Exploring Science Extra

How Science Works

Earthquakes

5

ALWAYS LEARNING

PEARSON

1 Earthquakes and tsunamis

Earthquakes can kill thousands of people. It is not the shaking of the ground that causes death and injury but the effects of the shaking on other things. Usually, deaths are due to people being hit by falling buildings or being trapped in collapsed buildings.

A very powerful earthquake hit San Francisco in 1906. Falling buildings killed some people, but many more were killed by fires. The earth movements broke gas pipes, and this caused fires that burned for 4 days. Water pipes were also broken, so firefighters did not have enough water to put out the fires.

A *Rescue workers often use dogs to help them to find people trapped beneath fallen buildings.*

Earthquakes beneath the sea can cause huge waves called tsunamis that spread out across the ocean. When it reaches land, a tsunami can drown people and damage buildings several miles inland. One of the worst tsunamis in recent times happened in 2004, when an earthquake under the Indian Ocean caused a tsunami that killed over 200 000 people in Indonesia.

B *Damage caused by the 2011 tsunami in Japan.*

On the 11th March 2011 an earthquake and tsunami hit eastern Japan. Over 15 000 people died, over 90% of them by drowning. The earthquake and tsunami also damaged a nuclear power station at Fukushima Daiichi. Although workers tried to shut down the power station safely, there were several explosions and radioactive material escaped into the environment.

2 After the disaster

The danger isn't over when the earth stops moving. There are usually more 'aftershocks' that follow a major earthquake, but these are not usually as powerful as the main earthquake.

An earthquake that destroys buildings is likely to have destroyed local hospitals, so there is nowhere for injured people to be treated. Railway tracks will be broken or bent, and roads blocked, so it is difficult to get food and medical help into the area. Many people will be made homeless because their houses have either been destroyed or damaged so badly that they are unsafe to live in. They need materials to build temporary shelters to use until their homes can be rebuilt.

Drains are also damaged by earthquakes. Sewage can easily get into drinking water and cause diseases, so disaster victims need to be supplied with clean water as well as food and shelter. If there are a lot of dead bodies around, they can also cause disease unless they are buried quickly. If there has been a major earthquake, many people will be buried in mass graves dug using bulldozers.

After the 2010 earthquake in Haiti, many aeroplanes carrying medical supplies were turned away because the airport was too busy. It took several days before the airport could accept all the incoming flights bringing help. In other places, some people in very remote villages need food and other supplies dropping by parachute because the roads leading to them have been destroyed.

C *Many people had to live in temporary shelters after the earthquake in Haiti in 2010. It is sometimes difficult to work out how many people died in a disaster, but estimates for this earthquake are between around 100 000 and over 300 000.*

D *This hospital laboratory was still operating in a tent 6 months after the Haiti earthquake.*

3 Earthquakes in the past

Earthquakes have always happened on Earth, but we only have records for those that have been written about by humans. The earliest recorded earthquake was in China in 1177 BCE. The earliest recorded in Europe was in 580 BCE.

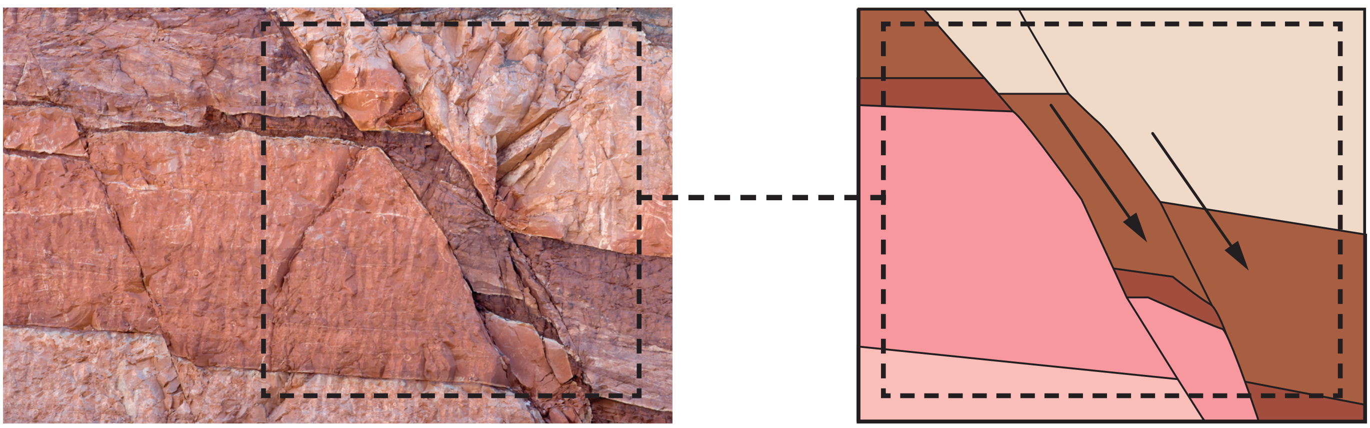
Earthquakes happen when forces build up in the Earth's crust, and the crust eventually breaks or moves. The line along which the rocks move is called a fault. Some faults can be detected using features in the landscape, such as kinks in streams, or long cliffs called scarps.

This part of the land moved up along the fault.

This part of the land moved down.

E *This is Malham Cove, in Yorkshire. The cliff was formed when the land in front of it moved downwards along part of the Craven Fault (which is no longer active).*

If a fault passes through different layers of rock or soil, geologists can see where the fault runs and how far the rocks have moved. On large, active faults, geologists can dig trenches down into the fault to look for evidence of movements in the past. This can help them to work out how often earthquakes might occur.

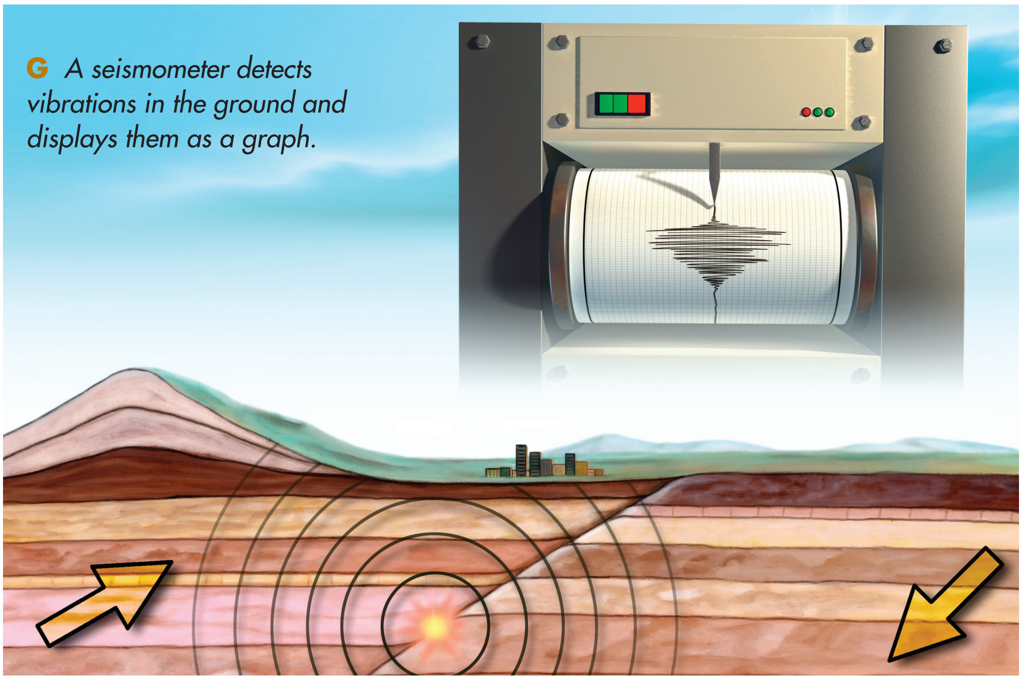


F *This rock shows two faults where the layers of rock on the right have moved down compared to the layers on the left. There would have been a small earthquake each time the rock moved.*

Not all faults can be seen. Rocks deep under the ground also move. Scientists can work out where an underground active fault is by detecting waves from small earthquakes that occur along the fault.

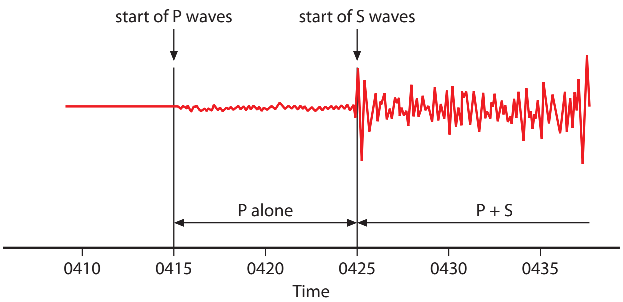
4 Locating earthquakes

If you feel the earth shaking, you know there has been an earthquake somewhere near you. However, geologists studying earthquakes need to know the location much more precisely than this. They can locate the focus of an earthquake (the place where the rocks broke and moved past each other) using seismic waves. Seismic waves are vibrations in the rocks that spread out from the focus, and are detected using seismometers.

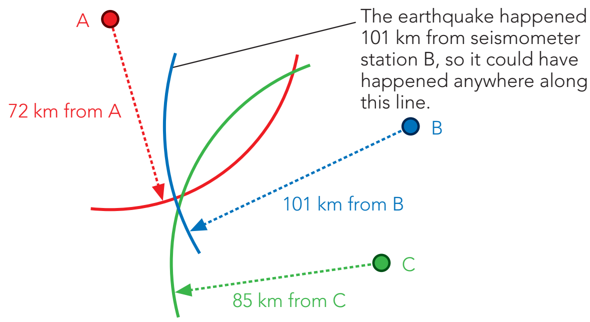


G *A seismometer detects vibrations in the ground and displays them as a graph.*

Earthquakes produce several different kinds of wave. P-waves are longitudinal waves, like sound waves. S-waves are transverse waves, which go up and down similar to waves on water. P-waves travel faster than S-waves. Scientists can compare the 'arrival times' of the P-waves and S-waves from an earthquake to work out how far away the focus was. If several seismometer stations detect the earthquake, scientists can work out exactly where the earthquake happened.



H *Scientists can use the time marked as 'P alone' to work out how far the focus of the earthquake was from the seismometer station.*

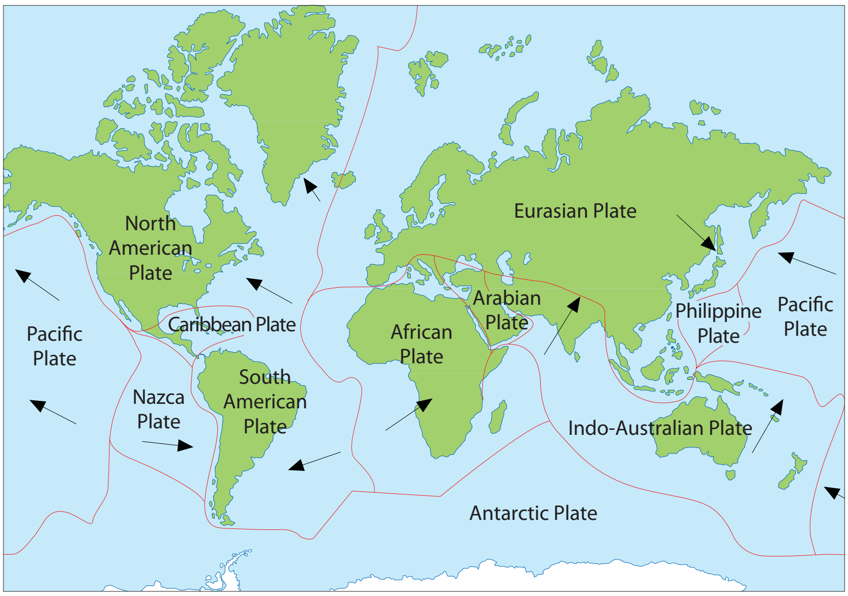


I *Information from several seismometers is used to locate the focus of the earthquake.*

5 Plate tectonics

If all the known earthquakes are plotted on a map of the world, most of them follow lines along the edges of continents or through the middles of the oceans. The pattern in the locations of earthquakes was one of many pieces of evidence that led to the theory of plate tectonics.

This theory says that the surface of the Earth is split into several 'plates' that move around slowly. Map J shows the plates and the directions in which they move. This theory explains many different observations made by geologists.



J *The surface of the Earth is split into slowly moving plates.*

In some places, such as the San Andreas fault in California, the plates can slip past each other. Earthquakes happen when the plates move in sudden jerks.

K *Tungurahua volcano is in Ecuador. The Nazca plate is descending below South America, and producing magma that forms volcanoes.*

In other places, the plates are moving towards or away from each other. Places where plates move apart are usually under oceans. Magma rises up from inside the Earth and creates new rocks in areas called mid-ocean ridges.

When plates move towards one another, one plate may be forced down into the Earth. This causes rock to melt, and the magma rises up and forms volcanoes. This is why many volcanoes are found on plate boundaries.

6 Reducing the risks

L *Many of the old buildings in and around Bam were built from mud bricks and many of the modern buildings did not follow local building codes. The earthquake in 2003 caused over 26 000 deaths and injured over 30 000 people.*

Earthquakes, volcanoes and tsunamis are geohazards. One way to reduce the risks of harm from geohazards is to avoid living where they are likely to occur. However millions of people live in these zones, so this is not always possible.

Predictions

Scientists can often predict when a volcano is about to erupt, and evacuate people from the danger area. However predicting earthquakes is not so easy. Although scientists know the areas in which earthquakes are likely to occur (along plate boundaries), they cannot predict *when* an earthquake will happen.

Safer Buildings

In some places, buildings are located on sandy soil or on land reclaimed from the sea. In these places the shaking caused by earthquakes can make the normally solid ground act more like a liquid that buildings can sink into.

The amount of damage to buildings depends on the strength of an earthquake and also on the materials and design of the buildings. Regulations in earthquake zones include ways to help stop buildings collapsing, but are not always followed.

The earthquakes in Bam, Iran in 2003 and in Christchurch, New Zealand, in 2011 were similar sizes. They caused very different numbers of deaths and injuries, mainly because of the different materials and designs used for the buildings.

M *The damage to this building in Christchurch was caused by the earthquake in February 2011. The earthquake killed 185 people and injured about 6000 people.*

5 Exploring Science Extra

Introduction

Welcome to the latest Exploring Science Extra pack. As ever, the pack contains a Student Booklet, a Teacher's Guide (containing suggested activities) and Activity Sheets (to support some of the activities).

The pack is designed to be topical and to inspire students, taking them slightly outside of the traditional Key Stage 3 curriculum areas whilst continuing to develop key scientific skills. Each activity is linked to a unit from Exploring Science: How Science Works, making it easy to incorporate them into your teaching.

The 12th of January marks the 3rd anniversary of the magnitude 7.0 Mw earthquake that hit Haiti, killing some 220 000 people and causing such devastation to this impoverished country that the clean-up and rebuilding operation is still in progress. The following year, a magnitude 9.0 Mw earthquake hit the east coast of Japan causing a massive tsunami. These events led to meltdowns in nuclear reactors and the deaths of some 16 000 people. The Christchurch earthquake also occurred in 2011, with a magnitude of 6.3 Mw and killing 185 people. This pack considers how earthquakes are caused, their widely different effects and they are studied. If you get really keen, you could set up a seismometer in school. Have a look at the British Geological Survey for more details: www.bgs.ac.uk

Did you know?

In this pack, we continue looking at how to start preparing Key Stage 3 students for the challenges of science GCSE and the new exam (probably called an EBC) for first examination in 2017.

In the last couple of packs we've considered how to structure longer pieces of writing. The Fireworks Pack considered how to develop and write clear arguments. The Christmas Trees Pack took a look at how to compare things in a long answer style. And in this pack, we provide help and opportunities to practice answering questions that demand descriptions of how things happen. There's an additional Skills Sheet in the pack to help with this.

As ever, we value your feedback and ideas. So keep them coming! Tell your rep or contact us through the website

http://www.pearsonschoolsandfecolleges.co.uk/Secondary/GlobalPages/ExploringScienceExtra/ExploringScienceExtra.aspx

With best wishes for the New Year,

Mark

Mark Levesley,
Series Editor

5 Earthquakes

There is a very good overview of earthquakes and how they are measured on the British Geological Survey's website at http://www.bgs.ac.uk/discoveringGeology/hazards/earthquakes/home.html. You can use this as background reading, and you may wish to show some of the images or small animations there to supplement the text in the Student Booklet.

Animal senses

***Exploring Science* link: 7A**

Introduce this activity by looking at the photograph of a dog being used to locate earthquake victims on page 1 of the Student Booklet. Ask students what the dogs can detect that humans cannot. Elicit the response that they have a better sense of smell. Then ask students to suggest senses that other animals have that humans do not.

Ask students to work in groups to research other animal senses. Groups could be challenged to find (say) 3 different animal senses and to report on what the animals sense and how this ability is an adaptation for the way they live. Alternatively, groups could be given suggestions from the following list:

- echolocation in bats and dolphins
- temperature sensing in snakes
- sense of smell in many animals, including snakes using their tongues, and moths using their antennae to detect pheromones
- birds and insects that can see ultraviolet radiation
- 'lateral lines' in fish that detect movement in the surrounding water
- sharks and platypuses detecting electrical fields
- animals using whiskers to sense their surroundings
- pigeons and migratory birds that may sense the earth's magnetic field.

Once students have gathered their information they should organise it, and then use their organised research to write short reports. Skills Sheets SS59 and SS62 (found in this pack) will help.

Resources: Skills sheets SS59 (provided with Exploring Science Extra pack 2), SS62 (found in this pack).

Why we cannot predict earthquakes

***Exploring Science* link: 7H**

Ask students to read the information on earthquakes in the past, and discuss the fact that earthquakes occur along fault lines. Explain that many earthquakes in California occur along a fault called the San Andreas fault, and that scientists know that future earthquakes are likely to occur along this fault.

Activity Sheet 1 provides a model that can be used to illustrate the difficulties involved in trying to predict when an earthquake will occur, even when scientists know about the fault along which it is expected. Ensure that students understand that the brick and the sandpaper represent the rocks on each side of the fault, and that an 'earthquake' occurs when the brick moves.

5 Earthquakes

Students follow the instructions on Activity Sheet 1 and gather data for up to 10 'earthquakes'. A scatter graph of time against distance moved is unlikely to show any correlation. Students may need to be reassured that not finding any pattern in results can be a valid scientific conclusion!

Discuss the results, and help students to see that, in addition to the difficulty of measuring the forces in actual rocks, there are also numerous other factors involved (such as rock strength, friction between already-broken sections of rock, etc) that makes the time at which an earthquake will occur unpredictable.

Groups could pool results to produce a master scatter graph. Some students may object that different groups may have pulled on the bungee cord harder than others; relate this to the fact that the forces on the rocks may not always be the same.

Resources (per group): Earthquake model (sheet of plywood with sandpaper glued onto it, brick, string, bungee cord – refer to diagram on Activity sheet 1); stopclock; metre rule; Activity sheet 1; skills sheet SS35. Optional: G-clamp or other means of holding the plywood board still (if this is not available, a student in each working group will have to hold the board still).

Measuring earthquakes

***Exploring Science* link: 7K**

This activity will introduce students to the idea of using descriptive scales to measure events that are not easily measurable directly. There are several different scales for recording the 'size' of an earthquake. The one most people have heard of is the Richter scale, but this is no longer used within the scientific community.

The moment magnitude scale (Mw) is a measure of the energy released in an earthquake, and is determined from the average amount of slip and the area over which the slip occurred. The details of this are too complex for the purposes of this exercise, but the 'magnitude' of an earthquake can just be described as ‘related to the energy’, which can be measured using the sizes of the deflections on seismograph traces.

The intensity of an earthquake is based on the effects on the ground. The intensity scale in current use is the Modified Mercalli Intensity scale (MMI). The intensity reduces with distance from the epicentre - the point on the Earth's surface directly above the focus (the point where the earthquake occurred). If an earthquake intensity is quoted it is likely to be for the epicentre.

There are a number of possible activities related to these scales:

- Ask students to find out about the descriptions in the Modified Mercalli Intensity scale for different intensity earthquakes.
- Use the BGS website to look up earthquakes in the UK in the past 40 years (http://mapapps2.bgs.ac.uk/earthquakes/home.html). Students could identify earthquakes that have happened in the local area, and note their magnitudes. The Wikipedia page (http://en.wikipedia.org/wiki/Mercalli_intensity_scale) has a table relating magnitude to intensity, so students could also be asked to suggest what people in the area at the time may have experienced. This could be developed into a piece of creative writing, with a scientific angle.
- Ask students to find out the magnitudes of earthquakes that have happened recently in California, New Zealand, Japan or Indonesia and relate these to intensities. The USGS site

has a facility to look up earthquakes over the last 30 days, including sliders to constrain time and intensity of the earthquake (http://earthquake.usgs.gov/earthquakes/map/).

- Ask students to find out what precautions are recommended for people living in earthquake zones, and against what intensities (or magnitudes) of earthquakes these would be effective.
- Discuss how a combination of the magnitude and intensity scales could be used by geologists investigating earthquakes that happened before seismometers were invented (i.e. using historical records and eyewitness accounts of damage to estimate the magnitude).

Resources (per group): access to the internet; skill sheets SS38, SS59 (SS59 is provided with Exploring Science Extra pack 2)

Disaster assistance

***Exploring Science* link: 8A, 8C**

This activity also links with *Emergency shelters* below.

This activity provides an opportunity to consolidate learning in Units 8A and 8C by asking students to design 'aid packs' to be sent to earthquake victims, and/or to make posters or leaflets advising victims how to avoid disease.

Introduce the activity by looking at *After the disaster* (page 2 in the Student Booklet). Students can work in groups to list the contents of an emergency pack designed to feed a family of four for a week. Their list should take into account:

- the energy needs of two adults and two children
- providing a reasonably balanced diet
- the lack of facilities for chilling foods, so all foods need to be dried, tinned or preserved in other ways
- ease of cooking – students should assume that cooking will be done in a single pot/pan over a stove or open fire. No ovens.

As an additional or alternative activity, students could design posters or leaflets with advice on avoiding disease. If being carried out together with the food part of the activity, students should be encouraged to suggest items such as soap, water purification tablets and mosquito nets for their emergency pack.

As an alternative activity, ask students to read page 2 of the Student Booklet and take notes to describe what needs to be done to help people affected by an earthquake. Skills Sheets SS59 and SS62 (found in this pack) will help.

Resources: (optional) access to computer with word processing/desk top publishing software, SS59 (found in pack 2), SS62 (found in this pack).

5 Earthquakes

Plate tectonics

***Exploring Science* link: 8H**

This activity gives students the chance to work with some real earthquake data. One of the activities leads students to find the locations of earthquake zones, and this activity is best carried out *before* students read *Plate tectonics* (page 5 in the Student Booklet).

The USGS website provides a facility to look at an interactive map showing the locations of earthquakes worldwide over the last 30 days, or to download a spreadsheet or Google Earth map showing the earthquakes (http://earthquake.usgs.gov/earthquakes/map/). For some of the activities below, set up the options on the website before students use it as noted below.

The file earthquakesmap.kml is a Google Earth file showing earthquakes for the 30 days up to 10.12.2012 (the date this worksheet was published). You can download a similar file for more recent earthquakes from the link above.

The file earthquakes.xls is an Excel file containing the same data. Again, you can download a more up to date file from the USGS website.

Ask students to find out where 'earthquake zones' are located. This can be done by:

- using the USGS website – students will gain most from this activity if they start with the faults and plate boundaries not shown
- using the Google Earth map – in this case ask students to pay particular attention to earthquakes in the middle of the oceans and what the globe shows at these points (they should notice that these earthquakes occur along the ridges shown – these are the constructive plate boundaries).
- using the spreadsheet and plotting a scatter graph of longitude and latitude, and then matching up the resulting pattern with a world map. This is done most easily by swapping the latitude and longitude columns in the spreadsheet and then using the chart wizard (swapping the columns is necessary to make longitude plot along the horizontal axis in Microsoft Excel™).

Following one or more of the above activities, students can read the Student Booklet page on plate tectonics, and look at the USGS website map with the plate boundaries switched on. Note that active volcanoes also produce small earthquakes due to magma movements, which explains the cluster of earthquakes in Hawaii (Hawaii is far from a plate boundary, and its activity is believed to be due to a plume of hot material rising from the core of the Earth).

Ask students to find out if large or small earthquakes, or deeper or shallower earthquakes are the most common, or if the magnitude depends on depth. The former can be done using the histogram facility in the Data Analysis pack that can be installed into Excel.

With some students you could extract the necessary columns into a new spreadsheet and set up the histogram formulae for them, so they just need to use the chart toolbar to plot scatter graphs or histograms and then discuss what the charts show. The results will vary with the time over which the earthquakes are sampled.

More able students could be given a ready-made spreadsheet as suggested above, based on the one supplied with this pack, and then asked to extract recent data from the USGS website and compare the two. Discuss why any conclusions they come to should be based on as many sampling intervals as possible.

Earthquakes

Ask students to compare the map showing the moving plates in the Student Booklet with the Google Earth globe. Ask them to try to identify the kind of landforms present when:

- two plates are moving away from each other (mid-ocean ridges)
- two plates with continents on them move together (mountain ranges form – e.g. Alps, Himalaya)
- a continental plate moves towards an ocean plate (a trench and a range of volcanoes/mountains – e.g. the western coast of South America)
- two ocean plates move together (a trench and a string of islands – e.g. Japan, Aleutian Islands, Philippines, Solomon Islands, etc).

Resources (per group): access to computer with spreadsheet program and/or Google Earth, access to the internet.

Emergency shelters

***Exploring Science* link: 8I**

This activity also links with *Disaster assistance* above.

This activity provides an opportunity to consolidate learning in Unit 8I by asking students to design emergency shelters or clothing/blankets to be sent to earthquake victims, or shelters that can be easily constructed from locally available materials. Introduce the activity by looking at *After the disaster* (page 2 in the Student Booklet).

Students could work in groups to design shelters:

- for particular locations (e.g. hot and wet, needing shelter from sun and rain but also requiring ventilation, or cold, wet and windy, requiring sturdy shelters that will also be warm)
- that can be easily transported and assembled and are relatively cheap, or than can be assembled from materials likely to be available locally.

Alternatively, students can find designs for emergency shelters on the internet (such as http://weburbanist.com/2008/11/12/lifesaving-temporary-emergency-shelters-buildings/ or http://inhabitat.com/tag/emergency-shelters/) and evaluate the designs in terms of insulation, availability of materials etc. Their findings could be presented in the form of a report to an aid agency recommending a design (or different designs for different parts of the world).

Resources (per group): Skills sheets SS38, SS39, SS40, SS59 (SS59 is provided with Exploring Science Extra pack 2).

Earthquakes

Animal warnings?

Exploring Science **link: 9D**

This activity gives students the opportunity to discuss the kind of evidence required to scientifically test a hypothesis. Page 6 in the Student Booklet explains why predictions of earthquakes would be useful, and Activity Sheet 2 provides some information about the idea that animal behaviour can be used to warn of an impending earthquake. Further details about items B to D can be found on the internet if students want to investigate these examples further.

Answers

1 Possible answer: animals may have exhibited similar behaviour at other times, but the owners only remembered the behaviour because it was followed by the earthquake, or only remember it because they have been asked about it after the earthquake. In item D, the animals' behaviour was being recorded on a regular basis for some time before the earthquake so this kind of bias is unlikely to have happened.

2 Possible suggestions: how often had the toads been observed in other years, had they ever deserted the breeding lake before, had this kind of desertion been observed anywhere else with or without a subsequent earthquake?

3 Possible answers: earthquakes are unpredictable, so even if the study is carried out in an area prone to many earthquakes researchers may have to keep observing for many years before an earthquake happens in the place they are making their observations; observing animals reacting before an earthquake still gives no indication of *how* they are detecting the coming movements, so researchers would also have to take many measurements of possible things that animals may be detecting, with all the same difficulties as already described.

4 Possible answers: B and D – A is just a single anecdote, and in Haicheng (C) the animals may have been reacting to the foreshocks or ground level changes – things that the humans had also detected.

Resources (per group): Activity sheet 2

Safer buildings

Exploring Science link: 9E

This activity allows students to consider the effect of building materials and design on safety in two different ways. Introduce the activity by looking at page 6 in the Student Booklet.

Videos are available on the internet illustrating the liquefaction mentioned in the Student Booklet. Liquefaction was the cause of much of the building damage caused in the 1906 San Francisco earthquake mentioned on page 1 in the Student Booklet.

Background notes: Two earthquakes are mentioned in the Student Booklet. The Bam earthquake had a moment magnitude of 6.6, and the February 2011 earthquake in Christchurch had a moment magnitude of 6.3. Both occurred within a few miles of the cities for which they are named.

The Christchurch earthquake is considered by some geologists to be just one of a series of aftershocks following a magnitude 7.1 earthquake in September 2010 (the Feb 2011 aftershock is chosen for discussion as it has a similar magnitude to the Bam earthquake). The 2010 earthquake did not kill anyone. The greater damage caused by the 2011 earthquake is in part due to building damage caused by earlier earthquakes, to more liquefaction occurring which undermined buildings and roads, and to greater ground accelerations.

Ask students to compare these and other pairs of earthquakes of similar magnitude, comparing casualties and any available comments about building styles. Discuss with students the criteria they should use in choosing earthquakes for comparison – similar magnitude (as close as possible, as magnitude is a logarithmic scale), similar proximity to populated areas, etc. Wikipedia has various pages listing earthquakes – these and the follow-up articles on Wikipedia would provide sufficient information, although students can search elsewhere on the web if they wish. Ask students to present their work as a short report, comparing one or two pairs of earthquakes. Skills Sheet SS61 (found in Exploring Science Extra pack 4) will help.

Ask students to find out *how* buildings are made more resistant to earthquakes. The How Stuff Works website has a useful sequence on How Earthquake-resistant Buildings Work (http://science.howstuffworks.com/engineering/structural/earthquake-resistant-buildings.htm). Students can report their findings in writing, via a short talk, computer presentation or poster. Key points they should identify are: building on rock rather than sand/soil where possible, fastening parts of the structure together, including steel reinforcement in buildings made of brittle materials such as brick, providing cross-bracing to building frames, and isolating the base of the building from the ground below using dampers.

Resources (per group): access to the internet, Skills Sheets SS38, SS39. SS59 (found in pack 2), SS61 (found in pack 4).

Warning systems

Exploring Science **link: 9K**

This activity gives students a chance to practice using the speed equation in the context of earthquake and tsunami warnings. Activity sheet 3 provides a context and some questions. Note that the speeds of P and S-waves quoted there are simplified – in practice calculation of times is more complex as most earthquakes occur below the surface and the speeds of seismic waves vary with depth.

Although a few seconds' warning of an earthquake may not seem a lot, it does give time for things like stopping or getting out of lifts, pausing surgical procedures, starting up emergency generators etc. Early warning systems are also in place or being developed in Mexico City, Istanbul, Bucharest, Italy, California and Taiwan.

Answers

1 **a** Calculate the travel time of the P-waves: t = d/s = 370 km / 7.4 km/s = 50 s

b t = d/s = 370 km / 4.0 km/s = 92.5 s = 1 m 32.5 s

2 **a** d = s x t = 7.4 km/s x 89 s = 659 km

b Time for S-waves to travel 659 km = 659 km / 4.0 km/s = 164 s

Difference = 164 s – 89 s = 75 s

3 Time for P-waves to arrive at Sendai + time for alert to be issued = 50 s +15 s = 65 s

Warning = 89 s – 65 s = 24 seconds

Or, difference in distance between Sendai and Sapporo = 659 - 370 = 289

Time taken for P-waves to travel 289 km = 289/7.4 = 39 s

Subtract additional time taken to issue alert = 39 – 15 = 24 s

4 **a** No warning. The P-waves were first detected at Sendai, so the earthquake was already happening there before the warning was issued.

b Assuming the tsunami alert is issued at the same time as the earthquake warning (i.e. 15 s after the earthquake occurs).

Time for tsunami wave to arrive = distance/speed = 370 km/0.22 km/s = 1681 s

Warning time = 1681 – 15 = 1666 sec (this is 27 min 46 sec).

5 Any sensible answers, such as sheltering under tables, etc. Moving away from buildings if they are outside.

6 Answers should take into account the difference in the warning times. Earthquake warnings only allow people to take immediate shelter or move away from things that might fall on them. The warning time available for a tsunami should be enough to allow people to move to higher ground. Students may be interested to know that taking refuge on upper floors of strong buildings is also a good survival strategy for tsunamis, as long as the location is far enough away from the epicentre of the original earthquake to have avoided damage from the shaking. There are some videos on the internet of the 2011 Japan tsunami taken from buildings whose lower stories were inundated.

Resources (per student): Activity sheet 3, calculator

1 Why can't we predict earthquakes?

Modelling an earthquake

An earthquake happens when forces in rocks build up and become large enough to make the rocks break. This often happens along an existing fault, because the rocks are weaker where they have been broken in the past. But even though scientists know that earthquakes are likely to happen along existing faults, they cannot predict *when* the next earthquake will happen.

The diagram shows some apparatus that can be used to model earthquakes. The brick and the sandpaper represent the rocks on each side of a fault. Pulling on the bungee cord represents the forces building up in the rocks.

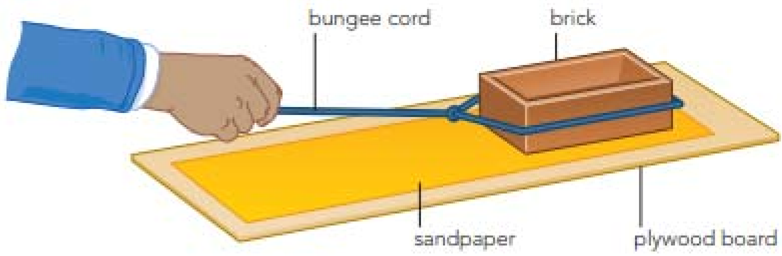
Apparatus

earthquake model

metre rule

stopwatch or stopclock

Optional: G-clamp



Method

A Set up the apparatus as shown in the diagram. Make sure the brick is positioned at one end of the sandpaper. One person needs to hold the board (so that it doesn't move) or use a clamp.

B Start the stopclock and gently pull on the bungee cord until the brick starts to move.

C Stop the stopclock when the brick moves and write down the time. Measure how far the brick moved, and write that down as well.

D Repeat steps A to C until you have 10 results. Try to pull the cord with the same force each time.

Recording your results

1 Draw up a table to record your results clearly.

Presenting data

2 Draw a scatter graph to show your results.

3 **a** Work out the range of times from your results (the longest time minus the shortest time).

b Work out the range of distances.

Considering your results/conclusions

4 Do your results show any pattern? If so, describe the pattern.

Evaluation

5 Do you think a scientist could use the size of an earthquake and the time between that earthquake and the next one to predict when the next earthquake will occur? Explain your reasoning.

6 Did you have any difficulties with this investigation? Suggest how you could improve the method if you did the investigation again.

2 Animal warnings?

Scientists can predict *where* earthquakes may happen, but not *when*. However some people think that animals know when an earthquake is about to happen.

Read the articles below and then answer these questions:

1 There are many stories similar to the one in A. So why is item D a better demonstration that animals may be able to detect earthquakes?

2 Suggest two questions that should be asked about the information in B to find out if the toads really had reacted to something connected with the earthquake.

3 Suggest why it is difficult to carry out a scientific investigation into the possibility that animals can predict earthquakes.

4 Which article (or articles) provides the best evidence that animals *may* be able to detect a pending earthquake? Explain your reasoning.

A

We had an earthquake here last week. Fido tried to warn me, he'd been behaving strangely – but I took no notice. Luckily the house was not damaged and no one in this town was hurt.

B

Scientists in Italy were studying the breeding of some common toads. The toads normally stay at the lake where they breed for up to 7 weeks, but the scientists noticed that almost all the toads suddenly left the lake. A few days later an earthquake was felt in the area. The focus of the earthquake was over 74 km away. It has been suggested that stresses (forces) in the rocks might cause charged particles to be released that the toads could detect, or that might have caused detectable changes in the lake water.

C

City officials in Haicheng, China, ordered an evacuation of the city after they became worried about animals behaving strangely. Parts of the land nearby had risen or fallen, and water levels in wells had changed. There had also been some smaller 'foreshocks'. When the main quake struck a few days later, around 2000 people died. However, without the evacuation the death toll could have been hundreds of thousands of people.

D

A researcher emailed 200 dog owners in Vancouver regularly to ask them about their pet's activities. He was investigating whether dogs suffer from depression in the winter. He found that they did not, but he also noticed something else in his data. He noticed that a day before an earthquake nearly half of the dogs were more active and more anxious than usual. He investigated further, and found that the dogs that were more likely to be able to hear high frequency sounds were the ones that had behaved strangely.

He hypothesised that the dogs may have been hearing high frequency sounds emitted by rocks breaking underground just before the earthquake happened. Other researchers are sceptical, though, pointing out that the focus of the earthquake was over 240 km away from Vancouver, and that such high frequency waves cannot travel very far through rock.

3 Warning systems

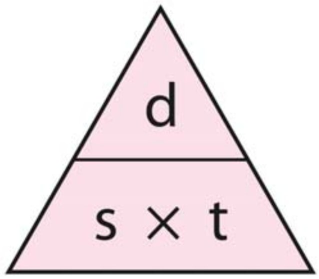
Japan has an early warning system for earthquakes. As there are a lot of earthquakes in Japan, the country has a lot of seismometers. As soon as two of these detect P-waves, the traces are automatically analysed and a warning is sent out.

Japan is also vulnerable to tsunamis. These can happen if an earthquake happens beneath the sea. In this case, people on the coast may get several hours' warning.

Two seismometers near Sendai detect P-waves at 14:05. The waves are analysed and an alert is issued. Later, when P and S-waves have arrived at several different seismometer stations, scientists work out that the earthquake happened in the Pacific Ocean 370 km from Sendai.

Use the information in the table to work out the answers to these questions.

Approximate speed of P-waves near the surface	7.4 km/s
Approximate speed of S-waves near the surface	4.0 km/s
Speed of tsunami waves in deep water	0.22 km/s



This triangle will help you to rearrange the formula for speed.

1 **a** How long did the P-waves take to travel to Sendai?

b How long did the S-waves take to travel to Sendai? Give your answer in minutes and seconds.

2 The first P-waves were felt in the city of Sapporo 89 seconds after the earthquake happened.

a How far is Sapporo from the focus of the earthquake?

b What was the difference in arrival times for the P-waves and the S-waves at Sapporo?

3 How much warning of the arrival of the P-waves would the inhabitants of Sapporo have had? Assume that it takes 15 seconds for the automatic warning system to issue an alert once the first P-waves are detected.

4 Sendai is on the coast, and parts of it were damaged in the 2011 tsunami.

a How much warning would the people in Sendai have had about the earthquake? Explain your answer.

b How much warning would they get if the earthquake also caused a tsunami? State any assumptions you make in working out your answer.

5 Suggest what precautions people in Sapporo could take once they received the earthquake warning.

6 What is the difference between the actions someone in a coastal city would take following an earthquake warning and a tsunami warning?

SS62 Planning long answers (describing)

Some questions ask you to describe things in a longer piece of writing.

What does the question mean?

These questions start with 'Describe' or 'Explain how'. Your answer needs to present a number of points in a logical order, clearly showing the links between them.

How to think about the question

Start your planning by writing down what you know. Use a list of short phrases. Then:

- draw lines between phrases to link them, or
- arrange them into a table with headings to show the links, or
- number the phrases in a logical order.

Examples:

1) Describe how the properties of gold, iron and copper relate to their uses.

Metal	Properties	Uses
gold	shiny, doesn't tarnish	jewellery
iron	cheap, strong	bridges, car bodies
copper	good conductor,	electrical wires

2) Ben boils some water in a kettle. Explain how the energy for this came from coal, and the energy in the coal originally came from the Sun.

7 heat energy in steam 1 light energy from sun 6 water turned to steam in power station

2 photosynthesis 3 chemical energy in plants 4 plants turn to fossils

5 coal 8 turbine and generator in power station 9 makes electricity

What makes a good answer?

You don't need to use all your points but make sure that those you do use are in a good order. You also need to show clearly how one point links with the next. You must use scientific words correctly, and use good grammar, punctuation, and spelling.