C2.6 Resolution in seismic reflection surveys

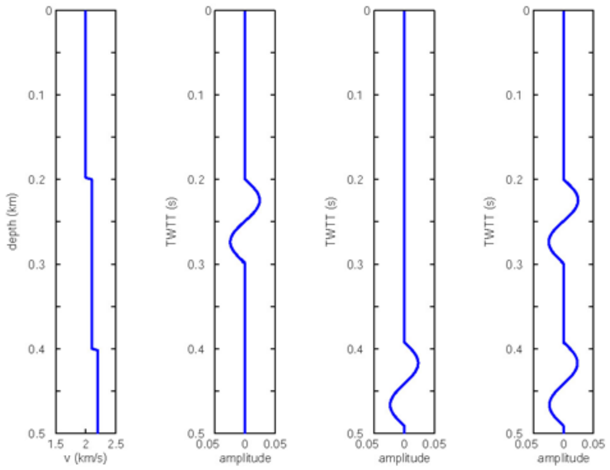
When interpreting geophysical data, it is very important to be aware of the **resolution** that is possible with the method being used.

C2.6.1 Vertical resolution

Consider the thin layer shown in the Figure C2.6 with the upper surface at a depth of 0.2 km. Seismic reflection data is collected at normal incidence. The reflections from the upper and lower surfaces were computed with MATLAB script **vert_resn_reflection.m**

t = 200 m

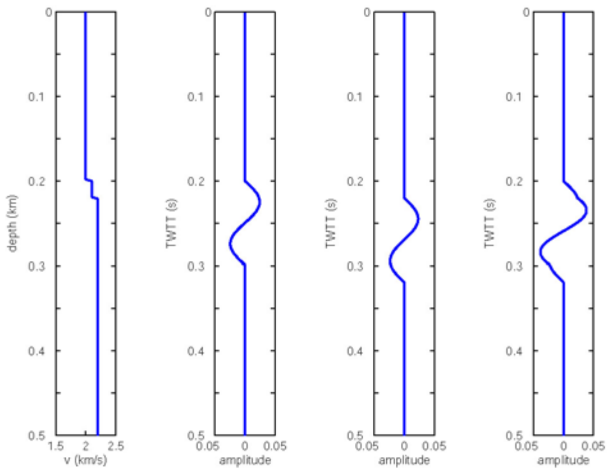
The seismic pulse has a wavelength, λ=200 m. When the layer is relatively thick, the two reflections are distinct in the combined seismic trace (right hand panel).



t = 20 m

When the layer is very thin (*t* = 20 m), the two reflections overlap and two separate reflections cannot be identified.

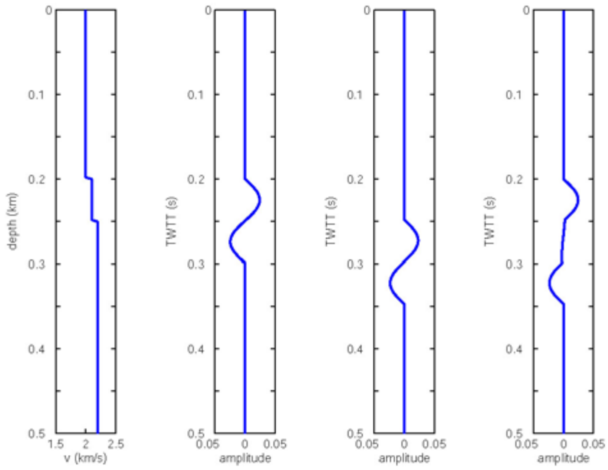
In this case, it is not possible to determine that two layers are present.



t = 50 m

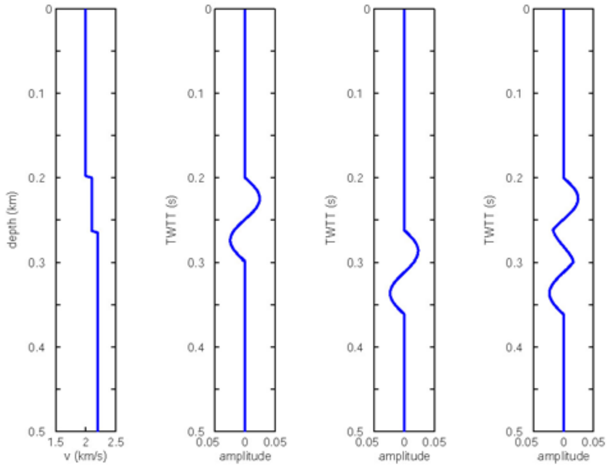
Note that the transition occurs when the crest of second arrival coincides with the trough of the first arrival.

This is produced by the second reflection travelling a distance *2t* greater than the first reflection.



t = 60 m

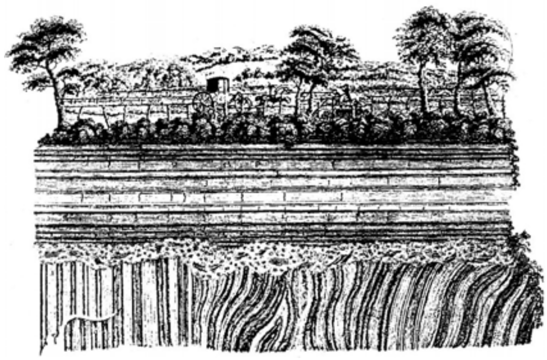
The second reflection can just be detected.



Two waves can be distinguished from each other if they are separated by distance $\lambda/2$. Now the reflection from the lower interface has travelled an additional distance of $2t$. Thus the best resolution occurs when $2t = \lambda/2$ which gives $t = \lambda/4$

Example: A 40 Hz seismic signal reflects from the top and bottom of a layer in a medium with v ~ 3000 m/s. What is the minimum layer thickness that could be detected?

How does this compare with features seen in an outcrop?

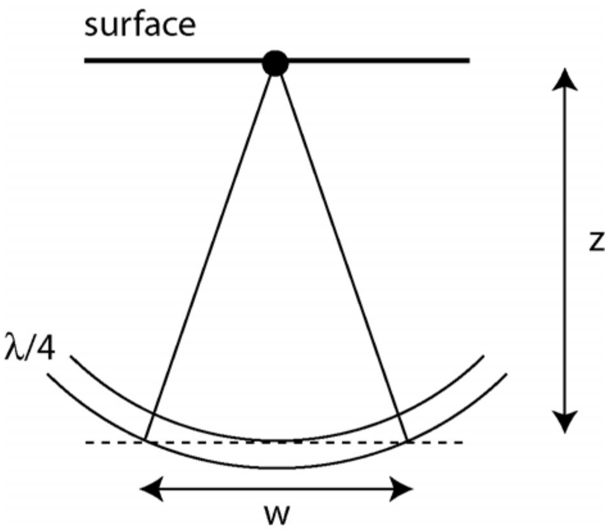


C2.6.2 Horizontal resolution

Two factors can limit horizontal resolution in a reflection survey. One is due to the physics of seismic wave propagation (Fresnel zones), and the other is due to the geophone spacing. The resolution will be which ever number is larger.

Fresnel zones

It is sometime tempting to imagine that a seismic reflection occurs only at the point where the ray hits an interface. However it is important to remember that a complte understanding of seismic wave propagation requires us to consider both **wavefronts** and **rays**.



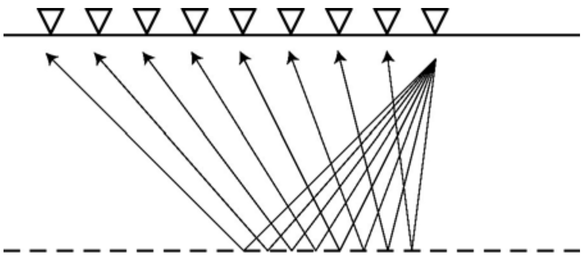
Consider seismic energy that strikes the interface at a distance from the point below the source (where normal reflection occurs). These signals are not predicted to return to the source by ray theory, but are expected according to Huyghens Principle. These arrivals will contribute to the seismic energy received at the source. However, they will travel a **greater distance** than the normal reflection. Following the logic of the previous section, these arrivals will be in phase with the normal reflection until their **round trip path length** is $\lambda/2$ greater than the normal reflection.

It can shown that the reflection essentially occurs from a circular disk, over which in phase reflections occur. This is called the **Fresnel zone** and has a width $w = \sqrt{2z\lambda}$

The width of this zone is the smallest feature that can be detected with the surface. Note again that higher resolution will be achieved by using short wavelengths. However this will result in more attenuation, and the signals will have limited penetration.

Example: A 40 Hz seismic signal reflects from the base of a 2000 m thick layer with v ~ 3000 m/s. What is the minimum size of horizontal feature that could be detected with this configuration?

Detector spacing



The reflection points on an interface will have a horizontal spacing equal to half the geophone/hydrophone spacing. By making this spacing **less than** the Fresnel zone, the survey resolution will not be limited by the layout, but by the physics of the wave propagation.