# Lesson Title: Seismic Surveys in Mineral Exploration
# Geophones: I "Heard" That!

## Overview

The seismic reflection method of geophysical exploration is used widely to map geology below the surface. Students will simulate the use of geophones and computers to record seismic signals travelling from the surface to a rock layer in the earth, reflected back up and recorded at the surface.

**Source:** This lesson was developed by the Saskatchewan Mining Association

**Duration:** One class

### Materials:

- 3 i-pods/i-phones/ i-pads or android tablets/phones
- Download the free app Seismometer 6th by SkyPaw Co. Ltd.
- Meter stick
- Question sheets

### Notes to Teacher:

This lesson is an introductory lesson prior to teaching either Looking Into the Earth or Seismic Surveys in Mineral Exploration.

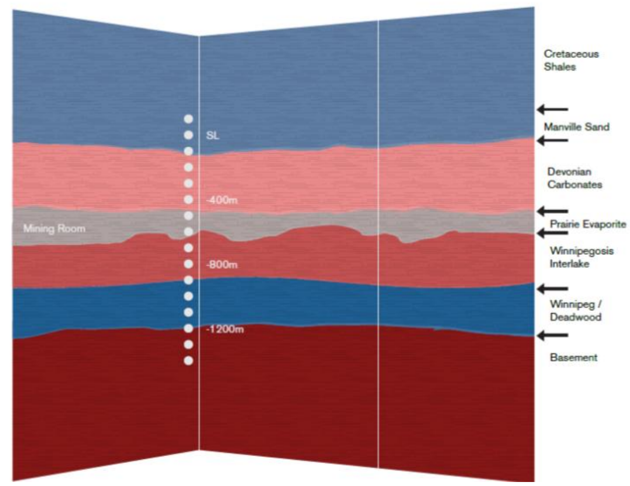
### Prior Knowledge:

Before attempting this activity students should have some understanding of the following:

- Seismic waves in earthquakes
- Movement of sound waves

### Instructional Methods:

- Simulation
- Inquiry




A typical interpreted seismic image, showing the cross-section of a potash mine. The numbers show the depth in metres below sea-level (SL). A mining room is labeled. Image courtesy of PotashCorp. (Source: Ore magazine, Spring –Summer 2013)

## Learning Outcomes and Indicators

**7ECR7.2 Identify locations and processes used to extract Earth's geological resources and examine the impacts of those locations and processes on society and the environment.**

f. Provide examples of technologies used to further scientific research related to extracting geological resources (e.g., satellite imaging, magnetometer, and core sample drilling).

h. Provide examples of Canadian contributions to the scientific understanding and technological developments related to surface and sub-surface geology and mining, and identify societal and economic factors that drive such exploration and research. (Indirect)

**7ECR7.1 Analyze societal and environmental impacts of historical and current catastrophic geological events, and scientific understanding of movements and forces within Earth's crust.**

c. Construct a visual representation of the composition of Earth, including the crust, upper and lower mantle, core, and inner core. (Indirect)

h. Explain the operation of tools scientists use to measure and describe the effects of catastrophic geological events, including earthquakes and volcanoes (e.g., seismograph, Mercalli intensity scale, and Richter magnitude scale).

**Earth Science 30: Lithosphere**

**ES30-LS3 Investigate the processes and technologies used to locate and extract mineral resources and fossil fuels locally, provincially and globally.**

d. Contrast the operation and utility of different imaging methods (e.g., gravity, magnetics, electromagnetics and seismic) for locating hard rock and soft rock resource deposits.

g. Model a seismic survey using tools such as an ultrasonic sensor (e.g., Vernier GoMotion).

Source: **Saskatchewan Evergreen Curriculum**

**Other:**

The students will:

• Understand how seismic data is collected.

## Big Picture Questions

1. **How can geoscientists determine what occurs beneath our feet in a relatively non-destructive way.**

## Background Information

In mining exploration, we ask one principal question: "What's under there?" The answer determines not only where to mine, but also how to mine – the risks and the rewards. The answer, in large measure, comes from geophysics. "Geophysics is used to map the earth's subsurface through the application of remote sensing survey techniques," "Changes in geology at depth, or of the same geological feature at depth, result in variations in the physical properties of the rocks. Exploration

geophysics is about mapping these changes from the air, on the earth's surface, or from within boreholes.

The properties of the rocks that we can measure include density, porosity, magnetic susceptibility, conductivity, **sonic velocities**, sulfide content and radioactivity."
The geophysicist is responsible not only for collecting this data, but also interpreting it. (ORE, spring-summer 2013).

Much of southern Saskatchewan is underlain by potash beds. Exploration of the potash deposits is mainly by surface seismic surveys which measure differences in seismic velocities among rock layers.

**Seismic geophysics** was pioneered in the oil and gas industry and is also now used extensively by the mineral industry. The main purpose for seismic surveys
In potash mining, is to identify anomalies –changes or peculiarities – and mine around them (ORE, spring-summer 2013).

A typical seismic survey can cost millions of dollars, but its well worth it. The 3D images produced by the echoes identify anomalies such as "collapse zones" and other problematic areas that could endanger workers, lower the ore grade or destroy a mine. Seismic surveys in southern Saskatchewan produce some of the best seismic images you'll find anywhere in the world. "It's all about the sonic frequency you can get into the earth and the frequency you get back," explains Craig Funk Chief Geophysicist with PotashCorp. "The higher the frequency you get back, the better the image resolution you have." (ORE, spring-summer 2013).

The seismic reflection method of geophysical exploration is used widely to map geology below the surface. Potash and uranium exploration requires detailed knowledge of the geology, particularly to accurately locate disruptive features such as faults and collapse structures.

Other practical applications of seismic reflection imaging are in mapping folds, ore deposits, groundwater, underground contamination, and site investigation for construction.

The seismic reflection method (Figure 1) requires a source of sound energy on or near Earth's surface. To create this energy, explosives or a large thumping device (e.g., Vibroseis truck "Dancing Elephant") are used. The sound (seismic) waves travel through the Earth and reflect back due to changes in the physical properties of rocks, in particular density. Sound waves also travel at different speeds through different types of rock. Faults and collapse structures can be recognized where rock layers distinguished by seismic characteristics are offset against each other.

When a seismic wave encounters a boundary between two different materials, some of the wave's energy gets reflected and the rest of the energy travels further into the Earth. The time it takes for this reflected energy to arrive at a detector makes it possible to estimate the depth of the boundary.

The reflected sound waves are heard by microphones (geophones) that are placed at defined distances along the surface of the ground. The geophones transmit the sound waves to computers in a truck. The particular rates at which the sound waves are reflected back create a picture of the underground geology

Great animations:
**http://www.iris.edu/hq/programs/education_and_outreach/animations/13**

## Vocabulary (hyperlink)

geophone
geophysicist
seismic

## LESSON PLAN

### Activity: Geophones: I"Heard" That! (Simulation) (one class)

**Teacher Preparation:**

1. If you have access to i-pads great, if not use student i-pods, i-phones or android tablets/phones and download the free app Seismometer 6th by SkyPaw Co. Ltd from Apple's App store. Seismometer 6th is also available for Android and Microsoft tablets. Practice with the tool tips prior to using.
2. **Seismometer Settings**:
   **Graph scale:** Linear
   **Update frequency:** Full right
   **Alert sensitivity**: High
   **Sound:** Off
   **Timeline:** Show
   **Sound FX**: Off
3. Practice with the app, stopping/starting/ clearing graph and reading the time.
4. Make sure that the time on all tablets/i-pods/phones is in sync.
5. Locate several areas within the school that have continuous floors. E.g. wooden floors, concrete floors, or outside. E.g. asphalt parking lots, concrete walks or a rock outcrop.
6. Depending upon the number of tablets/phones this could be done as a demonstration or as a small group activity. If several simulations are being conducted at one time make sure there is separation between the groups otherwise there will be interference of the data. *(Set up several locations and have the students rotate through them.)*

**Motivational Set: (10 minutes)**
**Source:**
**(**http://www.iris.edu/hq/files/programs/education_and_outreach/lessons_and_resources/docs/shallowearthstructure/RefractionLabv2_0.pdf**)**

1. Pose the question to students: How do geoscientists find out what's beneath our feet? Allow students to freely speculate and offer solutions, without correction.
2. What could we use to see inside something? (*X-rays may be suggested however an x-ray won't work because the rocks are too dense and too thick)*
3. What is an x-ray? *Lead students to the idea that an x-ray is a form of energy.*
4. Using a tuning fork, gently strike the fork against a variety of objects around the room. Note variations in sounds produced by different objects.
5. Discuss the sound*. It is a form of energy and occurs as waves.*
6. Strike the fork against a variety of rocks. Note variations in sounds produced by different rocks. Discuss with the students the differences in the sounds produced from different objects. Ask the students why they think there are differences in the sounds produced from different objects and rocks. *The density of the different objects/rocks causes the sound waves/ vibrations to vary causing different sounds.*
7. Ask them how scientists could use this information to help map the rock layers beneath the earth? *Scientist*

*could measure the time it takes for the sound waves to travel through the rocks.*

8. How could we create a seismic wave? Demonstration: Ask a student to go to the back of the room, place a clean piece of paper on the floor and put their ear to the ground. Then jump. Ask the student to describe what they experienced (felt the vibration of the floor). The person jumping created the sudden energy wave and the person on the ground was the sensor.

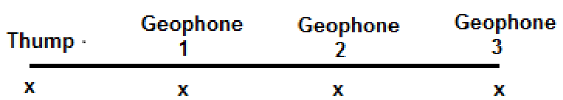
**9. Simplified Explanation of a Seismic Survey**

In a Seismic survey The Thumper trucks sometimes called "Dancing Elephants", are 25 ton trucks that pound the ground with huge hammers making it shake as an elephant would when stomping it's foot. Another way to create sound waves is by detonating explosives either on the earth's surface or in shallow pits underground.

The waves travel through the rock for up to tens of kilometers, bounce off a rock layer and travel back to the surface. The Seismologists measure the amount of time it takes for the wave to travel from the initial pounding/explosion back up to the surface to determine how far below the earth's surface the rock units are. The sound waves are "heard" by microphones (called geophones) that are placed at defined distances along the surface of the ground. The microphones are connected to computers in trucks equipped with high-tech equipment that read the speeds at which sound travels through the different types of rocks and interpret the sounds as a picture. Using this information and information from drill holes at the site, the **Geophyscists** identify rock formations and interpret the seismic information. Show the students the picture of a 2D seismic section (Figure 2.)

### The Activity: Geophones: I "Heard" That! (15 – 20 minutes)

1. Have students go to a location and measure out 1.5 meter intervals. Place "geophones" as shown.




2. Make sure the "geophone" has been turned on and the function **GRAPH** has been cleared.
3. Have all students stand in the Thumper Truck location. *It is important that no one is walking past the "geophones" during the simulation as the phones will pick up the vibrations and cause confusion.*
4. Have one student either pound the ground with one foot, or jump with both feet. Wait 10 seconds and repeat.
5. Wait another 30 seconds then return to the "geophones" and press the STOP button to stop recoding
6. Record the time that each sound wave occurred at each station. Take a screen shot for each station. Make sure students label each screen shot with station# (concrete, asphalt, wood) the trial number (1, 2, 3) and the geophone number.
7. Students will download the screen shots after they have finished testing each station. Students can then print out the images and glue onto answer sheets or import into a word document for use in their discussion.
8. Discussion Questions. Hand out the Question sheet.
9. Watch the video 3D Seismic. Although it explains seismic surveys in the search for oil and gas. It is the same method used to "map" the potash and surrounding units in Saskatchewan.

## Assessment Method and Evidence

✓ Simulation Check list and Data Collection Sheets

- Students will work cooperatively together conducting the simulation to acquire and record the data.

✓ Calculation Sheet/Discussion questions:

- Students will be able to explain how the use of seismic surveys further the geophysicists and mining companies knowledge of the Earths stratigraphy, how deep the resource occurs and how it could be used to determine where to mine.
- Students will be able to explain how geophysicists use small explosions or pounding to create seismic (sound) waves to measure the distance to geological boundaries in the earth's crust.
- Students will be able to explain that the wiggly lines recorded on a seismograph are the seismic waves after they have been reflected, refracted along geological boundaries and have returned to the surface where they are recorded by the geophones.

Students will be able to show that the geophones used in seismic surveys are a technology that is used by geophysicists to further scientific research related to finding and extracting potash.

In doing the simulation students will have constructed a visual representation of the use of seismic waves and their movement through a layer of the Earth illustrating how waves travel at different velocities through different mediums representing different layers or rock units of the earth.

Students will be able to explain the operation of geophones and their role in detecting artificial waves created to determine the underlying structure of the earth.

## Extension

1. Have students extend the separation between the geophones to see how far apart they can be to pick up a response.

2. Secondary: Show the video Travel Times Through Different media.

**http://www.iris.edu/hq/programs/education_and_outreach/animations/13**

## Resources

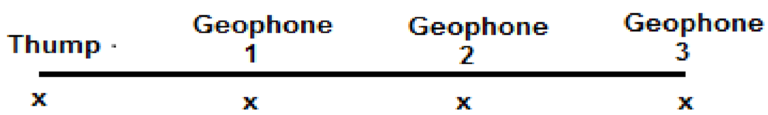
Hubenthal, M. and Taber, J. **How Shallow Earth Structure Is Determined: A Classroom Exercise Demonstrating Seismic Refraction Use in the Real World**. Available at: www.iris.edu/hq/files/programs/education_and_outreach/lessons_and_resources/docs/shallowearthstructure/RefractionLabv2_0.pdf

ge0physicsrocks. **3D Seismic** video Available at: https://www.youtube.com/watch?v=hxJa7EvYoFI

Saskatchewan Mining Association. **Looking Into the Earth,** ORE Magazine, Spring –Summer 2013, pg. 25 – 26.

## Geophones: I "Heard" That!

**Set Up:** Set your "geophones" up as shown in the diagram. Start with the geophones 1.5 metres apart.




**Using the app Seismometer 6th on each "geophone"**

2. Make sure the graph has been cleared and turn on each "geophone". Return to the Thumper Truck location.

3. Have one student either pound the ground with one foot, or jump with both feet. Wait 10 seconds (either use a stop watch, or count one one thousand, two two thousand …) and repeat.

4. Wait another 30 seconds then return to the "geophones" and press stop.

6. Record the times that each sound wave occurred at each station. Enter the time for each station. Take a screen shot for each station.

| **Ground surface:** | **Geophone 1 Time** | | **Geophone 2 Time** | | **Geophone 3 Time** | |
|---|---|---|---|---|---|---|
| **Wood floor** | **1st thump** | **2nd thump** | **1st thump** | **2nd thump** | **1st thump** | **2nd thump** |
| Time | | | | | | |
| | Insert screenshot | Insert screenshot | Insert screenshot | Insert screenshot | Insert screenshot | Insert screenshot |
| **Concrete/Asphalt** | **1st thump** | **2nd Thump** | **1st thump** | **2nd Thump** | **1st thump** | **2nd Thump** |
| Time | | | | | | |
| | Insert screenshot | Insert screenshot | Insert screenshot | Insert screenshot | Insert screenshot | Insert screenshot |

**DISCUSSION QUESTIONS**

1. Was there a difference in the times the wave reached each geophone?
   Difference between G1 and G2:
   Difference between G2 and G3:
   Difference between G1 and G3:

   Why do think this is so?

2. Determine an average velocity (speed) that the wave travelled for each of the surfaces you tested. **Velocity = Distance / Time**

| | Distance | Time | Velocity m/s | Average |
|---|---|---|---|---|
| **Surface 1** | 1.5 m | | | |
| **Surface 1** | 3.0 m | | | |
| **Surface 1** | 4.5 m | | | |
| | | | | |
| **Surface 2** | 1.5 m | | | |
| **Surface 2** | 3.0 m | | | |
| **Surface 2** | 4.5 m | | | |

Did you find a difference in the velocity? Did it take longer for the wave to get to G3 at Station 1 or Station 2? If so explain why?

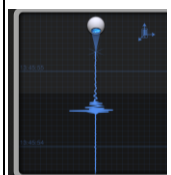
3. What would happen to your results if there was a crack in the surface you were measuring?
   If you have time test it!
   Relate this to a situation you might find in geology.

5. Explain what a seismic survey is and what geophones do.

4. What would happen if you increased the spacing of the geophones?
   If you have time try it!

## ACTIVITY AND DISCUSSION QUESTIONS: Teacher Answer Sheet

6. Record the times that each sound wave occurred at each station. Enter the time for each station. Take a screen shot for each station. **Example**

| Ground surface: | Geophone 1 Time | | Geophone 2 Time | | Geophone 3 Time | |
|---|---|---|---|---|---|---|
| **Wood floor** | **1st Thump** | **2nd Thump** | **1st Thump** | **2nd Thump** | **1st Thump** | **2nd Thump** |
| Time | 13:45:54:30 | | 13:45:56:00 | | 13:45:58:30 | |
| |  | Insert photo | Insert photo | Insert photo | Insert photo | Insert photo |
| **Concrete/Asph alt** | **1st thump** | **2nd Thump** | **1st thump** | **2nd Thump** | **1st thump** | **2nd Thump** |
| Time | | | | | | |
| | Insert photo | Insert photo | Insert photo | Insert photo | Insert photo | Insert photo |

**Questions:**

1. Was there a difference in the times the wave reached each geophone?
   Difference between G1 and G2: *Answers may vary*
   Difference between G2 and G3:
   Difference between G1 and G3:

   Why do think this is so? *This will depend upon how homogeneous the material is. Wood could have knots which may delay transmission of the wave. Asphalt or concrete may have small pebbles which could delay transmission. The more homogeneous the material the more consistent the times recorded at each of the geophones.*

2. Determine an average velocity (speed) that the wave travelled for each of the surfaces you tested. **Velocity = Distance / Time**

| | Distance | Time | Velocity m/s | Average |
|---|---|---|---|---|
| **Surface 1** | 1.5 m | | | |
| **Surface 1** | 3.0 m | | | |
| **Surface 1** | 4.5 m | | | |
| | | | | |
| **Surface 2** | 1.5 m | | | |
| **Surface 2** | 3.0 m | | | |
| **Surface 2** | 4.5 m | | | |

Did you find a difference in the velocity on different surfaces? *If the surface tested is sufficiently different there should be a difference in velocity.*

Did it take longer for the wave to get to G3 at Station 1 or Station 2?
If so explain why? *Again this is testing how well the waves travel through a medium. If the medium is sufficiently different (concrete and wood; concrete and asphalt; metal and concrete) there should be a difference with a more dense, homogeneous medium conducting the wave more quickly.*

3. What would happen to your results if there was a crack in the surface you were measuring? If you have time test it! *If a crack occurs in surface being tested (for example across wood floors, sidewalks or cracks in an asphalt parking lot) the wave will be terminated and should not continue on to the next "geophone".*

   Relate this to a situation you might find in geology. *A crack could represent a fault or a disruption in the bedrock.*

4. Explain what a seismic survey is and what geophones do.
   *A seismic survey creates energy waves that are sent into the earth. The waves "bounce" or are reflected (and refracted) off of the different rock types, back up to the surface where they are received by geophones. The time of their arrival (when the geophones "hear" them) is recorded by a computer which creates the seismic "picture"(profiles). It is the geophysicist who interprets the profiles.*

5. What would happen if you increased the spacing of the geophones?
   If you have time try it!
   - *You could lose the wave signal over further distances*
   - *Could get a more accurate velocity for that medium*
   - *Potential for more error due to inhomogeneous medium*

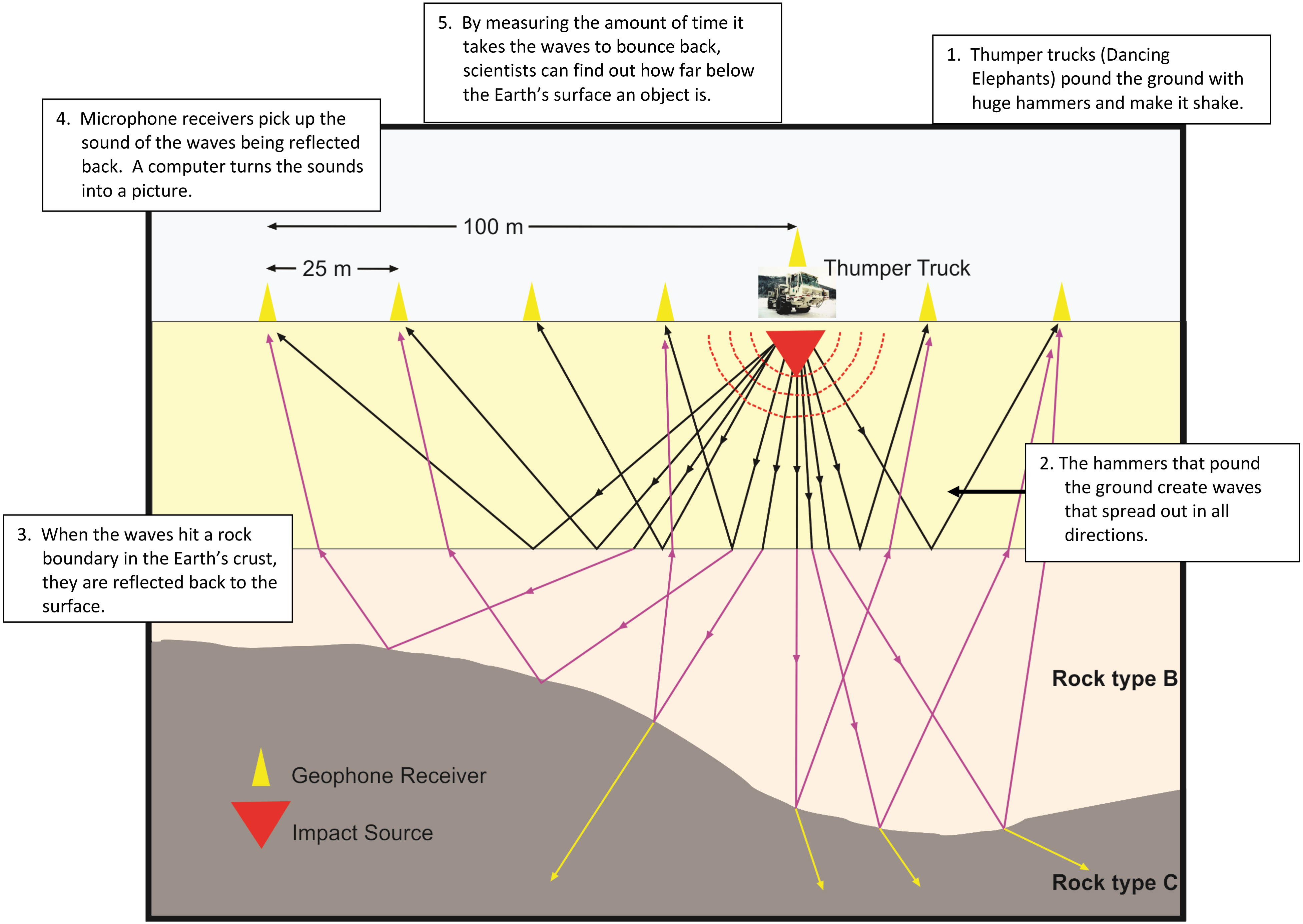



**Figure 3. Seismic Reflection Method** (Schematic of Lithoprobe's Exploration Technique)

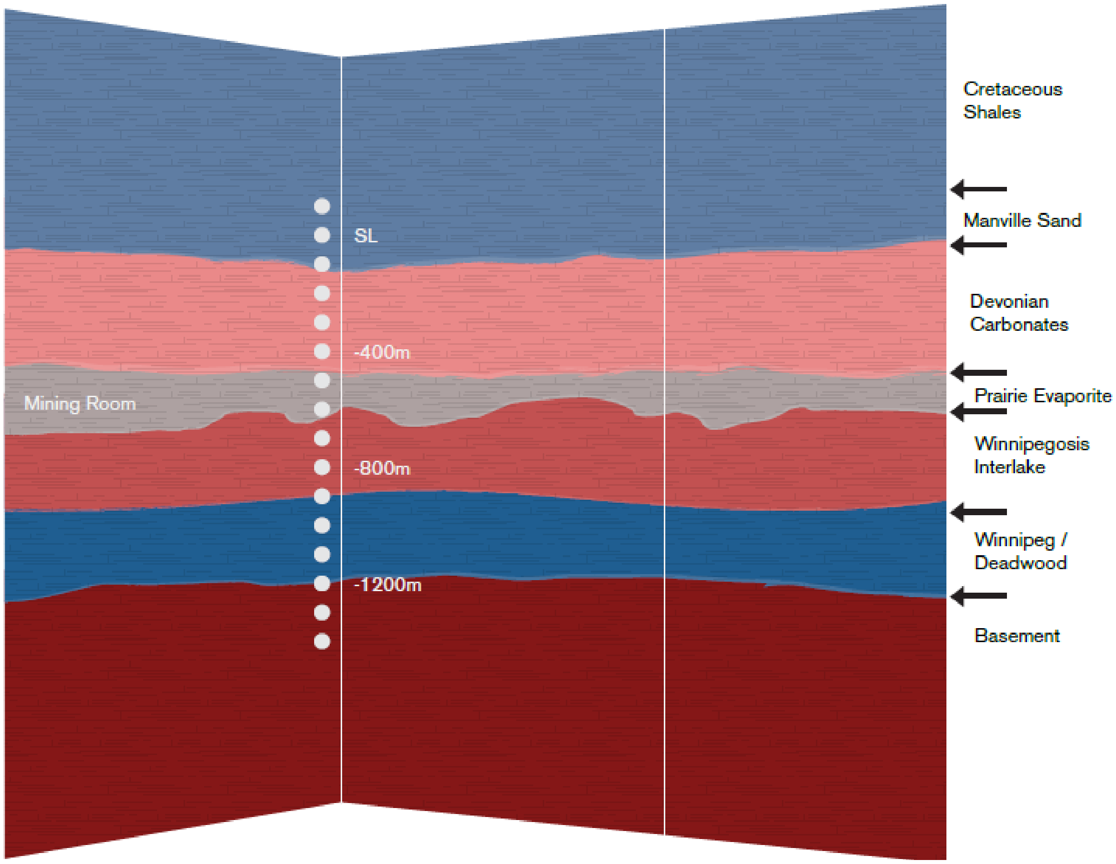



Fig. X . A typical interpreted seismic image, showing the cross-section of a potash mine. The numbers show the depth in metres below sea-level (SL). A “mining room” is labeled. Image courtesy of PotashCorp. (Source: Ore magazine, Spring –Summer 2013)