Exploring the Earth with Seismic Waves – Emily Wolin

Purpose

Seismology is an important tool in the Earth sciences because it allows us to remotely investigate the structure and properties of Earth's interior. For example, we know that the outer core is liquid because of seismological observations. On a smaller scale, seismological techniques can also be used to image shallow structures (depths < 100 m). In this activity, students will conduct their own seismic experiment to investigate the structure of the ground beneath their feet.

Please note: This lesson requires the assistance of a trained geophysicist or someone else who knows how to use a geophone system to record seismic data. They can help acquire the necessary equipment (by providing their own or borrowing it from PASSCAL; see "Materials" section for more information).

Overview

Using a sledgehammer and a string of geophones, students will create seismic waves and record them as they travel through the ground. Computer software plots a "record section" of time vs. distance, which the students will use to calculate the seismic velocities of the materials below the surface.

Student Outcomes

Objectives

- Students will understand that velocity is expressed in units of distance/time.
- Students will be able to draw a "best-fit" line on the graph and calculate its slope to determine the seismic velocity of the material.
- Students will understand that seismic waves travel at different velocities through different materials.
- Students will be able to compare their calculated velocities with typical velocities for various Earth materials (soil, sand, granite, etc.) and infer the probable composition of the subsurface.

Illinois State Science Standards

- 11.A.3a Formulate hypotheses that can be tested by collecting data.
- 11.A.3e Use data manipulation tools and quantitative (e.g., mean, mode, simple equations) and representational methods (e.g., simulations, image processing) to analyze measurements.
- 11.A.3f Interpret and represent results of analysis to produce findings.

Time

This activity required two 80-minute class periods: one to collect the data and make a field sketch of the setup, and one to interpret the data.

Level

This lesson was taught in a 6th grade class whose curriculum covers general physical science, beginning with the metric system and moving through atmospheric and earth sciences and astronomy.

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Materials and Tools

- Near-surface seismic refraction/reflection equipment is required for this activity. This includes geophones and a data recording system. We used standard seismic survey equipment from the PASSCAL group. (PASSCAL is a national office that oversees a "pool" of seismology equipment that can be borrowed or leased for scientific studies. See http://www.passcal.nmt.edu/ and http://www.passcal.nmt.edu/content/borrowing-equipment for more information.)
- A sledgehammer and steel strike plate are used as a source to create seismic waves.
- Rulers and calculators are useful when interpreting the record section.
- "A Whole Lotta Shakin' Goin' On" Lab

Preparation

The cables and recording system should be laid out, connected, and TESTED before the lab begins. Students can help attach the geophones to the cable and place them in the ground at the desired station spacing.

Prerequisites

Students should be familiar with line graphs. Specifically, they should be able to draw a "best-fit" line through data points, and they should know how to calculate the slope of a line. They will benefit from a basic introduction to seismic waves.

Background

How do we know what's below the surface of the Earth? Of course, we could just dig a hole a few meters deep and find out. But what if we wanted to know what lies 100 m below us? We could drill a really deep hole, but that gets expensive. What about 100 km, or 1000 km? Nobody can drill that far--the deepest hole ever drilled is only about 12 km deep! Despite this, we still know something about the composition of Earth's interior. We know this because of seismology.

You've already learned that an earthquake creates seismic waves. We can create seismic waves too, by hitting the ground with a hammer. We're going to measure how fast those waves travel through the upper few meters of the earth using devices called geophones.

Teaching Notes

The first part of this lesson requires one person to operate the geophone equipment while the teacher supervises students as they acquire the seismic data. Students are divided into different groups and placed at intervals along the line of geophones. One group sits with the operator and watches a live data stream on a laptop while other groups take turns jumping next to their geophone. The seismic waves created from the jump will be displayed on the laptop for the students to see. Each group rotates through so they get a chance to see the laptop screen. Finally, a few sledgehammer blows are recorded to provide data that is suitable for analysis.

One person can teach the second part of this lesson. Students draw a best-fit line through the first arrival on the record section. They then calculate the velocity of the material by calculating the slope of this line. We have found it helpful to walk the students all the way through one example of interpreting the record section, from drawing the best-fit line through the first arrival, then calculating the difference in times and distances, and calculating the velocity.

Assessment

A quiz or test problem could provide a new record section and ask the students to calculate a velocity. This would assess whether they could draw a best-fit line and calculate its slope. A less detailed evaluation might be an exit slip asking the students to identify which material would have a faster seismic velocity (e.g. soil vs. granite). Another exit slip question might ask students to first calculate the velocity from a best-fit line that has already been drawn on a record section, and then to compare their calculations with a table and identify a few candidate materials with the same velocity.