities*. By contrast, *group velocity* is the velocity of propagation of the wave energy packet. For a dispersive wave, group and phase velocities should differ. Try and identify the group and phase velocities of the ground roll in the plots; are they different?

Theory:

For a two-layer problem (a layer of thickness Z_1 and velocity V_1 overlying a medium of velocity V_2):

Travel-time equation of a direct Wave is: $t = \frac{x}{V_1}$.

The direct wave thus allows estimation of V_1.

First refraction (headwave) travel-time: $t = \frac{2Z_1\sqrt{V_2^2 - V_1^2}}{V_1 V_2} + \frac{x}{V_2}$.

For two layers, in the **X-T method** (see Box 5.3 in the text by Reynolds), from measuring the slope of the refraction in the (X,T), your determine V_2. Further, by extrapolating the refraction travel-time line to zero offset, you will measure thee zero-offset *intercept time,*

$t(0) = \frac{2Z_1\sqrt{V_2^2 - V_1^2}}{V_1 V_2}$, and from it, determine Z_1.

The intercept time $t(0)$ above can be found from the **cross-over distance** x_c. Cross-over occurs at a point where the head wave time equals that of the direct wave:

$$t(0) + \frac{x_c}{V_2} = \frac{x_c}{V_1},$$

and so:

$$t(0) = x_c\left(\frac{1}{V_1} - \frac{1}{V_2}\right).$$

To invert for refractor depths in a multi-layer case, you can use equations from Boxes 5.4 and 5.5 in Reynolds. However, a more elegant approach was discussed in the lectures. For example, to find the depth to the second refractor (of velocity V_3), first determine the *ray parameter* for the head wave propagating along that refractor:

$$p = \frac{1}{V_3}.$$

From p, you can determine the ray angles θ_i in each of the overlaying layers #i:

$$\sin\theta_i = pV_i.$$

Each of the corresponding ray segments contributes a term called "delay time" (δt_i) to the total intercept time $t(0)$. The delay time is the difference of the actual travel time with the travel time that would be recorded if both the source and receiver were located at the refractor:

$$\delta t_i = 2\left(\frac{Z_i}{V_i\cos\theta_i} - pZ_i\tan\theta_i\right) = \frac{2Z_i}{V_i\cos\theta_i}(1 - pV_i\sin\theta_i) = \frac{2Z_i}{V_i}\cos\theta_i \qquad (**)$$

and the total intercept time is simply a sum of the delay times from the top of the model to the layer in question:

$$t(0) = \delta t_1 + \delta t_2 + ... = \frac{2Z_1}{V_1}\cos\theta_1 + \frac{2Z_2}{V_2}\cos\theta_2 + \ldots$$

Thus, to obtain the thickness of the second layer Z_2, you need:

1) Determine the value of $p = \frac{1}{V_3}$ for the headwave refracting along the bottom of that layer;
2) Determine the angles θ in both layers;
3) Determine the intercept time $t(0)$ of the headwave from the record (from cross-over distance and V_3);
4) Determine the delay time $\delta t1$ in the first layer;
5) Subtract δt_1 from $t(0)$, this gives you the δt_2;
6) From δt_2, determine the thickness from eq. (**) above: $Z_2 = \delta t_2 \frac{V_2}{2\cos\theta_2}$

Note that problems with > 3 layers can be solved in exactly the same way by applying steps 5) and 6) while moving downward within the model.

The *X*²-*T*² method utilizes the hyperbolic shape of a reflection in (*X*,*T*) plane in order to estimate the optimum ("stacking") velocity. Travel time of the reflection recorded at offset *x* from the source is (from Pythagorean theorem):

$$t = \frac{2}{V_1}\sqrt{Z_1^2 + \left(\frac{x}{2}\right)^2}\ .$$

This equation describes a hyperbola $t(x)$. If we consider t^2 as a function of x^2 instead, the relation becomes:

$$t^2 = \frac{4Z_1^2}{V_1^2} + \frac{x^2}{V_1^2}$$

which is an equation of a straight line in (x^2,t^2) plane. From the slope of this line, you can determine V_1, and from its zero-offset intercept value, $\frac{4Z_1^2}{V_1^2}$, determine Z_1.

Hand in:

Annotated plots and write-up in a binder.