Team TBL # 3: Near-surface, SH-wave surveys in unconsolidated, alluvial sediments
Young & Hoyos, 2001

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Overview

This case history consolidates many of the basic concepts related to refraction and reflection seismology within the context of an environmental problem. In your individual TBL you summarized the case history within the context of the 7-Step process. Here you will address some additional questions regarding the case history. Please provide insightful but brief answers to the following questions.

Instructions

Answer the following questions within the context of the 7 step framework. Team exercise:

- Discuss the case history amongst yourselves
- As a team, answer the following questions
- You will hand this in at the end of the class

Resources

- GPG: Seismic
- SyntheticSeismogramTBL
- Seismic App
- Lab4SeisRefrac App

Data Processing & Interpretation

Q1. In the case history article, the authors make these two observation:

- 'P-wave reflections may be difficult to obtain because the top of the saturated zone often presents a very large P-wave impedance contrast that masks reflections from deeper horizons.':
- 'the water table is transparent to the SH-refraction'

Based on this observation, draw the reflected and refracted waves for both P- and SH-waves between a shot and a receiver shown in the figure 1.

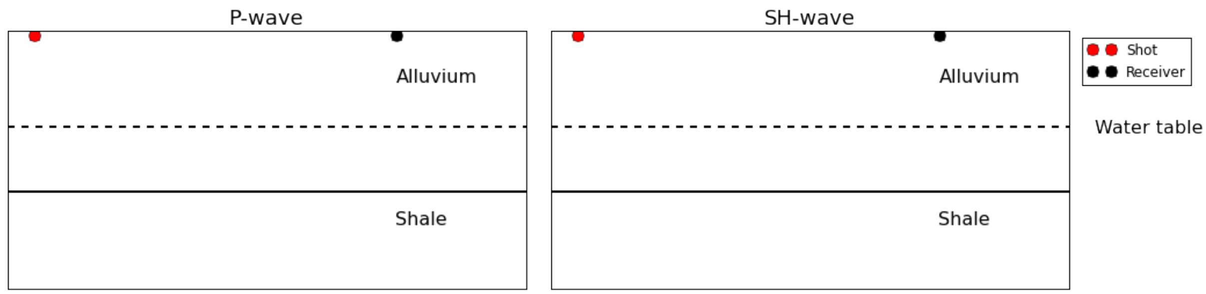

Figure 1

Q2. They mention "stacking fold is commonly low" (six or less). The fold is the number of times a particular point in the subsurface has been sampled by a source-receiver pair. The equation for the fold number is:

$$fold = \frac{N_r}{2 \text{ moveuprate}} \tag{1}$$

Where N_r is the number of receivers and "moveuprate" is an integer that tells the number of station spations that the source is moved.

a. Consider a survey with six geophones for every shot. The dots on the surface can be locations of shots (red) or geophones (black). Use the diagram to indicate where the reflections occur for each source (ie. For "Shot 1", indicate the location of the reflection on the line "Midpoint 1"). Assume that the moveup rate for the survey equipment is 1 unit. Successively move the survey and for each new location indicate where the reflections occur. Continue doing this for four moveups. How many times was each point in the subsurface sampled?

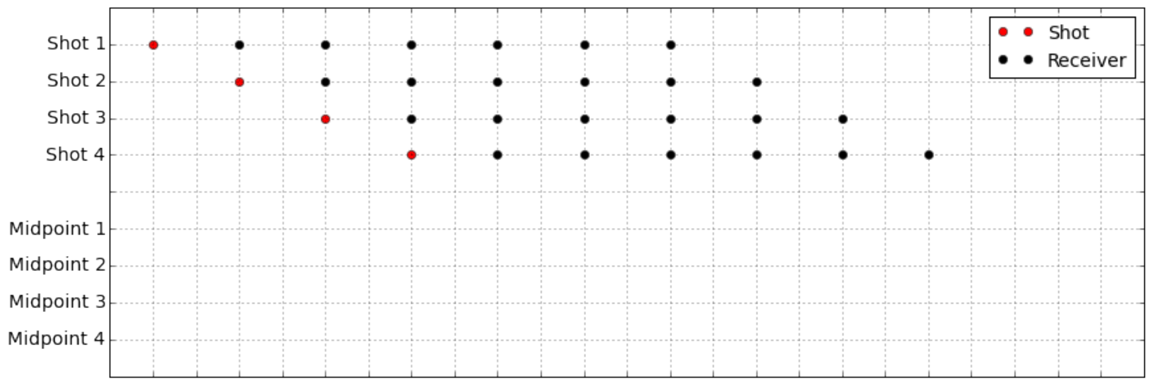

Figure 2

Q3. Consider the text:

"Soil borings at the Norman landfill commonly encounter a gravelly interval several feet thick at the base of the alluvium, and this zone is associated with high hydraulic conductivity (Scholl and Christenson, 1998). Our SH-refraction survey is unlikely to have seen this interval for two reasons: (1) If velocity decreases in the gravel, then a refraction will not exist, or (2) if the gravel velocity exceeds that of the shale, a refraction can exist, but it may never be a first arrival because it follows a path that is slower than the path along the shale. If the gravel layer exists, therefore, it would be a blind zone (Burger, 1992) to SH refractions."

Note that the refraction they are referring to is the critical refraction along the top of the gravel lens.

a. For the item (1) : Draw a refraction ray path from the interface between gravel lens and shale on the left panel of Figure 3.

b. For the item (2): There appears to be a typo in the authors' comment. (i) If they are referring to a critical refraction along the top of the gravel, which two layer velocities are important to consider? (ii) Assuming that the authors meant to say "if the gravel velocity exceeds that of the **alluvium**, a refraction can exist, but it may never be a first arrival because it follows a path that is slower than the path along the shale," explain this statemtent and support your explination by sketching ray paths for the refracted waves on the right panel of Figure 3. (You can use the Lab4SeisRefrac App to support your answer as well as the Seismic App)

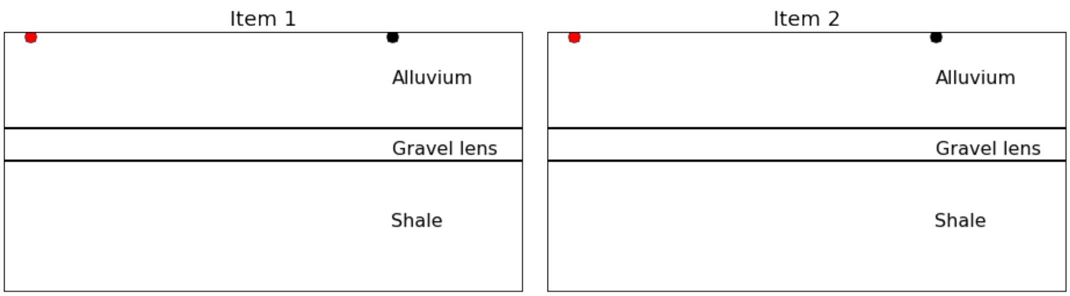

Figure 3

Synthesis

Characterization of the soils

Q4. As geological engineers, you might be most interested in top few meters where there is dry alluvium. Consolidate the information about Vp and Vs for that layer and use the equations below to estimate Youngs modulus, Shear wave modulus, and Poissons ratio. How can these numbers could be of use to you if you were carrying out a site investigation in this area. Connect them with a typical problem you might be dealing with (within the realm of your area of expertise)

- Young's modulus, E:

$$E = \rho V_s^2 \frac{3(\frac{Vp}{Vs})^2 - 4}{(\frac{Vp}{Vs})^2 - 1}$$

- Shear wave modulus, μ:

$$\mu = \rho V_s^2$$

- Poisson's ratio, ν:

$$\nu = \frac{V_p^2 - 2V_s^2}{2(V_p^2 - V_s^2)}$$

where ρ is density, V_p is P-wave velocity, and V_s is S-wave velocity. Assume that the dry alluvium has a density (ρ) of approximatley 1400 kg/m^3.

Resolution of seismic reflection data (SH-wave)

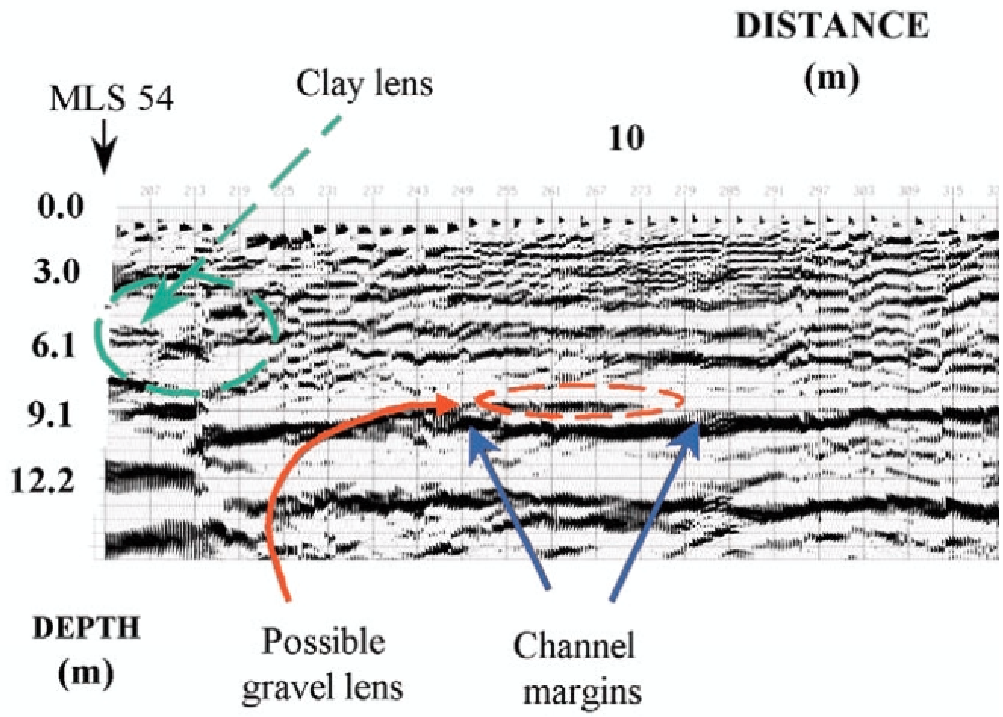

Figure 4: Depth-converted seismic stacked section from SH-wave data.

Q5. Consider the gravel lens. According to the case history, gravel lenses might be expected to exist above the shale and the thickness of these might be about a meter. These are zones of high permeability and sought after if ground water is to be extracted. The seismic reflection survey indicates a reflector about 9 meters away from the origin (Figure 4). To an untrained eye, this feature might not even be noticed when looking at this seismic image. However, closer scrutiny shows it is distinctive. The question is whether we can expect to see separate reflections from the top and bottom of the gravel lens. The frequency of seismic wavelet is 67 Hz.

a. What is the minimum thickness of layer that you can reasonably detect. $L = \frac{\lambda}{4}$. (See GPG: Seismic Vertical Resolution for more detail.) Show how you obtained this value. Assume Vs for the gravel lens is 200 m/s.

b. Now look at the seismic section shown in Figure 4. First, what are units of the vertical axis. Seismic data are recorded in time. How could they have made this switch?

c. What is the distance between the two reflections? (See Figure 4) How does this compare with your minimum layer thickness? What confidence does this give you that you might be able to see the top and bottom of the gravel layer.

d. The refection coefficient between the gravel and shale is likely positive. Do you think the gravel would have a higher or lower shear wave velocity than the alluvium. Do a quick internet search to find representative values of the shear wave velocities for the three units: alluvium, gravel, and shale. Use constant density for three of them (2300 kg/m^3) and compute the expected reflection coefficients.

e. Now we are going to use SyntheticSeismogramTBL . Default parameters of the app are set to d2 = 9 m, d3 = 9.5 m, which means 0.5 m thickness for the gravel lens; wavef = 67 Hz. First adjust v1, v2, and v3 based on Vs values that you found for alluvium, gravel, and shale. Can you recognize the op and bottom of the gravel lens? Increase d3 from 9.5 to 11.5, when do you recognize two distinctive wavelets from top and bottom of the gravel lens? How does it compare with the signature seen on the seismic section?

f. What are possible reasons to explain any differences in character between your synthetic results and the observed seismogram?