Lab #8. Spatial Resolution

In Lab #4, we utilized seismic modeling to understand different types of waves. Here, we will apply seismic modeling to understand spatial resolution.

Generally, two points are considered unresolvable when their two-way reflection times are separated by less than half of the dominant period of the signal (T):

$$\delta t < T/2. \quad (1)$$

In this lab, you will simulate two experiments and measure the effects of the wavelength on spatial resolution (Figure 1). In both experiments, the modeling area covers 1500 m horizontally. Collocated sources and receivers are distributed along the top of the model at 5-m intervals (stars in Figure 1). The time sampling interval is 1 ms.

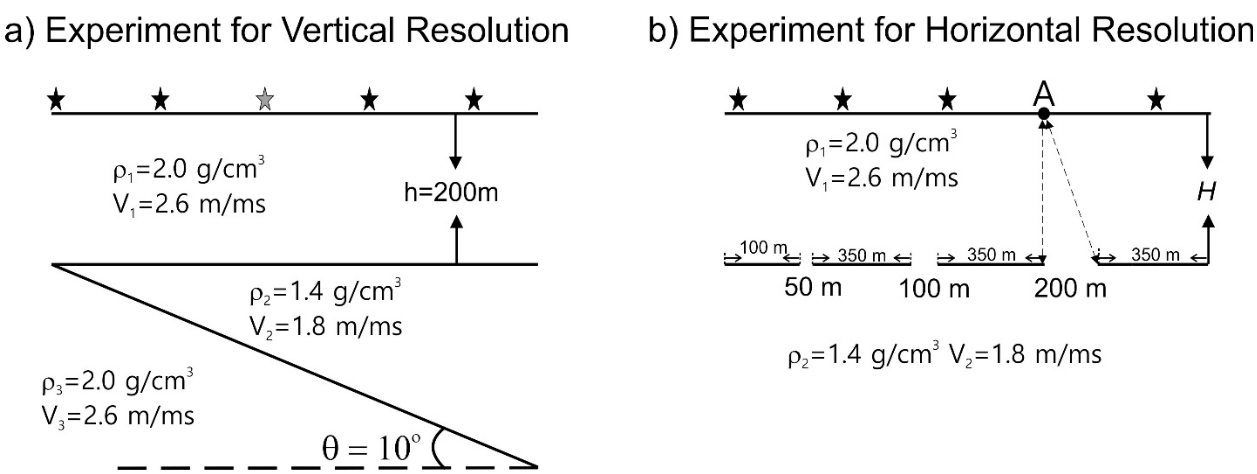

Figure 1. Experiments illustrating: a) vertical seismic resolution, and b) horizontal resolution.

a) Vertical Resolution

Vertical resolution is the ability to separate reflections in vertical direction. Generally, the vertical separation of resolvable reflections δz can be derived from (1) as

$$\delta z = \frac{\lambda}{4} \; , \quad (2)$$

where λ is the wavelength. To illustrate this relation between λ and δz, consider reflections from the top and bottom of the wedge structure shown in Figure 1a. Because of varying thickness of the wedge, its top and bottom are resolvable on the right and unresolvable on the left. Your task will be to identify the location separating these two zones (schematically shown by the grey star).

b) Horizontal resolution

Horizontal resolution measures the ability to separate reflecting points laterally. From the same criterion (1), the minimal horizontal separation between resolvable reflectors equals

$$\delta x = \sqrt{\frac{1}{2} H \lambda} \ , \qquad (3)$$

where H is the depth. The experiment for horizontal resolution is shown in Figure 1b. The depth H of the reflector will be 200 m, 700 m or 1400 m in order to investigate the effect of H. The widths of the gaps are as shown in Figure 1b. The reflectivity for these gaps are zero, which means no reflections will come from these gaps.

Note that for the sources and receivers located above an edge of the gap (for example, point A in Figure 1b), reflection from the other edge of the gap will be recorded as well. The gap will be considered unresolvable if the two reflections from the two sides of the gap look like a single reflection at point A.

Things to do

- **Experiment a)**

  1) Model the zero-offset reflections with a 30-Hz wavelet by using Matlab functions from lab #4. (15%)
  2) Identify the traces with a single peak or double peaks. Note that the reflection from the bottom (sloping) surface of the wedge have opposite polarities, and so the reflection from the top gives a positive peak, and reflection from the bottom is a negative-polarity peak. Identify the rightmost position where the two peaks still cannot be recognized. Measure the thickness of the wedge at this location. How does it relate to δz in formula (2)? (25%)

3) Try to model the reflection received from the identified rightmost position in step 2), but change the dominant frequency to 60 Hz for the input source wavelet. In this case, can those two peaks be distinguished? Why? (5%)

- **Experiment b)**

1) With *H* = 200 m, model zero-offset reflections by using a 30-Hz source wavelet. To achieve this, for each source/receiver on the surface, calculate the reflection travel times from the horizontal reflector beneath it and from the two nearest edges of the gaps. Place the resulting (two or three) times in an array and use the code from lab #4 to produce the reflection waveform at this source/receiver pair. (15%)
2) Compare the seismograms at the edges of each of the three gaps. Identify those where you can differentiate between the reflections from the two sides of the gap. (5%)
3) With *H* = 200 m, model zero-offset reflections by using wavelet with dominant frequency equals 10 Hz, 60 Hz. At which dominant frequency does the seismogram have a higher horizontal resolution? (15%)
4) Perform two more simulations with *H* = 700 m and 1400 m using the 30-Hz wavelet. Compare the obtained reflections. How does the horizontal resolution change with *H*? (20%)