Chapter 7: Reflection Seismology Homework Solutions (Jan. 2010)

1. **Why do marine seismic reflection surveys not record (a) S-waves? (b) refracted rays?**

   a) For ideal fluid, μ=0, thus, $v_s^2 = \frac{\mu}{\rho} = 0$

   b) Reflection offsets by definition are at offset less than the critical refraction distance

2. **How does a migrated reflection seismic section differ from an unmigrated one? In what circumstances would they be the same?**

   Migration is the spatial repositioning (migration) of seismic arrivals from the initial assumption that the arrivals come from flat and continuous layers. Migrations do three primary things: a) steepens dipping layers, b) collapses diffractions, c) moves reflectors to deeper levels.

   They would be the same if the layers (interfaces) are flat and continuous.

3. **How can a primary reflection be distinguished from a multiple one?**

   Multiple reflections have greater temporal moveout compared to primary reflections. Thus, multiples stack with a lower velocity.

4. **Will a migrated section correct for 'sideswipe'?**

   'Sideswipe' is due to 3-dimensional effects that 'contaminate' a 2-D migration. The only way to account for 'sideswipe' is to do a fully 3-D migration.

5. **Is the dip of a reflector in an unmigrated seismic section more or less than its actual dip? Explain with the aid of a sketch.**

   Unmigrated apparent dips are less than the true migrated dips. This is because the deeper reflection migration arcs have a radius of curvature that is larger than the shallower migration arcs and consequently have a larger depth correction.

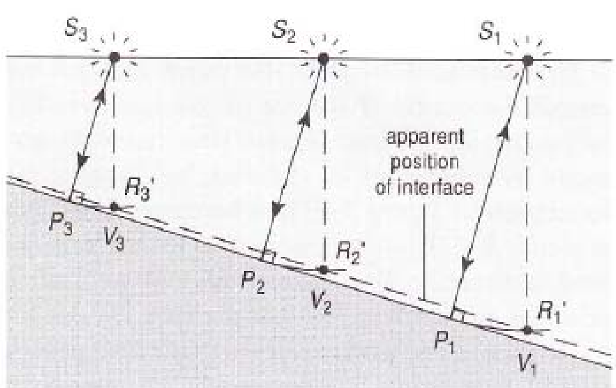


Figure 7.7 Displacement of a dipping reflector.

6. **What is the main way in which the Vibroseis system differs from other data acquisition systems? Name two advantages that it has over other methods of land surveying.**

   The source is a frequency sweep (chirp).
   Advantages:
   (a) Allows better matching of recorded data because the entire pulse can be correlated.
   (b) Required energy is lower which is beneficial for non-invasive surveys.
   (c) Trucks can be moved in and out without drilling.

7. **What are the main purposes of stacking?**

   Stacking is the seismic equivalent of 'averaging' numbers to improve one's estimate of the quantity. Stacking constructively adds together the signal, while the random noise tends to cancel, thereby increasing the signal to noise ratio.

8. **How can a reflection coefficient be negative? How can it be recognized?**

   The sign of the reflection coefficient depends on the seismic impedence difference between the lower layer (assuming downgoing wave) and the upper layer.

$$R = \frac{a_{reflected}}{a_{incident}} = \frac{\rho_2 v_2 - \rho_1 v_1}{\rho_2 v_2 + \rho_1 v_1}$$

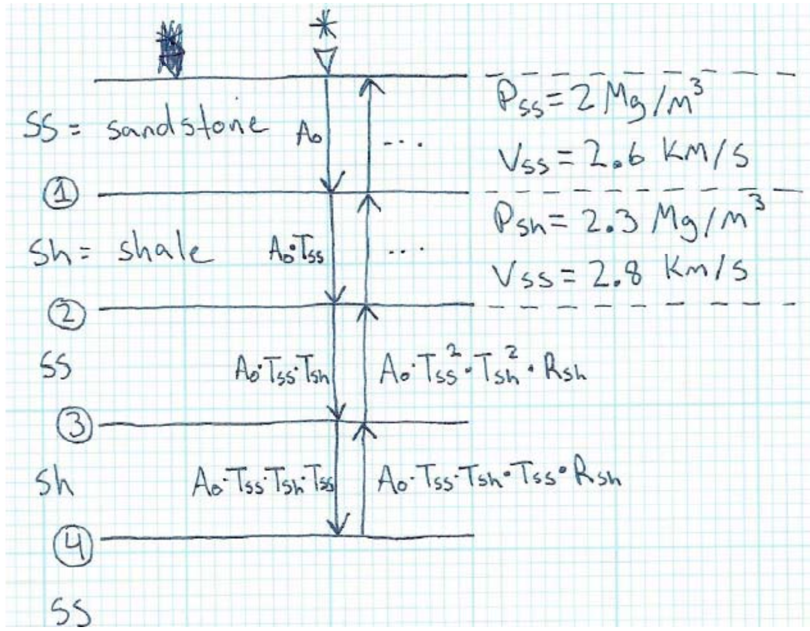
   Thus, if $Z_2 = \rho_2 v_2 > Z_1 = \rho_1 v_1$, then R>0. If $Z_2 = \rho_2 v_2 < Z_1 = \rho_1 v_1$, then R<0. The way that a negative reflection coefficient is manifested in a seismogram, is that the wave is inverted.

9. **How many synclines and anticlines appear in an unmigrated seismic section?**

   It depends on the individual seismic section! Would have to study a section to identify them. Anticlines appear spatially broader on an unmigrated section. The signature of a syncline depends on its depth relative to its curvature. If it is shallower than the radius of curvature, it tends to be narrower on the unmigrated section. If the reflector is deeper than the radius of curvature, it produces the 'bow tie' on the unmigrated section.

10. **A succession consists of alternating sandstones and shales, with the top layer being sandstone. Calculate how the amplitude diminishes for reflections from each of the top four interfaces (ignore spreading of the wavefront and absorption), if the densities and velocities are as follows: sandstone ρ=2Mg/m³, v=2.6 km/s; shale ρ=2.3 Mg/m³, v=2.8 km/s.**

$$R = \frac{\rho_2 v_2 - \rho_1 v_1}{\rho_2 v_2 + \rho_1 v_1} \qquad T = \frac{2\rho_1 v_1}{\rho_2 v_2 + \rho_1 v_1}$$



$$R = \frac{\rho_2 v_2 - \rho_1 v_1}{\rho_2 v_2 + \rho_1 v_1} \qquad T = \frac{2\rho_1 v_1}{\rho_2 v_2 + \rho_1 v_1}$$

R and T for ss 'over' sh

$$R_{ss,sh} = \frac{\rho_{sh} v_{sh} - \rho_{ss} v_{ss}}{\rho_{sh} v_{sh} + \rho_{ss} v_{ss}} = \frac{(2.3)(2.8)-(2.0)(2.6)}{(2.3)(2.8)+(2.0)(2.6)} = 0.106$$

$$T_{ss,sh} = \frac{2\rho_{ss} v_{ss}}{\rho_{sh} v_{sh} + \rho_{ss} v_{ss}} = \frac{(2)(2.0)(2.6)}{(2.3)(2.8)+(2.0)(2.6)} = 0.893$$

R and T for sh 'over' ss

$$R_{sh,ss} = \frac{\rho_{ss} v_{ss} - \rho_{sh} v_{sh}}{\rho_{sh} v_{sh} + \rho_{ss} v_{ss}} = \frac{(2.0)(2.6)-(2.3)(2.8)}{(2.3)(2.8)+(2.0)(2.6)} = -0.106$$

$$T_{sh,ss} = \frac{2\rho_{ss} v_{ss}}{\rho_{sh} v_{sh} + \rho_{ss} v_{ss}} = \frac{(2)(2.3)(2.8)}{(2.3)(2.8)+(2.0)(2.6)} = 1.106$$

Reflection coefficients (effective)

$$R_1 = R_{ss} = 0.106$$

$$R_2 = (T_{ss,sh})(R_{sh,ss})(T_{sh,ss}) = (0.893)(-0.106)(1.106) = -0.105$$

$$R_3 = (T_{ss,sh})(T_{sh,ss})(R_{ss,sh})(T_{ss,sh})(T_{sh,ss})$$
$$= (0.893)(1.106)(0.106)(0.893)(1.106) = 0.103$$

$$R_4 = (T_{ss,sh})(T_{sh,ss})(T_{ss,sh})(R_{sh,ss})(T_{sh,ss})(T_{ss,sh})(T_{sh,ss})$$
$$= (0.893)(1.106)(0.893)(-0.106)(1.106)(0.893)(1.106) = -0.102$$

11. **Seismic sections are not always what they appear. Explain how an apparent reflector may (a) have an incorrect slope, (b) may have an incorrect curvature, or (c) may not exist at all, while (d) three horizontal reflectors spaced equally one above the other may not be equqlly spaced, in reality?**

    (a) Unmigrated sections have lesser dips.
    (b) Synclines (concave up) and anticlines (concave down) will have their curvatures modified in unmigrated sections.
    (c) Multiple reflections can produce an apparent reflector
    (d) The scale on a seismic section is TWT, not distance. $TWT = \frac{2(thickness)}{velocity}$, hence, variations in the combination of thickness and velocity can make it appear that they are equally spaced, when in reality, they are only equally spaced in TWT.

12. **What determines vertical resolution? Why does less than the required resolution sometimes have to be accepted?**

    For all waves (elastic, electromagnetic, etc), the spatial resolution increases with higher frequencies that have smaller wavelengths ($\lambda = \frac{v}{f}$). A typical reflection survey has a frequency of 40 Hz and a velocity of 5 km/s, hence the wavelength of 125 meters, and a quarter wavelength of approximately 31.2 meters.
    Because higher frequencies have more attenuation (dissipated energy), they don't travel as far in depth. Thus, if we want to look for deep reflectors, we must settle for looking for large layers as well.

13. **Explain why a reflector on a seismic section need not correspond to a particular interface.**

    When layers are thinner than a quarter wavelength, the reflections and transmitted waves can interfere causing waves that don't necessarily correspond with a real reflector.

14. **Why is a very strong horizontal reflection usually indicative of a gas-water interface? Why may a gas water interface not always appear as a horizontal reflector?**

    Because the acoustic impedance of a gas-liquid is very different than the surrounding rock, it can produce a 'bright spot' on a section. Since gas-liquid is generally less dense than the surrounding rock, it will tend to move upward until it reaches an impermeable boundary, which is often horizontal.

    However, traps can exist that are not horizontal, therefore the interface may not always be horizontal

15. **A strong reflector that lies below several layers with different seismic velocities has the same TWT as the base of a single layer elsewhere. What do the total thicknesses above the two reflectors have in common?**

The total thicknesses above the reflector would have to have the same RMS velocity to have the same TWT to the reflector.

16. **Explain why a seismic interface may not be a lithological boundary, and vice-versa. Give an example of each.**

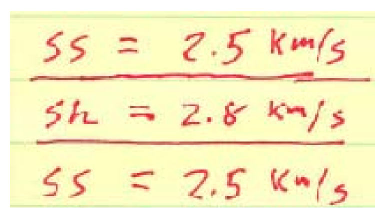
A seismic interface may be an artifact from reflective interference of several layers. An example is alternating layers of sandstone and shale, which can produce spurious reflectors.

A lithologic boundary may not produce a seismic reflector because the combination of density and velocity (impedance) may not be such as to produce a significant reflector even though they are distinctly different. An example is given in section 7.8.1 with the example of sandstone and limestone.

17. **In what ways does shallow seismic land surveying differ from deep surveying?**

Shallow land surveys require higher resolution, hence high-frequency sources and receivers that can detect the higher frequencies., typically up to around 400 Hz.

18. **A thin, horizontal layer of shale (v_p = 2.8 km/sec) lies within sandstone (v_p = 2.5 km/sec). What is the minimum thickness of shale that can be resolved in a Vibroseis survey? (Use an average frequency.)**



Use an average frequency of 50 Hz.

$$\lambda = \frac{v}{f} = \frac{2.8\times10^3}{50} = 56 \text{ meters}$$

$$\text{Resolution} = \frac{\lambda}{4} = \frac{56}{4} = 14 \text{ meters}$$

19. **Explain how (a) an interface may show up by seismic reflection, but not by seismic refraction, and (b) vice versa?**

a) 1: Source receiver distance less than the critical distance.. 2: A thin hidden layer will possibly be visible on reflection, but not on refraction. 3: A low velocity layer is present therefore no critical angle, hence no refracted wave.
b) A gradual interface can be seen with refraction, but not with reflection