Unit 2: “How seismic waves travel through the ground” Student exercise

Andy Parsekian, University of Wyoming

# 1.1 Introduction

Unit 2 contains the theory component for this module, including underlying principles needed to understand refraction seismology concepts including refraction of rays, types of seismic waves, interpreting information about subsurface materials from seismic properties and developing conceptual models of the subsurface environment.

Part 1 introduces the idea of seismic (acoustic) waves in the subsurface. The content describes compressional waves used in refraction experiments and provides diagrams of raypaths. This part finishes with a prompt to think about ‘what is underground?’ and how that is related to basic conceptualizations of the subsurface structure and materials.

Part 2 describes how velocities of seismic waves are calculated in refraction experiments, and the basic equations that govern velocity and travel time. Snell's law is introduced in the context of a 2-layer refraction problem. Travel-time/offset plots are described and context is given for how information can be taken off of these plots and used to calculate a subsurface structure. Finally, we revisit the concept of material properties and think about both the structure and seismic properties of the subsurface near to the student’s home.

Seismic refraction measurement of the shallow subsurface is important for urban environmental problems because geoscientists and engineers often want to know about ground material properties and depth to bedrock when planning for utilities and building construction. Also, in the case of contaminated sites, the information about subsurface structure may allow for interpretation of likely volumes of contaminated soils, or the possible flow paths of contaminants.

The material provided in this unit is important for understanding the principles of how the measurement and associated calculations work. You will use this newly developed understanding of seismic refraction when you move on to practical exercises of data collection and data analysis. In a professional environment, the knowledge of seismic refraction measurements may be used for planning engineering projects or managing environmental remediation.

This unit contains slideshows, MS Excel-based exercises, conceptual exercises, and links to associated resources that are needed to approach these problems (e.g., Excel tutorial, trigonometry).

# 1.2 How seismic waves travel in the earth

Answer the following questions as you go through the lecture materials:

1. The direction of movement for a P-wave is best described as:\_\_\_\_\_\_\_\_\_\_.
2. List some examples of seismic sources:

3. The velocity of which layer allows the refracted arrival to overtake the direct arrival in a refraction experiment?

4. What are some good qualities of a “conceptual model,” or simplified diagram of the shallow subsurface?

5. \_\_\_\_\_\_\_ is an example of a material with SLOW seismic wave velocity, while \_\_\_\_\_\_\_\_ is an example of a material with a FAST seismic wave velocity.

6. To calculate the travel time of a refracted wave, we need to know the angle between the \_\_\_\_\_\_\_\_\_\_ and the \_\_\_\_\_\_\_\_\_\_\_\_ in order to determine the distance that the downgoing energy traveled in layer 1.

7. A “Travel-time/offset plot” is generated from field data by plotting \_\_\_\_\_\_\_\_\_\_\_\_ and the first arrivals on each trace are used to determine the \_\_\_\_\_\_\_\_\_\_\_\_.

8. An earth material that has more voids and less water, would likely be \_\_\_\_\_\_\_\_\_\_\_\_velocity.

# 1.3 Refraction calculations and conceptual models

**Exercise 1:** Snell’s Law: In this MS Excel-based exercise, you will demonstrate that the angle that the refracted ray intersects the interface between two geologic layers is determined by the velocity of the lower layer, the contrast between the two layers, and the thickness of the upper layer. Suppose you are tasked with determining the thickness of the soil layer over bedrock using seismic refraction in order to estimate the amount of excavation required for a building foundation. The first step to solving this problem is being able to predict how the seismic waves with bend, or refract, across the soil-bedrock interface. You will show that, for a set thickness and velocity of the soil layer, the angle of the raypath between the source and the interface is controlled by the lower layer velocity.

**Exercise 2:** A two-layer refraction problem: In this MS Excel-based exercise, you will use the concepts of refraction to calculate the thickness and velocity of the upper layer, along with the velocity of the lower layer for the provided field-measured dataset. You will complete a simple, guided interpretation of the provided seismogram image. Finally, you will produce a simple conceptual earth model diagram based on your findings, including interpretations of possible material properties and justifications for why you made these interpretations.

**Exercise 3:** In-class exercise: Think back to the first part of this unit where we diagrammed the subsurface. Now, try to create a similar diagram of the subsurface that has materials AND seismic velocities assigned for both layers. What do you think this diagram might looks like for the ground outside your building, at your home, or in a nearby park? Why?