http://www.ausis.edu.au

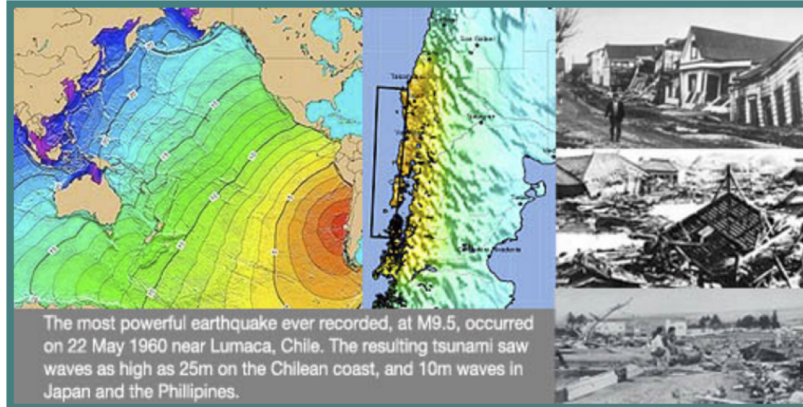# Australian Seismometers in Schools

| Home | About AuSIS | Seismic Data | Resources | Community |

The most powerful earthquake ever recorded, at M9.5, occurred on 22 May 1960 near Lumaca, Chile. The resulting tsunami saw waves as high as 25m on the Chilean coast, and 10m waves in Japan and the Phillipines.

Latest Quakes

AuSIS in a School Near You

Get Your School Involved

Significant Events

Educational Resources

Latest News

2016-06-16 11:27:34 local
2016-06-16 01:27:34 UTC

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Contents

1 Online Earthquake Exploration

What is the difference between UTC, GMT and Local System Time?

Earthquakes events can be listed with different time zones, this can be confusing if you don't notice. Here the definitions for the different ways time is given.

UTC Co-ordinated Universal Time is the global time standard. UTC time is the same everywhere in the world.

GMT Greenwich Mean Time is the mean solar time at the Royal Observatory, Greenwich. It does not include daylight savings and has been replaced by UTC. GMT=UTC

Local System Time Local time is the time where you are currently located and includes the effects of daylight savings. E.g. Sydney local system time is UTC+10 in the winter and UTC+11 during daylight savings.

Looking at a seismometer near you

To find a seismometer near you you can use the IRIS Station monitor website.

https://www.iris.edu/app/station_monitor/

The website begins with the question - *Did the ground move near me?* You can simply click on the *Find Stations Near Me* button and choose a site, or you can click on the map and choose one from the area you are interested in. Lastly if you are interested in a specific site then you can type it in. To get a list of all available AuSIS sites type AU into the *Search by Zip Code or Station Name* box.
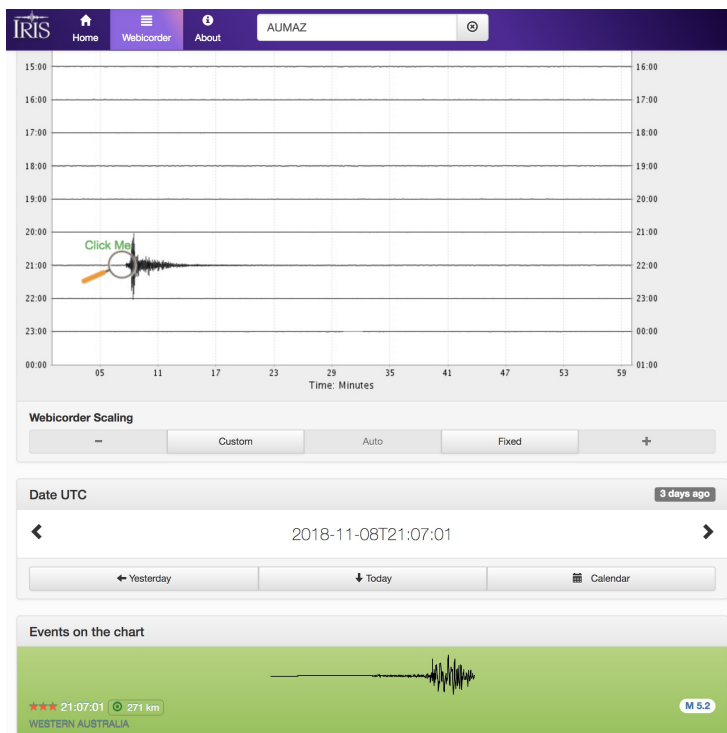
The Webicorder will initially show the current days data, but you can choose a date from the calendar or choose a recent or notable event listed below or beside the webicorder. If you click on the Click Me magnifying glass you will be taken to more detailed information about the event.

This website is also available as an App for iOS and Android devices on Google Play and the Apple store.

How to view recordings of an earthquake event

We recommend using the Wilber3 to view large earthquakes from around the world

http://ds.iris.edu/wilber3/find_event.

When you open this web page it will automatically show global earthquakes for the last month on the map.

There are tools on the right that allow you to customize the area, time range and earthquake magnitude range of the search. You can also use the **Draw Selection Box** button on map or the zoom buttons to limit the area you are interested in. At the bottom of the page the earthquakes on the map are listed.

Once you have found an earthquake of interest, click on it in the list. This will take you to a screen that will allow you to choose earthquake recorder stations you might want to look at. Each of the triangles shown is a station. The default network is the GSN network, which is global but has very few recorders in Australia, so we are going to explore the AuSIS network.

Wilber 3: Select Stations

2014-06-23 MWW7.9 Rat Islands, Aleutian Islands

Latitude	Longitude	Date	Depth	Magnitude	Description	Related Pages
51.7972° N	178.7604° E	2014-06-23 20:53:09 UTC	107.5 km	MWW7.9	Rat Islands, Aleutian Islands	IRIS Data Products

The map below shows stations operational during this event, filtered by the criteria in the form to the right.

Request Only

Networks
× S

Channels
× BHZ

Set default networks/channels

Distance Range
0 - 180

Azimuth Range
-180 - 180 ☐ Invert

Actions
Show Record Section   Request Data

Use the checkboxes below to add/remove individual stations from your request.

Selected **34** out of 34 stations.   Select | All | None | One station every ▾

	Station	Network	Latitude	Longitude	Distance	Azimuth	Elevation	Name
☑	AUCSH	S	-16.92°	145.77°	74.48°	-147.27°	17 m	Cairns State High School, QLD
☑	AUDHS	S	-12.44°	130.83°	76.39°	-131.77°	26 m	Darwin High School, NT
☑	AUAYR	S	-19.58°	147.41°	76.45°	-149.72°	13 m	Ayr State High School, QLD
☑	AUKAT	S	-14.46°	132.28°	77.52°	-134.02°	122 m	Katherine High School, NT

1. **Choose a network:**

   To look at the AuSIS network click on the cross next to GSN and type in **school** in the box. As you type the option **S: Seismographs in Schools** will show up, choose this option. To see the rest of the Australian National network type in **AU** and choose **AU: Geoscience Australia**

2. **Choose a channel:**

   Ground movement is recorded in three different directions, vertical, N-S, and E-W and at different sampling rates. The different directions and sample rates are referred to as **channels**. The BHZ channel is usually best for looking at distant earthquakes, it shows vertical movement at a mid range sample rate. You should see **BH?** under Channels which will allow you to look all the mid range sample rate channels including BHZ (vertical movement) BHN (north-south movement) and BHE (east-west movement)

3. **Show record section:**

   Now you are ready to show a record section. Click on the show record section button. This will show you recordings from the earthquake and stations you have chosen. Traces for each station will be plotted against distance from the earthquake (in degrees).

The record section will initially show you the movement at each station from 1 minute before the P-wave arrival till 10 minutes after the P wave arrival. The P-wave is a compressional

3

Latitude	Longitude	Date	Depth	Magnitude	Description
51.7972° N	178.7604° E	2014-06-23 20:53:09 UTC	107.5 km	MWW7.9	Rat Islands, Aleutian Islands
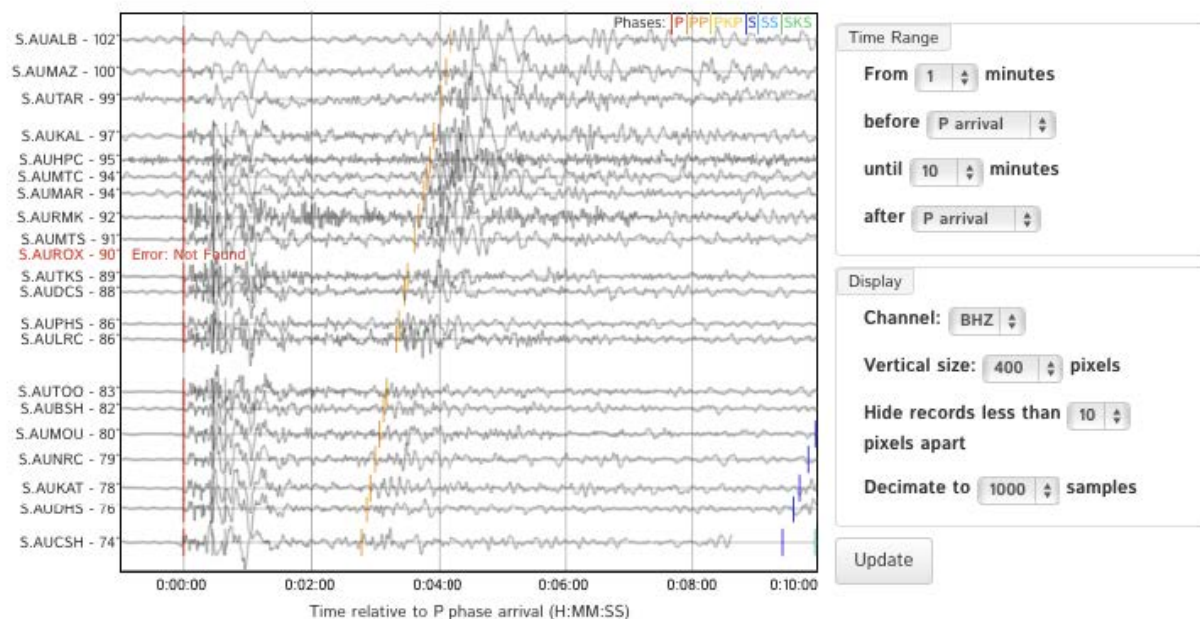
wave that travels through the earth in the same way sound travels in the air. The P-wave is the fastest wave and will arrive first. It's predicted arrival is marked at each station in red.

What follows after the P-wave will depend on where the earthquake occurred. This is because as waves travel they are reflected and refracted at boundaries within the earth (see image below). Some of the other waves arriving are also labelled http://ds.iris.edu/data/vocab.htm provides details on what each of these seismic **phases**.
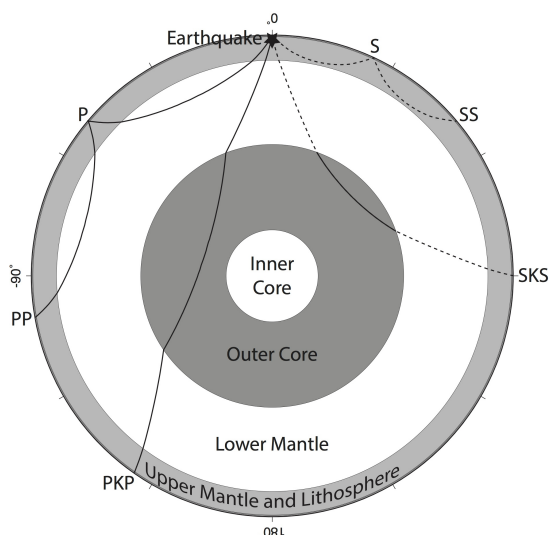
Figure: Raypath's showing how different seismic phases travel though the interior of the Earth. Solid lines represent P waves and dotted lines represent S waves.

4

In the record section on the previous page we can only see compressional waves since this earthquake is a long way away. S waves, or shear waves travel much slower than P waves. Surface waves travel even slower again, but these are usually the biggest waves. So we might want to look at a longer time window. You can change the time window using the tools on the right hand side.
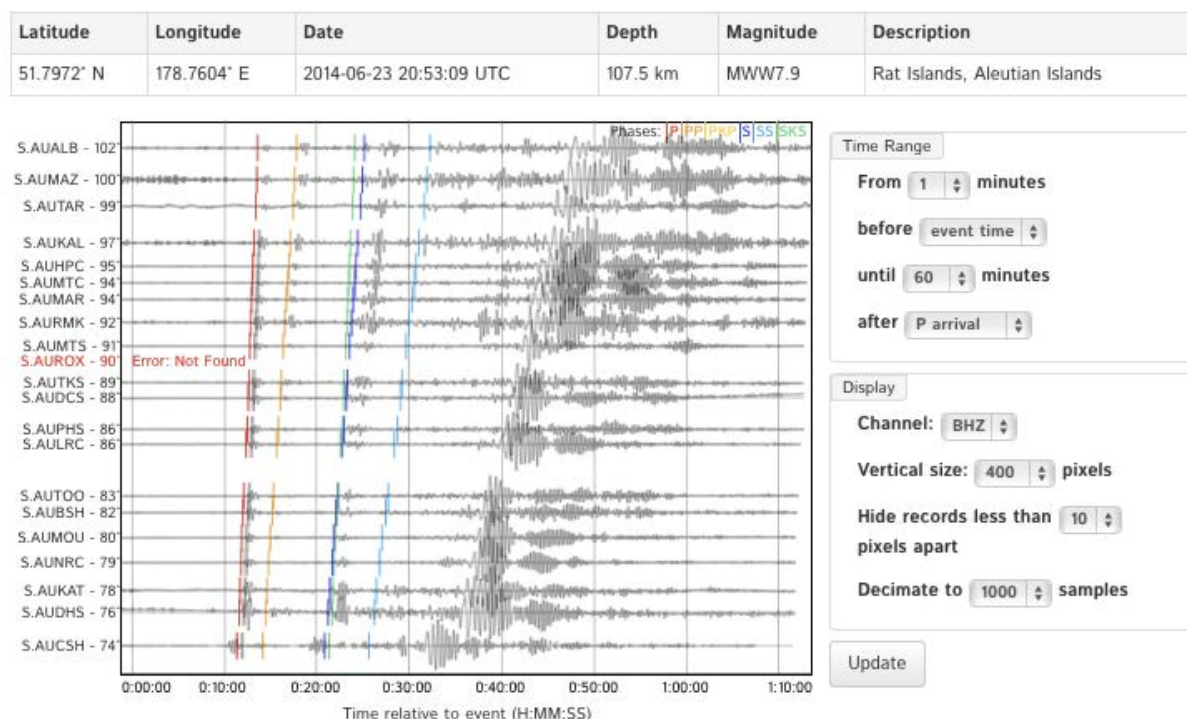
This record section now shows from 1 minute before the earthquake occurred to 60 minutes after the P wave arrival. We can now see the P, S and the surface waves arriving. The surface waves are the big unlabelled ones. To print a section you will need to take a screen shot.

Plate tectonics activity

In this activity we will explore some different tectonic settings around the world by looking at various regions where earthquakes occur.

We will start by looking at the IRIS seismic monitor:

https://ds.iris.edu/seismon/

This monitor shows all the earthquakes that have occurred in the last 2 weeks. Usually there is a lot more activity than people expect. The size of the circle relates to the magnitude of the earthquake and the colour relates to how recently it occurred. Earthquakes over the last 5 years are shown as pink dots.
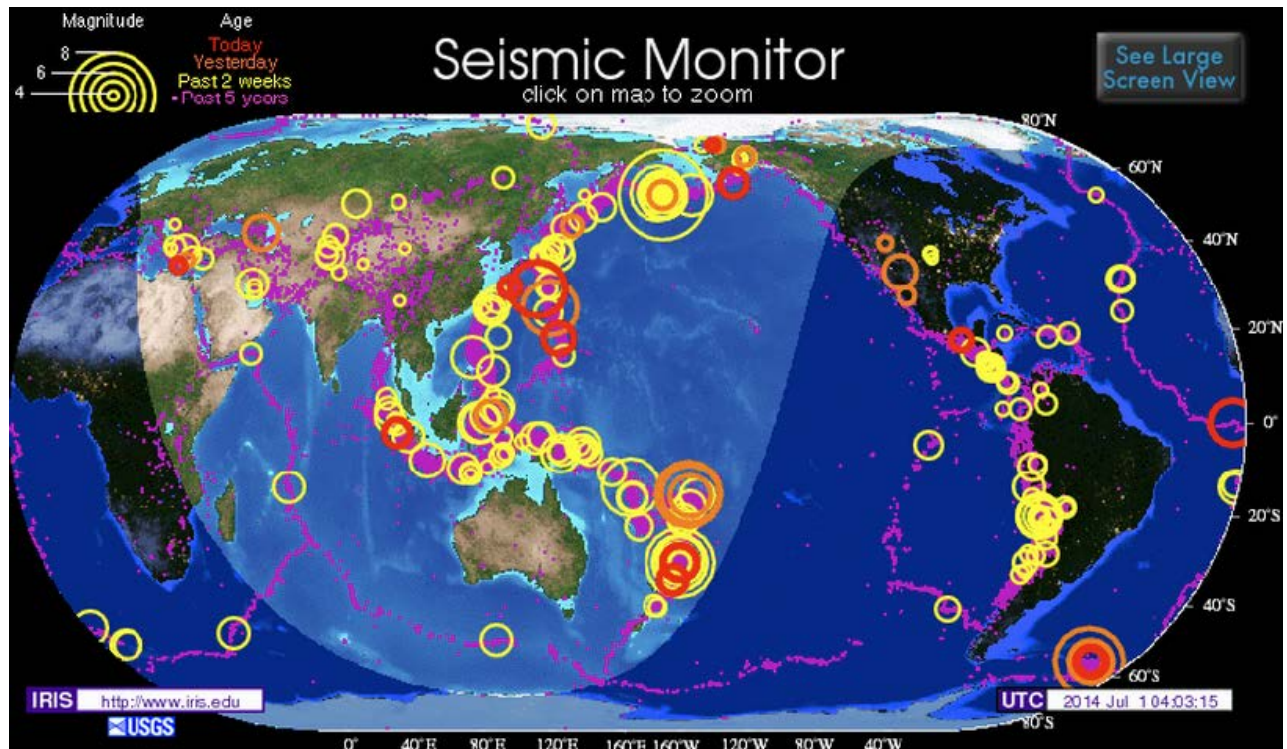
Questions

1. Can you see a pattern in the occurrence of earthquakes?

Now go to the IRIS earthquake browser website http://ds.iris.edu/ieb/. This browser will allow us to explore all the earthquakes that have occurred since 1970.
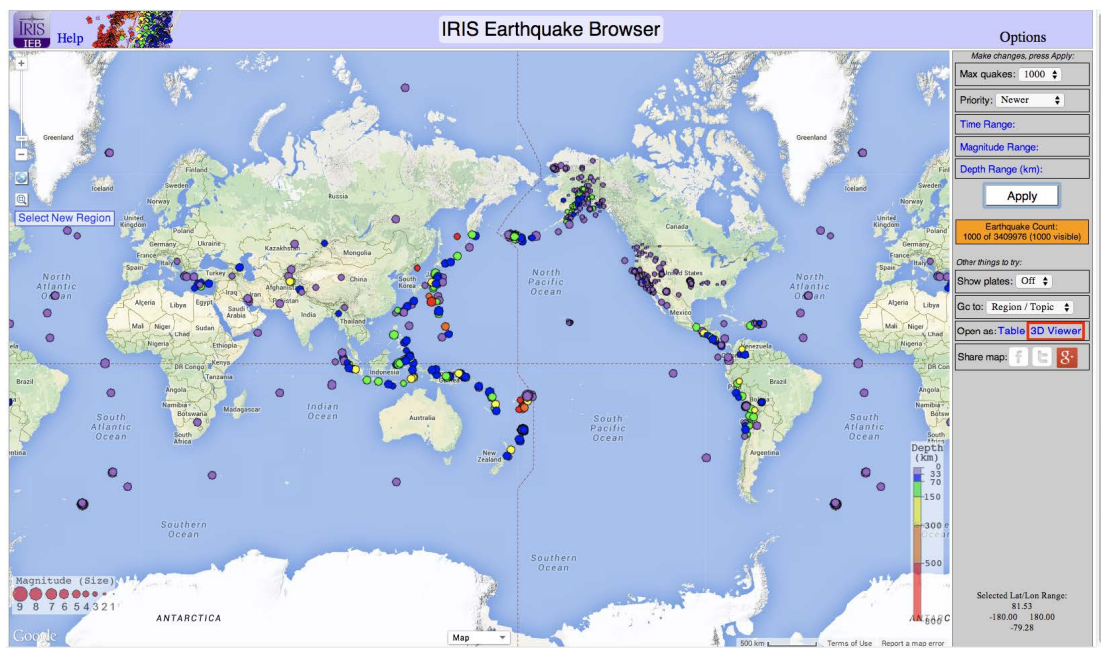
Now turn on the **show plates** option. This will show where the plate boundaries are.
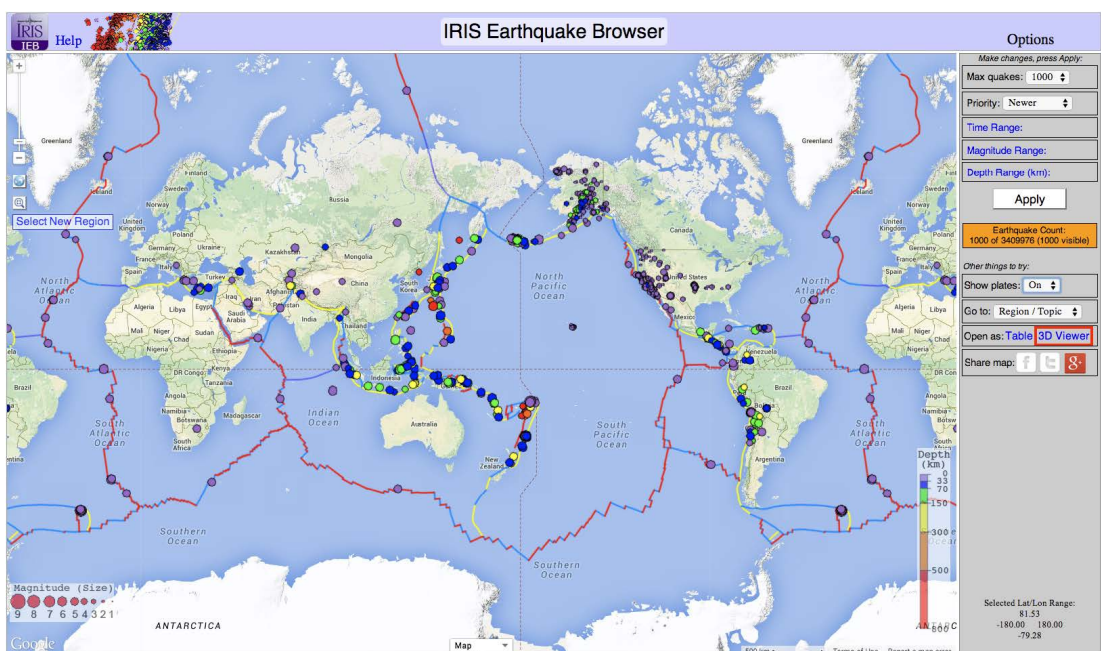
There are four different types of plate boundaries shown in different colours. If you click on each colour it will tell you what type of boundary it is.

Questions

2. Can you describe each of the plate boundaries and how you think the plates on either side might move relative to each other?

3. Can you think of any geographical features that might correlate with the different types of plate boundaries?

Initially it will show you the latest 200 earthquakes around the world. We are going to change that to 1000 by using the **Max quakes** option in the top right-hand corner.

Questions

4. Describe where earthquakes appear to occur.

We have just looked at the 1000 most recent earthquakes that have occurred. Under the priority menu select **largest**.

Questions

5. On what type of plate boundary does the majority of the largest earthquakes occur?

6. In what countries have the largest 10 earthquakes occurred? Where else might be at risk of large earthquakes?

7. What sort of plate boundary do you think would be most dangerous to live near and why?

Switch it back to the **Newer** earthquakes before you continue.

Now we are going to examine each of the different type of plate boundary. Click on the **Select New Region** below the zoom bar on the left. Choose a type of plate boundary e.g. **Convergent** and use your mouse to draw a box around part of that plate boundary. Make your box about the same size as Australia.

Zoom into the region you have chosen and describe the region you have chosen and any patterns you can see in the earthquakes. Use the **3D Viewer** on the right hand side of the screen to inspect your earthquakes in more detail.

Repeat this for the other 3 types of plate boundaries. Make sure you look at more than one area for each type of plate boundary to confirm your findings.

Questions

8. Describe any differences you see in the earthquakes at each type of boundary? Why might they be different?

9. From the exercise so far it doesnt look much like there are many earthquakes in Australia. Why is this the case?

Now lets look more closely at Australia. Use **Select New Region** again to draw a box around just Australia.

Questions

10. Are there any regions of Australia you can see have more earthquakes than others. If so can you think of any geographical features that might help to explain the earthquakes?

Impacts of Earthquakes on Society

Earthquakes often take us by surprise but what is sometimes just as surprising is the variety of impacts they can have on communities. Earthquakes of the same magnitude can cause quite different levels of damage depending on their location.

Investigate the link below with lists of the deadliest, costliest and largest earthquakes.

http://en.wikipedia.org/wiki/Lists_of_earthquakes

Questions

11. In general, where and when have the deadliest earthquakes occurred?

12. In general, where and when have the costliest earthquakes occurred?

13. Are these the same? Explain why or why not?

14. Are the costliest and deadliest earthquakes the largest earthquakes? Explain why or why not?

2 Magnitudes Demystified

Aim

To introduce students to the different ways earthquake size is described. The size of an earthquake is described in two ways:

- Magnitude: the amount of energy released by an earthquake

- Intensity: the amount of shaking that is experienced at a specific location

Earthquake Magnitude

Earthquake magnitude is a measure of the amount of energy released during an earthquake. The scale is logarithmic, meaning that every time you go up one whole number the approximate amount of ground shaking from the earthquake goes up 10 times and the amount of energy released is increased by a factor of 32. For example, a magnitude 6 earthquake would have 10 times more ground shaking and 32 times more energy than a magnitude 5.

Demonstration: Pasta Quake

- Bend a piece of spaghetti between your hands until it breaks. Notice the work it takes to break the spaghetti and the vibration through the spaghetti as the energy is released. Call this a 5 on the Pasta Magnitude scale.

- Take a bundle of 32 pieces of spaghetti. Bend the bundle until it breaks. Notice the work it takes to break the bundle. If the pasta magnitude scale were like the earthquake magnitude scale this would be a Pasta Magnitude 6 break.

- To make a Pasta Quake of magnitude 7 we need to increase the magnitude 6 quake 32 times, which will require a total of 1024 pieces of spaghetti.

Exercise 1: Mythbusters! Small earthquakes can stop large ones, right?

One of the most common questions seismologists get asked is *"If several small earthquakes occur does that reduce the chance of a large earthquake?"*. Using what we know about the magnitude scale lets fill in this table below...

Magnitude	Total Seismic Moment Energy (Joules)	Energy compared to a magnitude 4
4	1.233105E+15	1
5	3.899420E+16	
6	1.233105E+18	
7		32 768
8		
9	3.899420E+22	

How many magnitude 4 earthquakes would be required to release the same amount of stored energy as a magnitude 8?

Magnitude Scales: So many magnitude scales, which one is correct?

You have probably heard of the Richter magnitude scale but there are many more, e.g., local magnitude (M_L, equivalent to Richter scale but for areas outside of California), surface wave magnitude (M_S) and moment magnitude (M_W).

Why do we have so many?
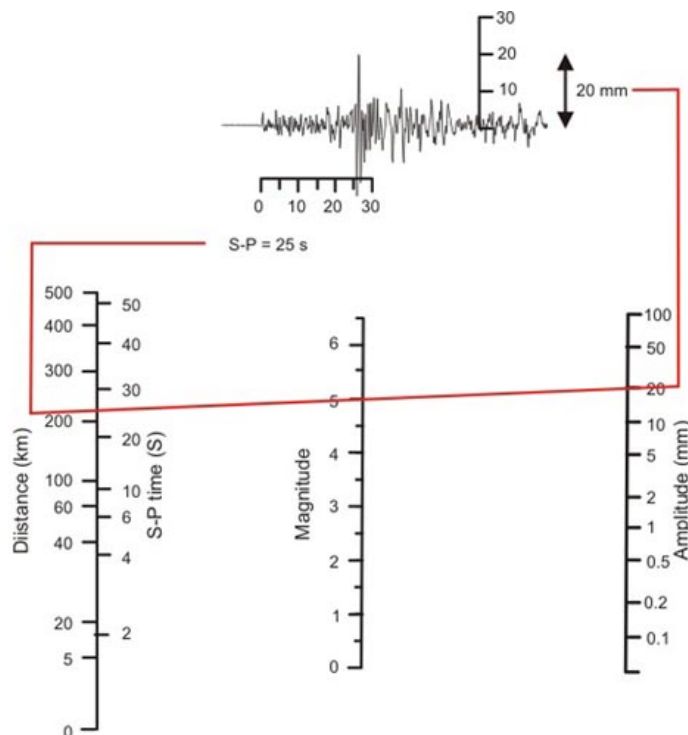
Figure 1: The original magnitude scale developed by Charles Richter in 1935 and was based on local earthquakes that occurred in California. The Richter scale uses observations of the maximum amplitude of a seismic wave and takes into account the distance of the seismometer from the earthquake, since seismic waves decay with distance.

Early recordings of earthquakes could only detect high frequency events, typical of moderate

size ($<$ M 7) local earthquakes. The scale didn't work for larger earthquakes that have their highest amplitudes at lower frequencies. Imagine listening to jazz music on your stereo that includes a deep double bass sound but you have the treble turned up and the bass turned down on your mixer. It just doesn't give you the true representation of the music.

Over time earthquake recording instrumentation has improved and new scales were created for earthquakes with larger magnitudes. However, they are all slightly different and all based on amplitude. Eventually, seismologists decided it would be better if all earthquakes, no matter what their size, could be directly described by the amount of energy that they release. This was called the Seismic Moment (M_0). The seismic moment is determined by the following formula, where A is the area of the fault ($W * L$) that was ruptured during an earthquake, D is how far the fault area slipped and μ is the rigidity of the rock (how difficult it is to break).

$$M_0 = \mu * D * A$$
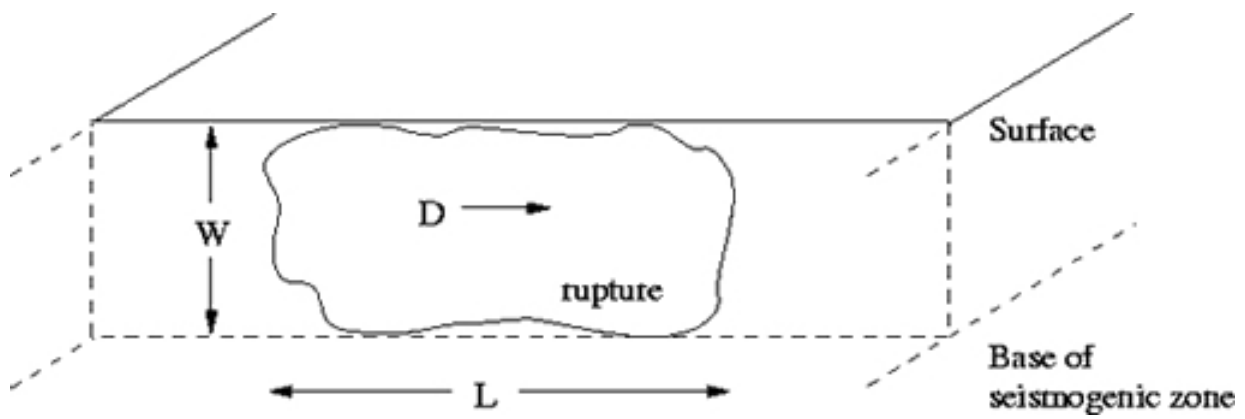
Figure 2: Seismic moment uses the fault rupture dimensions and the distance slipped.

Since magnitude scales have been used for so long it was important to be able to relate the seismic moment to a magnitude, which is now known as the Moment Magnitude (M_W).

$$M_W = \frac{2}{3} * \log(M_0) - 10.7$$

Moment Magnitude is now the preferred description of the size of an earthquake, however you will still see M_L (local/Richter magnitude) or M_b (body wave magnitude) for small earthquakes (< 4).

Earthquake Magnitude Energy Equivalents:

It's hard to imagine just how much energy is released during an earthquake. To help here is a table and figure of common things that produce energy based on the equivalent magnitude. Most of the values in the table are based on an online calculator http://earthalabama.com/energy.html. Why not get your students to make their own table based on the energy produced by their school or town.

Magnitude	Seismic Moment (Joules)	Tonnes TNT	Years of power for one home	Days of power for Australia	Hiroshima Bombs
1	3.90E+10	9	0.4	less than 0.1	less than 0.1
2	1.23E+12	295	13	less than 0.1	less than 0.1
3	3.90E+13	9 320	410	less than 0.1	0.6
4	1.23E+15	295 720	12 980	1	20
5	3.90E+16	9 419 837	410 465	39	617
6	1.23E+18	394 719 128	12 980 050	1 233	19 511
7		9 319 837 157	410 465 249	38 995	616 996
8		294 719 128 400	12 980 050 876	1 233 105	19 511 152
9	3.90E+22	9 319 837 157 661	410 465 249 133	38 994 200	616 996 814

Earthquake frequency and destructive power

Left side of the chart shows the magnitude of the earthquake and right side represents the amount of high explosive required to produce the energy released by the earthquake. The middle of the chart shows the relative frequencies.
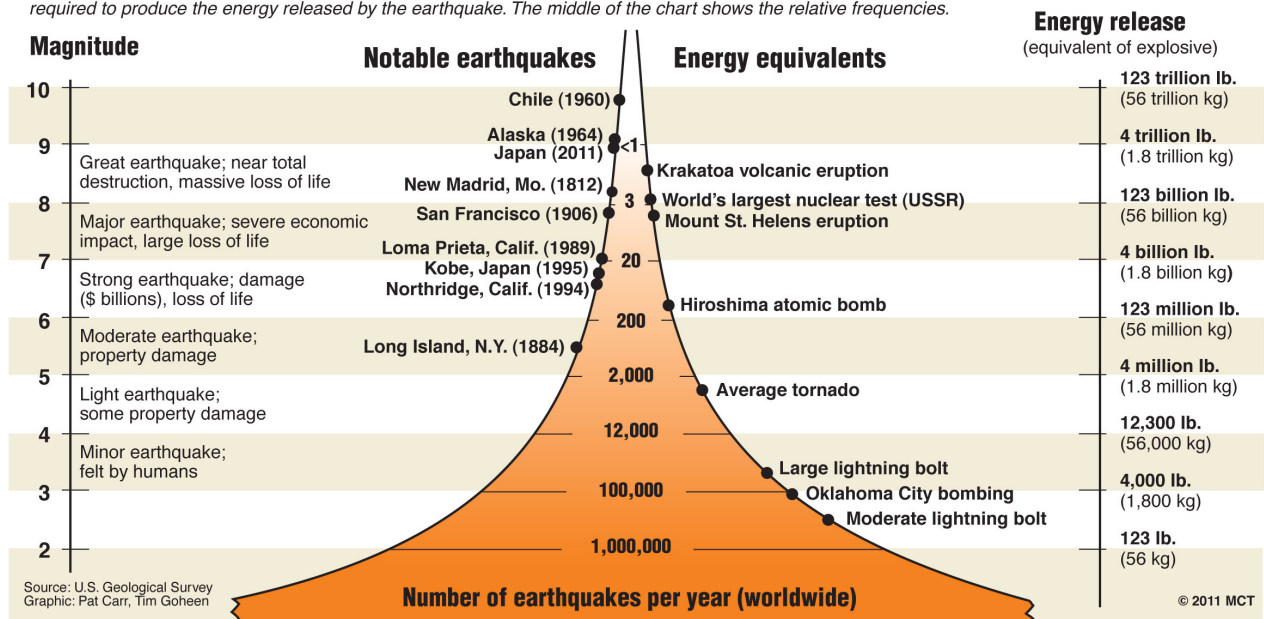

Figure 3

Earthquake Intensity:

Earthquake intensity, commonly known as The Modified Mercalli Intensity Scale, is a description of the severity or amount of damage caused by an earthquake. Intensity decreases with distance from the earthquake and is often determined based on peoples accounts of what happened during the earthquake (known as felt reports) and surveys of damage.

The intensity for the same magnitude earthquake in two different cities is likely to be different. The intensity will be influenced by:

- Earthquake magnitude

- Distance from the earthquakes epicenter

- Local site effects, such as, rock type at location (hard rock vs sand) and geological structure (sedimentary basins can trap and/or amplify waves)

This table provides a brief description of the scale:

MMI	Description	Impact
I	Instrumental	Not Felt
II	Weak	Felt by persons at rest, on upper floors or very sensitive
III	Slight	Felt indoors. Vibration is like the passing of a light truck.
IV	Moderate	Felt by many. Vibration is like the passing of heavy trucks
V	Rather Strong	Felt by most, including outdoors. Small unstable objects displaced
VI	Strong	Felt by all. Furniture moved. Weak plaster/masonry cracks. People frightened and run outdoors.
VII	Very Strong	Difficult to stand. Damage to masonry and chimneys.
VIII	Destructive	Partial collapse of masonry. Frame houses moved. Heavy furniture moved.
IX	Violent	General panic. Masonry seriously damaged or destroyed.
X	Intense	Many buildings and bridges destroyed.
XI	Extreme	Few structures remaining. Rails bent greatly. Pipelines severely damaged.
XII	Catastrophic	Nearly total destruction.

3 Seismic Waves

Aim

To introduce to students the fundamental seismic waves, how they propagate through the earth and how we observe them.

Introduction

There are three fundamental types of seismic waves.

1. Compressional waves

   These are also known as Primary waves or P-waves as they travel through the earth the fastest and they are therefore the first waves from an earthquake to arrive at an earthquake recorder. P-waves are similar to sound waves but travel through the earth faster than the speed of sound. Particle motion of a P-wave is in the direction of propagation. For an earthquake below the surface this means that the P-wave is observed as mainly a vertical motion.

2. Shear waves

   These are also known as Secondary or S-waves. These waves travel slower than P-waves and are the second waves from an earthquake to arrive at an earthquake recorder. Particle motion of an S-wave is perpendicular to the direction of propagation similar to how a snake moves. This means that it is observed as mainly a horizontal motion.

   Both P- and S-waves are body waves and propagate through the volume (or body) of the earth.
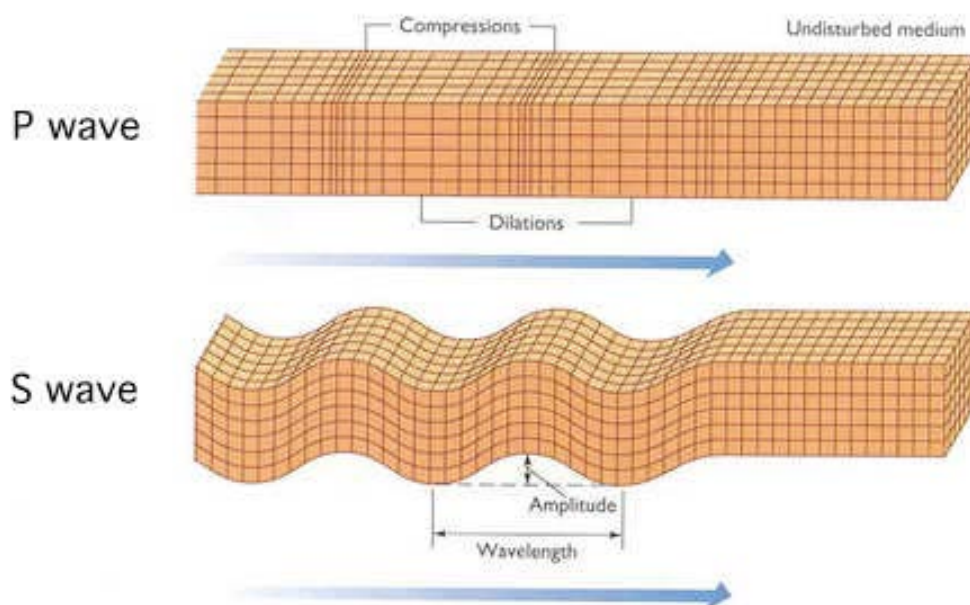
Figure 4: Body waves.

3. Surface waves

Unlike P- and S-waves, surface waves only propagate along the surface of the earth. There are several types of surface waves; the simplest to demonstrate is called a Rayleigh wave. The motion of this wave is similar to ocean waves. Particle motion is elliptical and it therefore is observed as both a vertical and horizontal motion.

Rayleigh Wave

Figure 5: Rayleigh wave

Activity 1: Slinky seismic waves

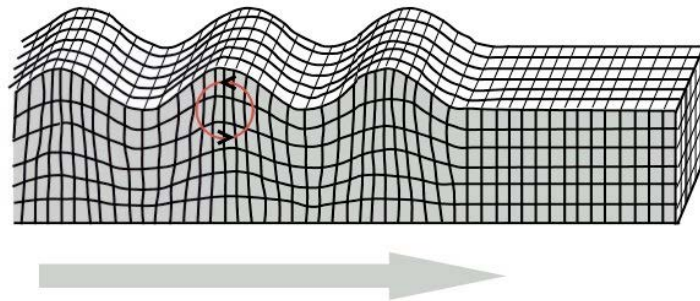*Adapted from Braile, 2006. Seismic waves and the slinky. Purdue University. Available at http://web.ics.purdue.edu/~braile/edumod/slinky/slinky4*

Purpose:

To introduce different types of seismic waves and how they propagate. Here we will look at the difference between the direction of particle motion and wave propagation.

Exercise:

Using the slinky to simulate the three types of seismic waves described above.

1. Pull the slinky tight between two people along a smooth surface such as a table or floor. Get one person to pull a couple of coils of the slinky towards them with one finger and then release the coils quickly. What direction does each coil move in? Which wave does this simulate?

2. Repeat step 1 but pull a coil sideways and release it. What direction does each coil move in? Which wave does this simulate?

3. Lift the slinky off the surface and give yourselves a little room. Have one person rotate one end in a circular motion and see if you can get a wave along the coil. What direction does each coil move in? Which wave does this simulate?

Additional questions:

1. Which type of wave would you expect to be more damaging? Hint: Think about how the energy of a wave might spread out over a surface and a volume.

2. What kind of wave would be best for early detection of an earthquake?

Additional resource:

A great document that describes several activities with Slinkys and seismology (including the exercise above) can be found on this website http://web.ics.purdue.edu/~braile/edumod/slinky/slinky

Activity 2: Quake Catcher

Adapted from Quaker Catcher Network, 2013. Stanford University

Purpose

To introduce the way seismologists observe earthquakes.

Introduction to the Quake Catcher:

The quake catcher is an accelerometer that can be used to monitor earthquakes. It senses changes in ground motion at the surface of the earth in three directions. Accelerometers are less sensitive than seismometers, such as those used in the AuSIS-program, and they are generally used close to where the earthquake occurs. Accelerometers have many other everyday uses. For example they are used to trigger airbags in cars and they are used in Wii handsets. In fact the Quake Catcher uses the chip from a Wii handset. They are also used in smart phones and laptops. Please see http://qcn.stanford.edu/ for more information regarding Quake Catchers.

Exercise:

1. Using the Quake Catcher software, examine the three traces of the accelerometer. Work out what the orientation of the axes inside the Quake Catcher is.

2. Below is a seismic record from an earthquake in Sumatra (Magnitude 7.1) recorded in Canberra that shows the three different types of seismic waves. See if you can replicate the recordings of the three fundamental waves. For the P- and S-wave try to do so without touching the Quake Catcher.

You can also do this exercise using an ipad/iphone (using the iSeismometer app), ipad, apple laptop (using the SeisMac software) or android phone (using the Seismograph app).

Questions:

1. Why would you want a less sensitive instrument closer to an earthquake?

2. How could you tell if you are seeing and earthquake rather than someone shaking the instrument?

The Quake Catchers have been used to provide information to scientists about aftershocks from earthquakes such as the 2010-2011 Christchurch Earthquakes. There is a worldwide network of these little accelerometers (http://qcn.stanford.edu/qcn-map) including here in Australia. The software also allows real time earthquake viewing around the globe that can be used without the Quake Catcher (http://qcn.stanford.edu/learning-center/qcn-interactve). If your school is interested in getting their own seismometer or Quake Catcher, please visit the Australian Seismometers in Schools website and apply using the online form http://ausis.edu.au.
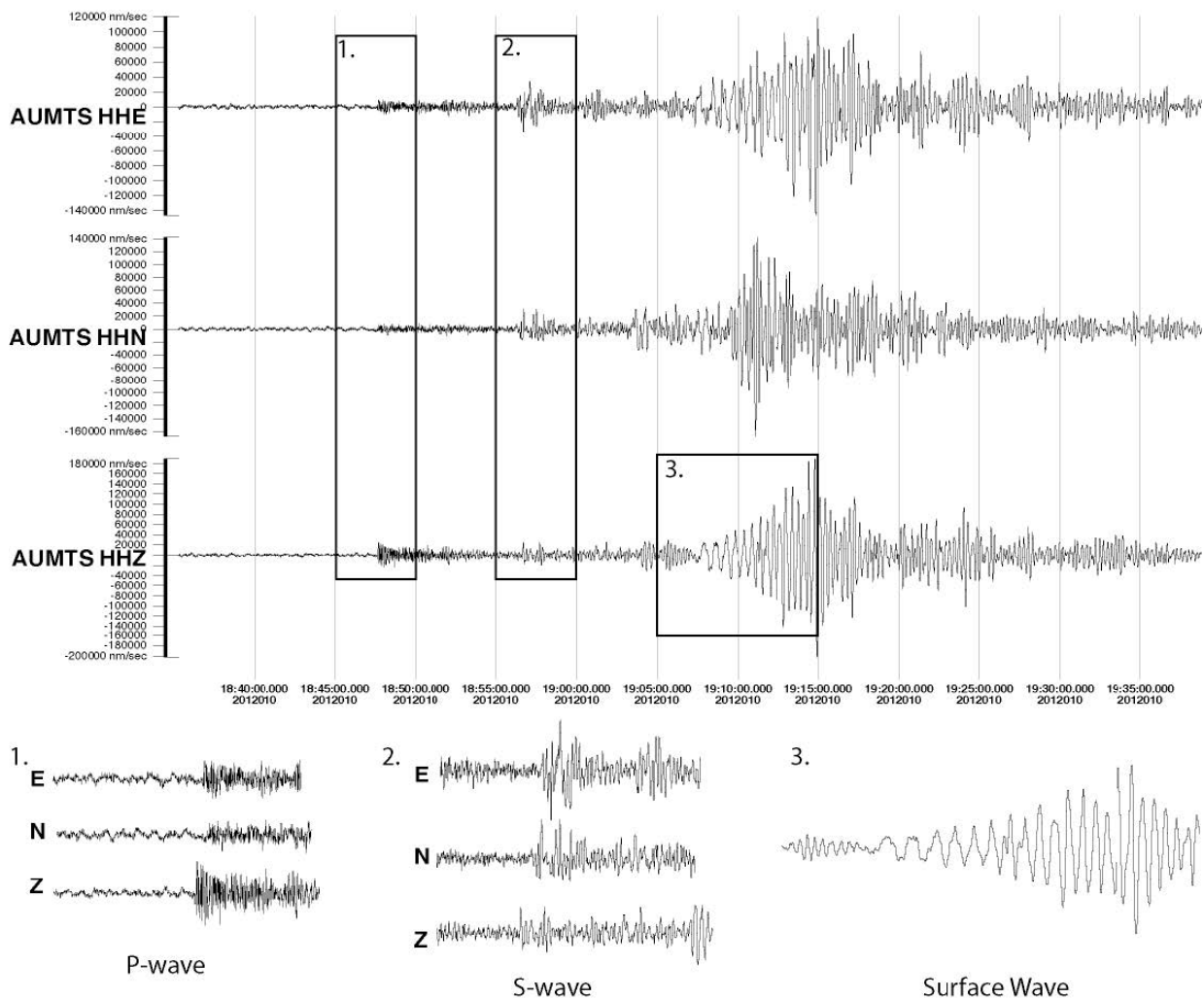
Figure 6: Different types of seismic waves as seen on a seismic recording.

4 QuakeCaster

Adapted from K. Linton and R.S. Stein, 2011. How to build and teach with QuakeCaster, an earthquake demonstration and exploration tool. U.S. Geological Survey Open-File Report20111158, 35 p.

Aim

The aim of this module is to explore the reoccurring behavior of earthquakes. The activity uses a QuakeCaster model, which was developed by the USGS (http://pubs.usgs.gov/of/2011/1158/). The model can be used to test four leading hypotheses for predicting earthquakes, which are:

- **Earthquakes are periodic**. This means that the same amount of fault slip is separated by the same amount of time.

- **Earthquakes are time predictable**. This means that the larger the amount of fault slip in the last earthquake, the longer the time until the next earthquake.

- **Earthquakes are slip-predictable**. This means that the longer the time stress accumulates, the greater the amount of fault slip in the next earthquake. Another way of stating this hypothesis is that earthquakes decrease the amount of stress along a fault to a fixed minimum or to a background amount.

- **Earthquakes occur randomly and have randomly varying size**.

Introduction

QuakeCaster is an interactive, hands-on teaching model that simulates earthquakes and their interactions along a plate-boundary fault. QuakeCaster contains the minimum number of physical processes needed to demonstrate most observable earthquake features.

A winch to steadily reel in a line simulates the steady plate tectonic motions far from the plate boundaries. A granite slider in frictional contact with another surface simulates a fault at a plate boundary. A rubber band connecting the line to the slider simulates the elastic character of the earths crust. By stacking and unstacking sliders (or weights) and cranking in the winch, one can see the results of changing the shear stress and the clamping stress on a fault. By placing sliders in series with rubber bands between them, one can simulate the interaction of earthquakes along a fault, such as cascading or toggling shocks. By inserting a load scale into the line, one can measure the stress acting on the fault throughout the earthquake cycle. As observed for real earthquakes, QuakeCaster events are neither periodic nor time- or slip-predictable. QuakeCaster produces rare but unreliable "foreshocks". When fault gouge builds up, the friction goes to zero and fault creep is seen without large quakes. If QuakeCaster is used on a rock-like surface, events produce very small amounts of fault gouge that strongly alter its behavior, resulting in smaller, more frequent shocks as the gouge accumulates. It can also show the result of low friction on a fault if one of the sliders is used with the polished side down. QuakeCaster is designed so that students or audience members can operate it and record its output. With a stopwatch and ruler one can measure and plot the timing, slip distance, and force results of simulated earthquakes.
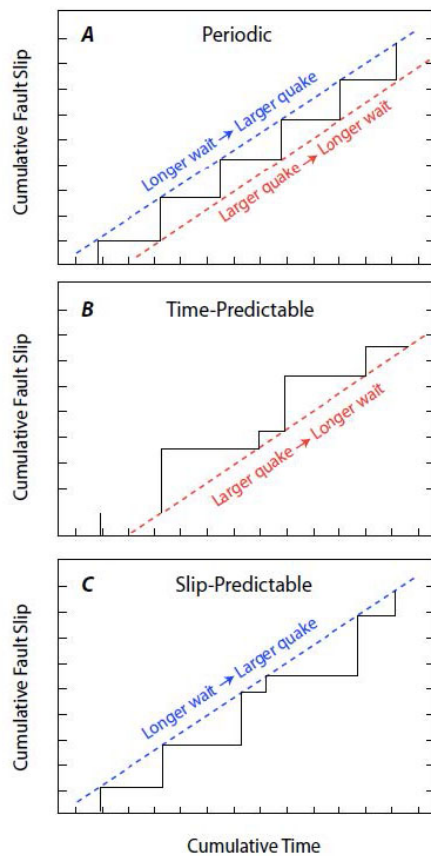
Figure 7: Expected behaviour under three earthquake hypotheses. A. The top graph illustrates what we would expect to see if earthquakes were periodic. B. The middle graph illustrates what we would expect to see if the earthquakes were time-predictable. C. The bottom graph illustrates what we would expect to see if earthquakes were slip-predictable. The blue dashed lines represents the best fit with slip-predictable hypothesis and the red dashed line represents the best fit with time-predictable hypothesis.

Activity

Equipment

- QuakeCaster or Similar

- At least 3 participants

- A stopwatch that can record splits

- A marker or whiteboard pen

- A ruler
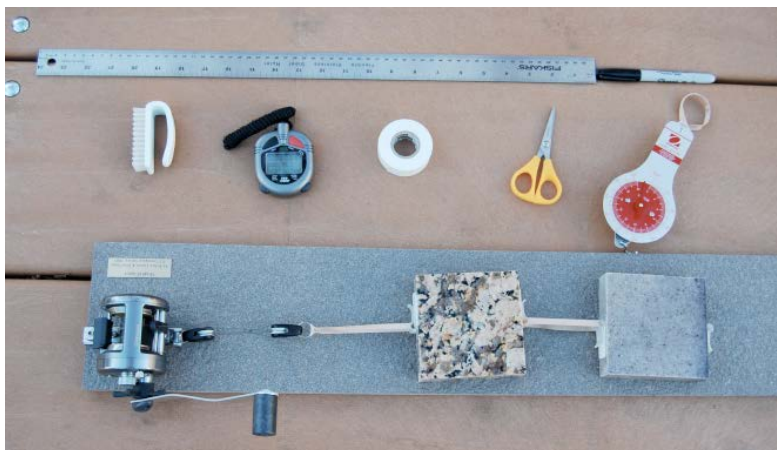
Method

Place a piece of tape along the base or use the ruler if provided. To perform the experiment at least 3 people are required:

- One person will reel in the line at a constant rate (which simulates constant plate motion).

- One person will use a pen or whiteboard marker to mark the slip distance after each event (earthquake).

- One person will hold the stopwatch and record the time of each event.

- An additional person can be used to observe the force before and after an event occurs. The force can be related to the shear stress along the fault.

- It is best to run this experiment several times to get an understanding of the behavior.

Record the cumulative time and cumulative slip in a table (below).

Plot the cumulative time and cumulative slip on the graph paper.

Join the plotted points using a step-like function.

- How consistent is the slip distance?

- How consistent is the time between events?

- Did your results fit the time-predictable or slip-predictable hypotheses?

Additional runs can be made by altering the conditions along the fault, for example:

- What happens when you change the weight of the slider?

- What happens when you use the polished side of the slider?

- What happens when you join multiple sliders together using rubber bands? (This one is difficult to measure but the observations are interesting.)

Event #	Lapse Time (seconds)	Cumulative Time (seconds)	Cumulative Slip (cm)

Event #	Lapse Time	Cumulative Time	Cumulative Slip

Summary

What participants should have observed during the experiment is that earthquakes do not behave in a regular manner. They have tried to compare the hypotheses with their results and although they are similar there is still variation between events. This can be related to the behaviour of earthquakes in the real world and to how difficult it is to predict earthquakes. Think of changing the time scale between events to the $10 - 100$ s of years between earthquakes. The small variations from the time-predictable hypothesis in the QuakeCaster experiment is only fractions of a second, however, this starts to become many years from when we would expect and earthquake in the real world.

We have only focused on one of the activities that you can do with a QuakeCaster. A more in-depth guide to the QuakeCaster, including how to build your own, is in the USGS report http://pubs.usgs.gov/of/2011/1158/. The website with the report also contains videos for the experiment and explains the concepts. The report contains lesson plans, more activities and a glossary.

5 Australian Earthquakes

Aim

The purpose of this module is for students to explore where earthquakes occur in Australia and how that relates to seismic hazard and risk.

Introduction

Earthquakes can occur at any location but large earthquakes occur most often where two tectonic plates collide, e.g. around the edge of the Pacific Ocean (New Zealand, Japan, South America). Australia sits in the middle of the Indo-Australian tectonic plate and has no plate boundaries running through it. This is why large earthquakes in Australia are relatively rare, although you will be surprised by how many small earthquakes do occur and how big earthquakes can get in Australia.

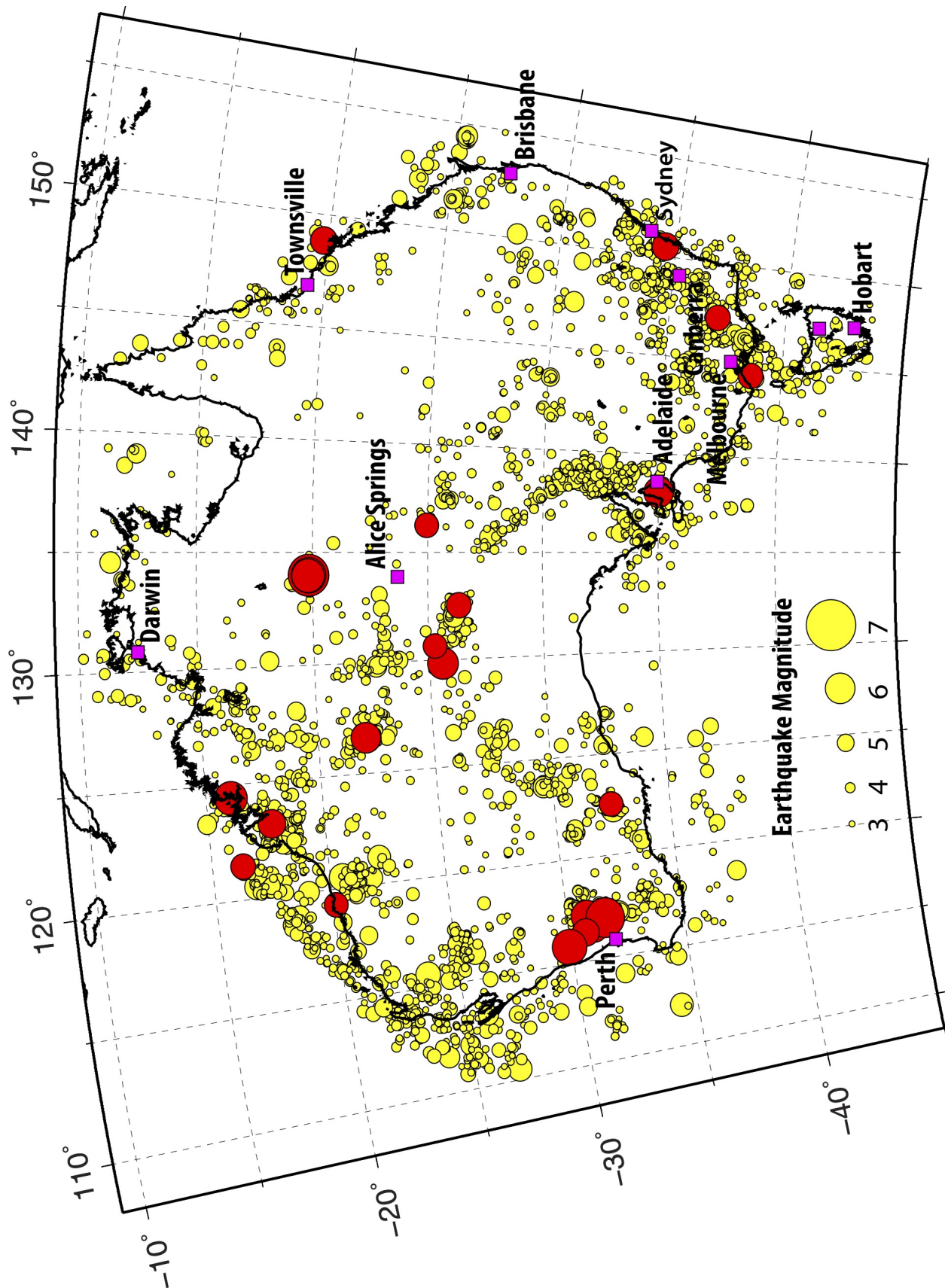## Activity: Historical Seismicity in Australia

Examine the map of Australian Earthquakes on the next page

- Do you see any patterns in where earthquakes occur in Australia?

- Which State has the largest earthquakes?

- Find where you live on the map, have there been any large earthquakes close to you?

- Based on seismicity which city is most likely to experience a large earthquake?

There are on average 80 earthquakes of magnitude 3.0 or greater every year in Australia. Many of these earthquakes are not felt but are recorded on seismometers around Australia. By comparison New Zealand have around 500 earthquakes of magnitude 4 or greater every year (for a land area that is 10% of Australia).

The largest onshore earthquake in Australia since 1900 was in Tennant Creek, NT with an estimated magnitude of 6.6. If we include offshore areas of Australia the largest earthquake is a magnitude 8.1 that occurred about 300 km from Macquarie Island on the Macquarie ridge in (a divergent plate boundary).

- What was the most damaging earthquake in Australia? How big was it? http://www.ga.gov.au/scientific-topics/hazards/earthquake/basics/historic

Figure 8: Australian earthquakes ≥ M3 1955 to present. Yellow circles indicate the location and size of the earthquake. Red circles indicate historically significant earthquakes ≥ M5.6 since 1900 with revised magnitudes http://www.ga.gov.au/scientific-topics/hazards/earthquake/basics/historic/revisions-to-australias-historical-earthquakes.

Activity: Seismic Hazard map of Australia

Seismic hazard describes the likelihood of a certain level of ground shaking for a particular region.

What goes into a seismic hazard map?

Scientists build seismic hazard maps by studying faults, past earthquakes and geodetic measurement of the movements of the earths surface. The history of a fault provides information about how big and how often the earthquakes that formed it have occurred. This geological information provides a longer history than human records. Historical information on earthquake shaking and damage from newspapers, personal accounts and seismograms from more recent earthquakes provide information on how much shaking a given earthquake is likely to cause. Geodetic deformation rates can help us to understand how big an earthquake is likely to be in the future. The amount of shaking at different frequencies also depends on type of soil, soft basin sediments will shake more than hard rock. So geology and topography are also incorporated into hazard maps.

Examine the Geoscience Australia's Seismic Hazard Map of Australia at on the next page. Note that there is an interactive online version of this map at:

http://www.ga.gov.au/interactive-maps/#/theme/hazards/map/earthquakehazards.

This map looks a bit like a rain forecast map, but instead of rain this map indicates the expected level of ground acceleration for a 500-year period at a specified frequency. This actually equates to a 10% chance of the level of shaking indicated to be exceeded over 50 years (or the life of a building). The acceleration is measured as units of g (gravity at the Earth's surface $\sim 9.81\text{m/s}^2$)

- Can you see any correlations between the seismicity map and the hazard map?

- Which city has the highest seismic hazard?

- Which city has the lowest seismic hazard?

- What is the seismic hazard where you live?

- Can you think of any hazards other than shaking that an earthquake can cause?

Examine the global seismic hazard. http://www.seismo.ethz.ch/static/GSHAP/

- How does the seismic hazard of Australia compare to our nearest neighbors?

- How does the seismic hazard of Australia compare to other regions away from plate boundaries?

- Which areas have the highest seismic hazard?
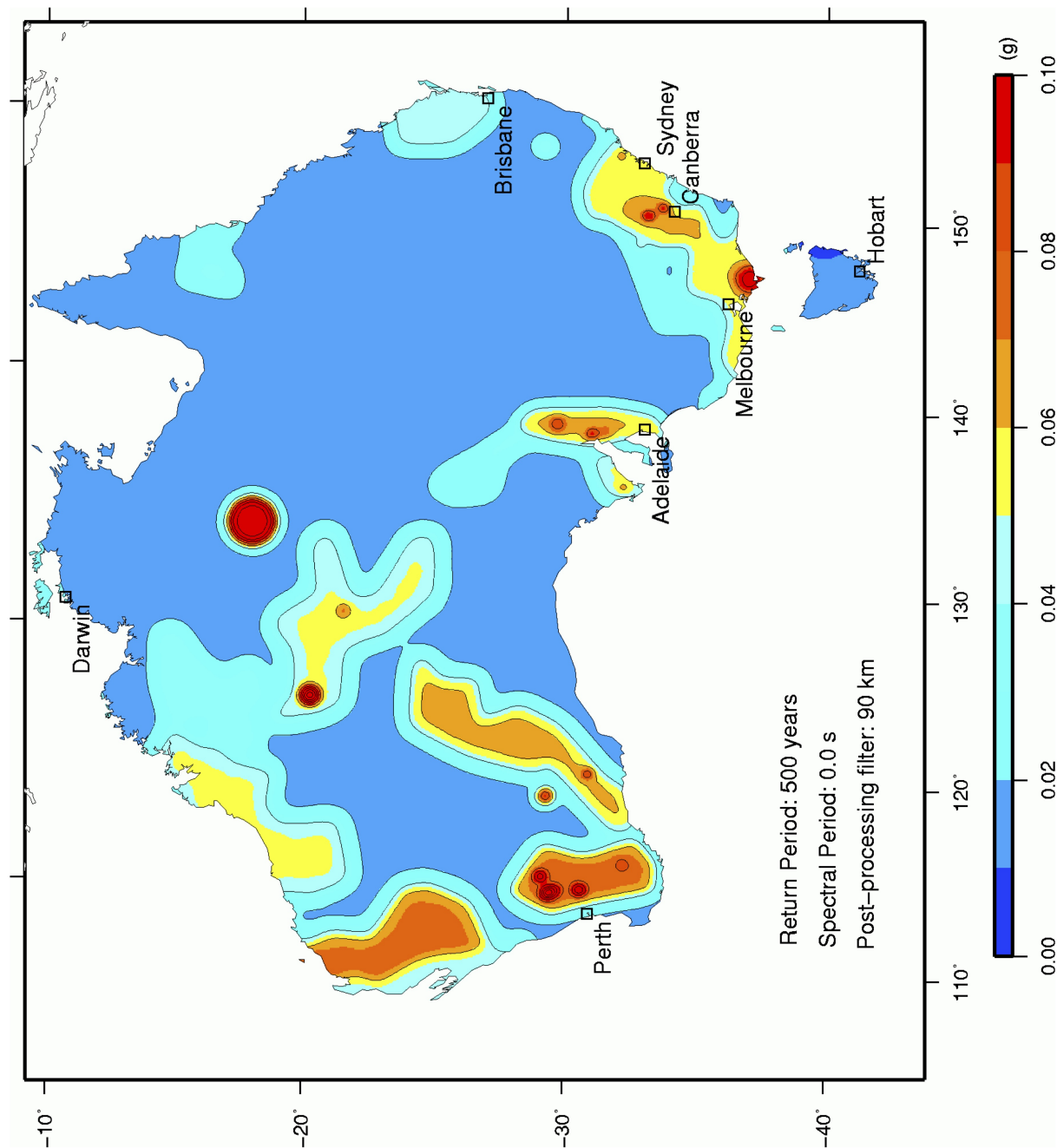
Figure 9: The 2012 Australian Earthquake from Burbidge, D.R. (ed.), 2012. Record 2012/71. Geoscience Australia: Canberra.

Figure 10: Global seismic hazard map http://static.seismo.ethz.ch/GSHAP/

Activity: Risky Business – Hazard vs Risk

We cannot change the seismic hazard that exists; this is determined by the awesome forces acting on the Earth. But we can influence how much the shaking affects us by reducing the risk.

Risk = Hazard × Vulnerability × Exposure

Vulnerability includes things like the potential effects of damage or loss to the built environment it includes information about population density, construction quality, economic importance.

Exposure quantifies what is at risk and is a stocktake of man-made or natural elements in the area. It can include buildings, economic activity, roads, people, waterways...

A high seismic hazard area can have a low risk if there are few people affected by the shaking.

- Can you find a high hazard area of Australia that you think has low risk?

- Which areas of Australia do you think have high risk and why?

Compare the earthquakes

	Haiti 2010	**Darfield NZ 2010**
Magnitude	7.0 Mw	7.1 Mw
Depth	13 km	10 km
Distance to City	25 km to Port-au-Prince	45 km to Christchurch
Deaths	316000	1 heart attack
Injuries	300000	2
Economic Loss	$7.8 billion	$15 million

- Why were there so many deaths in Haiti compared to New Zealand for such a similar earthquake?

- What factors do you think influenced the economic losses?

6   How to view Australian seismometers

Online station monitor- Webicorder

You can use the IRIS online station monitor https://www.iris.edu/app/station_monitor/ to look at available seismometers close to you or around the world.

jAmaSeis

jAmaSeis is a cross-platform software that allows users to view near-realtime seismic data from a local sensor or from around the world.

Warning some school firewalls will prevent jAmaSeis from accessing data. If this is the case you will not be able to use this program using the school network. Please let us know and so we can talk to the developers about this issue.

jAmaSeis can be downloaded for free from https://www.iris.edu/hq/jamaseis. You should download the manual and the *Calculating Distance Practice (worksheet/data)*. Installing jAmaSeis is just a matter or running the software.

Setting up jAmaSeis

1. When you run jAmaSeis for the first time it will run a configuration wizard. Unless you have your own seismometer this will not be very helpful, you can just push the cancel button.

2. From the file menu choose *Manage Sources*. Click on the *Add Source* button. Click on the *IRIS DMC* button. This will give you access to seismometers around the world.

3. Choose *Map View* and once the Map View Selection window is up click on *Network Selection*.

4. You will need to add **S** (the Australian Seismometers in Schools network) and **AU** (the Australian National Network) to the list of networks on the left. Scroll down the list on the right and click on AU and then click *Add*. Do the same for S and then click *OK*

5. You can then zoom into your area of Australia to see what seismometers are available. Note that more seismometers will show up as you zoom in.

6. Click on a seismometer you want to look at. Information on that seismometers will show up in the left hand panel. Check the seismometers Status. If it says Online then you can look at this seismometer. Click *OK* in the Map Selection View window and the Sources Manager window.

7. It may take a few minutes for the data to show in the Stream View window. You can repeat this process to show up to 3 different stations at a time.

8. You can change the stations you are viewing by deleting one using *Manage Sources*. By default you will get the low resolution channel that measures ground velocity in the vertical direction.

Note that from time to time different stations will go offline. You can either change the station or just wait till it comes back online.

Extension

If you want to look at higher resolution data or the horizontal ground velocity you will need to use the *Manual* configuration instead of *Map View* at step 3. Click on *Full Station List* and scroll down to S. You can use the http://www.ausis.edu.au/stations map to help you decide which stations you want. Click on the station you are after, −− under location and then you can choose any of the channels available. BHE, BHN, BHZ are the low resolution channels measuring velocity East-West, North-South and Up-Down respectively. HHE, HHN and HHZ are the high resolution channels that measure velocity East-West, North-South and Up-Down respectively. Click on the channel you want and wait to see if it is online. If it is online then click OK.

For each station you can scale and filter the data, just click on the *Scale Data* button. Sometimes the signal will be very small making it look like there is no signal. If the network status says *Connected* try increasing the *Amplitude Magnification* to 10.

7 Earthquake Location

Earthquake Location

Seismograms are used to determine the location of an earthquake. P-waves (longitudinal) and S-waves (transverse) travel at different speeds and this difference tells us how far the earthquake was from the seismometer recording it. It is a bit like the difference between the speed of light and sound when lightening strikes. The P-wave travels faster so is like the lighting flash and the S-wave is like the thunder. The closer in time the P-wave and S-wave arrive the closer you are to where the earthquake occurred. Unfortunately, we can't tell from just a single seismogram what direction it came from, so we need many.

Exercise: Locating an earthquake using triangulation

1. Mark the first arrival of a P-wave and S-wave on each of the seismographs in figure 11. The P-wave should be picked at the onset of shaking and the S-wave should be picked where you see an increase in shaking.

2. Measure the time in seconds between the P-wave and S-wave. This is often referred to as the S-P time. Fill in the table with your results.

3. From the travel time graph in figure 12 determine the how far away the earthquake was from the station. Fill in the column "Distance" in the table. Note that we use this graph because it also allows us to estimate the time of the earthquake.

4. Using the map provided (figure 13), draw a circle around each station that has a radius corresponding to the distance you computed.

5. Estimate the location (a point) of the earthquake based on where the circles intersect.

Station Code	Latitude (deg)	Longitude (deg)	S-P time (s)	Distance (km)
RKGY	-34.6094	116.9773		
AUALB	-34.9995	117.9046		
AUBUS	-33.6601	115.3828		
AUHAR	-33.0927	115.8912		
AUMAZ	-32.0069	116.0384		

Your earthquake location estimate:

Latitude: _____   Longitude: _____

Questions

1. The circles don't seem to all intersect at one point. Explain why this might be?

2. Draw a region (rather than a point) of around where the earthquake could occur. This is the uncertainty in your earthquake location. What might cause errors using this method?

3. If you had one more seismometer to install to record this earthquake where would you put it? Explain why you choose that location.

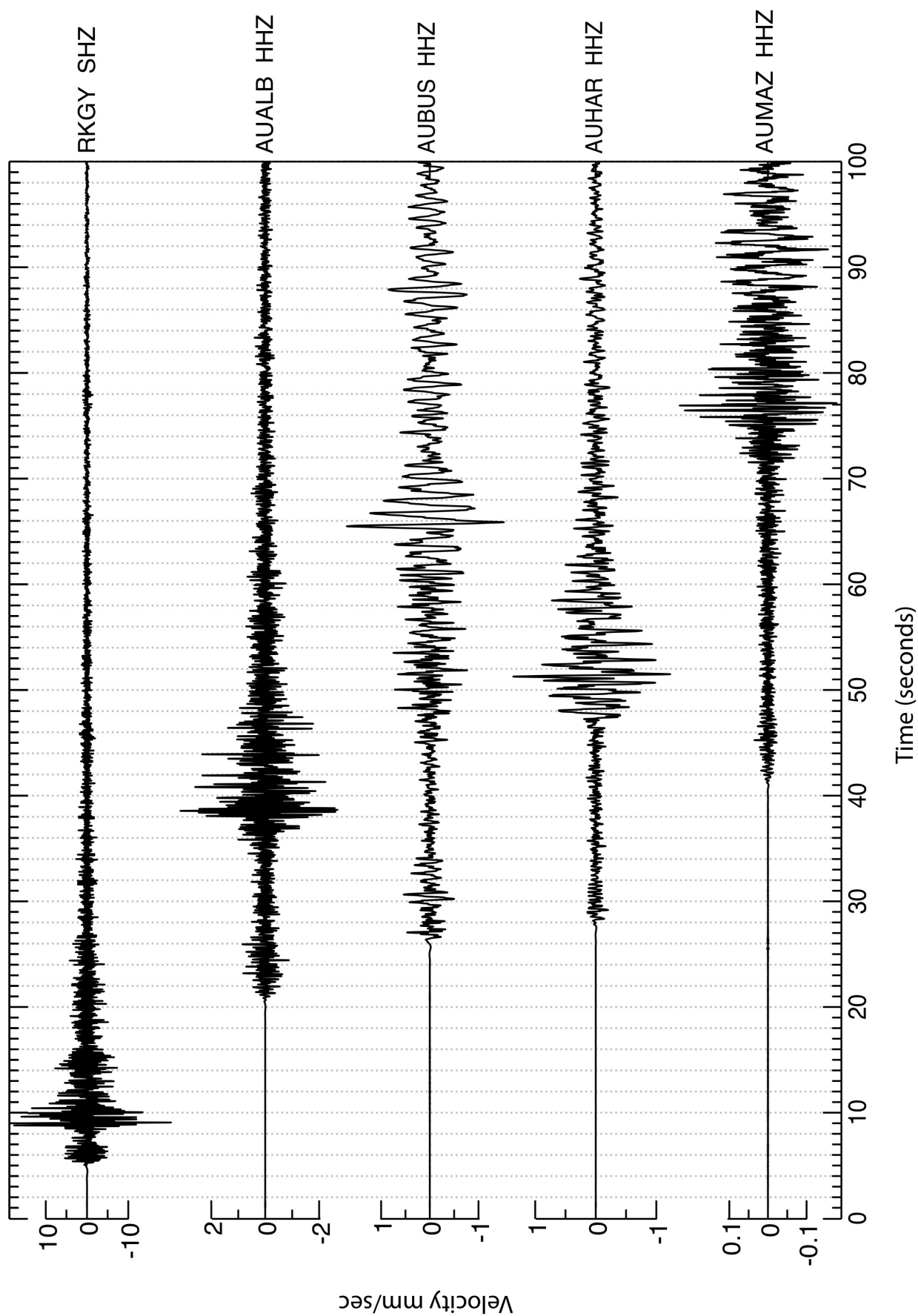4. What is the minimum number of stations you need to locate an earthquake?

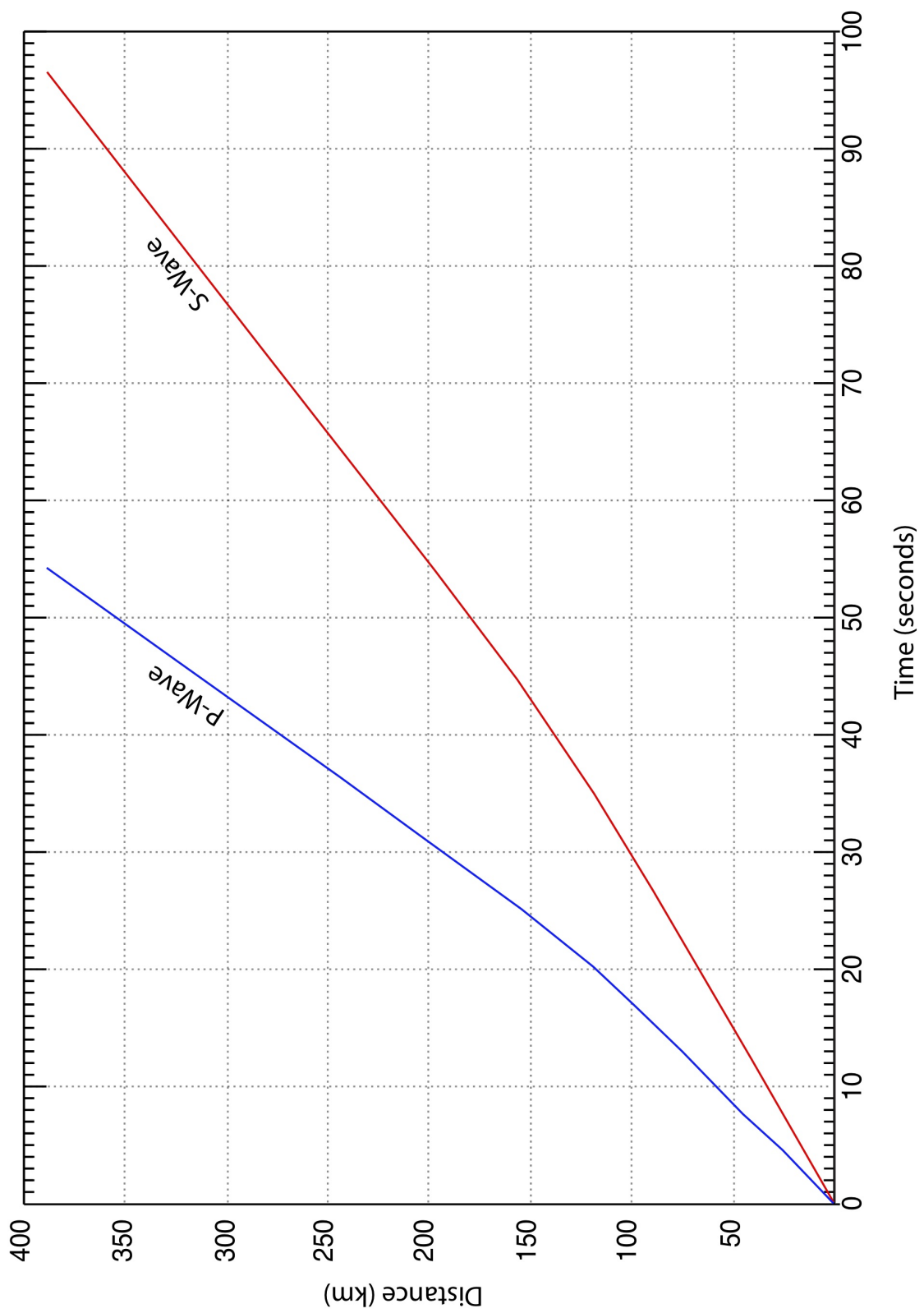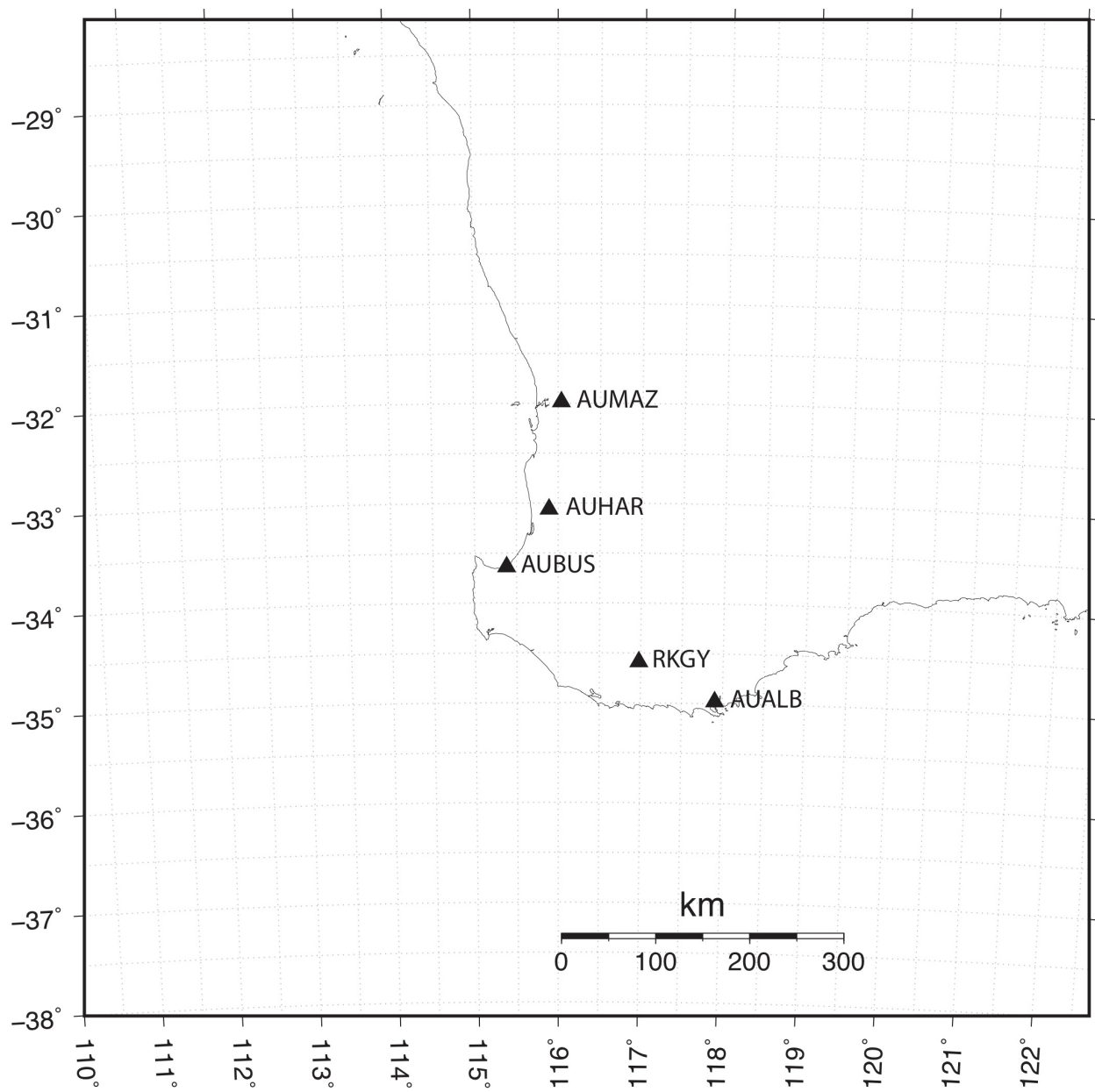**Figure 11:** West Australian Seismographs

Figure 12: Distance vs travel time

Figure 13: Location map

8 Building Response

Aim

The purpose of this module is for students to explore what happens to buildings during an earthquake. This module includes the concepts of frequency, wavelength and resonance.

Definitions

Frequency, f - the frequency of a wave is the number of waves or repetitions that pass through a point in one second. Frequency can also refer to the number of times something oscillates or rotates in one second. Frequency is measured in Hertz ($Hz = cycles/s$)

Period, T - the period of a wave is the time it takes to complete one full oscillation measured in seconds. $T = 1/f$

Wavelength, λ - wavelength is the distance between two peaks in a wave. Wavelength is related to the wavespeed (v) and the frequency $\lambda = v/f$

Natural frequency - Objects will tend to vibrate at a specific frequency. This frequency is determined by the size shape and composition of the object and is called the natural or resonant frequency. Note that $T = 1/f$ allows us to determine the natural period from the natural frequency.

Resonance - When an object is subjected to oscillations at it's natural frequency the object will vibrate strongly. This phenomenon is called resonance and can be destructive.

Introduction

The vast majority of injuries and fatalities reported from earthquakes are not from the earthquake shaking itself but from the effect shaking has on buildings and infrastructure. In most countries, new buildings are designed to a code (set of standards or rules) that is based on the potential earthquake hazard in the region.

There are a number of considerations taken into account when building in an earthquake prone area:

- Site Selection
  - Avoid building on slopes or cliffs
  - Avoid soft soil or landfill
  - Avoid building over multiple types of rock/soil
- Foundation
  - Bolt structure to the foundation to avoid the building 'walking' off the foundation during vertical shaking.
- Building Materials
  - Wood - Very good, light and flexible.

- Steel - Good, strong in tension (can fail in compression).
- Masonry (brick or stone) - Poor, heavy and weak in horizontal shaking. Can easily collapse if unreinforced.
- Concrete - Poor, especially if unreinforced.
- Adobe - Poor, heavy and weak.
- Grass hut - Very good (if roof is attached), light and flexible.

When buildings are designed, vertical forces are usually well accommodated because the building must be strong enough to hold its own weight and contents. However, earthquakes impose both vertical and horizontal shaking, and so it is generally the horizontal shaking that does the most damage during an earthquake.

Building an earthquake proof building can be very expensive, so engineers have to trade-off safety versus the cost. A rough guide to the required level of safety is that:

- There is no damage in a minor earthquake.

- There is no structural damage in a moderate earthquake.

- There is no collapse in the largest expected earthquake.

The use of a structure may determine how strong it needs to be. For example hospitals are usually designed to be stronger than most buidings because it is often difficult to move patients to a safe place. Hospitals also provide an important lifeline after an earthquake and would ideally be operational to deal with casualties.

- Can you think of any other structures/building that might be important to keep operational?

Activity 1: Resonance

Purpose

This activity allows students to investigate why some buildings shake more than others during an earthquake.

Introduction

In this case, resonance is the tendency for shaking to be amplified when the frequency of the earthquake matches the natural frequency of a building or of particular site characteristics. When designing a building the engineer should avoid:

- Matching the building resonance to the site resonance; and

- Matching the building resonance to the expected earthquake frequency.

Building resonance can match site resonance when there is a near-surface layer of weak (soft) sediment. This may occur in areas where there has been a lake or riverbed that is filled with sediment. In this case, seismic waves reverberating within the layer can constructively

interfere with later waves arriving in the layer, which causes the waves to amplify (figure 14 A). This occurs when the wavelength (λ) of the seismic waves is approximately 4 times the thickness of the layer (h) (figure 14 B).
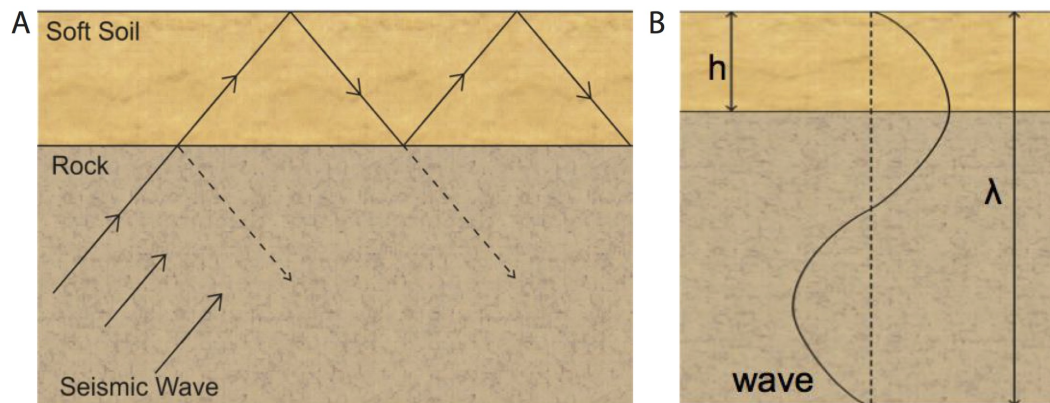
Figure 14

Scientists can assist engineers by providing some understanding of what frequency shaking the building might experience from an earthquake. If the potential shaking is from an earthquake nearby, a building will experience high frequency shaking. In this case, tall and flexible buildings that have lower natural frequencies will experience little damage, however short and stiff buildings might experience more damage. If the potential shaking is from a large, distant earthquake, the building will experience lower frequency shaking and the opposite will be true.

Exercise

Adapated from M. Hubenthal, 2006. Revisiting the BOSS model to explore building resonance phenomena with students. The Earth Scientist, 22(2), 12-16

1. Build the model.

   - Create buildings from a manila file folder or card. Measure out the following lengths of 1 in wide strips (lengths = 2,5,6,7,8 in), use two of each length if the card is not strong enough.

   - Place the two equal length strips together and clip at one end with the binder clips.

   - Drill in each end of the two blocks of wood large enough for the bolts to pass through.

   - Pass one bolt through each end of the blocks of wood and begin to tighten using wing nuts.

   - Place all five buildings equally spaced between the two wood blocks and tighten the wing nuts until secure.

The finished model should look like this.

Let the class inspect the model. Each stick/strip represents a building and the weight on top represents the roof and building services such as air-conditioning/ventilation units on the top of the building.
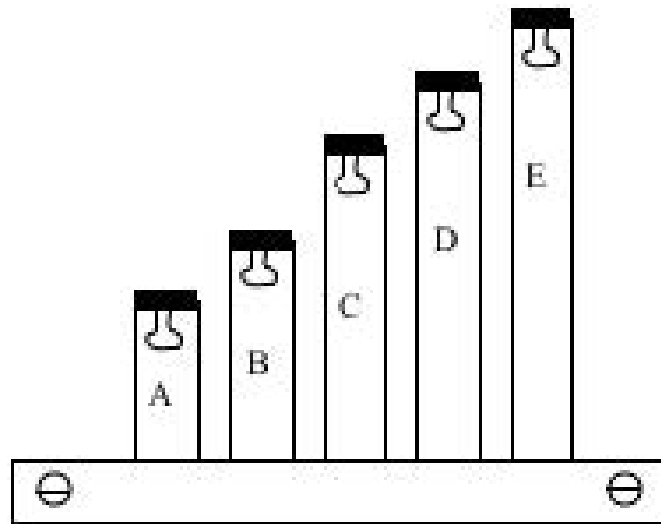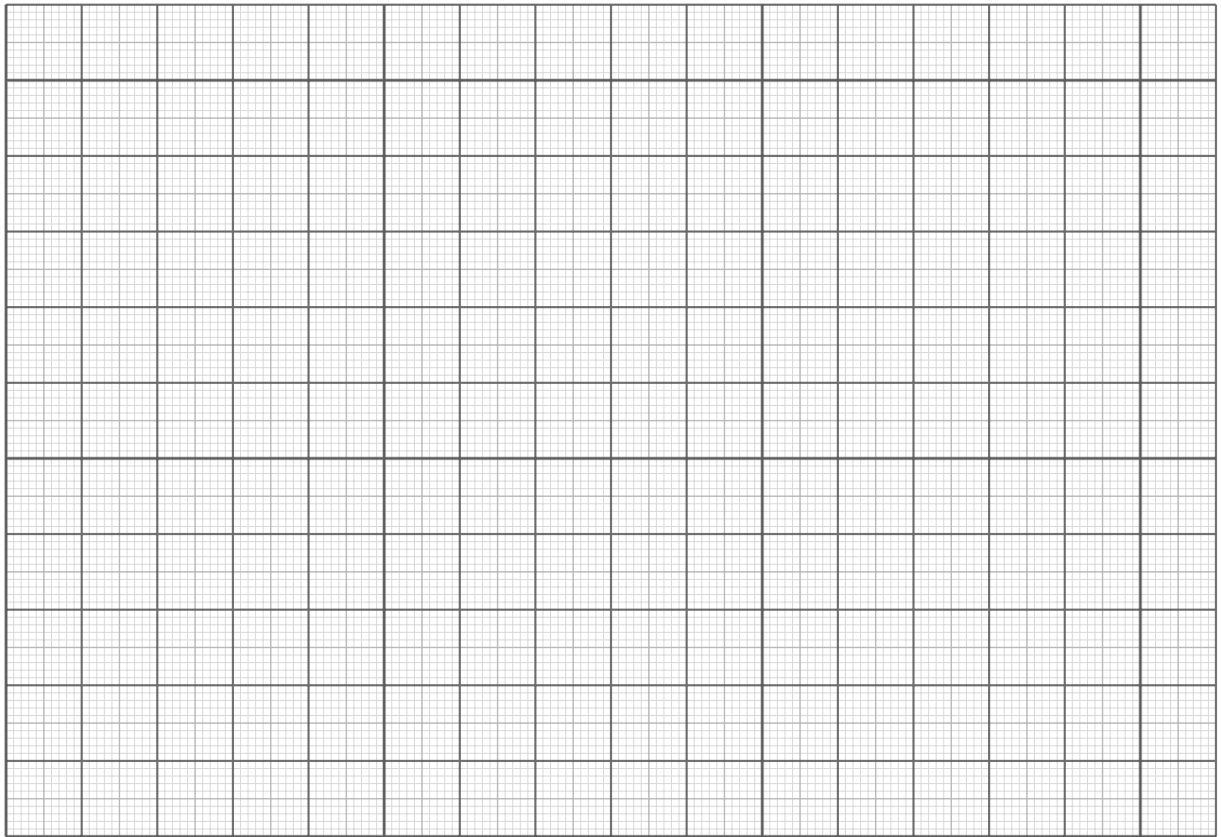
Figure 15

- Which building would you rather be in during an earthquake and why?

Now that students have predicted which building is the most likely to survive an earthquake, begin to create an earthquake by oscillating the base of the model at a low frequency. At low frequencies the tallest building will respond with an amplified displacement of the top of the building. Now progress through the spectrum of frequencies towards higher frequencies. As you do, students will notice that the tall building no longer responds, but progressively the small and smaller buildings do! (It is important that you keep the amplitude of the oscillations as consistent as possible for all frequencies). Get the students to record their observations.

Building height	Oscillations time (sec/10 cycles)				Avg. Oscillation times	Natural Frequncy Hertz
	Ttial 1	Trial 2	Trial 3	Trial 4	(sec/10 cycles)	(cycles/s)

Plot the height vs the natural frequency of each building.

- Did your observations change you mind about which building you would prefer to be in during an earthquake? Why.

- What pattern do you see in the Natural frequencies of the buildings?

Summary

All buildings are at risk of shaking during an earthquake; however, the building response to the shaking is related to the frequencies of the seismic waves that reach the building. To avoid this behavior one can:

- Select an appropriate number of floors for a building if the site resonance is known.

- Move weight to lower floors.

- Change the shape of the building.

Food for thought: What influences the frequency of earthquake waves?

Building Resonance Case Study

In 1985, Mexico City was shaken by a magnitude 8.1 earthquake that occurred ~400 km away. The city experienced considerable damage from the distant earthquake due to amplification of the seismic waves. The most severe damage occurred to buildings between 10-16 storeys, while buildings taller and shorter had far less damage. So what happened?

1. The city is built on an old lake bed made of soft clay. The soft, weak layer is ~40 m thick (h=40 m) and the velocity of the shear-wave was ~100 m/s. That meant the resonant period was ~1.6 s.

2. Buildings have resonant periods where shaking is amplifies, typically this is T = 0.1 s/storey. Therefore the resonant period for a 16-storey building is 1.6 s; this is the same period as the waves in the underlying weak sediment layer.

The combination of these two points plus poor building construction lead to the collapse of ~500 buildings and ~8000 fatalities in Mexico City.

Figure 16: Pina Suarez Apartment Complex after the 1985 Mexico City earthquake

Additional Resources

https://www.iris.edu/hq/inclass/animation/building_resonance_the_resonant_frequency_of_different_seismic_waves

10   Resources

This section provides links to places you can find additional resources.

Software

jAmaSeis https://www.iris.edu/hq/jamaseis/

jAmaseis is free cross-platform software that allows users to collect and view near real-time seismic data from a local sensor or from around the world.

QNCLive http://quakecatcher.net/education/qcn-interactive/

Quake Catcher Network software allows you to use a USB accelerometer to record your own seismic signals.

Seismograph Apps

Seismo - Android

iSeismometer - iPhone

Online Educational Resources

http://www.ausis.edu.au - Education modules are provided under the **Resources** tab or the **Educational Resources** button.

http://www.ga.gov.au/education - Classroom resources, teacher and student programs and education centre, including virtual tours.

https://earthquakes.ga.gov.au/ Realtime local and global earthquake catalogue and a place to report a felt earthquake.

https://www.iris.edu/hq/ - Animations, videos, teachable moments and classroom activities are all provided under their **Education** tab.

https://earthquake.usgs.gov/learn - FAQs, Today in Earthquake history, teaching resources and much more.

http://www.earthscope.org/birthquake/ - Find the most powerful earthquake that occurred on your date of birth.

http://quakecatcher.net/education/ - Lessons and activities and an online earthquake simulator.