Geol 335.3

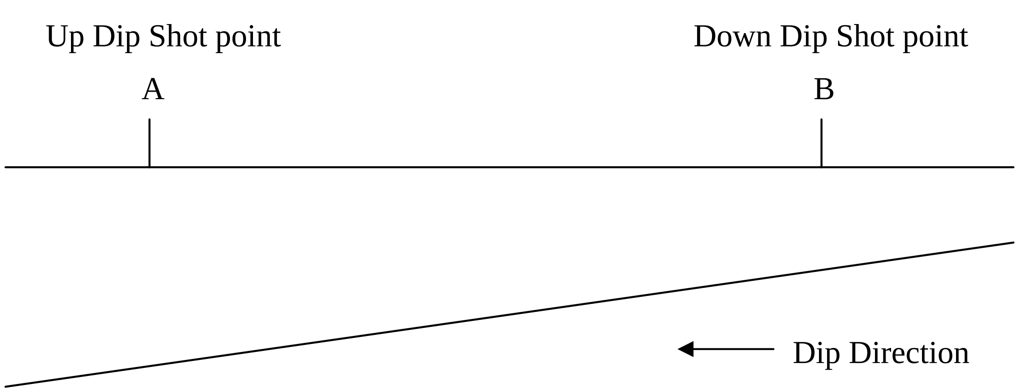
Lab #1 – Geometrical Seismics and Huygens' Principle

Part II: Inverse problem - Locating Refracting Interfaces

It is possible to use wave front method to determine the depth and position of the equal-time contact zone between two layers, if some field data is provided: Consider the following travel-time data, given in terms of *apparent velocities* and cross-over distances.

Up Dip Profile	Down Dip Profile
$V_1 = 1800$ m/s	$V_1 = 1800$ m/s
$V_{2u} = 3400$ m/s	$V_{2d} = 2700$ m/s
$X_{12u} = 820$ m	$X_{12d} = 210.6$ m

Here, X_{12u} and X_{12d} are the crossover distances from the up-dip and down-dip shot points, and $V_{2u,d}$ are the corresponding apparent velocities When the interface is dipping, the shot points are referred to as follows:



Shot point spacing AB=2300m.

Question 1: Before we proceed, how do we know that the interface is dipping to the left?

1. Calculate the *intercept times* for each of the two headwaves.

2. Using scale of 1 cm = 150 m = 0.1 s, draw a plot of the travel-times. Use 2500 m for the length of your horizontal axis and 1 s for the time axis. Label the shot points and crossover distances. On the time axes for each of the shots, indicate and label the intercept times. Indicate and label the reciprocal times.
3. Using the same spatial scale, prepare **two copies** of (X,Z) plot area for your depth models.

You will use two complementary methods to identify the position of the refracting interface.

<u>Method 1: Using the contact surfaces</u>

The critical incidence angle, α, and the dip angle, θ, of the dipping refracting horizon can be found as follows:

$$\alpha = \frac{1}{2}\left(\sin^{-1}\frac{V_1}{V_{2d}} + \sin^{-1}\frac{V_1}{V_{2u}} \right)$$

$$\theta = \frac{1}{2}\left(\sin^{-1}\frac{V_1}{V_{2d}} - \sin^{-1}\frac{V_1}{V_{2u}} \right)$$

To locate the refracting interface of a dipping bed, the process used in the first part of this lab is reversed:

4. Draw concentric circles about the two shot points. The spacing (ΔS_1) must be such that one circle from each shot point passes directly through that shot points crossover distance point.
5. Draw the head waves in. This is done by laying off an angle of ($\alpha - \theta$) from the horizontal through the up-dip crossover point distance. An angle of ($\alpha + \theta$) is used for the down dip cross over point distance. Parallel lines with perpendicular spacing of ΔS_1 are drawn in parallel to these two initial lines.

Question 2: What is the spacing between the head wave fronts?

Question 3: What are the spacings between the intersections of the head wave fronts with the surface?

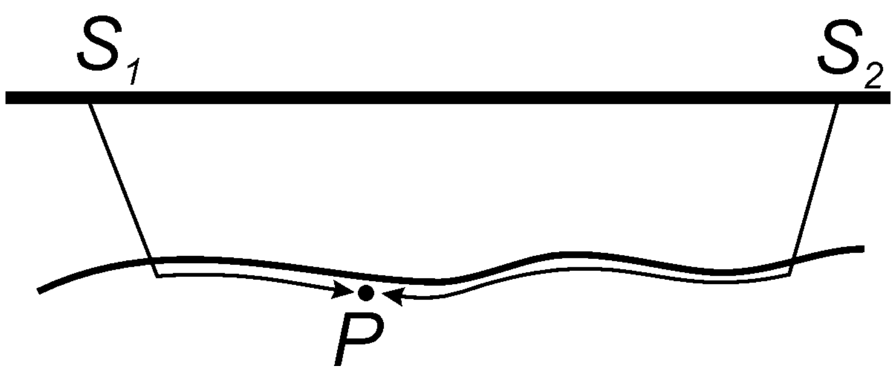
6. As in part I of this Lab, the points of the intersection of the corresponding head waves form an equal time contact line. Draw and label them CS^1 and CS^2 for the first and second shot point, respectively.

7. Draw the refracting surface by joining the points of maximum depth on the up dip and down dip contact lines.

Method 2: Downward travel-time continuation

This method is used in what is called "refraction migration". A nice feature of this approach is its using the entire offset extents of the headwaves. Also, it can be used to map the refracted *waveforms* onto the interface, thereby providing additional information about the detailed properties of the interface.

The method employs the fact that for any point (*P* in Figure below) on a refracting interface, with *reversed* coverage (i.e., covered by two shots in opposite directions) the sum of travel times to each of the two shots is constant:



$$t_{S_1 \to P} + t_{S_2 \to P} = t_{S_1 \to S_2} = t_{S_{21} \to S_1} = T \quad ,$$

which is the ***reciprocal travel time*** corresponding to wave propagation from one source point to another. Note that this method works even for varying interface depth between the shot points.

To build the interface:

1. Calculate the reciprocal times, *T*, in both directions.

Question 4: Are these times equal?

2. Choose a time increment: $\Delta t = T/20$.
3. Build a system of head wave fronts for shot S_1. Start with a wave front passing through S_2 and progress backward toward the source. The wave fronts will intersect the surface at intervals equal $V_{2u}\Delta t$, and the distance between the wave fronts will be $V_1\Delta t$.
4. On the resulting mesh of travel time fronts, find nodes for which the combined time to both source points equals *T*. Connect these nodes. This is your interface.

Hand in:

1. Plots, including labels, as described above.
2. Write-up including all calculations and answers to all questions.