Educator Resources

About This Investigation

Welcome to the Layered Earth lab! In this lab you will explore Earth's interior! upon completion of the lab you will receive a personalized certificate of completion, and a printout of all your responses to the questions asked throughout the lab

What is inside of our Earth?

Exploring how we know, what we know, about Earth's interior structure

What is your name?

Brainstorm #1 from video: What is beneath your feet?

Brainstorm #2 from video: What is deep in Earth below the dirt and foundations of buildings?

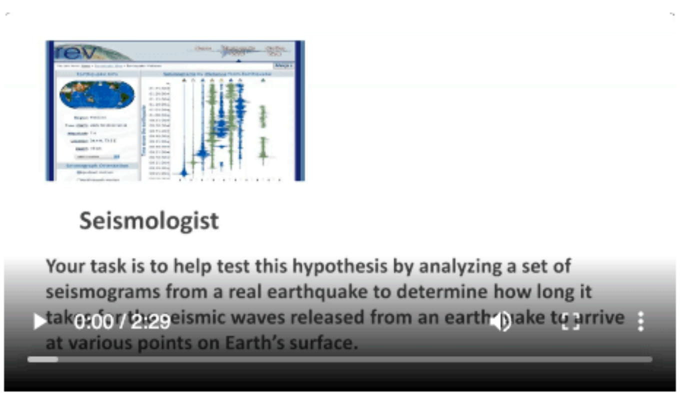
Brainstorm #3 What evidence do you have for what is deep inside of the Earth?

Which of the following may be true about Earth's interior based on the direct evidence discussed in the videos above?

- ◯ Earth is filled with lava that comes out at volcanoes
- ◯ Earth is made up of layers of different materials
- ◯ The Earth is made of rock similar to what we can see on the surface.
- ◯ Earth is hollow inside, like a cave

Seismologists

Collecting and analyzing when seismic waves arrive around the Earth



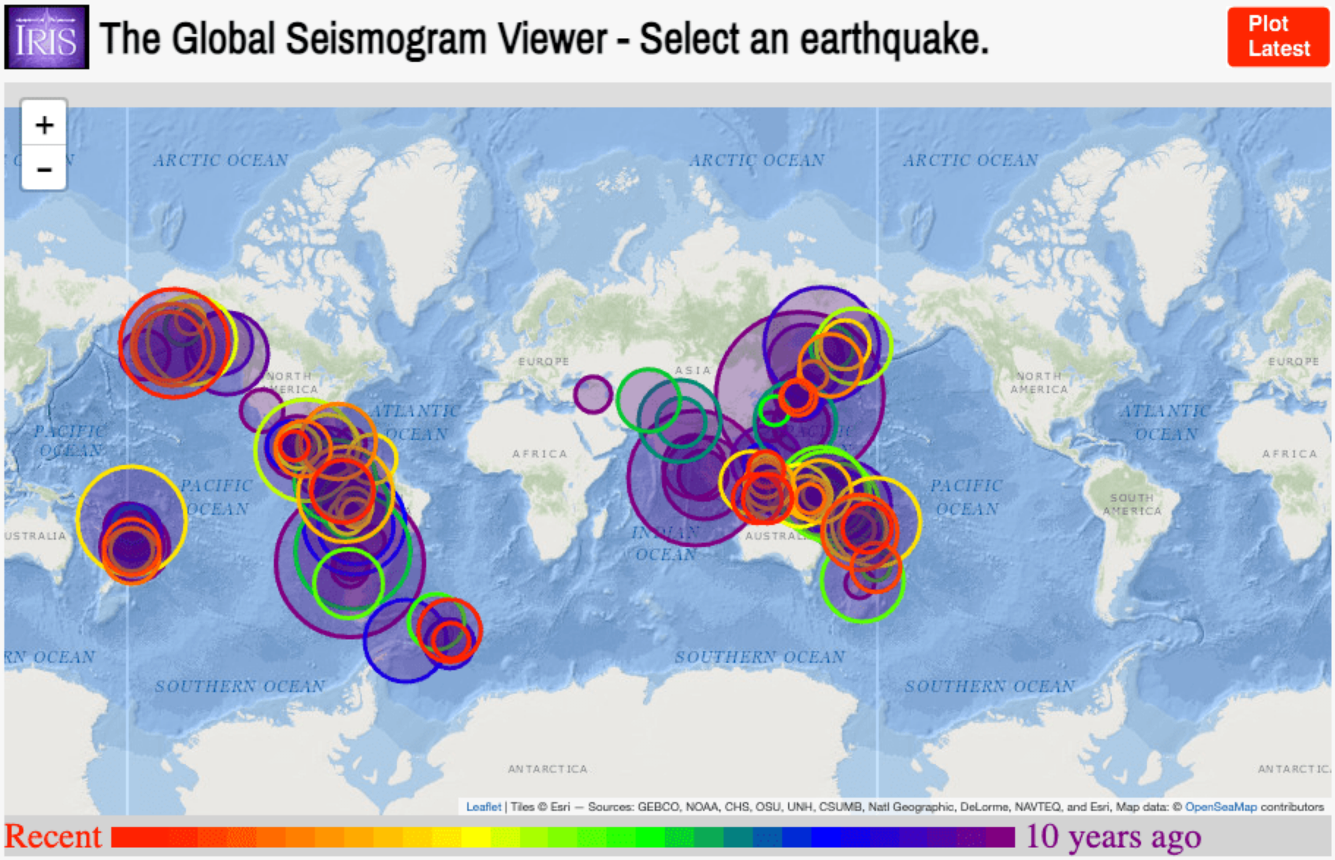
Background: The simplest solution to the question: "What is beneath our feet" is a homogeneous Earth, or one comprised entirely of the rock we see at the surface. Since seismic waves travel through Earth, they make a useful tool to "probe" the inside of Earth to discover what might actually be inside.

Hypothesis: The Earth is comprised entirely of rock similar to what we see at the surface.

Task: Your task is to help test this hypothesis by analyzing a set of seismograms from a single earthquake to determine how long it actually takes for the seismic waves released from an earthquake to arrive at various points on Earth's surface.

Step 1: Obtain a seismic data from a recent earthquake

On the map below, please select an earthquake to use for this exploration of Earth's interior. Choose one of the earthquakes shown, or selected the "Plot Latest" button to use the latest earthquake recorded.



Step 2: Exploring your data

As you can see above, your request returned many seismograms. This plot is called a record section and it displays a collection of seismograms from the same earthquake, but each is the recording from a different seismic station. We will use the record section to answer two questions about each seismic station.

1. How far away was each station from the epicenter of the earthquake?
2. How long did it take the seismic energy from the earthquake arrive at each station?

On a record section, each seismogram is plotted according to the distance from the seismograph to the epicenter, on the x-axis. This distance, as measured by the geocentric angle , is provided in degrees, where 1 degree is ~111km on Earth surface. The time since the earthquake is shown on the y-axis and is displayed in seconds.

Use the information on the record section to answer the following questions.

What is the magnitude of the event?

Show Hint

Where did the event occur?

Show Hint

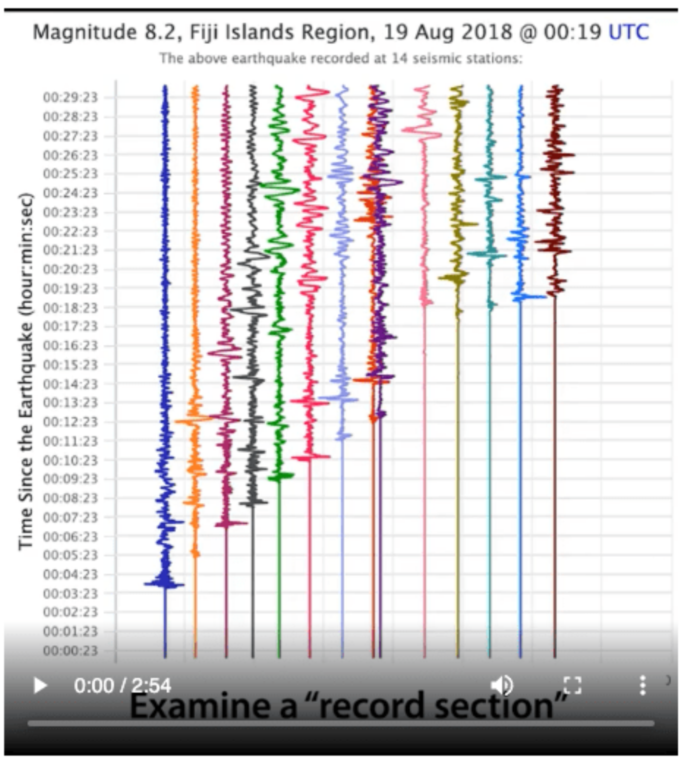
When did this event occur (mm/dd/yy)?

Show Hint

How many seismograms are shown on the record section?

Show Hint

Step 3: Analyze the record section



1. Click "Show Record Section" below to reveal the record section you selected previously.
2. Starting with the first seismogram on the left, move your cursor up or down the seismogram until it is over the point the seismic energy first arrived. An information bubble will display the travel time, or the time it took the seismic energy to travel from the epicenter to the station, and the number of degrees the station is away from the epicenter.
3. Record the travel time and station distance in the appropriate windows below.
4. Click "Add Data Point" to add this information into the data table and associated graph.
5. Repeat these previous steps for each seismogram in the record section to complete the plot.

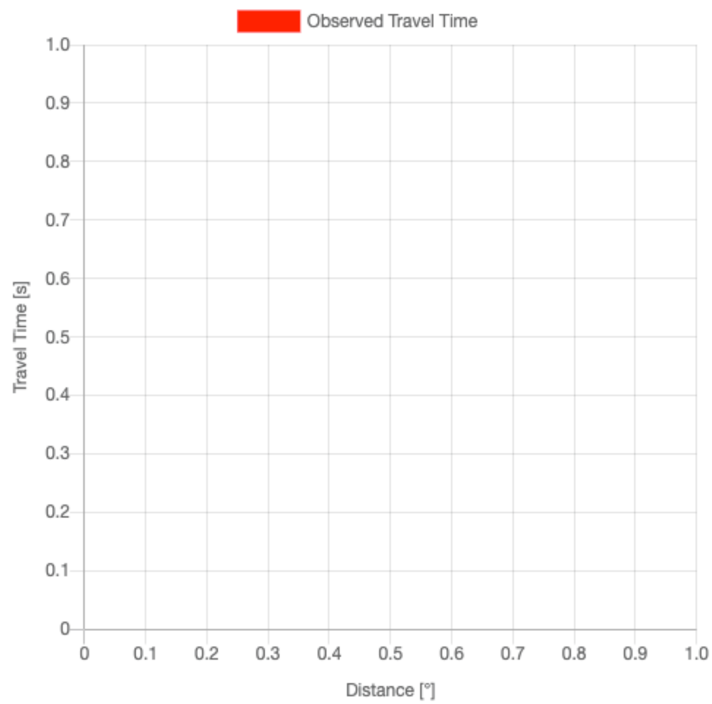
Repeat this process for each seismogram in the record section to complete the plot.

Show Record Section Station Distance [deg] 0 Travel Time [HH:MM:SS] 00 : 00 : 00

Add Data Point

Data Table

Station Distance [deg]	Travel Time [s]	Travel Time [HH:MM:SS]



Clear all data points...

Step 4: Examine your data

What information did we collect from the record section?

- ◯ How long the ground moved at the seismic stations.
- ◯ When the ground moved at the seismic stations
- ◯ The depth of the earthquake
- ◯ The cause of the earthquake

Could you easily fit a single line to the data you've collected?

- ◯ Yes
- ◯ No

Which of the following statements best describes your data? (Select all that apply)

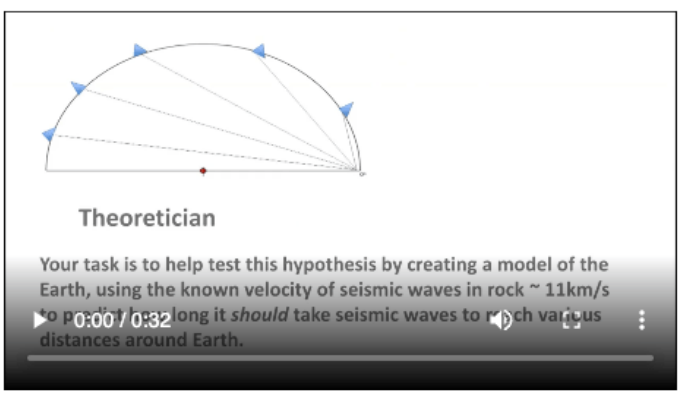
- [ ] Seismic waves take hours to travel through the Earth and reach the opposite side.
- [ ] The ground closest to the earthquake records the ground shaking before distant stations.
- [ ] When a large earthquake occurs, the ground on the other side of Earth shakes as well.

In your own words, summarize two things you have learned so far.

Describe any trends or oddities you notice in your data.

Working as a Theoretician

Building a model to predict when seismic waves should arrive



Background: The simplest solution to the question: “What is beneath our feet” is a homogeneous Earth, or one comprised entirely of the rock we see at the surface. Since seismic waves travel through Earth, they make a useful tool to “probe” the inside of Earth to discover what might actually be inside.

Hypothesis: The Earth is comprised entirely of rock similar to what we see at the surface.

Task: Your task is to help test this hypothesis by creating a model of a homogeneous Earth, using the known velocity of seismic waves in rock ~ 11km/s. From this model you will predict how long it should take seismic waves to reach various distances around Earth.

Step 1: Building Your Model

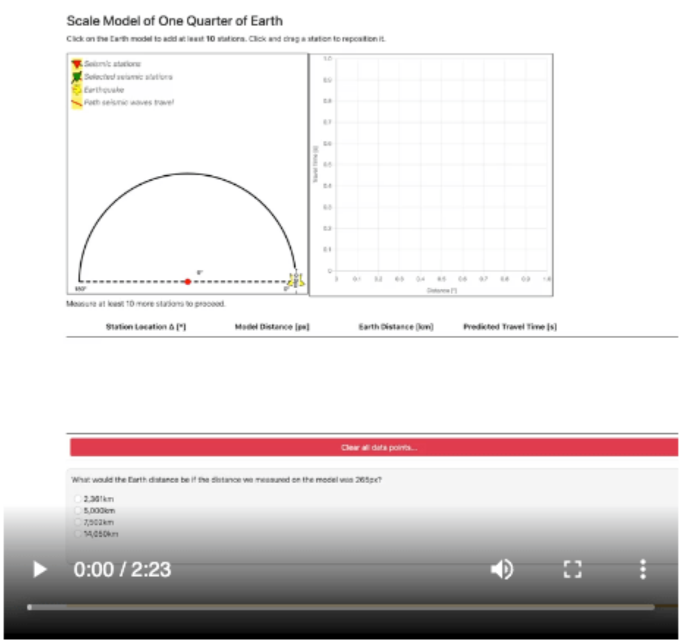
We want to build a model that will determine how long it should take seismic waves to travel from an earthquake to various distances around Earth if it is comprised entirely of the rock we see at the surface.
Which of the following information should be included as a parameter in the construction of our model that will help answer this question? (Select all that apply)

- ☐ There are three types of seismic waves
- ☐ Seismic waves travel at ~11km/s in rock
- ☐ Earth is roughly spherical with an average radius of 6371 km
- ☐ A 3m long slinky can be used as a model for how seismic waves propagate

Build your model by putting the following steps into the proper sequence. The model should allow you to solve for how long it should take seismic waves to reach various distances around Earth if it is homogeneous.

- ☐ Divide the real Earth distance by 11km/s or the speed of seismic waves in rock
- ☐ Convert the distance measured on the model to an actual Earth distance
- ☐ Select a point on model's surface and measure how far it is from that point to the imaginary epicenter on the model
- ☐ Build a scale model of earth with a radius proportional to Earth's actual radius of 6371 km

Step 2: Using the model to predict travel times

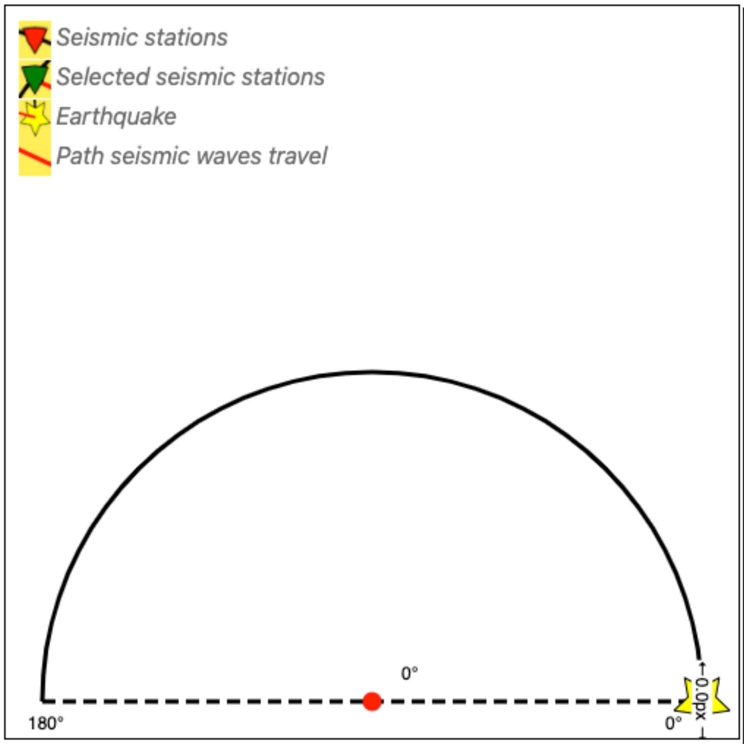


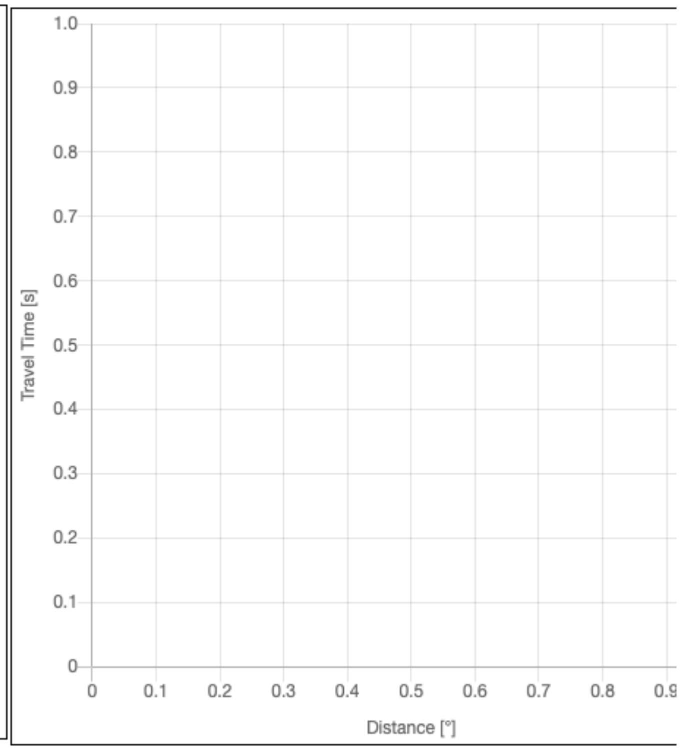
Now that you have built your model let's use it to determine how long it should take seismic waves to travel from an earthquake to various distances around Earth if it is homogeneous.

1. Select a point on model's surface by clicking on it to add a station. Note that you can adjust the position of a station you have added by clicking on it to select and then dragging it around.
2. Once your station is added to the model, its position, in degrees from the epicenter, will be recorded in the table below.
3. The distance of the travel path from the epicenter to the station (red line) will also be measured and reported in the data table.
4. Use the "Calculate" buttons in the data table to convert the distance in the model to an Earth distance, and to calculate the time it would take seismic energy to travel this path assuming an 11km/s velocity. Your results will be plotted on the graph.
5. Repeat this process for a total of at least 10 stations, that are evenly distributed across the surface of the model.

Scale Model of One Quarter of Earth

Click on the Earth model to add at least **10** stations. Click and drag a station to reposition it.





Measure at least 10 more stations to proceed.

Station Location Δ [°]	Model Distance [px]	Earth Distance [km]	Predicted Travel Time [s]

Clear all data points...

What would the Earth distance be if the distance we measured on the model was 265px?

- 14,050km
- 7,502km
- 5,000km
- 2,361km

What would the predicted travel time be if the Earth distance were 12,096km?

- 1450s
- 1100s
- 845s
- 600s

Compare Observed & Modeled Data

Background: To test our hypothesis, described below, you have already collected observations of when seismic waves arrive at stations around the earth as a seismologist. You have also worked as a Theoretician and used a model to predict when seismic waves should arrive at various points around the Earth.

Hypothesis: The Earth is comprised entirely of rock similar to what we see at the surface

Task: Your task is to compare the model data and the observed data to see if they match. If the two data sets match, then we can conclude that Earth is homogeneous or all rock throughout. However, if your observations do not match the seismologists' findings, than we can reasonably assume that the Earth is not homogenous or made entirely of rock and will need to develop a new model.

Step 1: Plot both data sets on the same graph

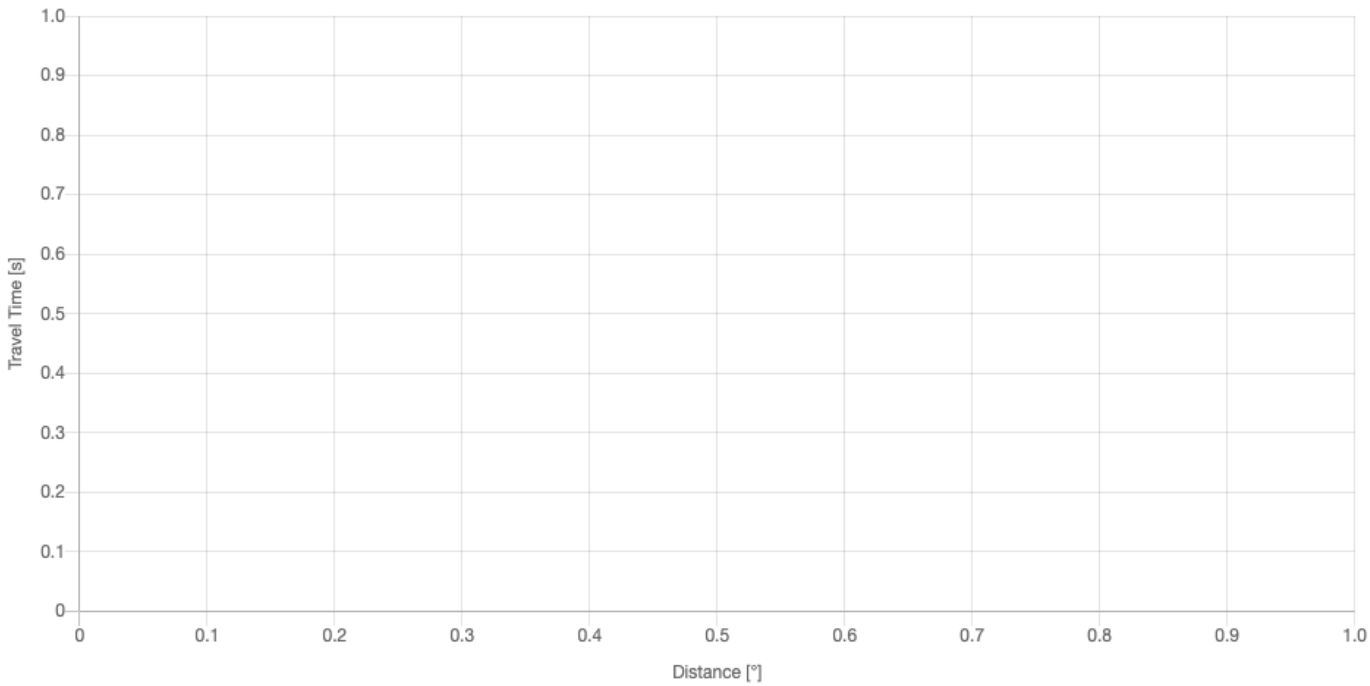
Use the button below to plot the travel times you observed from the seismograms above.

Plot Observed Data

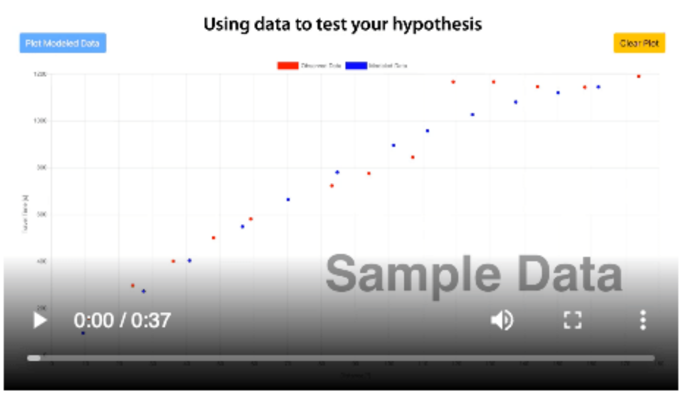
Then plot the predicted travel times that you generated from your model

Plot Modeled Data

Clear Plot



Step 2: Compare the data

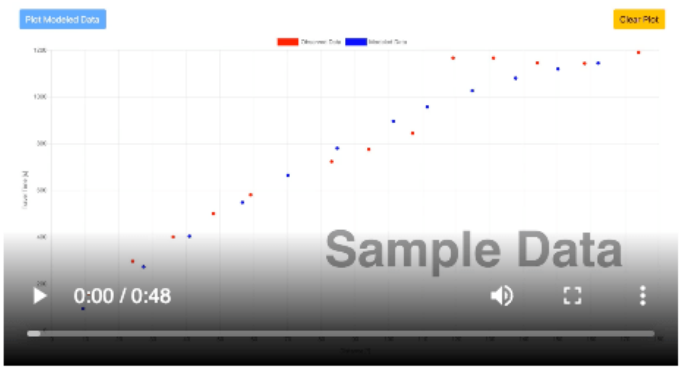


How does our model data match the observed data?

- ◯ The data sets are a perfect match
- ◯ The two data sets don't match

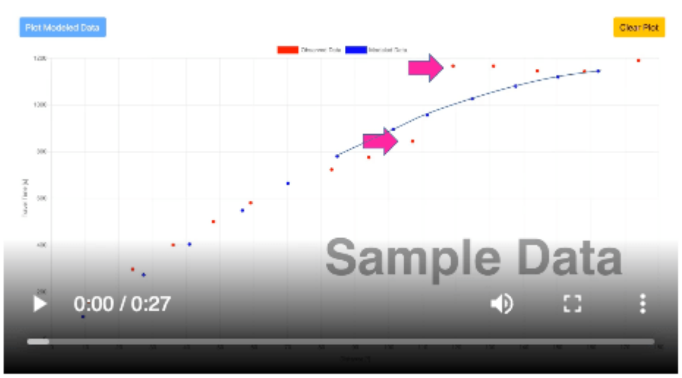
What does your answer above imply about our hypothesis that Earth's interior might consist of a homogenous material (e.g. rock) with a constant velocity of 11 km/s?

- ◯ Earth IS homogenous.
- ◯ Earth IS NOT homogenous.

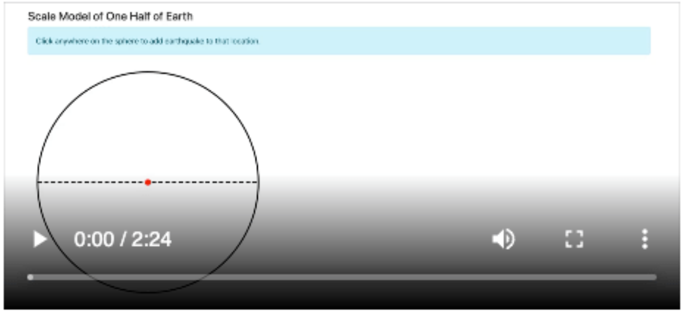


Examine your observed data again. After what distance, in degrees, do you see the noticeable jump in the arrival of seismic waves where they suddenly arrive much later than expected?

Brainstorm #4 What do you think might cause the seismic waves to arrive later than anticipated beyond the distance you identified above? Briefly describe some initial guesses you might have.



Step 3: Interpret the Results

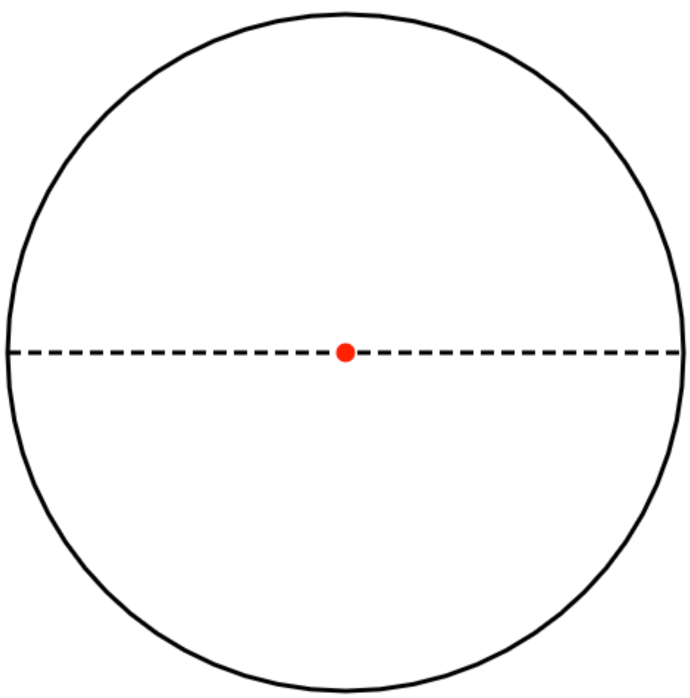


What might be causing the seismic waves to arrive late at this distance and beyond? One possibility is that something inside of the Earth is blocking the direct seismic waves, but some seismic waves still arrive just later than expected. This is similar to the way a tree blocks the direct light from the sun, but some light still falls behind the tree after bending around it and reflecting off other things.

We can test this idea by using another scale model Earth. This time we will plot the regions where the seismic waves arrive "on time" and "late" relative to one another.

Scale Model of One Half of Earth

Click anywhere on the sphere to add earthquake to that location.



Do we have enough information to define the shape of what might be blocking the seismic waves?

- No
- Yes

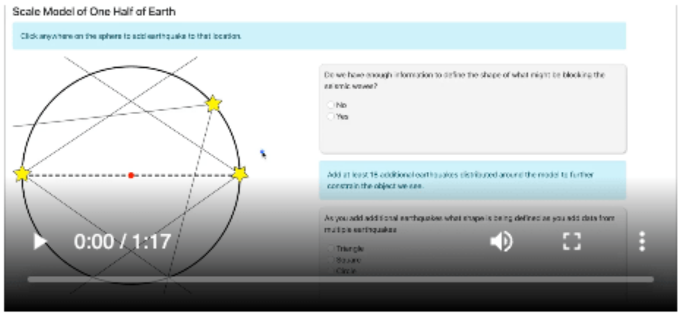
Add at least 20 additional earthquakes distributed around the model to further constrain the object we see.

Ruler ON

As you add additional earthquakes what shape is being defined as you add data from multiple earthquakes

- Circle
- Square
- Triangle

What do you think this inner circle represents?



Since we used a scale model, we can measure the size of the core you have discovered from the seismic data. To measure the size of the core turn “on” the ruler which will appear in the center of the model above. Drag the orange circle to measure the radius of the core (e.g. from Earth’s center to the edge of the circle you have defined with seismic waves. Once completed… compare your finding to the accepted value of Earth’s core.

What is the radius of object you just measured in Earth?

The difference between the radius you found and the accepted value can be expressed as the percent error using the following formula.

Vo = Observed Value

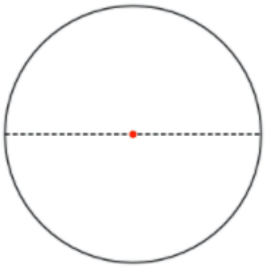
Va = Accepted Value = 3,486km

| Vo - Va | / | Va | * 100% = Percent Error

What is your percent error? You may use scrap paper, a calculator, or this online tool to solve.

Congratulations !

You have used seismic waves from the M earthquake that occurred on near to discover and measure Earth’s core!

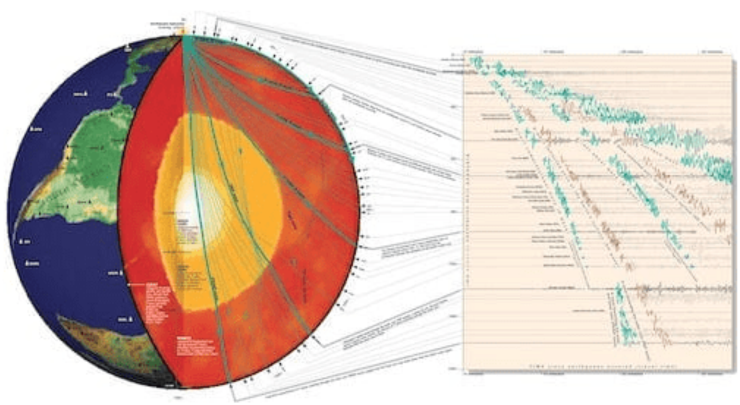


You observed changes in seismic wave propagation at ~° from the earthquake. Using this you calculated that the radius for the core was km.The currently accepted radius of Earth's core is 3486km. That means that your response was within % of this!

Discovery of Earth’s Core

Although Earth’s core had been previously inferred from the Earth’s gravity, Irish geologist Richard Oldham, provided the first direct evidence that the Earth had a central core in 1906. Using a process similar to the lab you just completed, he examined the arrivals of the P waves from a number of earthquakes that occurred in different locations on Earth. Oldham saw a change in seismic arrivals at ~120° and concluded that the radius of the core was 40% of the radius of Earth... or ~2548km. While this measurement differs from what you calculated (and todays accepted value)... you were using seismograms from seismic stations that are far more sensitive than those available when Oldham was alive.

Earthquakes create seismic waves that travel through the Earth. By analyzing these seismic waves, seismologists can explore the Earth’s deep interior. On January 17, 1994 a magnitude 6.9 earthquake near Northridge, California released energy equivalent to almost 2 billion kilograms of high explosive. The earthquake killed 51 people, caused over $20 billion in damage, and raised the Santa Susana Mountains north of Los Angeles by 70 centimeters. It also created seismic waves that ricocheted throughout the Earth’s interior and were recorded at geophysical observatories around the world.



The paths of some of those seismic waves and the ground motion that they caused are shown below. On the right, the horizontal traces of ground motion (seismograms recorded at various locations around the world) show the arrival of the different seismic waves. Although the seismic waves are generated together, they travel at different speeds. Shear waves (S waves), for example, travel through the Earth at approximately one-half the speed of compressional waves (P waves). Stations close to the earthquake record strong P, S and Surface waves in quick succession just after the earthquake occurred. Stations farther away record the arrival of these waves after a few minutes, and the times between the arrivals are greater. At about 100 degrees distance from the earthquake, the travel paths of the P and S waves start to touch the edge of the Earth's outer core. Beyond this distance, the first arriving wave — the P wave — decreases in size and then disappears. P waves that travel through the outer core are called the PKP waves. They start to appear beyond 140 degrees. The distance between 100 and 140 degrees is often referred to as the “shadow zone”. We do not see shear (S) waves passing through the outer core. Because liquids cannot be sheared, we infer that the outer core is molten. We do, however, see waves that travel through the outer core as P waves, and then transform into S waves as they go through the inner core. Because the inner core does transmit shear energy, we assume it is solid.

You used seismic waves to detect and measure Earth's core. What else do seismic waves tell us about Earth's core?

- ○ That it is cold
- ○ That it is molten
- ○ That it is hollow
- ○ That it is lava

"Candling" an egg is the process of holding a light or candle near the egg to see the inner contents. It is used to see whether the egg is fertile or not. Describe how the process of candling might be similar to exploring Earth's interior.

What are two other things you learned from this reading?

What are two questions that you have about Earth's interior after the reading?

Download your certificate of completion and answer sheet below.

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