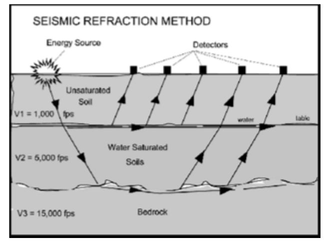
GG450 Lab

March 30, 2010

Seismic Refraction



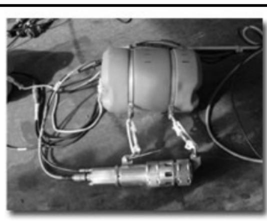
Seismic refraction uses a type of geometry with the source remaining at one spot and the receivers spaced at increasing distances from the source.

SEISMIC SOURCES

We need to put enough energy into the seismic waves to be sure we can see the necessary signals at our receivers.

- Explosives for land work
- Airguns for marine work

Explosives:
Can be made as large as desired but have somewhat unpredictable amplitudes, expensive, and dangerous. Permitting and drilling required.



Airguns fire a pulse of air into the water as a marine seismic source. A problem is that the bubble of air oscillates generating a complex “bubble pulse.” Many guns are used to kill the bubble pulse and add more energy.

Hammer

The hammer source is good for small-scale shallow studies.

SEISMIC INSTRUMENTS

What is a seismometer?

What is meant by "motion of the ground"?

What does a seismometer measure?

Displacement?
Velocity?
Acceleration?
Stress?
Strain?
Propagation velocity?

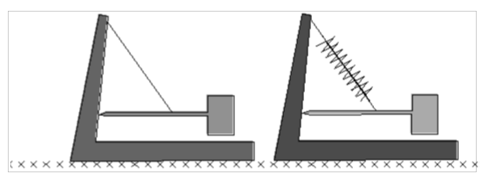
A *transducer* changes one type of energy into another [motors, generators, etc.]. In seismometers we change ground shaking into electrical signals.

There are several ways to do this. If we use a magnet surrounded by a coil of wire to generate an electric signal when the magnet and coil are moved with respect to each other, then the VELOCITY of the coil relative to the magnet gives us the signal.

Nearly all land seismic sensors used for exploration have velocity transducers.

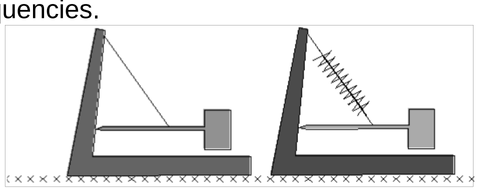
To measure the motion of the earth, we need to be able to measure the motion of some point connected to the earth RELATIVE to some point that is NOT moving with the earth.

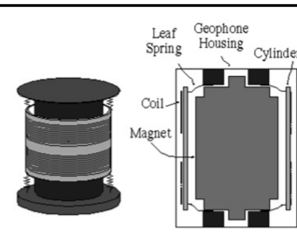
The simplest way we know of to do this is with mechanical oscillators, of which there are two basic types: masses attached to springs (used for detection of VERTICAL motion of the earth), and pendulums, used to measure HORIZONTAL motion of the earth.



While these two instruments look pretty much alike, one measures horizontal motion in-and-out-of the page, and one measures vertical motion.

The SIGNAL is the relative motion between the frame fixed to the earth and the mass. The frame moves with the ground at all frequencies.





This seismometer is called a GEOPHONE. The ground motion is detected by a coil of wire moving through a magnet attached to the frame generating a current. If the coil is not moving relative to the frame, no signal is generated. Geophones sense the VELOCITY of the ground at high frequency.

Seismic Arrivals

When you start a seismic wave at the earth's surface - as we will with the refraction system - several waves fan out in more-or-less spherical (waves that go through the earth) and cylindrical wave fronts.

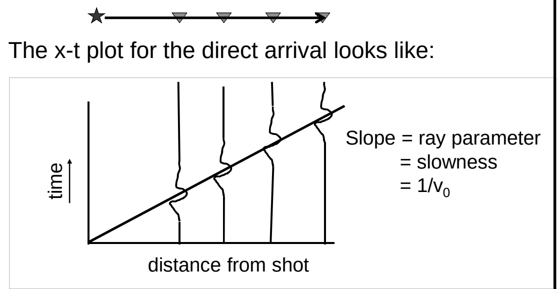
Air wave: travels through the air at about 330 m/s (1,083 ft/s), only seen close to the source (if at all). Velocity is constant, so a plot of arrival time of the air wave vs. distance from the source is a line with a slope of 0.92 ms/foot. This is a SLOW wave, usually mixed in with surface wave arrivals.

How far away is lightning?

Seismic Arrivals

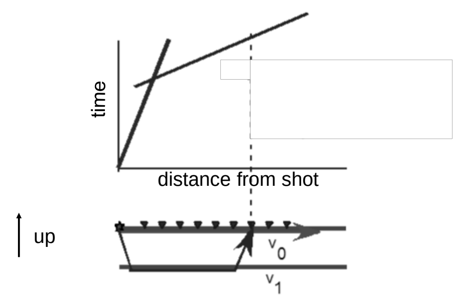
The *Direct Wave* travels straight from the seismic source to the seismometer.

The x-t plot for the direct arrival looks like:



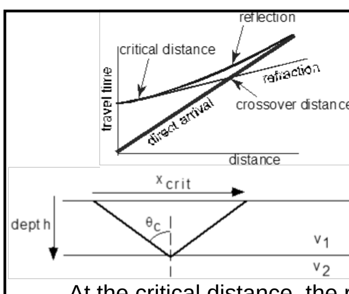
If we let velocity change with depth <u>in a flat model</u>, the x-t graph will no longer be a straight line, as the ray path between any two points will no longer be a straight line, in general.

If the earth is made up of constant-velocity layers, the x-t plot will be made up of a sequence of straight lines, one for each layer *IF* the velocity always increases with depth.



When we have a single horizontal interface separating two layers that have constant velocities, it's relatively simple to describe the resulting refracted arrival.

The ray that will arrive at the geophones along the *critical path* (horizontal in the lower layer) hitting the lower layer at the critical angle, thus:



The *critical distance* is the distance from the source to where the refraction can first be observed.

At the critical distance, the reflection from the layer and the refraction have the same travel time *AND* the ray parameter (slope) of both the reflection and the refraction are the same. The *cross-over distance* is the distance where the direct arrival and the refracted arrival come in at the same time.

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.

Evaluation of refraction data using these formulae, and their expansion to multiple layers, has been used extensively - so much that many people have been given the impression that the earth is made up of constant velocity layers! While the models often fit the data quite well, so do models with gradients and low velocity zones.

Great care must be taken to not over interpret model results!

Surface waves = Ground roll

Ground roll are Rayleigh waves traveling at the surface of the earth. They are usually the largest signals on a seismic record, but are considered NOISE in most studies, because they only yield information about shallow layers.

SLOWNESS: The <u>slope</u> of the arrival time vs distance curve – or *slowness* - is 1/velocity of the wave at its deepest point. *Slowness* is another name for the *Ray Parameter*.