GG450

April, 2010

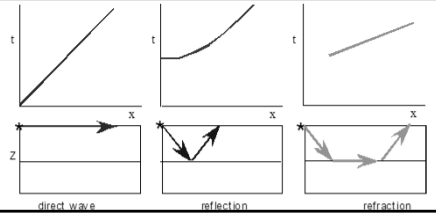
Seismic Refraction (cont.)

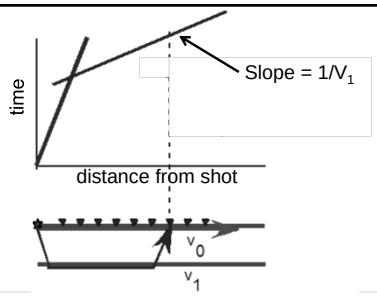
Today's material comes from p. 42-62 in the text book. Please read and understand all of this material!

Direct Wave: Travels at the p-wave velocity of the uppermost layer of the ground, directly to the receiver. Direct waves come in first close to the source, but often disappear at larger distances or are lost in earlier, faster arrivals. The direct wave arrival time is usually a straight line or curved slightly downward.

Reflections: Reflections arrive from sharp changes in velocity (actually impedance, ρv) below. When plotted on a x-t plot, the first reflection arrival time is asymptotic to the direct arrival. Reflections bend upwards on x-t plots.

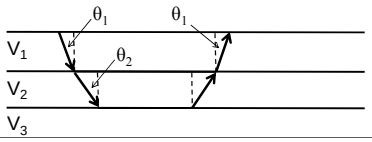
Refractions **(head waves)**: Refractions are arrivals from faster deeper layers that arrive first at larger distances. They are usually straight or bending slightly downwards with increasing distance on x-t plots. Refractions are often very small amplitude arrivals, but often easy to see because they come in first.





SLOWNESS: The slope of the arrival time vs distance curve = 1/velocity of the wave at its deepest point = *RAY PARAMETER*.

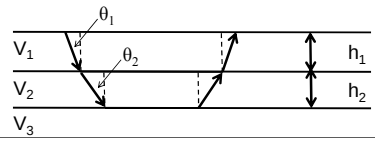
Refraction - 2 Flat Layers



The angle of incidence on the layer 1-2 boundary needed for the ray to be critically refracted at the layer 2-3 boundary is easily determined since the ray parameter is constant:

$$p = \frac{1}{V_1} = \frac{1}{V_2} = \frac{1}{V_3}, \quad \text{therefore:} \quad \frac{\sin\theta_1}{V_1} = \frac{1}{V_3}, \text{ and } \sin\theta_1 = \frac{V_1}{V_3}$$

Refraction - 2 Flat Layers



The SLOPE of the arrival refracted in layer i is equal to $1/V_i$ for that layer, and thus equals the ray parameter of the critical ray in that layer:

$$p = \frac{1}{V_3}, \quad \text{therefore:} \quad \frac{\sin\theta_1}{V_1} = \frac{1}{V_3}, \text{ and } \sin\theta_1 = \frac{V_1}{V_3}$$

The travel time from source to receiver for a refraction through a flat 2-layer model is:

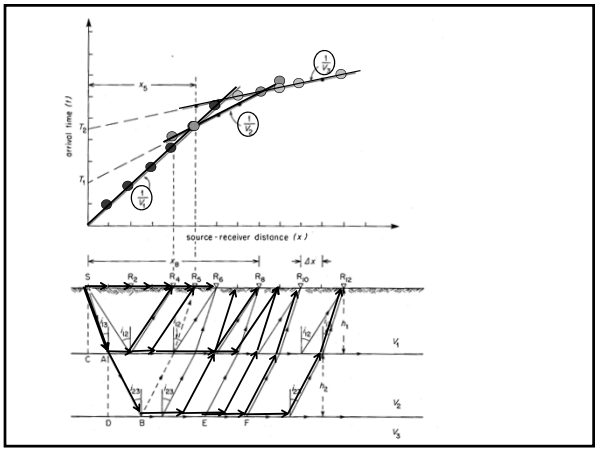
$$t_{rfr} = \frac{2h_1\sqrt{v_1^2 - v_0^2}}{v_0 v_1} + \frac{x}{v_1}$$

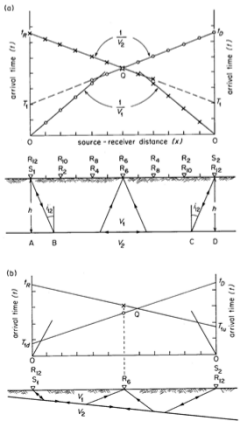
The t_{rfr} equation is much simpler than it looks, since x only appears in the 2nd term, it is a *straight line* with slope equal to the ray parameter and a y-intercept equal to the first term.

Since we can measure the y-intercept of the refraction (called the *intercept time*), and the two velocities can be measured from the slopes of the direct and refracted arrival, we can solve the above equation for h_1, and obtain the depth to the layer:

$$h_i = \frac{t_i}{2}\frac{v_0 v_1}{\left(v_1^2 - v_0^2\right)^{1/2}}$$

where t_i is the y intercept time of the refraction arrival.





Horizontal layers

Dipping layers

Refraction - dipping layers

Important points for dipping layers are:

1) The ray parameter no longer is a constant for any particular ray. A ray that is affected by a dipping layer will change direction based on a combination of its incident angle, the layer velocities, and the layer dips. When it reaches the surface again it will have a different ray parameter.

2) If shots are fired and recorded from BOTH ends of a refraction line, the forward refracted arrivals come in at <u>different times</u> than those from the reversed arrivals.

3) The equations that give the travel time for the refracted arrivals yield straight lines.

4) The SLOPE of the refracted arrivals from any dipping layer is NOT equal to 1/V for that layer. It depends on the dip. If dips are small, the AVERAGE slope between the forward and reverse lines is very close to the actual velocity.

5) The ONLY true **reciprocal path** for forward and reversed lines are the two end points. Since reciprocity must work, the travel time on the two ends of the forward and reverse lines must be the same if the shot and receiver are in the reciprocal locations.

6) Since nothing is changed for the direct arrival, the slope of the *direct* arrival for both the forward and reverse lines should be the same.

7) The dip observed on one refraction line is the APPARENT dip. We need to shoot two orthogonal lines to determine true dip. And, that assumes that the boundary between layers is a plane.

Note: THESE STATEMENTS ARE FOR A MODEL, NOT for reality. Never try to fit your data to the model, try to fit the model to the data. If it doesn't fit, do the best you can and state how you think the model might differ from reality. This requires GEOLOGICAL INSIGHT.