

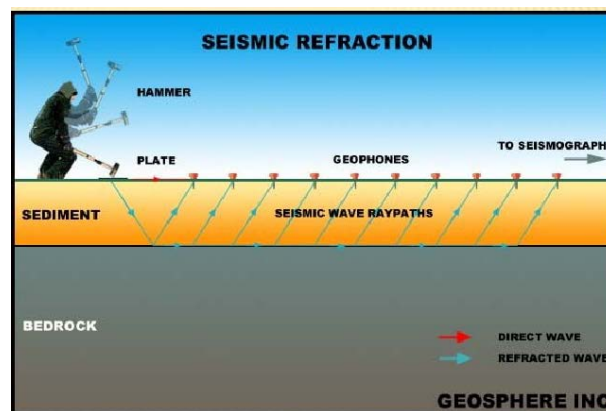
## 201 GPH

### Unit 2 (Review)

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#### **Q. What is seismic refraction?**

A. Seismic refraction is a geophysical principle governed by Snell's Law. The seismic refraction method utilizes the refraction of seismic waves on geologic layers and rock/soil units in order to characterize the subsurface geologic conditions and geologic structure.



#### **Q. Which exploration techniques are used in seismic refraction?**

A. Active Methods (Induced Sources): a signal is injected into the earth and then measure how the earth respond to the signal

#### **Q. What are the applications of seismic reflection?**

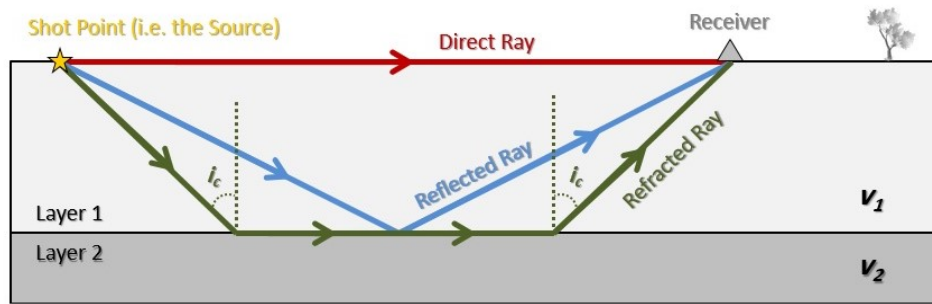
A. They are:

1. Depth to bedrock.
2. Groundwater exploration.
3. Crustal structure and tectonics.

#### **Q. What are the three main rays recorded when doing a seismic refraction survey?**

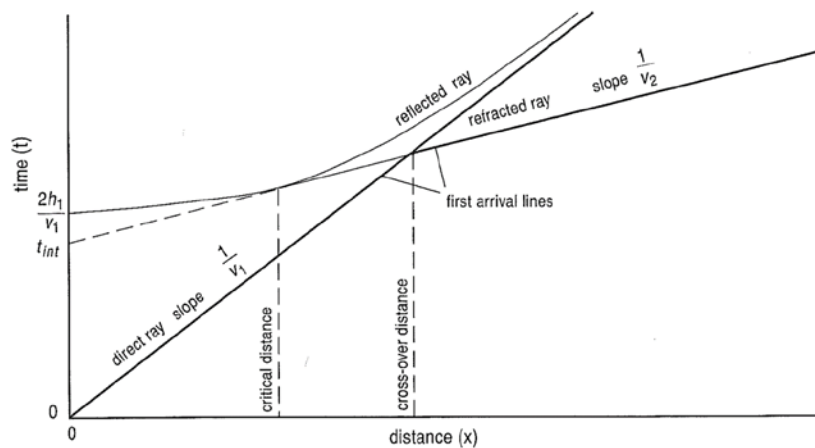
A. They are:

1. The direct ray.
2. The reflected ray.
3. The refracted ray.



### Q. What is time-distance (t-x) diagram?

A. Time-distance (t-x) diagram shows the relationship between the travel-time and distance of seismic energy propagating from the source to receivers.

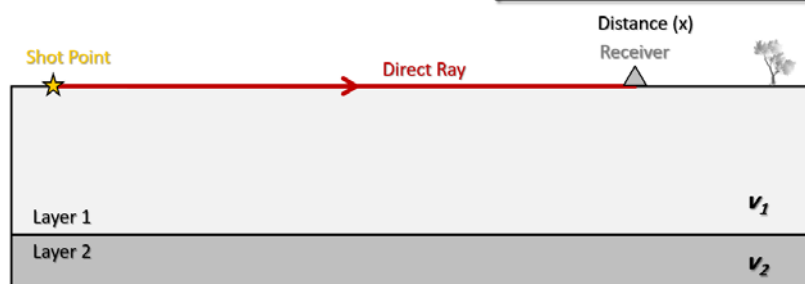
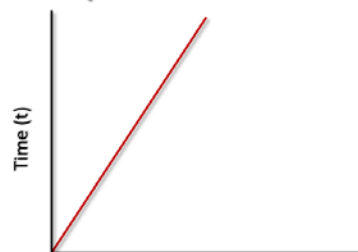


### Q. Plot the direct ray on (t-x) diagram?

#### The Direct Ray

- The Direct Ray Arrival Time:
  - Simply a linear function of the seismic velocity and the shot point to receiver distance

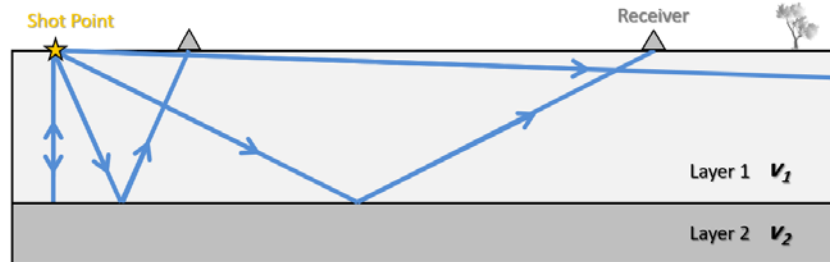
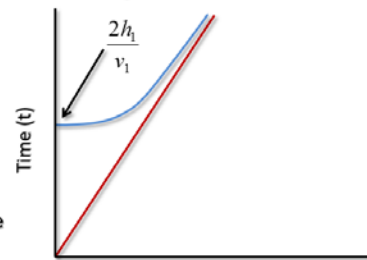
$$t_{direct} = \frac{x}{v_1}$$



## Q. Plot the reflected ray on (t-x) diagram?

### The Reflected Ray

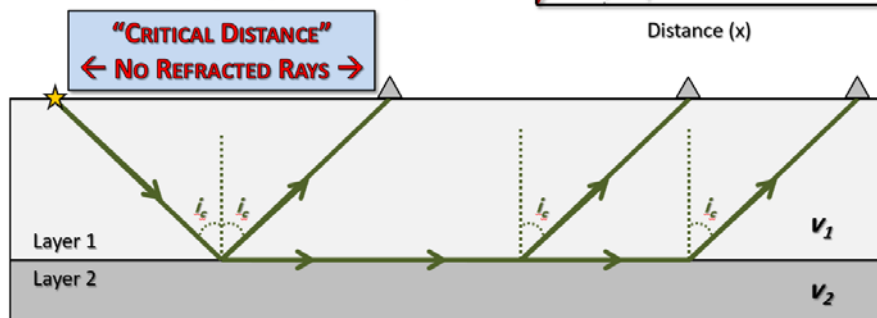
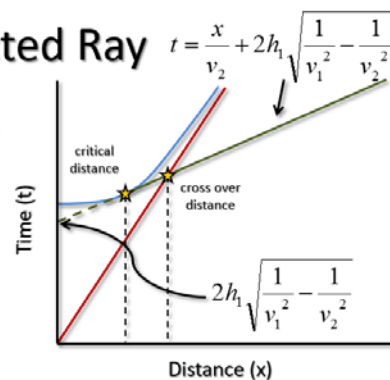
- The Reflected Ray Arrival Time:
  - is never a first arrival
  - Plots as a curved path on t-x diagram
  - Asymptotic with direct ray
  - Y-intercept (time) gives thickness
    - Why do we not use this to estimate layer thickness?



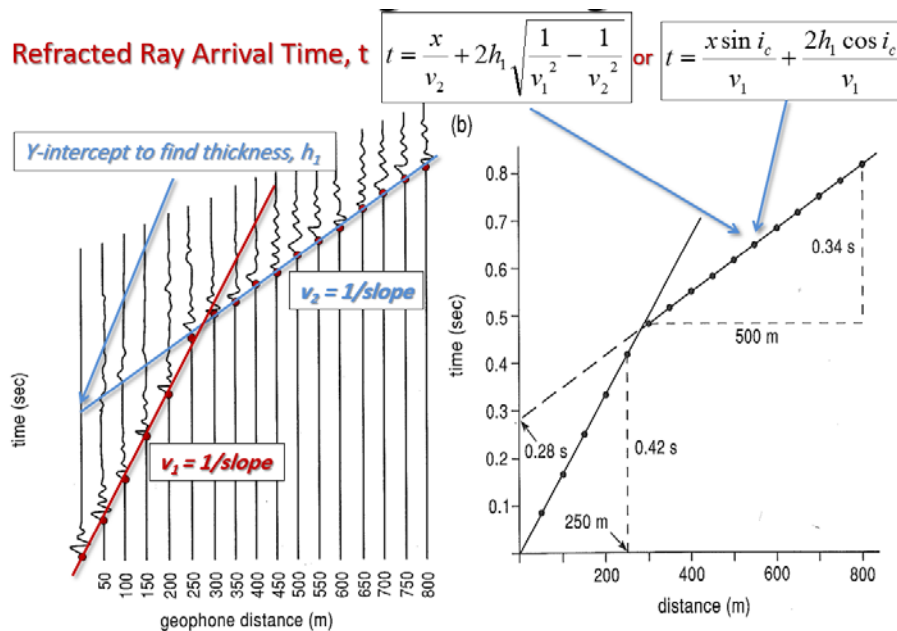
## Q. Plot the refracted ray on (t-x) diagram?

### The Refracted Ray

- The Refracted Ray Arrival Time:
  - Plots as a linear path on t-x diagram
    - Part travels in upper layer (constant)
    - Part travels in lower layer (function of x)
  - Only arrives after **critical distance**
  - Is first arrival only after **cross over distance**
    - Travels long enough in the faster layer



**Q. Write down the equation of the refracted ray arrival time?**



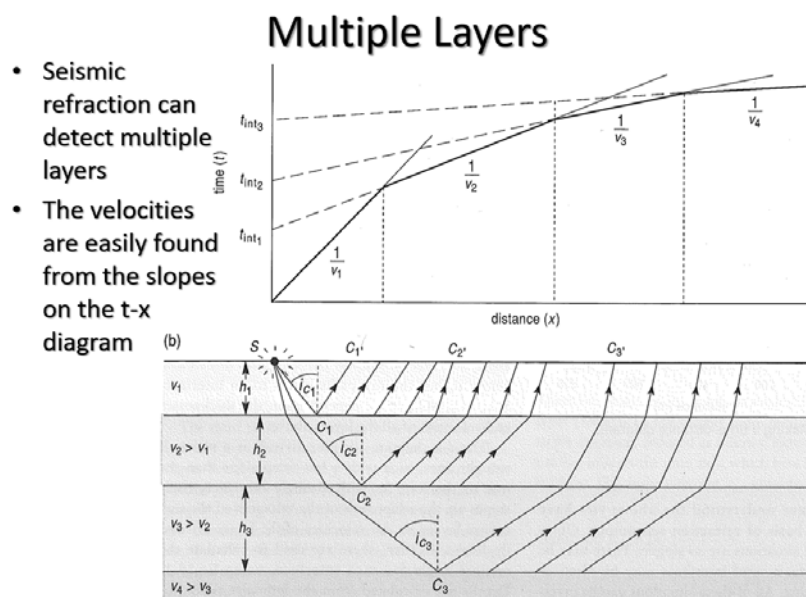
**Q. What does seismic refraction reveals?**

A. It reveal two main pieces of information, they are:

1. Velocity structure (used to infer rock type).
2. Depth to interface (lithology change and water table).

**Q. Can seismic refraction detect multiple layers?**

A. Yes, the velocities are easily found from the slopes on the t-x diagram.



## Q. What if the critically refracted interface is not horizontal? What to do?

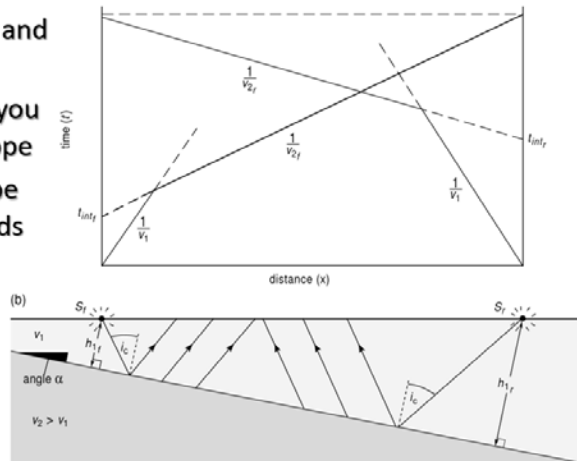
A. A dipping interface produces a pattern that looks just like a horizontal interface. Velocities are called “apparent velocities”.

### Dipping Interfaces

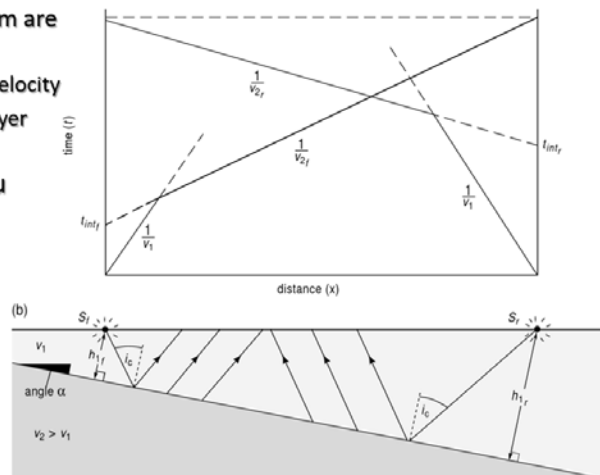
- To determine if interfaces are dipping...
- Shoot lines forward and reversed
- If dip is small ( $< 5^\circ$ ) you can take average slope
- The intercepts will be different at both ends
  - Implies different thickness



Beware: the calculated thicknesses will be perpendicular to the interface, not vertical

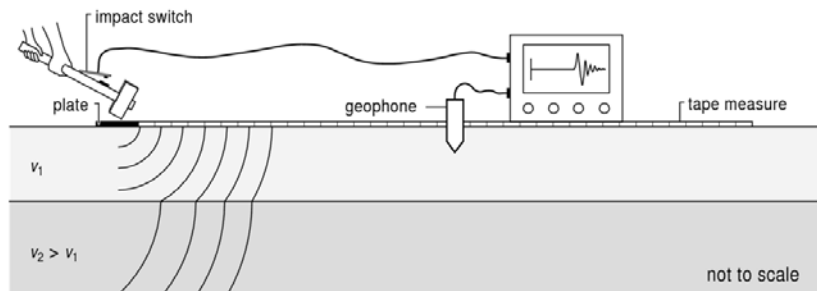


- If you shoot down-dip
  - Slopes on t-x diagram are too steep
    - Underestimates velocity
  - May underestimate layer thickness
- Converse is true if you shoot up-dip
- In both cases the calculated direct ray velocity is the same.
- The intercepts  $t_{int}$  will also be different at both ends of survey



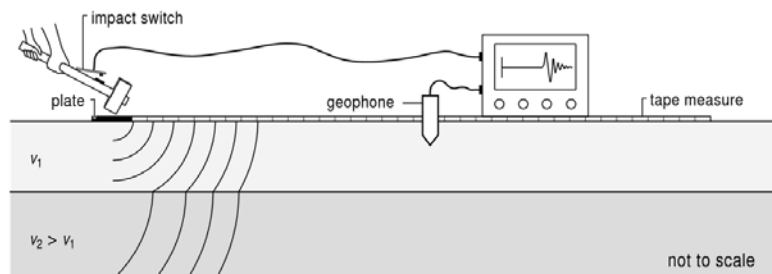
## Q. What is the simplest and cheapest type of survey?

- The simplest (and cheapest) type of survey is called a hammer seismic survey
  - A sledgehammer is whacked into a steel plate
  - Impact switch tells time=0
  - First arrivals are read digitally or inferred from seismogram
  - Because swinging a hammer is free, only one geophone is needed
    - More can be used, but single geophones must be along a linear transect

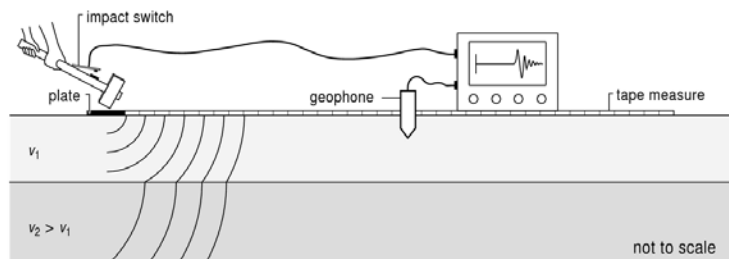


- The maximum workable distance depends on:

- The sensitivity of the system
- The strength of the sledgehammer whacks
- The amount of noise
  - Wind shakes trees, etc...
  - Cars, footsteps, HVAC, traffic, etc...
  - Surveys may be done at night to minimize noise



- Often the signal to noise ratio is very poor:
  - Stacking is often used to help delineate first arrivals
- General rule of thumb:
  - Geophone array should be about 10x the depth to interface
  - 100 meters is the typical upper limit on length of hammer seismic transect
    - So hammer seismics are best for shallow interfaces (< 10 m)

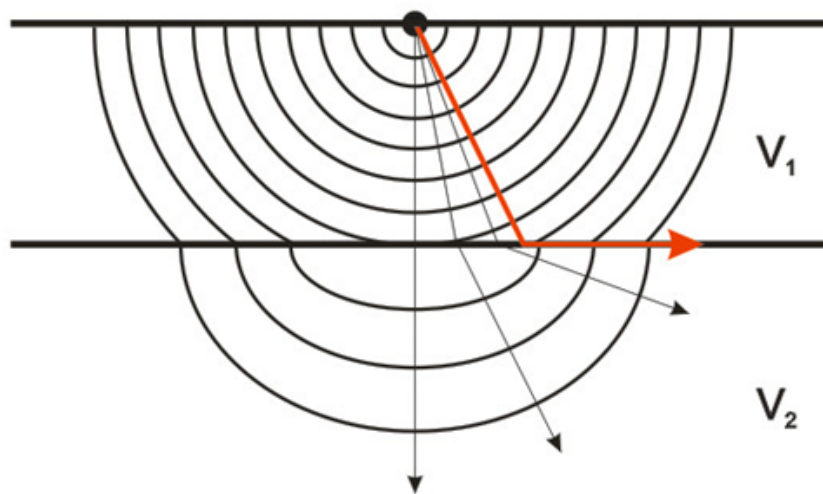


## Q. What are other survey types?

- Explosion seismics
  - Offers a much stronger signal
    - Can detect deeper features
    - Often involves water explosions (much cheaper)
    - Geophones / Seismometers are often linked wirelessly (RF / radio waves)
- Marine Surveys
  - Sometimes use explosives, compressed air, high voltage charges, or many other types.
  - Usually use hydrophones
    - Respond to pressure changes (p-waves)
    - Surveying is often done while the ship is moving, so very long transects can be done at a lower cost

## Q. What is critical refraction?

At Critical Angle of incidence  $i_c$ , angle of refraction  $r = 90^\circ$



**Q. Calculate the crossover distance from the below figure?**

The crossover distance ( $X_{cr}$ ) can be computed from the following equation:

$$X_{cr} = 2h \sqrt{\frac{V_2 + V_1}{V_2 - V_1}}$$

**where:**

$$h = 100 \text{ m}$$

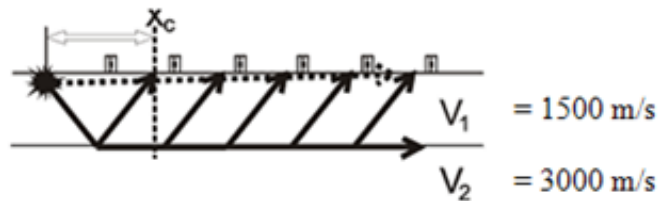
$$V_1 = 1500 \text{ m/s}$$

$$V_2 = 3000 \text{ m/s}$$

$$X_{cr} = 2(100) \sqrt{\frac{3000 + 1500}{3000 - 1500}}$$

$$X_{cr} = 200 \sqrt{\frac{4500}{1500}}$$

Therefore:  **$X_{cr} = 346.410$  meters**



**Q. Using Snell's law, calculate the reflected angle if  $V_1 = 4$  km/s,  $V_2 = 6$  km/s, and  $i = 30^\circ$ ?**

$$\frac{V_i}{\sin i} = \frac{V_r}{\sin r}$$

$$\frac{4}{\sin 30^\circ} = \frac{6}{\sin r}$$

$$r = \sin^{-1} \left( \frac{\sin 30^\circ (4)}{6} \right)$$

$$r \approx 49^\circ$$



**Q. An incident P-wave strikes an interface between two different rock types. The upper layer has a P-wave velocity of 1500 m/s, and the lower layer has a P-wave velocity of 3900 m/s. The incident angle is 19 degrees:**

**a. Calculate the angles of refraction for P-wave.**

**b. Calculate the angles of refraction for S-wave**

a. The angle of refraction for P-wave can be calculated from Snell's law:

$$\sin \theta_i / V_{p1} = \sin \theta_{\text{refr}} / V_{p2}$$

Where:

$$V_{p1} = 1500 \text{ m/s}, \quad V_{p2} = 3900 \text{ m/s}, \quad \text{and} \quad \theta_i = 19^\circ$$

$$\sin (19)/1500 = \sin \theta_{\text{refr}}/3900$$

$$0.325/1500 = \sin \theta_{\text{refr}}/3900$$

$$\theta_{\text{refr}} = \sin^{-1} (0.325) (3900)/1500$$

$$\theta_{\text{refr}} = 57.67^\circ$$

b. The angle of refraction for S-wave can be calculated from Snell's law:

$$\sin \theta_i / V_{p1} = \sin \theta_{\text{refr}} / V_{s2}$$

Where:

$$V_{p1} = 1500 \text{ m/s}$$

$$V_{s2} = V_{p2} / (1.732) = (3900) / (1.732) = 2251.73 \text{ m/s}, \quad \text{and} \quad \theta_i = 19^\circ$$

$$\sin (19)/1500 = \sin \theta_{\text{refr}}/2251.73$$

$$0.325/1500 = \sin \theta_{\text{refr}}/2251.73$$

$$\theta_{\text{refr}} = \sin^{-1} (0.325) (2251.73)/1500$$

$$\theta_{\text{refr}} = 29.20^\circ$$