EARTHQUAKES

WHAT IS THIS?

This activity pack will help you discover the topic of earthquakes and seismic waves. You will find out what causes an earthquake, the dramatic effects they have and what they can tell us about the Earth's deep interior.

These activities have been designed for Years 9 – 11 but they also include challenging activities that would be suitable for Years 12 – 13. Younger students are encouraged to use these activities and skip any tasks that are too challenging.

The activities all build from each other and we recommend that you follow them in order. This will give you a detailed insight into the world of seismology (that's the study of seismic waves). However, if you'd like to attempt any one of the activities on its own – go ahead! Just be aware that you might need to look back at previous worksheets to find out the answers to some of the questions. We have also included challenging optional activities (1b and 2b) if you want to put your geophysics skills to the test!

WHAT DO I NEED?

You will need a pen, pencil and ideally you will also need access to a printer. If you do not have a printer many of our activities can be completed on your computer using PDF annotation software such as Notability, Foxit, PDF Annotate & Fill plus many more.

The experiments and building challenges will require items from your home. We will give alternatives to make them as accessible as possible but if you don't have access to the correct equipment don't be afraid to be creative – as long as it is safe and you have checked with an adult first. If you have an idea for alternatives to any of our experiments or if you think your creation is particularly nifty we'd love it if you'd share it with us on Twitter @GeoBus_UCL but make sure you check with a parent or guardian first.

You may also need to use your school notes, books and the internet to help you complete the activities and challenges, but if you're really stuck, you'll also find answer packs on the GeoBus website (but no peeking until you've had a go first).

WHAT ARE THE ACTIVITIES?

Activity	Equipment	Time	Difficulty
1. Seismic Waves and Seismographs	Pen, paper, box, scissors, string, cup, coins	60 - 90 minutes	Medium
1b. The Epicentre of an Earthquake.	Pen, paper, scissors, string, Blu-Tac, sticky tape, ruler	45 - 60 minutes	Challenging
2. The Structure of the Earth	Pen, pencil, ruler	60 - 90 minutes	Medium
2b. Trace the Seismic Waves	Pen or pencil	15 - 30 minutes	Challenging
3. Building a shake-proof home	Scissors, box, marbles/pens, building materials	45 - 60 minutes	Easy

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Seismic Waves and Seismographs

The surface of the Earth is split up into tectonic plates. Tectonic plates move slowly and can grind past each other, pull apart and crash into each other. Friction can cause the plates to stick together at the edges. Eventually the rocks holding the plates together will break, releasing energy in the form of **seismic waves.**

Seismic waves cause the ground to shake which we feel as an **earthquake**.

What are waves?

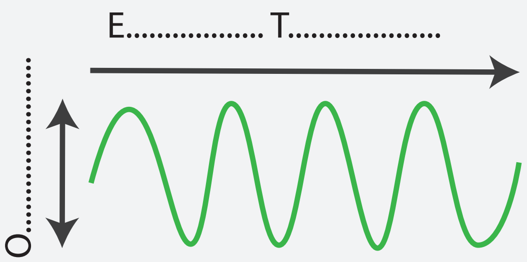
Waves transport energy, not matter.

How many different types of wave can you think of? Sound, light ...? All of these waves transfer energy from one place to another. When you speak and produce sound waves, you vibrate air particles, which causes the particles next to them to vibrate and so on (electromagnetic waves such as light behave quite differently). In both cases, it is the energy that is being transferred not the particles (matter).

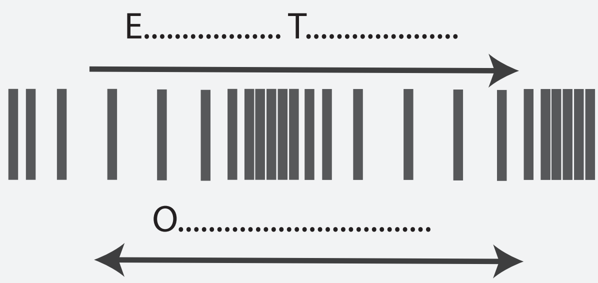
There are two types of waves: **transverse and longitudinal**.

Use the Seismic Keywords at the bottom of the page to fill in the gaps below and show the differences between transverse and longitudinal waves.

Transverse Waves



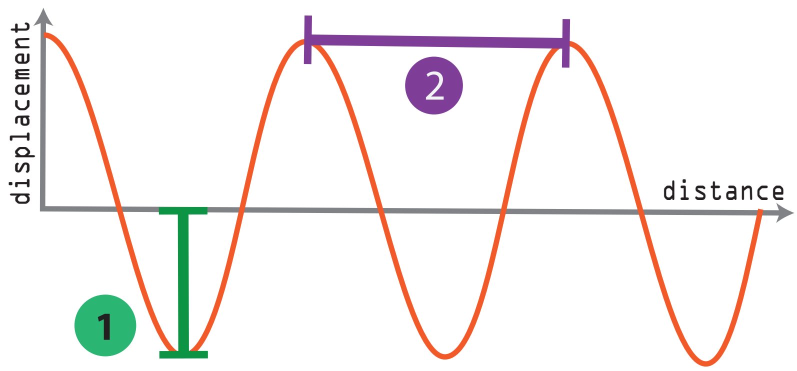
Longitudinal Waves



There are two types of seismic wave; P (primary) and S (secondary) waves.

P waves are longitudinal waves.
S waves are transverse waves.

Don't forget that all waves have the same set of terminology. Use the Seismic Keywords to identify the wave properties in the diagram below.



1 A ....

2 W ....

Seismic Keywords

energy transfer
oscillations
amplitude
wavelength

How do we measure seismic waves?

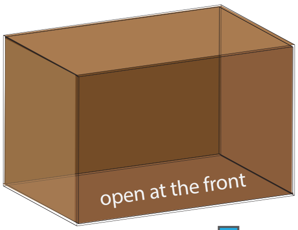
Earthquakes are an unpredictable and dangerous natural hazard that can affect millions of people. Scientists that study earthquakes and seismic waves are called **seismologists.** They use seismometers to detect and measure seismic waves.

Put your seismology skills to the test and follow the instructions carefully to **build your own seismometer.**

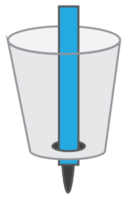
Equipment:

Pen or Pencil
Coins/Pebbles
Scissors
String (or twine, shoe lace)
Cardboard box
Paper
Sticky Tape
Paper or plastic cup

Step 1: Take a cardboard box (roughly square, although a cereal box works well too) and turn it onto its side so that the opening is at the front (or cut off the front side if using a cereal box).

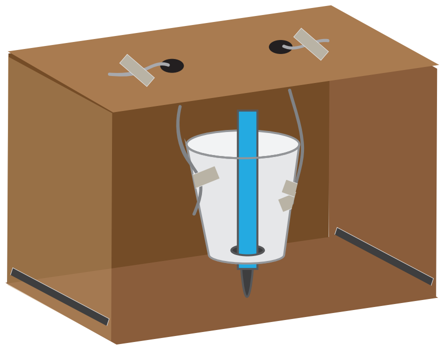


Step 2: Cut a small hole in the bottom of the cup, large enough that the tip of your pen can poke through.



Step 3: Cut two holes in the top of your box.

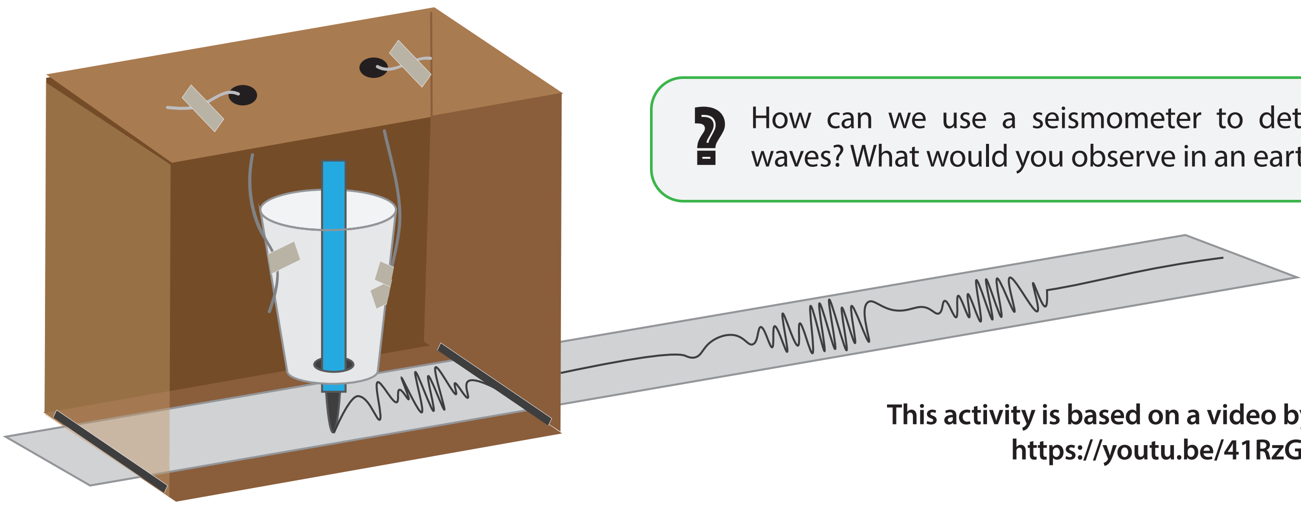
Step 4: Secure a piece of string to either side of your cup using sticky tape. Thread the two pieces of string (attached to either side of your cup) through holes in the top of your box and secure using sticky tape. The cup will need to hang low enough such that your pen will lightly touch the bottom of the box. Once your pen is in place, add coins/pebbles/weights to your cup to weigh it down and keep it steady.



Step 5: Finally, using scissors, carefully cut small slits in either side of the box (wide enough to thread strips of paper through). Your seismometer is now ready to go!

Step 6: It's time to measure an earthquake. Cut an A4 piece of paper into long strips and stick them together to create one long strip. Thread the paper through the two slits in your box, making sure your pen is resting on the paper. Slowly pull the strip of paper past the pen at the same time as shaking the box forward and back. You'll notice the pen starts to jump around and draw a wave pattern on the paper!

When the box is stationary the line of pen will stay flat. As soon as the box starts to shake, the pen will swing back and forth and creates waves on your paper. If you shake the box more, the amplitude of the wave will increase.



? How can we use a seismometer to detect seismic waves? What would you observe in an earthquake?

This activity is based on a video by Science Buddies!
https://youtu.be/41RzGwZINOk

What does a seismic wave look like?

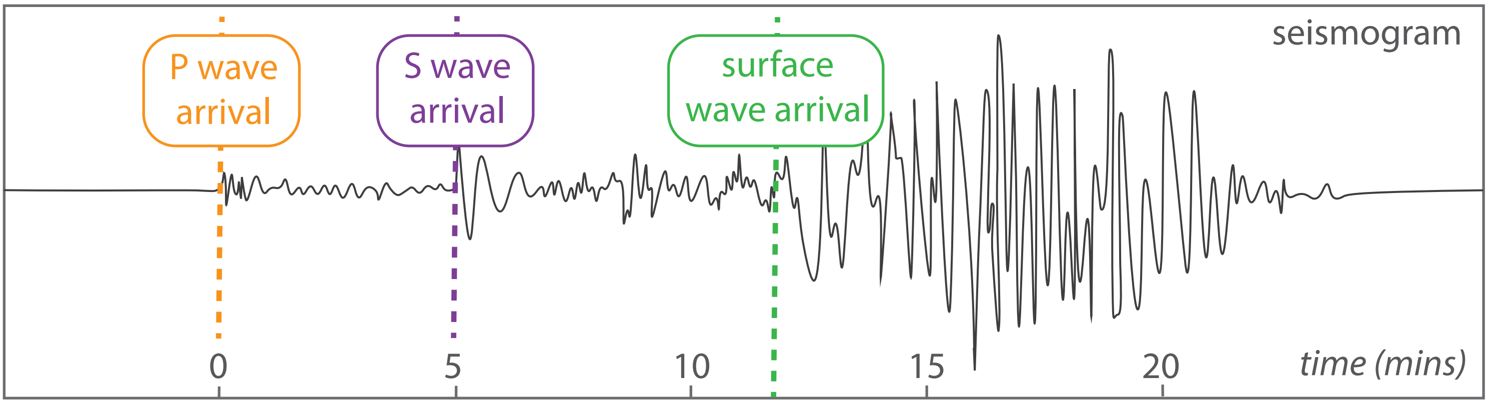
Seismograms can not only be used to detect if an earthquake is happening, but can also be used to locate the epicentre of an earthquake. Different seismic waves arrive at different times. There are many types of seismic wave (not just P and S) such as surface waves.

Use the seismogram below to answer the following questions:

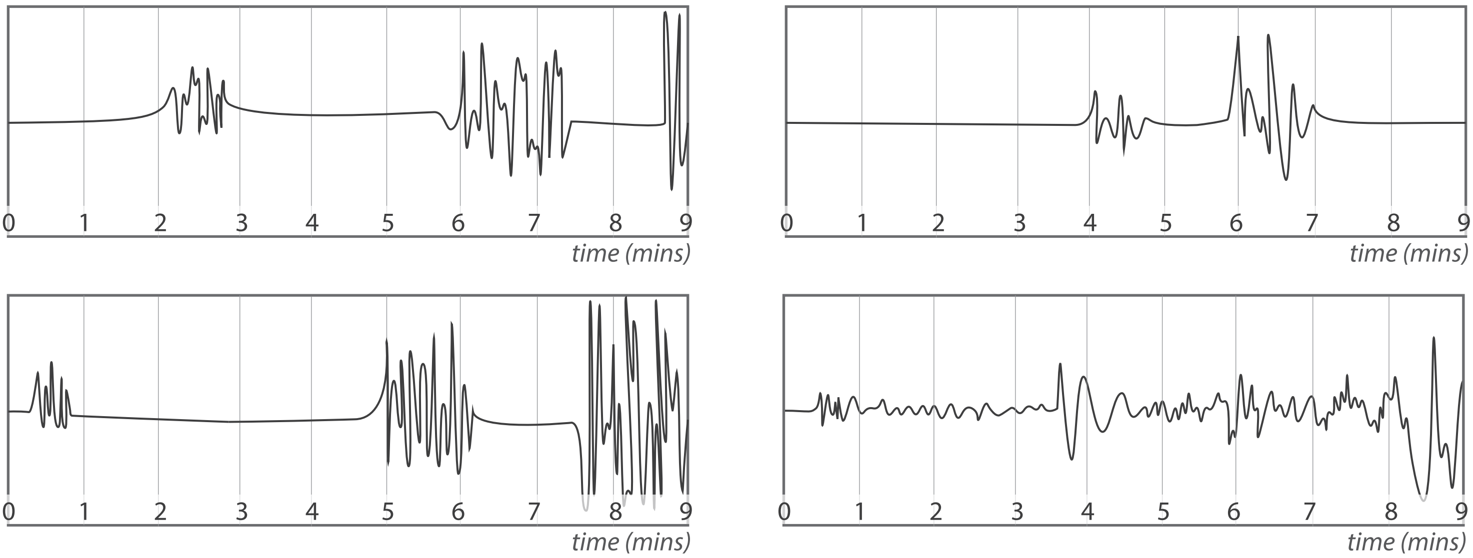
1. Which wave arrives first? ....

2. What is the time difference between the arrival of the P and S waves? ....

3. Which wave is fastest? ....



4. Identify the P and S wave arrival times on the seismograms below.



5. Summarise everything you've learnt so far by filling in the gaps in the paragraph below.

The shaking experienced during an earthquake is caused by seismic waves. Seismic waves travel outwards from the epicentre through the Earth in all directions. The first wave to arrive is a .... wave (primary wave). Primary waves are .... The second wave to arrive is a transverse wave called .... or secondary waves.

Why might P waves travel faster through the Earth than S waves?
Could this be due to differences in transverse and longitudinal waves?

The Epicentre of an Earthquake

The epicentre of an earthquake is the location on the Earth's surface directly above the origin or focus of the earthquake (as this is usually deep underground).

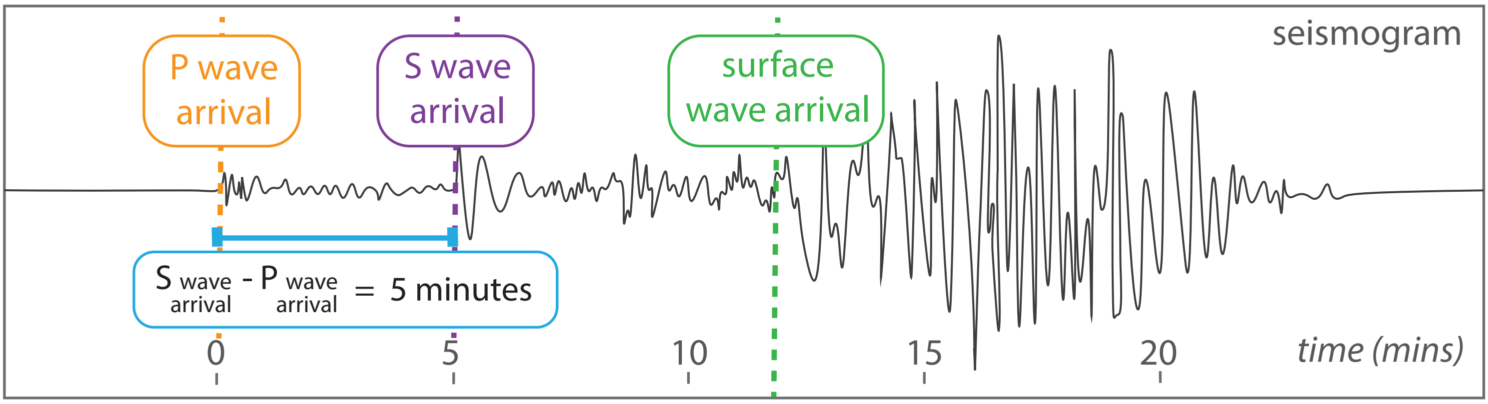
To locate the epicentre of the earthquake we need to know how far away it is and in what direction.

Earthquakes produce seismic waves called P and S waves. P waves and S waves travel through the Earth at different speeds and and will arrive at different times.

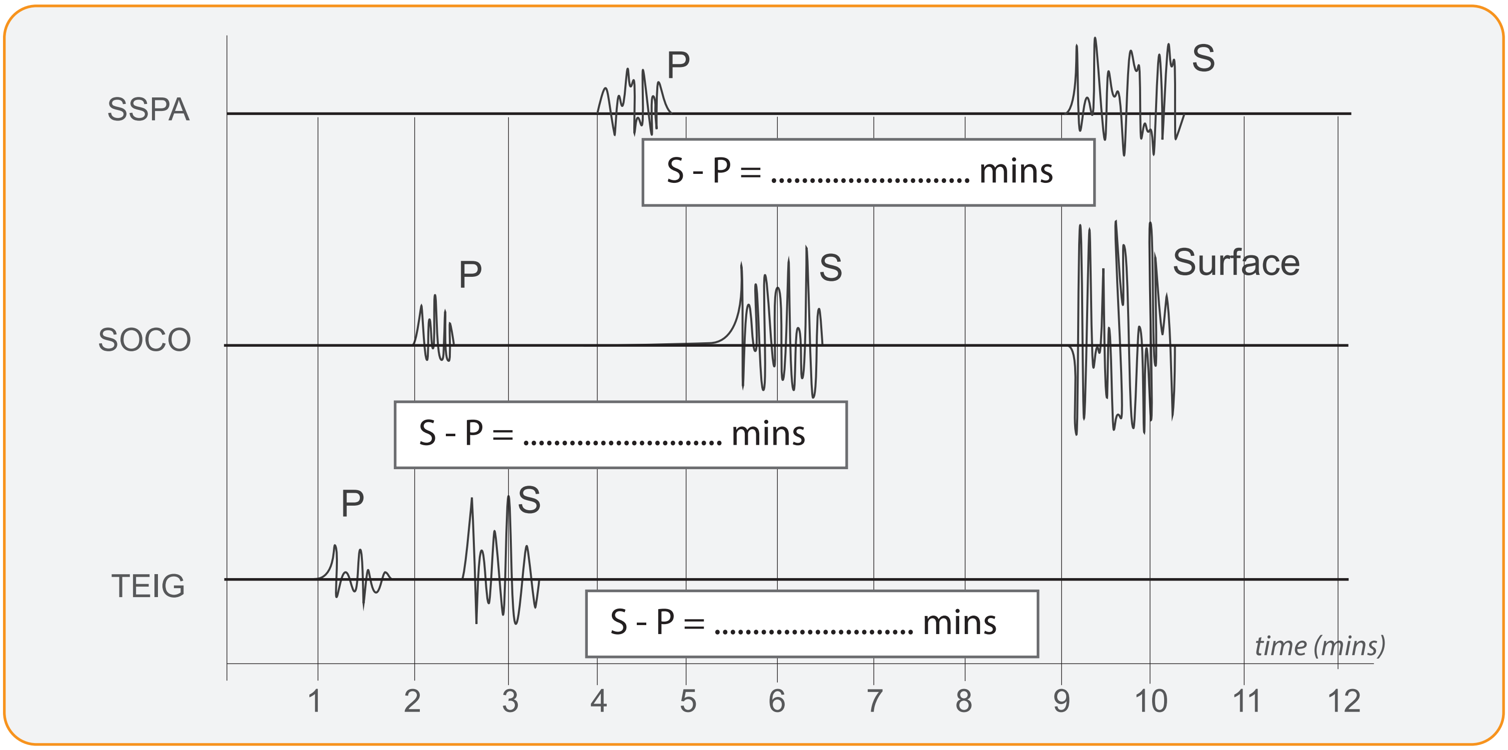
A P wave will arrive first and an S wave will arrive second.

Part 1: Find the time

The time difference between the arrival of the P wave and S wave can be used to calculate the distance of the earthquake epicentre from the seismometer (and hence seismic recording station itself).

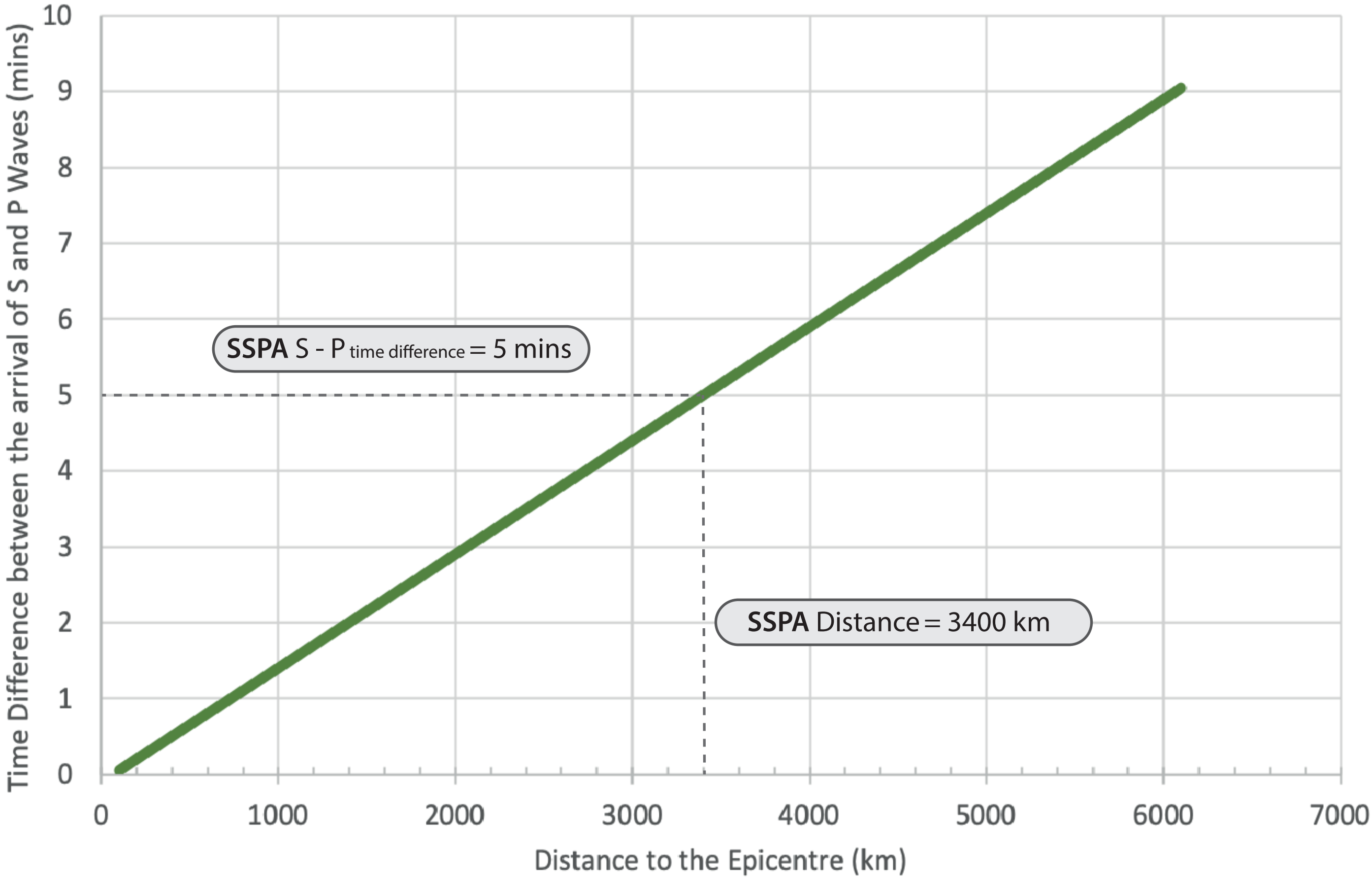


Use the example above to help you measure and record the time difference between the arrivals of the P and S wave at the three seismic recording stations (SSPA, SOCO and TEIG) on the seismogram below.



Part 2: Find the distance

The graph given below shows a general plot of S – P time difference against distance to the earthquake epicentre. Use this graph and your S – P time differences to work out the distance of each seismometer from the epicentre. The SSPA seismic station has been done for you.



Seismic Station	Time Difference (mins)	Distance (km)
SSPA	5	3400
SOCO		
TEIG		

Part 3: Set up the map

Step 1: For this activity you will need to use the map on page four. You have three seismic stations on your map, SSPA, SOCO and TEIG. Find each one and put a small blob of blu tac on each location (on top of the star).

Step 2: Look at the scale in the bottom left corner of the map. Use it to work out how many centimetres would represent 1000 km of the map. NB: This scale factor is correct for A4 paper, other paper sizes might change this a bit.

Equipment:

Pen or Pencil
Paper
Scissors
String (or twine, shoe lace)
Blu-tac
Sticky Tape

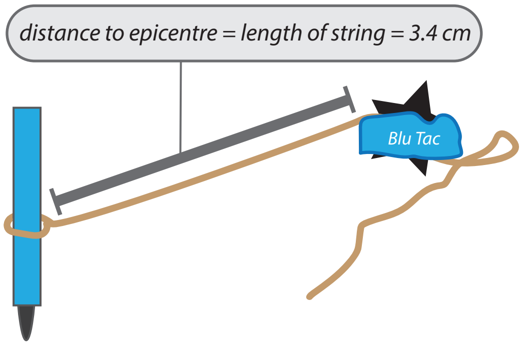
Use the scale factor on the map to calculate how many kilometres are represented by 1 cm on your map.

1 cm = ... km

Part 4: Find the epicentre

Step 1: Using the scale on the map (e.g. 1 cm = 1000 km), work out the length of string needed to represent the distance of each seismic station to the epicentre (e.g. for SSPA, 3400 km would be scaled to 3.4 cm of string).

Step 2: Now is time to create a compass. If you have a compass already - you can of course use that instead!



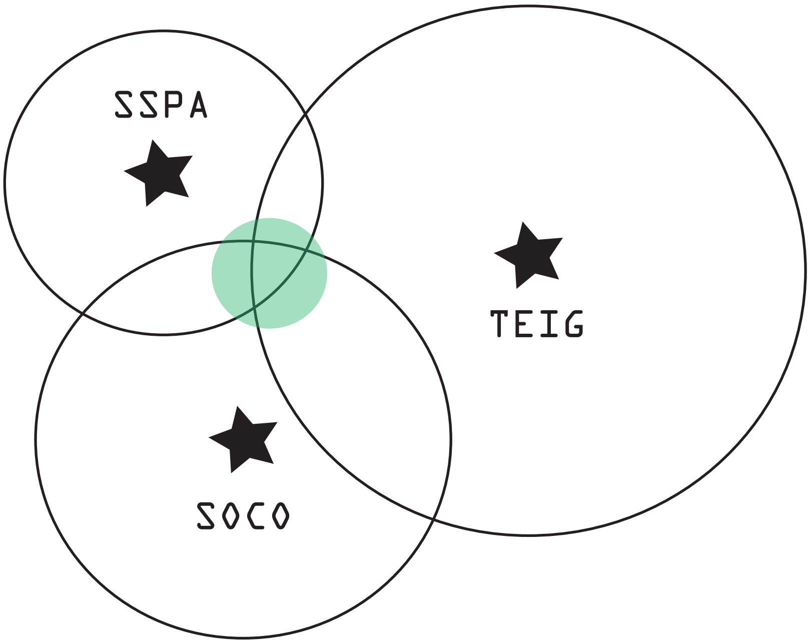
Take your pen and a long length of string. Tie a loop in the end of the string so that your pen fits inside the loop (stick to the pen using sticky tape if needed).

Measure the correct length for one of the three seismic stations (SSPA, TEIG or SOCO) and stick the opposite end of the string to the blu tac on the matching seismic station.

You might be asking why you need to create a compass to calculate the epicentre. This is because although you have calculated the distance from the seismometer to the epicentre, you don't know which direction it is in. By drawing a circle at the scaled distance around the seismic station, you know that the epicentre will be somewhere on the edge of the circle.

Step 3: Use your compass to draw a circle round the station. Repeat this for each seismic station, remeasuring the string so that it is the correct length for each seismic station.

Where all three circles overlap is the epicentre of the earthquake! (green circle)



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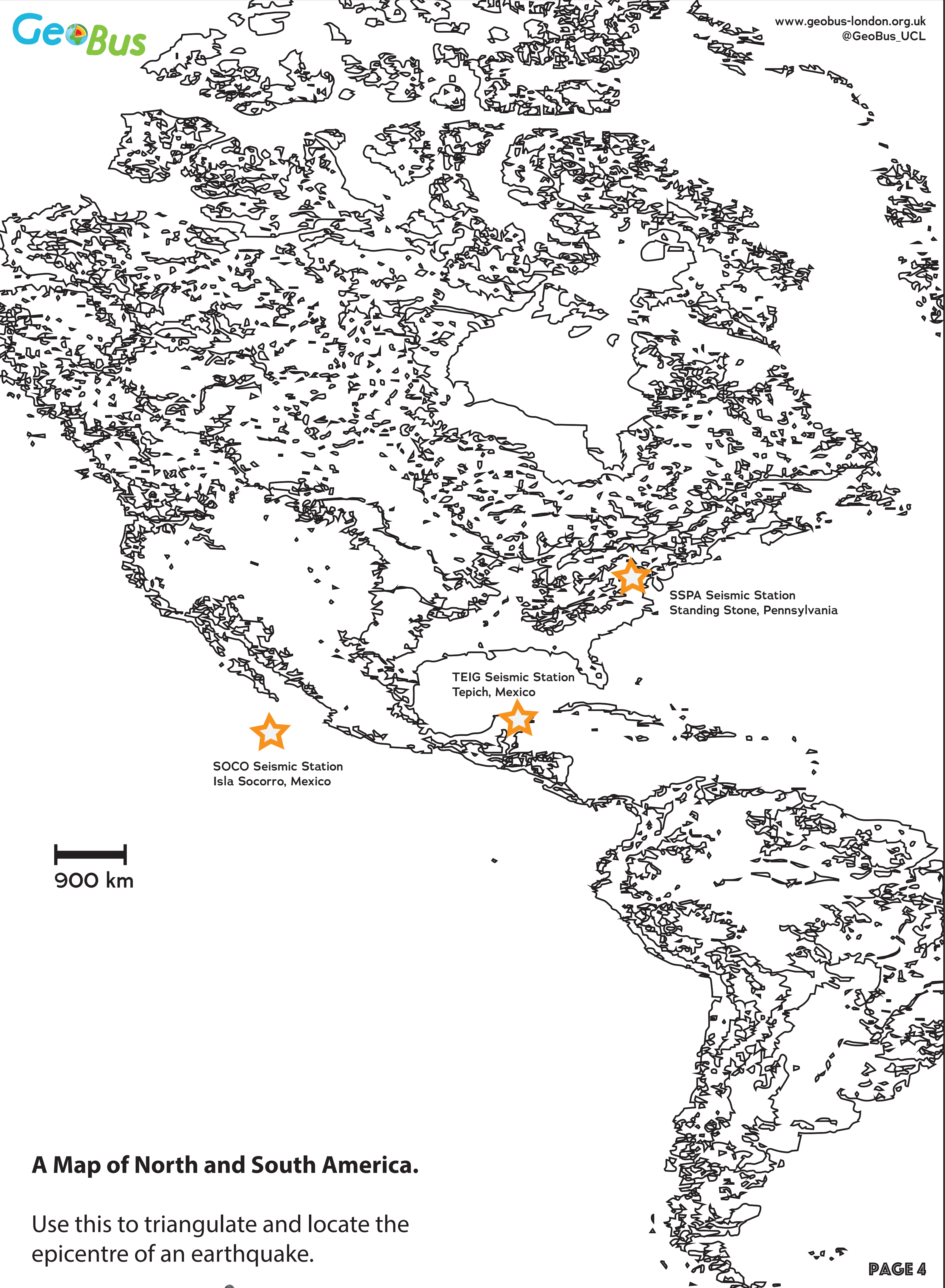


A Map of North and South America.

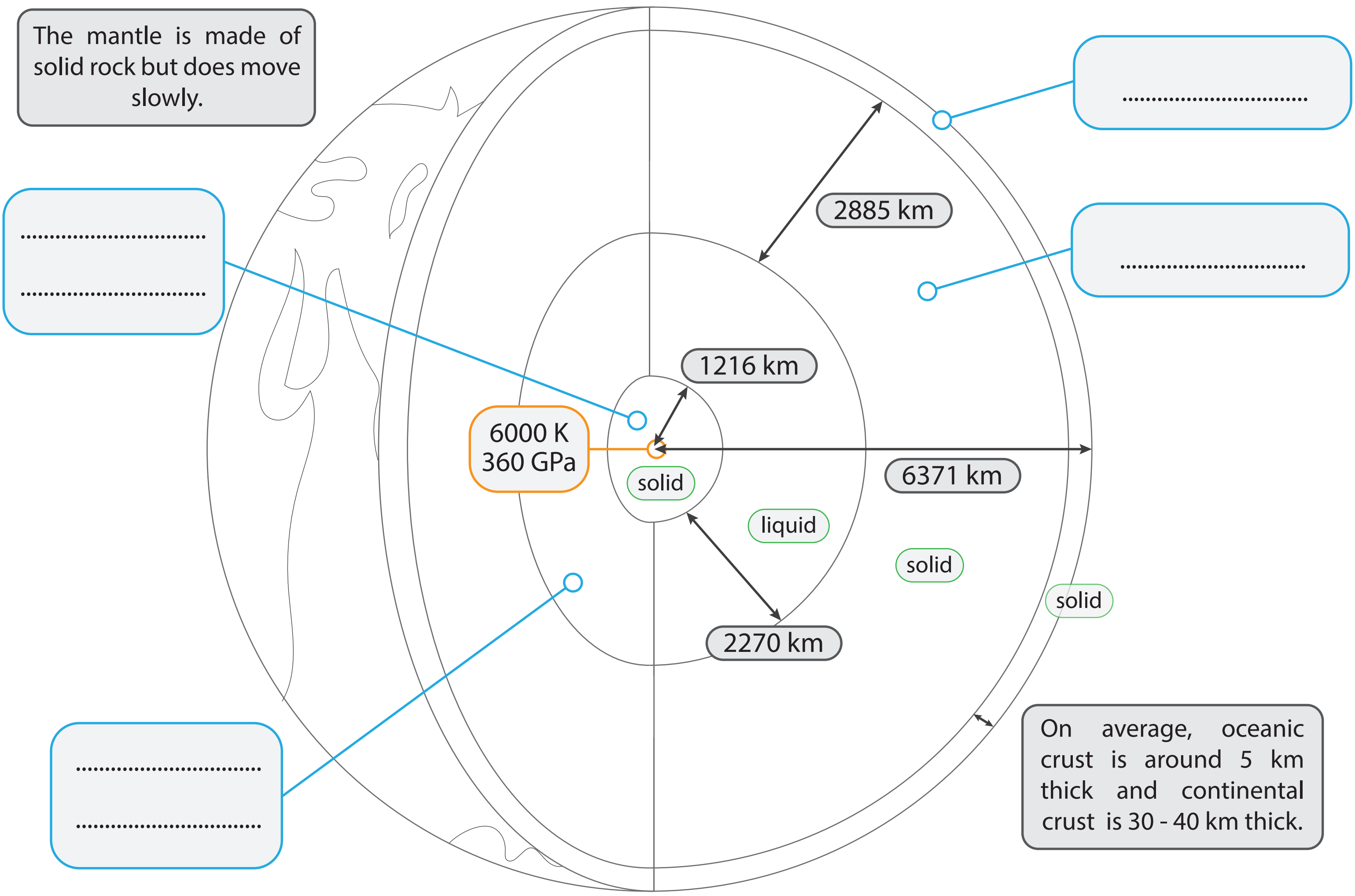
Use this to triangulate and locate the epicentre of an earthquake.

The Structure of the Earth

Our Earth is split up into layers.

The outer layer of the Earth (the one you are standing on) is called **the crust**. Below that you will find the solid **mantle** and right in the centre of the Earth you will find the core, split into the solid iron ball called **the inner core** and the surrounding liquid outer layer called **the outer core**.

Using the bold words in the text above to help you, fill in the missing names in the following diagram (in the blue boxes), then colour in your picture to create a labelled structure of the Earth.



In the diagram above you have identified the major layers in the Earth, but the question we are seeking to answer here is how do we know about them?

The deepest anyone has dug into the Earth is the Kola Superdeep Borehole, a 7.6 mile (12.2 km) deep hole that's 9 inch (23 cm) in diameter and can be found in Russia. But even at that depth it's still a long way to the centre of the Earth!

One of the major pieces of evidence for layers in the Earth comes from seismic waves.

Seismic Waves in the Earth

Use the previous activities and your notes to help you answer the following questions:

1. Which seismic wave is detected first on a seismometer? ....

2. What seismic wave (P or S) is a longitudinal wave?..

3. What causes an earthquake? ....

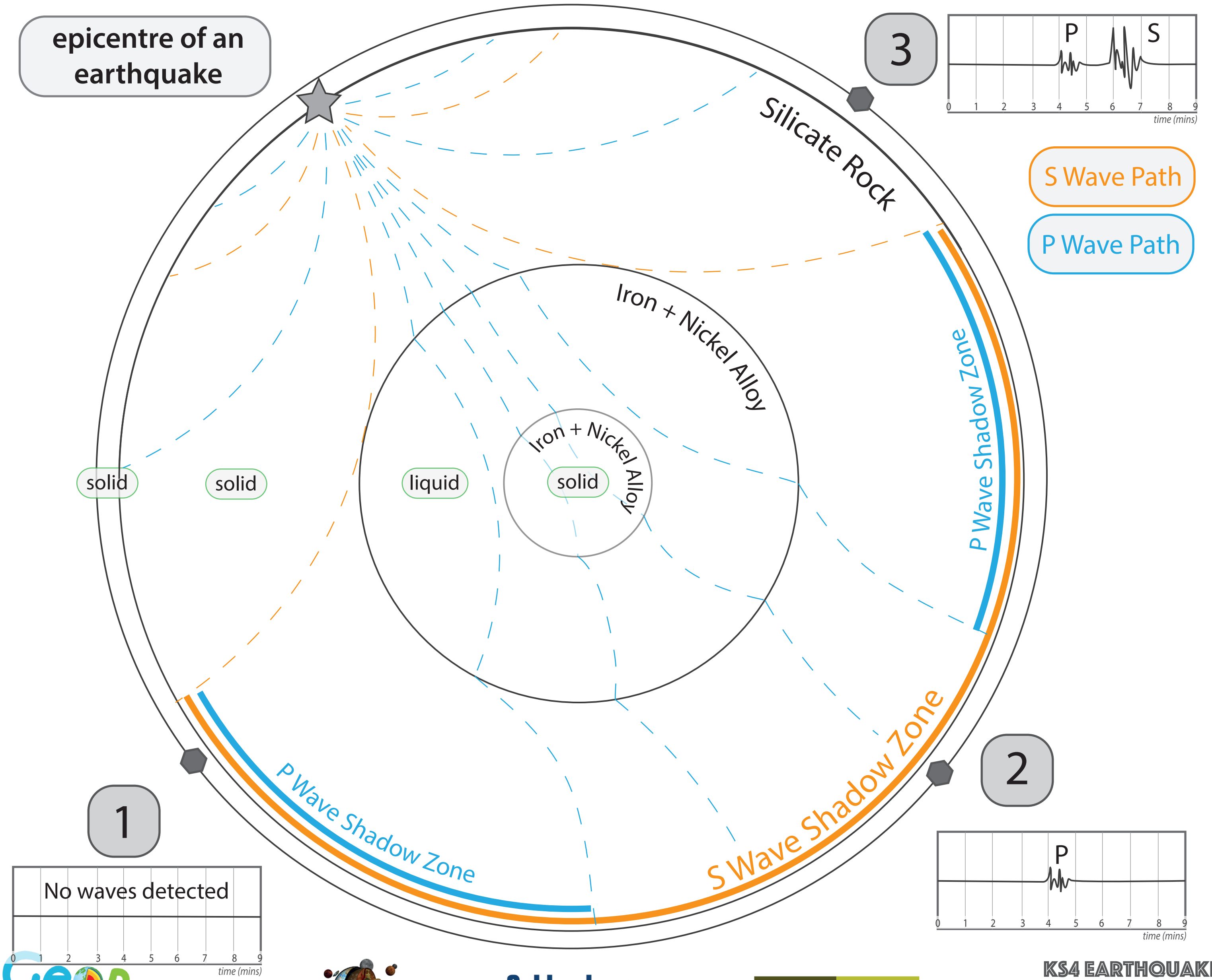
P waves are longitudinal waves that travel at different speeds inside the different layers of the Earth.

S waves are transverse and cannot travel through the liquid outer core.

Seismometers can then be used to identify the varying density and layers inside of the Earth.

When waves travel from one material into another with a different density, they change direction. At a boundary, waves can reflect, refract or become absorbed, so when they travel through the Earth they will form curved lines. *Seismic waves travelling through the Earth can also change into other waves, but more on that later!*

The dashed lines on the diagram below show the paths followed by S and P waves away from the epicentre of an earthquake and through the Earth. Seismograms show which seismic waves are detected at three points on the Earth. What do you notice?



The Shadow Zone

The S wave shadow zone is evidence for the Earth's liquid outer core.

Seismic S waves cannot propagate through liquids, and so they are not able to travel through the liquid outer core of the Earth.

The P wave shadow zone is caused by P waves refracting at the core-mantle boundary.

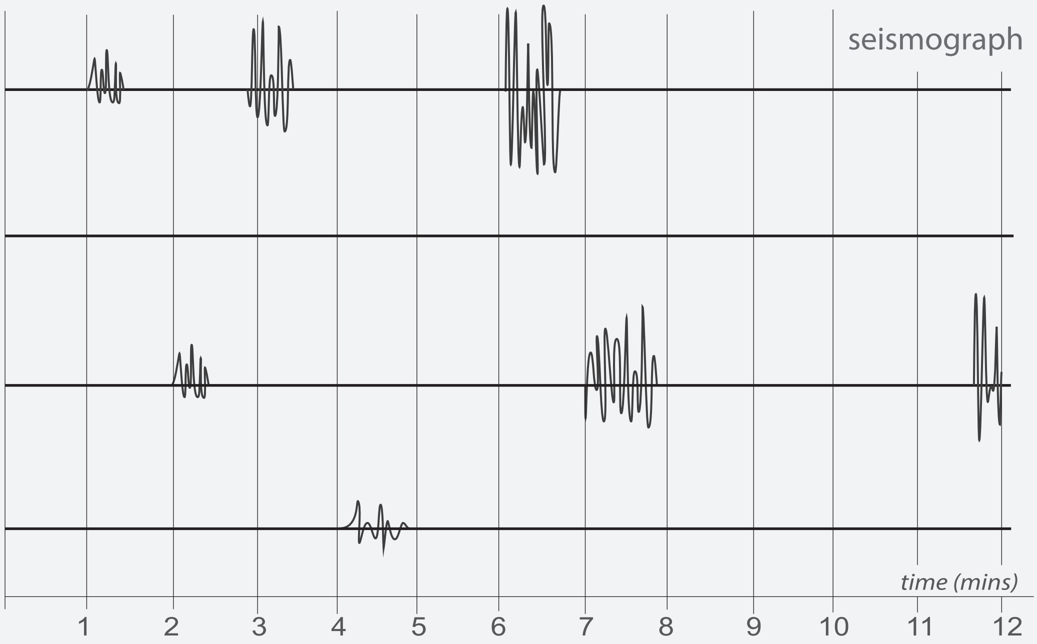
Put your sesimology skills to the test and match the seismic traces in the seismogram below to the correct seismic stations (A, B, C or D).
You will need to identify the seismic waves detected, the correct location and the S -P time difference (see Activity 1b for help) to correctly match all four stations.

Seismic Station ....

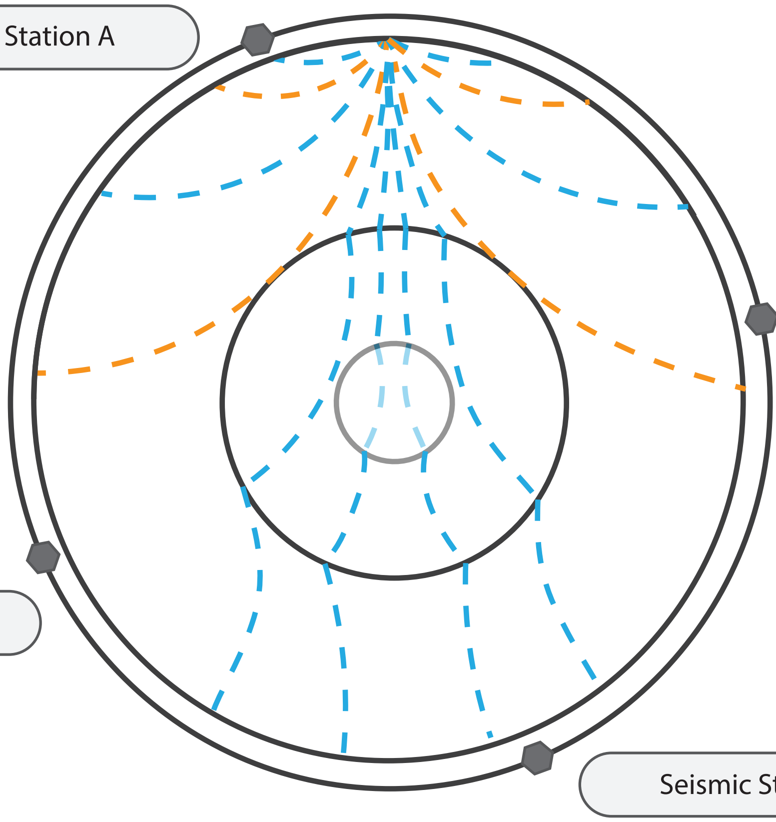
Seismic Station ....

Seismic Station ....

Seismic Station ....



When there is a short time difference in the arrival of P and S waves the epicentre is close to the seismic station.



When there is a long time difference in the arrival of P and S waves the epicentre is far away from the seismic station.

Create your own 3D globe

How to make your own globe:

Step 1: Cut along all the dashed lines (the outlines of the two shapes and along the edges to create tabs - these will be used for sticking the globe together!). Create folds along all the remaining coloured edges.

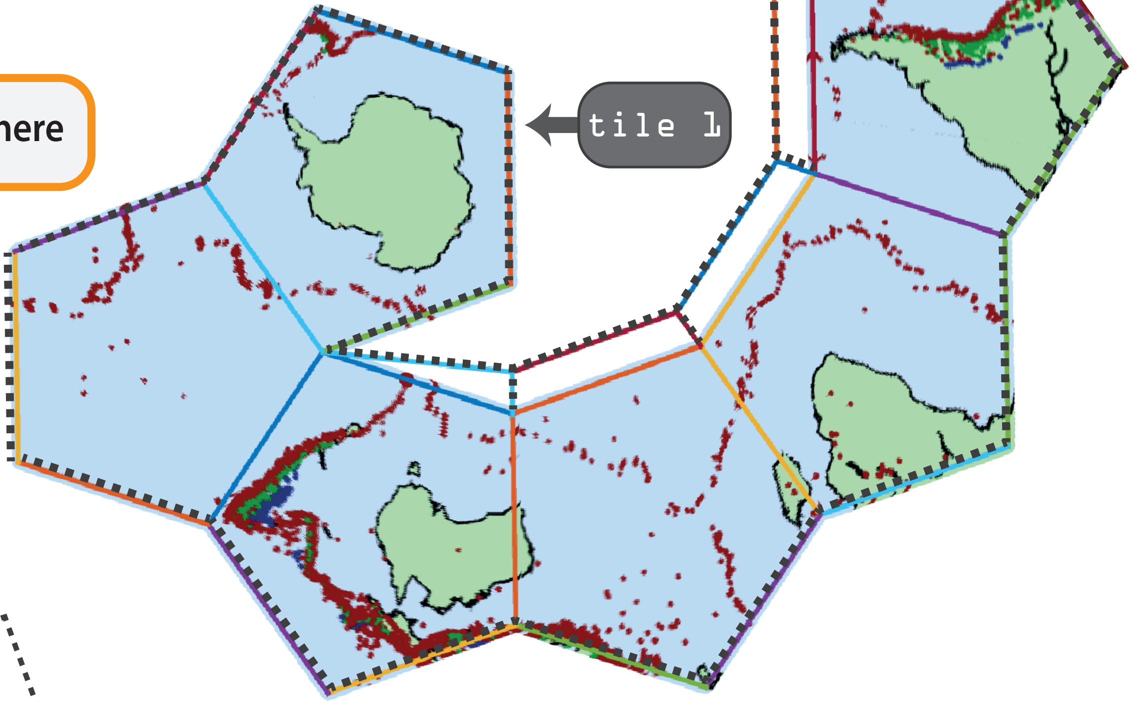
Step 2: Starting with the southern hemisphere spiral the polygons around tile 1.

Step 3: Use either glue or sticky tape to secure the polygon using the tabs (sticking them on the inside of the globe).

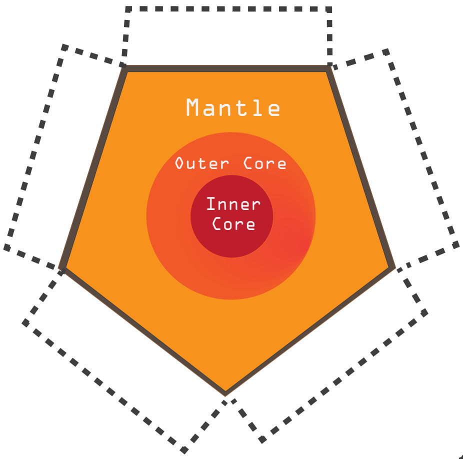
Step 4: Repeat steps 1 - 4 for the northern hemisphere, spiralling the polygons around tile 2.

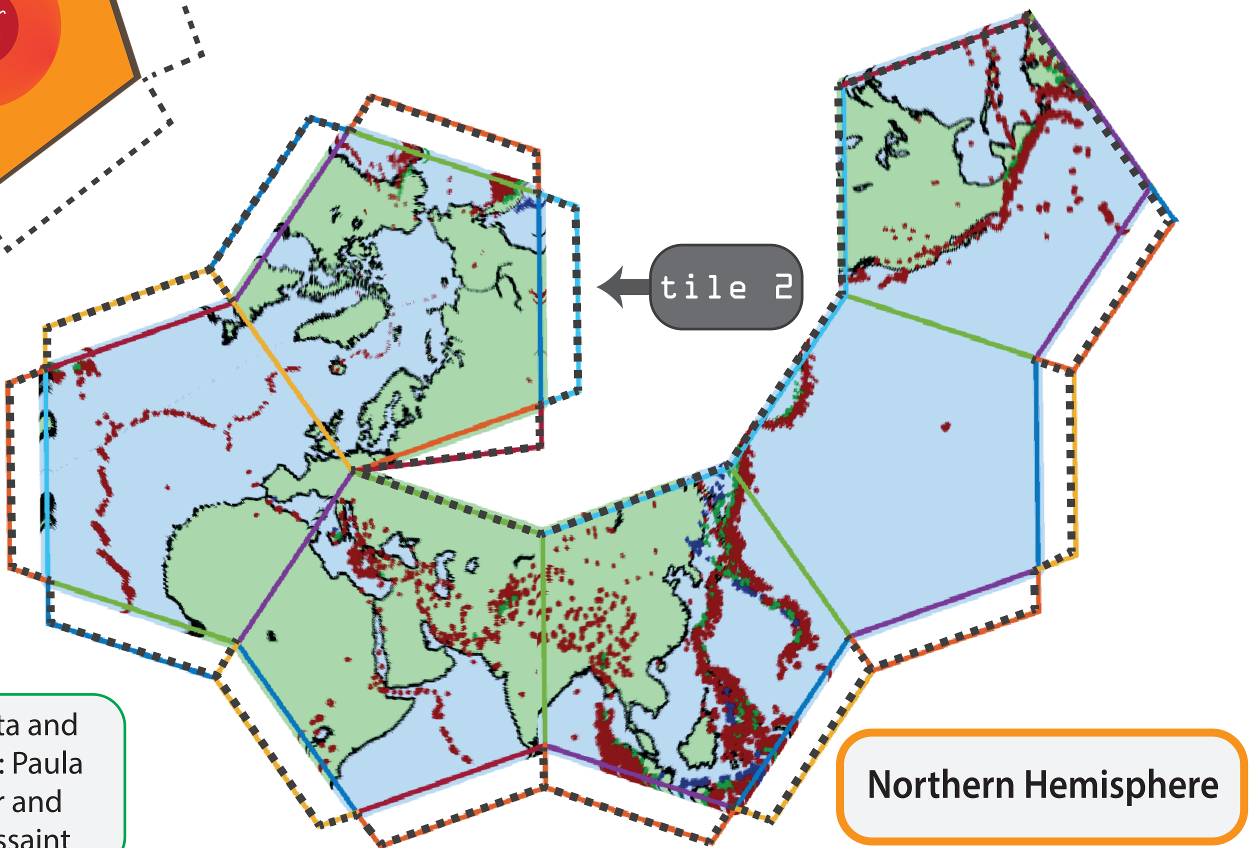
Step 5: Finally, cut along the dashed lines around the interior polygon. Fold the tabs under the polygon. Place this inside the southern hemisphere dome and it will stand inside (optionally you can glue the tabs to the dome - but this can be very tricky!).

Southern Hemisphere



interior polygon





Northern Hemisphere

3D Globe data and design credit: Paula Koelemeijer and Renaud Toussaint

Trace the Seismic Waves

When seismic waves travel through the Earth they will encounter different densities.

A change in density results in a change in velocity of the wave and causes seismic waves to refract, reflect or even convert into a different type of seismic wave!

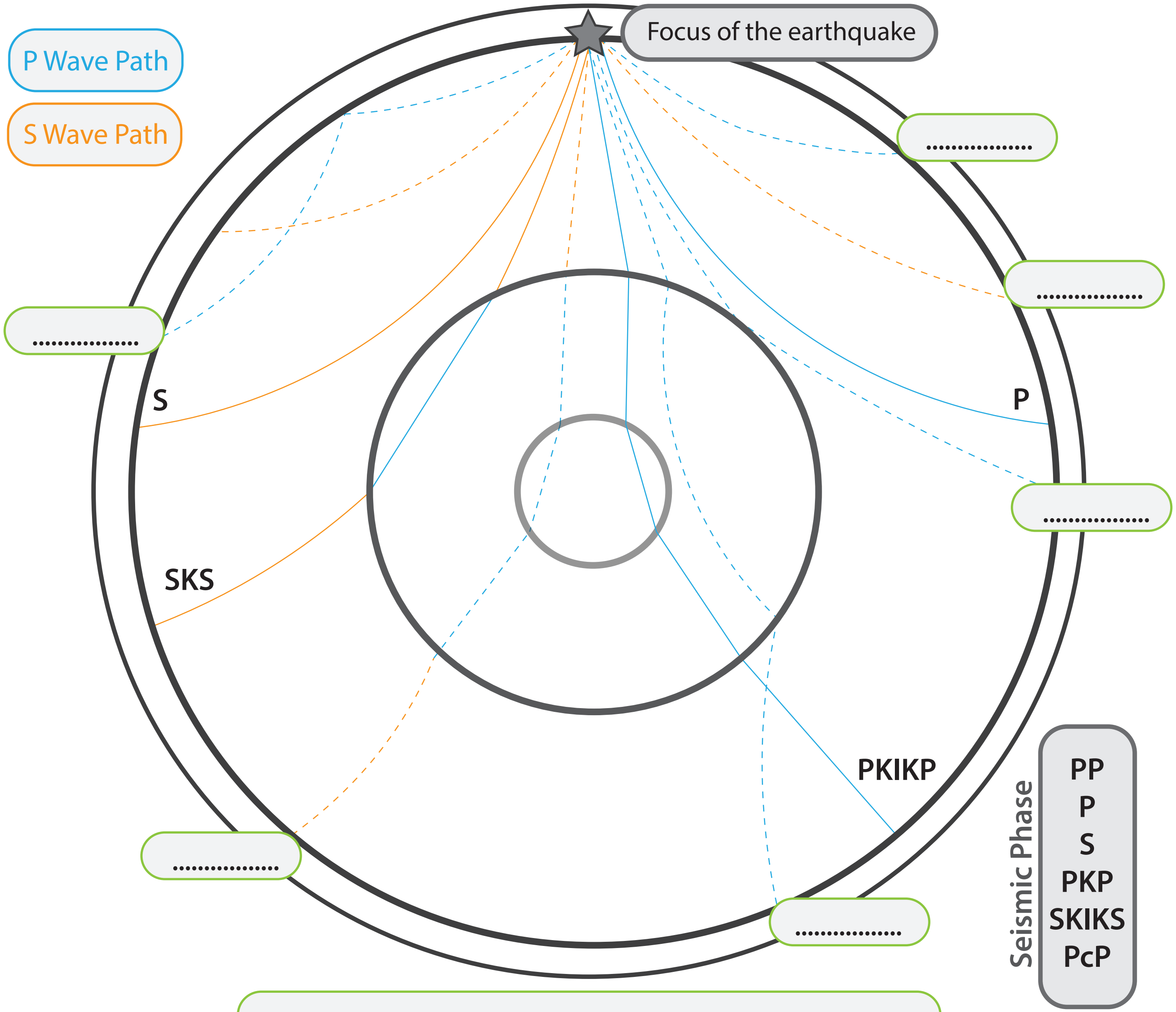
There are many possible paths a wave can take through the Earth, e.g. through the mantle, reflected off the core and then travelling through the mantle again. Each unique path will create a seperate seismic phase which can be identified on a seismogram.

A seismic phase can be decribed by one or more letters that describes its path through the Earth.

Seismograms can be used to identify P and S waves but also each of the seperate phases, so they can be used to identify waves and tell where that wave has been in the Earth!

Symbol	Definition
P	A P wave in the crust or mantle.
S	An S wave in the crust or mantle.
p	A P wave travelling upwards from the focus of the earthquake and reflected down from the Earth's surface.
s	An S wave travelling upwards from the focus of the earthquake and reflected down from the Earth's surface.
c	Reflection at the mantle-core boundary.
K	A P wave in the outer core.
I	A P wave in the inner core.
i	Reflection at the outer core-inner core boundary.
J	An S wave in the inner core.

Follow the seismic paths shown below and fill in the correct seismic phase in each box.
Use the table and examples shown to help you identify the seismic phases.



Challenge yourself: Draw the following seismic phases on the diagram above: pPcS, pSSS, PKiKP, sPcS, sSS.

Building a Shake-proof Home

Earthquakes are caused by rocks breaking underground.

When rocks break suddenly, seismic waves are generated. These travel through through the Earth and cause the ground to shake. Most earthquakes occur at tectonic plate boundaries, and they are a dangerous natural hazard. Large populations of people live along these boundaries, and so houses and large buildings must be built to withstand the shaking.

The challenge in this activity is to create and build your own shake-proof building, but before this can be attempted, you will need to create a shaking table to test your construction!

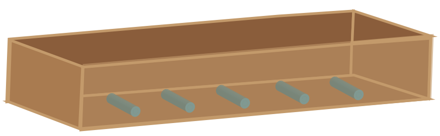
How to create a shaking test table

Step 1: Take a cardboard box (a cereal box works well for this) and cut off the front panel. Save the front panel of the box - you will need this later. Use sticky tape to secure the edges.

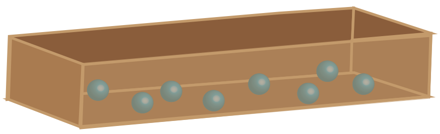
Equipment:

Pens/Pencils/Marbles/Tennis balls
Cardboard box
Scissors

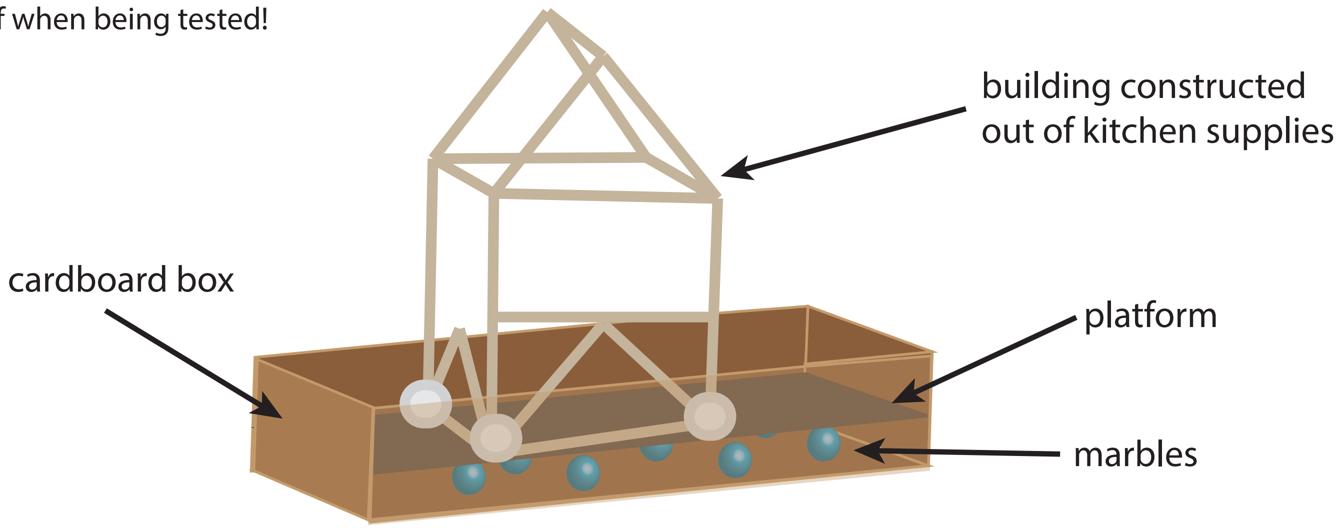
Step 2: Now add either marbles, pens/pencils or small bouncy balls to create an unstable layer in the bottom of the box. You don't need to add too many, just enough to create an unstable base.



or...



Step 3: Cut the front panel in half, such that it fits easily ontop of the marbles. This will create a platform to test your building (it will be very wobbly!). You will need to construct your building on top of the front panel (that you cut away from the box earlier). Make sure you secure it to the cardboard platform or it will immediately fall off when being tested!



Step 4: When you're ready to test, place your platform on top of the unstable base (pens, marbles, tennis balls etc). Then gently shake the box forward and back and side to side to put your building to the shake test.

Design and build your shake-proof home

Buildings that are prone to earthquakes are designed to protect them from collapse.

Engineers will determine the seismic risk for the building and will then need to consider this in the building design. In general, asymmetric or T shaped buildings are avoided as these can be prone to twisting! A very strong shape is the triangle. Triangular building shapesas well as the use of crossbeams and beams can be used to create very stable buildings.

Now it's your turn to create your own building. Gather your building materials. Think about the walls, will this be made out of lego, spaghetti, sweets, strips of cardboard, construction sticks... ? Then you will need something to connect and stick your materials together such as marshmallows, Blu Tac, soft gummy/foam sweets or many more.

Take inspiration from your gathered materials and design your building below. Use the internet to research famous buildings that are prone to earthquakes and see if their design helps inspire yours.

Building design

Once you are happy with your design, it's time to create your building. Make sure not to shake it too much when it is being tested (you don't want flying spaghetti!).

? Did your building survive? If so, try to make it taller! If not, what can you add to make it more stable?