7 The changing Earth

Planning page

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Essential Learnings for Chapter 7

Essential Learnings	References		
	Student book (page number)	***Workbook (page number)***	***Teacher Edition CD (Assessment task)***
Knowledge and understanding ***Earth and beyond*** Geological evidence can be interpreted to provide information about past and present events	pp. 159–162	pp. 49–62	Assessment task 7 Dinosaurs and megafauna
Energy and change An unbalanced force acting on a body results in a change in motion	pp. 148, 152	Exercise 6 p. 53	
Ways of working Evaluate data, information and evidence to identify connections, construct arguments and link results to theory	Activity p. 142 Activity p. 149	pp. 49–52, 56	
Research and analyse data, information and evidence	Activities pp. 142, 149, 160	p. 54	
Communicate scientific ideas, explanations, conclusions, decisions and data, using scientific argument and terminology, in appropriate formats		p. 55	Assessment task 7 Dinosaurs and megafauna

QSA Science Essential Learnings by the end of Year 9

Vocabulary

anticline
asthenosphere
continental
epicentre
extinct
fault
fossilised
geological
Gondwana
lithosphere
magma
magnitude
mantle
organism
palaeontologist
petrification
porous
Richter
sedimentary
seismograph
syncline
tectonics
tsunami

Focus for learning

Make inferences about past life on Earth from observations of fossils and modern-day animals (page 137).

Equipment and chemicals (per group)

Investigate 16 page 141 modelling clay or plasticine, plaster of Paris (quick-setting), cooking oil (about 5 mL) and small brush, object to mould (eg shell, bone, twig, leaf), small bucket for mixing plaster, aluminium pie dish, old newspapers, Bunsen burner

Activity page 144 roll of toilet paper

Activity page 149 photocopy of sedimentary layers

Investigate 17 page 155 **Part A:** spiral spring (slinky)

Part B: stand and clamp, metal can with holes in sides for string, one-holed rubber stopper, felt pen, string, roll of paper, glue, hardwood block, adhesive tape, sand

Activity page 156 enlarged photocopy of map of Australia, drawing compass

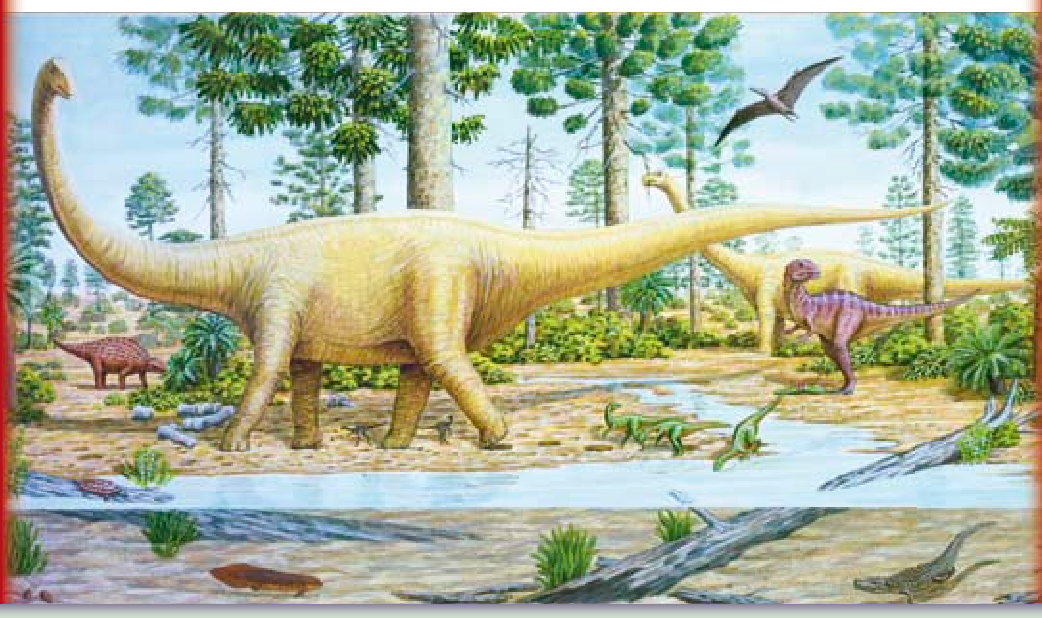
Activity page 160 photocopy of continents from page 159, scissors, glue

7 The changing Earth

Getting Started

The drawing shows an artist's impression of a number of dinosaurs—ancient reptiles that lived in eastern Australia about 100 million years ago.

- From your knowledge of modern-day animals, what evidence would you need to decide which of the dinosaurs ate plants and which were meat-eaters?
- All of the animals in the drawing are now extinct. Suggest inferences to explain why this might have happened.
- Scientists generally construct the size and shape of a dinosaur from incomplete fossil remains such as a few legbones or a jawbone. What assumptions would scientists have to make to do this?



Starting point

1 Planning for learning and teaching is essential at the beginning of any new topic. As a teacher, make sure you have identified what the following are:
   - *Teaching focus*: What do the students already know? What would they like to know? What do they need to know?
   - *Learning activities*: What do the students need to do to learn the knowledge or develop the required thinking skills?
   - *Resources*: What resources will be used in order to clarify and/or reinforce concepts and develop learning?
   - *Real-world applications*: What are some real-world applications of this learning that the students may find interesting?

2 Make use of current science curriculum documents already written for the chapter. If the school doesn't have such documents, then the above 'planning and learning' model is a good starting point when developing them.

3 If possible, pass around some fossils for the students to examine. Ask them to try to guess what they are fossils of, why they are fossils, how old they might be, and how they became fossilised. A class discussion is likely to occur and can be used to identify what the students already know about this topic. It is worth continuing the discussion by asking more complex questions to find out which aspects of the topic the students find most fascinating.

4 Be creative and come up with a story about finding a bone that you think may be prehistoric, or a fossil, but you are not really sure if it is this old. Ask the class to devise an action plan to help identify what the discovery is. Lead them through their action plan by using a cognitive learning structure such as Bloom's taxonomy (remembering, understanding, applying, analysing, evaluating and creating). A task like this requires students to identify what they know, promotes creativity and problem solving, and directs self-learning and evaluation. A class project could be formulated around the action plan as it incorporates many areas of science (scientific method, forensics, chemistry, ecology, palaeontology). Creativity is the key here; consider developing a project around them being a palaeontologist.

5 Compile an extensive table listing extinct creatures, with inferred physical descriptions of each, the time frame in which they lived, where fossilised remains were found, etc. Spend some time researching with the class to add creatures found in Australia to the table.

6 It is particularly important to reinforce the difference between scientific facts and inferences throughout this chapter.

Hints and tips

Girls can sometimes be a little uninterested in this topic, so ensure it is exciting and just as appealing to them as it is to boys. If you are fortunate enough to have some amber jewellery, bring it to class for 'show and tell'—the girls will be quite impressed. Set up a binocular (dissecting) microscope for the students (under teacher supervision as amber is very fragile) to see if they can identify any remains of fossilised organisms encapsulated in it. If this is not possible, obtain some images and put together a PowerPoint presentation, or show students some photos of amber jewellery or pieces.

7.1 Life in the past

By studying fossils scientists can infer what life existed on Earth millions of years ago. When you hear the word 'fossil' you probably think of something like the one in Fig 2 below. Most fossils form from the bones and shells of animals. These hard parts decay very slowly and have a greater chance of being preserved than the softer organs and muscles.

Fig 2 The fossilised head and neck bones of Ichthyosaurus, a dinosaur that lived in the sea

Fig 4 Large and small dinosaur footprints found in central Queensland

However, Figs 3 and 4 are also fossils. **Fossils** are the preserved remains, impressions or traces of past life on Earth. For example, the insect in Fig 3 was caught in the sticky sap of an ancient tree. The sap hardened over a long time and became amber, preserving the insect inside.

Fig 3 An ancient fly thought to be about 30 million years old was caught in the sticky sap of a tree.

Fossil formation

When a land animal or plant dies, it is attacked by decomposers (bacteria and fungi) and scavengers such as ants, birds and maggots. After a short time, the dead organism is completely decomposed or eaten and very little apart from some bones, teeth or shell remains of it. This is why there is only a very small chance that a dead organism will become a fossil.

The formation of a fossil begins with the dead organism being covered with sediment such as mud, silt or sand. Therefore, organisms that live in or near water are more likely to become fossilised when they die. The sediment slows down or stops decay by decomposers and attack by scavengers. This increases the possibility that all or some of the organism will be preserved.

The first layer of sediment is compressed by the weight of the other sediments and water on top of it. Gradually these sediments form sedimentary rock, trapping the fossils inside.

Learning experience

Are all fossils the remains of extinct organisms or can you find fossils of species that exist today? Explore this question with your class. What species exist today that are considered ancient/prehistoric (eg Wollemi pine)?

Learning experience

The students could construct a '5W chart' around the theme of fossils. The five Ws are 'Who', 'When', 'Where', 'What' and 'Why'. The word 'fossil' should be the central word on the page, with five branches or balloons extending from it. Students then develop a series of questions using the five Ws and write them in the balloons.

A chart like this is an effective strategy to help students identify the important aspects of the topic. You may like to generate a class 5W chart on the board and get students to come out to the front and add to it. Make sure all the W questions have been adequately addressed.

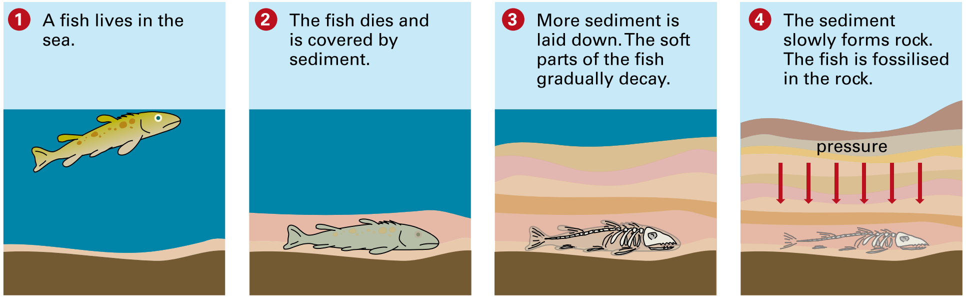


Fig 5 The formation of a fossil. Most fossils are found in rock layers that were formed from sediments under water.

Petrified fossils

The chemicals which make up the bones, shells and other hard parts of ancient organisms are often replaced by minerals from the surrounding rock. This change happens very slowly, over millions of years. The process is called **petrification** and the organism is said to be *petrified*. The minerals that form the petrified fossil are usually harder than the surrounding rock. So when the rock is eroded away, the fossil is exposed.

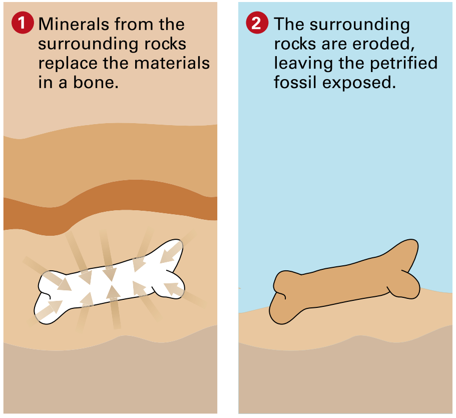


Fig 6 The formation of a petrified fossil

Fig 7 This petrified log in Arizona, USA, was exposed after the surrounding rock was eroded. The fossil formed about 225 million years ago.

Carbonised fossils

Sometimes the rocks in which dead organisms are trapped are subjected to extreme heat and pressure. Under these conditions, chemical changes occur and all of the materials in the organism's body, except carbon, are converted to gases. The remaining fossil is generally black in colour and is called a *carbonised fossil*.

Hints and tips

There is an amazing outcrop of fossils, particularly shells, at a place called Fossil Bluff, in Wynyard in Tasmania. The succession of layers of sediment can be seen from the shore platform, interspersed with layers of shell and other fossilised remains. The fossil record of *Wynyardia bassiana* provides one of the earliest records of mammals in Australia.

Research

Ask the students to gather some information about an Australian geological site of interest containing fossils (eg the Pinnacles in Western Australia, Petrified Forest at Cape Bridgewater in Victoria, Riversleigh in north-west Queensland, Lark Quarry near Winton in central Queensland, Naracoorte Caves in South Australia). Once they have collected their information, they could present it to the class as an oral presentation, a multimedia presentation or an information booklet similar to those found at tourist centres.

Learning experience

The students could make their own 'flip book' of the formation of a fossil, using Fig 5 as a guide. A flip book needs about 10 pictures to work successfully. This exercise promotes thinking and reasoning, especially when students draw their own original interpretive diagrams. Medium-sized blocks of post-it notes are ideal. Get the students to write captions (descriptors) at the top of each page so they don't interfere with the diagrams. When they are tired of flipping the book, they can separate it and stick each page in sequence into their notebooks.

Hints and tips

- Bacteria and fungi generally prefer moist warm conditions. However, many fossilised leaves found are those from subtropical/tropical plant species. Explain why the leaves in Fig 8 were not destroyed through decomposition, and explain the climatic or geological processes that scientists have inferred took place for this fossilisation to occur.
- Review the difference between predators, scavengers and decomposers (*ScienceWorld 1* Chapter 7).

Fig 8 Carbonised fossil leaves of an ancient fern

Unaltered fossils

Whole fossilised organisms are very rarely found. This is because dead organisms are attacked by predators, scavengers and decomposers before their bodies are covered up and preserved.

The fossilised insect in amber in Fig 3 on page 138 is a complete organism. Entire woolly mammoths have been found preserved by the ice in glaciers, while animals that have fallen into tar pits have also been preserved intact. Animals that have died in deep, dry caves have sometimes become mummified because bacteria and fungi cannot live in the dry air of caves.

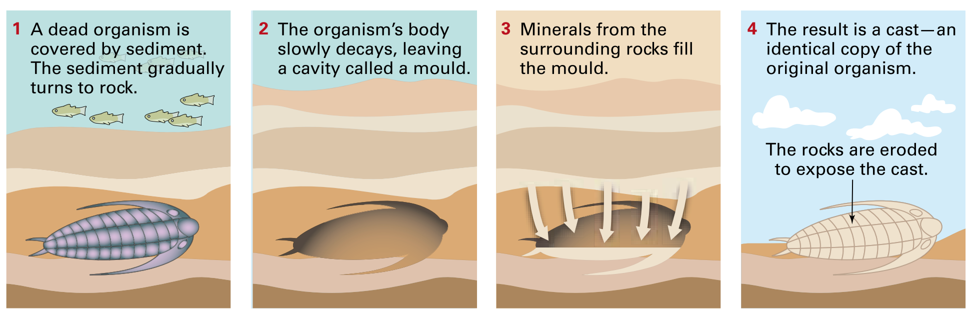
Fig 10 A reconstruction of a mammoth in a tar pit. When the animal died it was preserved intact with little decay.

Moulds and casts

Sometimes the remains of an organism trapped in sediment decompose over a long period of time inside the rock. This leaves a cavity inside the rock called a **mould**. The mould is the exact shape and size of the original organism.

In certain conditions, minerals from the surrounding rock seep into the mould and refill it. These minerals then harden to form a **cast**, which is a copy of the original organism. The diagrams below show the formation of a mould and cast.

An impression can also form a cast. Suppose a dinosaur trod in the mud on the shore of a lake, and the footprint hardened in the sun. It then filled up with sand or mud which hardened over time to form a cast of the footprint.



Homework

In 2006, the media reported that some scientists had 'brought back to life' a mammoth that had been frozen in perfect condition. (See, for example, <science.howstuffworks.com/mammoth-news.htm> and online news sites.) Did this really occur? The students could research mammoths, making sure they link their information to the content of this chapter.

Research

A large fossilised skeleton of a plesiosaur (reptilian equivalent of a seal) was unearthed in Australia in 1968 at Andamooka in South Australia. It made headline news because the fossil cast formed is so far the largest opal fossil discovered. Ask the students to investigate more about this find, or research other opal fossils. A homework task could be developed around this.

Learning experience

Students can watch some segments from a movie like *Jurassic Park* to scientifically critique and write a synopsis. They should consider the movie's accuracy, if the scenarios could really occur, how they inferred what terrain the creatures lived in and so on. Students should apply their past knowledge from the Getting Started points on page 137 to help explore issues.

Investigate

16 MAKING MOULDS AND CASTS

Aim

To make moulds and casts of organisms.

Materials

- modelling clay or plasticine
- plaster of Paris (quick-setting)
- cooking oil (about 5 mL) and small brush
- object to mould, eg shell, bone, twig, leaf
- small bucket for mixing plaster
- aluminium pie dish
- old newspapers
- Bunsen burner

Planning and Safety Check

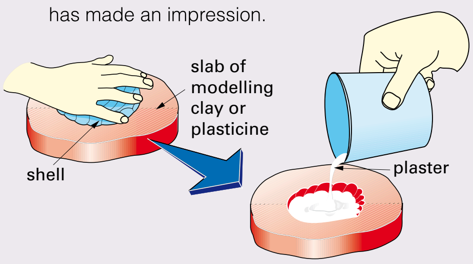
- Work with a partner. Carefully read through Part A then close the book and describe to your partner what you have to do. Swap roles and do the same for Part B.
- List the things you have to do to prepare and also to clean up after this experiment.
- Make a list of the safety precautions you will need to take.

PART A
Mould and cast

Method

1 Cover the bench with old newspapers. Form the modelling clay into a slab.

2 Brush the shell with some cooking oil to stop it from sticking to the clay. Then press it firmly into the clay until the whole of the shell has made an impression.



3 Carefully remove the shell from the clay. You now have a mould of the shell.

4 Brush the mould with a little more oil.

5 Make up the plaster by adding water, a little at a time, to the white powder. Stir constantly to avoid lumps. The result should be a thick creamy mixture.

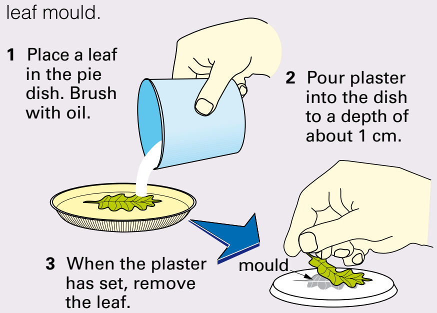
6 Pour the plaster into the mould. Smooth off the top and leave the plaster to set. While you are waiting, go on with Part B.

7 When the plaster has set, carefully remove it from the clay.

How does your cast compare with the original object? Has any detail been lost in making the cast?

PART B
Leaf mould

Follow the instructions in the diagrams to make a leaf mould.



PART C
Carbonised fossil

To make a model carbonised leaf fossil, repeat Steps 1 and 2 in the diagram in Part B but do not remove the leaf from the set plaster.

Light a burner and hold the plaster over a gentle flame. The leaf will burn away leaving the carbon remains.

Lab notes

Parts A and B

Plaster of Paris is quite expensive and sets quickly. A good alternative is cornice cement from the local hardware store. Damp sand in a bucket or tray can be used as an alternative to the modelling clay if you would like to form a large cast.

This investigation can be very messy, so:

- use liberal amounts of newspaper to cover all of the benches and the sinks
- have a broom and dustpan available to sweep the floor afterwards
- do the investigation in a lesson before recess or lunch so that the class (or a few offenders) can stay to clean up if necessary.

Stress the importance of not allowing anything to go down the sinks as it may solidify and cause plumbing problems. Warn and watch for students putting modelling clay in gas or water taps.

Part C

Make sure you revise with students the safety procedure when using a Bunsen burner (heatproof mat, safety flame, etc).

Activity notes

- Revise how sedimentary rocks are formed, taking care to remind students of the relationship between the words *sediment* and *sedimentary*.
- Organise a class excursion to a geological site in your local area that has layers of sedimentary rock (and fossils if possible) like in this activity.
- To enhance visual learning aspects, demonstrate to the students how different sedimentary rock layers can form. Students find this tactile activity appealing.
  1. In a large beaker (1000 mL or greater) put a layer of fine soil, preferably clay, and make it quite moist.
  2. Place some green leaves on top of the clay (first sediment layer) and add a little more water.
  3. Now place on top of this a second layer of different soil (soil and sand) and put some shells or small bones (eg chicken bones) on top. Again, make it quite moist.
  4. Continue this process with differing layers of sediment until the beaker is full.
  5. Place a sheet of tracing paper and a heavy weight on the final layer. Hopefully, you should see the layers through the side of the beaker, together with some 'fossils'.
  6. In a few days' time, when the layers are almost dry (they still need to be damp), carefully tip out the solid mass and cut cross-sections for the students to examine. You may even find the leaves in the bottom layer have turned black/brown.

Activity

Inferring from fossils

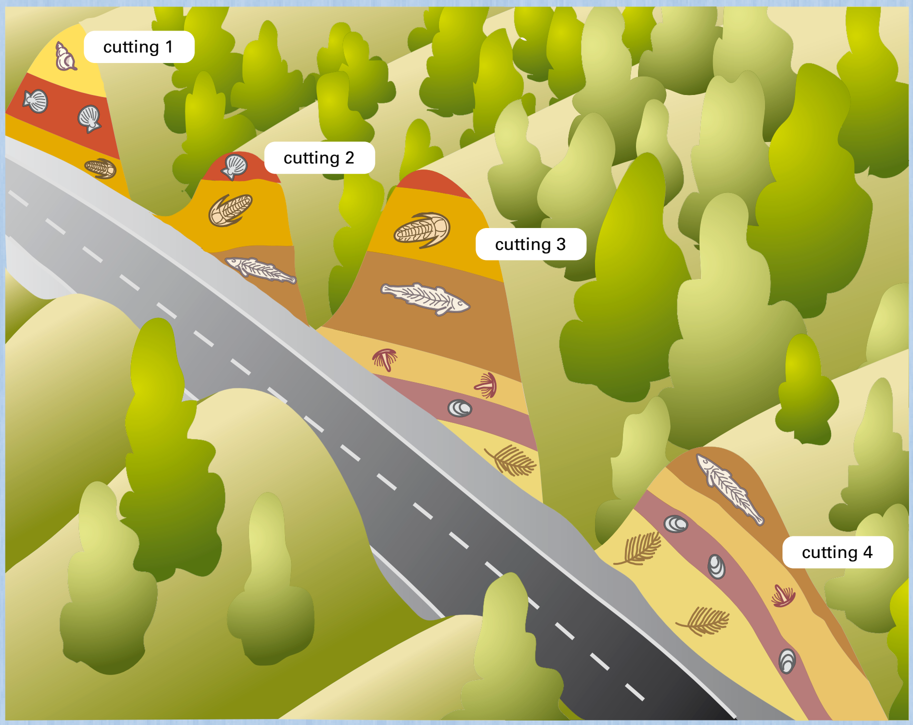
A road worker noticed a number of different fossils in several road cuttings along a new freeway.

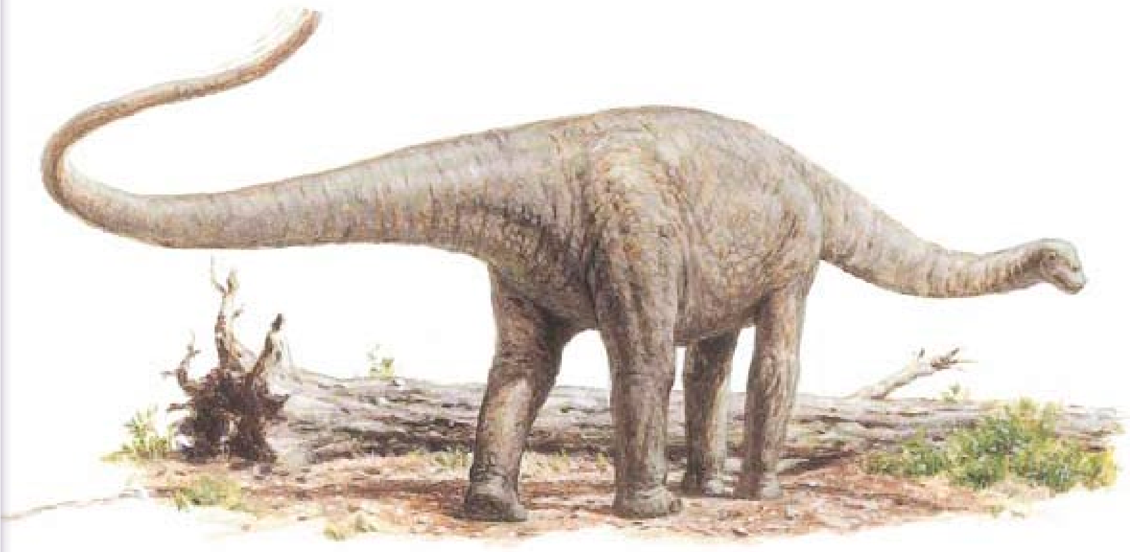
He called in a scientist who specialises in fossils to inspect them. A scientist who studies fossils is called a *palaeontologist* (PAY-lee-un-TOLL-a-gist).

The scientist observed a number of layers of sedimentary rock in each of the road cuttings. She observed that each layer contained one main type of fossil and this was different in each of the layers. She drew the sketch below of the cuttings, the sedimentary rock layers and the main fossils in each layer.

Imagine you are the scientist. Write inferences for each of the following questions. (Assume that rock layers are in the order in which they were deposited.)

1. Which is the oldest sedimentary rock? How do you know?
2. Which is the youngest fossil?
3. Why is the fish fossil higher in cutting 4 than in cutting 2?
4. Why aren't there any fossil fish in the rocks in cutting 1?
5. The area is bushland now. Infer what it was like when these fossils were formed.





Australia's history

From fossil remains scientists have reconstructed the sauropod dinosaur nicknamed Elliot, shown in the illustration above. They infer that Elliot was one of the largest plant-eating dinosaurs to live in Australia. This reptile grew up to 20 metres in length and lived about 95 million years ago near the mouth of a large river flowing into an inland sea.

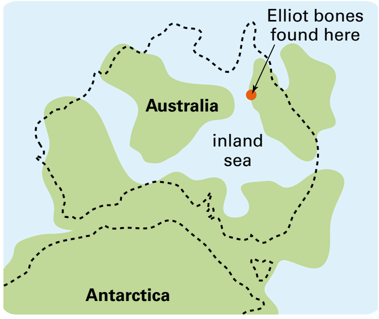


Fig 15 Geologists infer that there was a vast inland sea in Australia about 95 million years ago.

Geologists infer that the coastline of Australia was far different 95 million years ago from what it is now. At that time shallow inland seas existed in what is now the Great Artesian Basin. Plant fossils found in the Great Artesian Basin suggest that the climate there was warm and humid. In this climate, lush, thick forests provided a rich source of plant food for sauropods and other herbivorous dinosaurs.

Scientists throughout the world have used fossils and the ages of rocks to work out a description of Earth's history. This is called the **geological time scale**. It divides the history of the Earth into a series of eras and periods.

The geological time scale shows the times when various organisms lived on the Earth. To work this out, scientists have dated rocks and matched fossil remains from many sites around the world. The time scale shows the inferred order of life on this planet. For example, it is inferred that ferns were alive well before flowering plants, because fossil ferns are found in older rocks. It also shows that dinosaurs were found on Earth for many millions of years and are now extinct.

Hints and tips

Investigate more about the Great Artesian Basin. Some scientists believe we can access more of this water than we are currently using, and use it to help alleviate our water shortage. Would the water need to be purified, and what long-term problems could arise from draining the water? Although this doesn't directly relate to this chapter, it may be worth exploring this topical issue.

Assessment task

This would be a good place to set *Assessment task 7: Dinosaurs and megafauna*, found on the CD.

Learning experience

The students could create their own report on an Australian dinosaur or prehistoric animal. Constructing a chart is an excellent way of organising data, with two columns and about 10 rows containing headings as shown.

The second column is for the students' researched information. They should include a glossary to define any technical/scientific terms, and a bibliography.

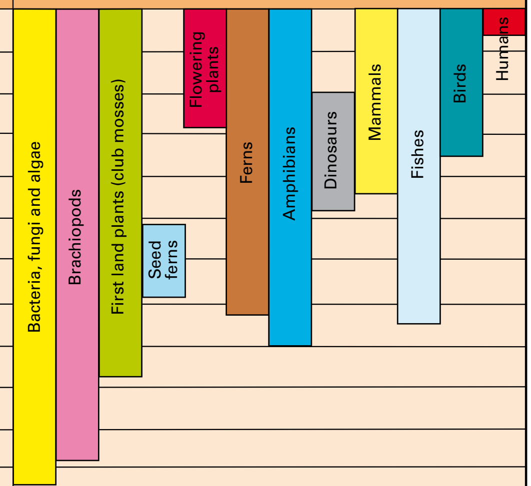
As an extension to this activity, they could construct a scale model of their animal and present their findings in an oral presentation to the class.

Name (its meaning and who named it)	
Classification	
Anatomy (size, number of legs/tentacles, tail, etc)	
Diet (herbivore, carnivore, omnivore)	
Geography (habitat, range and location, climate, etc)	
Enemies	
Protection (what defence mechanisms it had)	
When it lived	
Fossil record (what fossils have been found)	
Interesting facts	

Hints and tips

Have a class discussion to come up with inferences about why dinosaurs and other species became extinct. Why is the climate inferred to have changed so dramatically? (For example, volcanic ash blocking sun's rays, meteorite strikes, etc.)

ERA	PERIOD	TIME (millions of years)
CAINOZOIC	Quaternary	0–2
	Tertiary	2–65
MESOZOIC	Cretaceous	65–145
	Jurassic	145–210
	Triassic	210–245
PALAEOZOIC	Permian	245–290
	Carboniferous	290–360
	Devonian	360–410
	Silurian	410–440
	Ordovician	440–510
	Cambrian	510–570
PRE-CAMBRIAN		570 +



Activity notes

If using a roll of toilet paper, one-ply recycled paper is easier to write on because it is not too soft. Alternatively, strips of A4 photocopied paper from the recycling box taped together work just as well. Pre-cut the strips with a guillotine so they are about 10 cm wide to save time.

The geological time scale is divided into four large divisions called *eras*. The eras are then divided into smaller units called *periods*. The divisions of eras and periods are based on major events such as widespread volcanic activity, ice ages or the appearance or disappearance of many types of animals and plants.

The names of the eras come from Greek words for life: Cainozoic (CANE-a-ZOE-ic) means *recent life*; Mesozoic (MEES-a-ZOE-ic) means *middle life*; and Palaeozoic (PALE-ee-a-ZOE-ic) means *ancient life*. The Pre-Cambrian is the earliest and longest era. It spans the time from the birth of the Earth about 4600 million years ago to when life first appeared about 570 million years ago.

The most dramatic change of eras occurred at the end of the Mesozoic. Scientists infer that over a relatively short period of time (200 000 years) 70% of all animal species on Earth became extinct, including almost all of the large reptiles.

You can make a time scale model in the activity on the right.

Activity

1 Use a roll of toilet paper to make your time scale. Let one sheet represent 20 million years.

2 Use the figures in the time scale above to mark off the eras and periods on the toilet paper. For example, the Cainozoic era, which spans 65 million years, will occupy the first 3.3 sheets.

In which eras and periods did the following organisms first appear?

mammals amphibians dinosaurs
fishes flowering plants

Are seed ferns still found on Earth?

Fossils are more common in Tertiary rocks than in Silurian rocks? Suggest a reason for this.

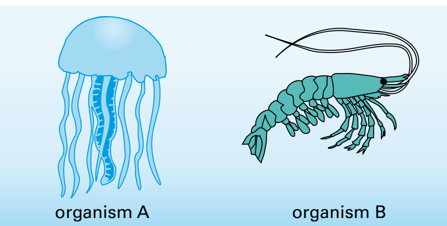
Learning experience

Again, using the idea of making a flip book, the students could draw different organisms from each period. The book should show when the first type(s) of organisms are inferred to have appeared. So, flipping through, you should first see diagrams of bacteria, fungi and algae, then brachiopods and so on until humans finally appear.

Check!

1 Copy and complete the following sentences.
   a When an organism dies it is usually attacked by scavengers and ______.
   b A dead animal can be preserved when its body is covered with _______.
   c Petrification occurs when ______ from the surrounding rock replace the substances in the organism's body.
   d An identical copy of a fossilised organism is called a ______.

2 Suppose the two organisms below die and fall into the silt at the bottom of a river. Which organism is more likely to form a fossil? Give a reason for your prediction.



3 Which parts of organisms are most commonly found as fossils?

4 Explain the difference between a mould and a cast.

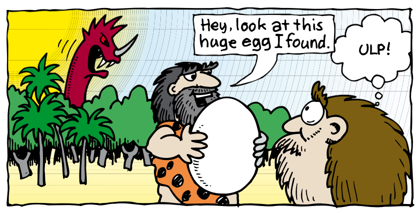
5 Describe, using labelled sketches, how a goanna might become a fossil.

6 Look at the cartoon top right.

   a What is the cartoon about?
   b Could real footprints be formed in this way?

7 Many of the coal and oil deposits in Australia were formed from ancient plants and microscopic organisms during the Carboniferous period. Use the geological time scale to find out how old these deposits are.

8 You may have seen movies where human cave-dwellers are chased by dinosaurs. Could this have happened?



challenge

The photo on the right shows a coelacanth (SEAL-a-canth), a type of fish similar to ancient fishes which were abundant in the Palaeozoic and Mesozoic eras. These fish were thought to have been extinct until one was brought up from deep water off the South African coast in 1938. Since then many have been caught. Suggest why this type of fish has lived until the present, while many other organisms have become extinct.

Challenge solutions

Extinction occurs when the environment of an organism changes more quickly than the organism can change to live in the new conditions. It is reasonable to infer that the Coelacanth is quite well suited to its environment and that its environment has not changed very much over the past few hundred million years.

Check! solutions

1 a When an organism dies it is usually attacked by scavengers and *decomposers*.
   b A dead animal can be preserved when its body is covered with *sediments*.
   c Petrification occurs when *minerals* from the surrounding rock replace the substances in the organism's body.
   d An identical copy of a fossilised organism is called a *cast*.

2 Organism B is much more likely to form a fossil because it has hard body parts which will not easily decompose. Organism A, which has only soft tissues, will decompose very quickly, leaving no fossil remains.

3 The parts of organisms that are most common as fossils are the hard parts. In plants these are the leaves and stems or trunks. In animals they are shells, bones and teeth.

4 A mould is formed when the remains of an organism decompose over a long time, leaving a cavity inside a rock. This cavity is the same size and shape as the organism. A cast is formed when material from surrounding rocks fills a space such as a mould and then hardens. This usually forms a copy of the organism which is the same size and shape as the original organism.

5 The general steps for the formation of a goanna fossil would be as follows:

i

The goanna dies and is covered by sand.

ii

The soft parts of the body dry out and decompose. More and more sand is deposited on top of the fossil, preventing further decomposition.

iii

The fossil may become petrified or carbonised, or form a mould, depending on other conditions.

6 a Obviously the footprints are fake, but in a million years people may incorrectly infer that they are genuine.
   b No, footprints would not usually be formed in this way. Animals would not walk on molten lava because it is too hot.

7 These deposits are 290–360 million years old.

8 According to current fossil evidence and the table on page 144, humans did not exist at the same time as dinosaurs, so the movies are fiction.

Hints and tips

The word *volcano* derives from the name of the Roman god of fire, Vulcan. The largest known volcano on Earth is Mauna Loa in Hawaii. It is about 10 km high from the sea floor to its summit. From sea level to its summit is about 4 km. This volcano has the largest volume of any volcano—about 75 000 km^3.

Did you know that other planets and moons have volcanoes? The largest known volcano in our solar system is Olympus Mons on the planet Mars. It is 27 km high and 520 km wide!

7.2 Earth movements

Inside the Earth

Volcanoes are more evidence that the Earth is constantly changing. They form when molten rock from inside the Earth forces its way to the surface through a crack in the ground. This molten rock indicates the nature of the material in the Earth's interior. You probably know that the Earth is made up of three main layers—the crust, the mantle and the core, as shown below.

The layered structure of the Earth can be compared to that of a soft-boiled egg. The outermost layer is called the **crust** and is rigid and very thin compared with the other two layers. It is thicker under the continents than under the oceans. Like the shell of an egg, the Earth's crust is brittle and can break.

Below the crust is the **mantle**, which can be thought of as the white of the egg. It is a layer of semi-solid rock almost 3000 km thick. It is hotter and denser than the crust because temperature and pressure inside the Earth increase with depth.

At the centre of the Earth is the **core**. Unlike the yolk of an egg, however, it is made of two distinct parts—a liquid outer core and a solid inner core.

The crust and the upper part of the mantle form a rigid layer called the *lithosphere* (LITH-os-fear). Scientists infer that below this is the *asthenosphere* (ass-THEN-os-fear). This layer is composed of hot, semi-solid material which can soften and flow due to the high temperatures and pressures over millions of years. The heat causes convection currents which cause the asthenosphere to flow. The rigid lithosphere is thought to 'float' on top of the asthenosphere.

When the molten rock (magma) is forced upwards from the asthenosphere it may cause cracks in weaker regions of the crust. When this happens volcanoes form.

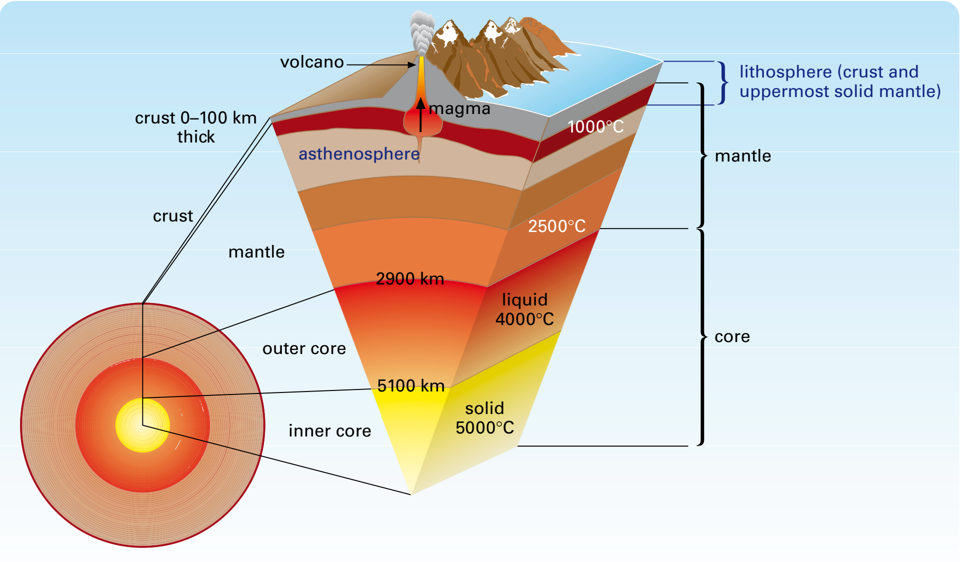
WEBwatch

Go to www.scienceworld.net.au and follow the links to the websites below.

Structure of the Earth
Click on each layer for information on it.

Convection in the Earth's mantle
Animation showing how the hot rock in the asthenosphere moves by convection over millions of years.

Fig 21 Cutaway view showing the interior of the Earth



Homework

Ask students to investigate what the Ring of Fire refers to, why it is called this and where it is located.

Learning experience

Most students have probably made their own model volcano from baking soda and vinegar. An easy but messy way to demonstrate what happens in an eruption is to use a bottle of soft drink. Soda water is a cheap option.

1 Explain to the students that a volcano forms when chambers of magma, or hot molten rock, reach the surface of the Earth. These magma chambers can often remain sealed for many years—in some cases, hundreds of years—between eruptions, until the pressure builds up sufficiently and the magma chamber ruptures, causing magma to be released through a vent. A large amount of gas also mixes with the molten rock, causing the build-up in pressure.
2 Ask students to imagine the drink inside the bottle is the magma and the bottle is the magma chamber.
3 Shake the bottle a few times, then open the lid. The drink fizzes out—just like a volcano—because the built-up pressure from the carbon dioxide gas forces the drink (molten rock) out of the bottle (chamber).

Fig 22 A volcanologist studying lava on the slopes of Mt. Etna in Italy

Folds in rocks

Some of the largest mountain ranges in the world contain sedimentary rocks. For example, the rocks in Mt Everest were originally laid down under water, and fossil marine shells have been found in some of the rocks on the mountain. Also, many of the rock layers in these mountains are bent and buckled. How could sedimentary rocks be found on the highest mountains on Earth? And how could they be bent and buckled?

Huge forces caused by movements in the mantle cause changes in the Earth's crust. These forces result in the formation of volcanoes, and the uplifting and buckling of the solid crustal rocks. Scientists have experimented with models of rocks under enormous heat and pressure, and have shown that these solid rocks can soften and bend slowly without breaking. When this happens the rocks form **folds**, as shown in Fig 23. The folds which bend downwards to form a U-shape are called **synclines**. Those that bend upwards like a dome are called **anticlines**.

Minerals are often found near folds. During folding the rocks in a syncline are subject to enormous compressive forces. As a result the rock may be metamorphosed (changed) to form new minerals, often containing large crystals. The gold at Bendigo in Victoria was formed this way. The compressive forces may also cause the top of an anticline to crack. Later on, various mineral solutions may flow through these rocks and crystallisation may occur.

Anticlines can also form a trap for oil, which tends to move upwards through porous rocks like sandstone. However, it cannot move through non-porous rocks like shale. As a result, oil is sometimes trapped in an anticline, as shown in Fig 24. This oil can be tapped by drilling into the anticline. If the drill is too far to the left or right of the anticline, no oil will be struck. Hence it is important to know exactly where anticlines are when searching for oil.

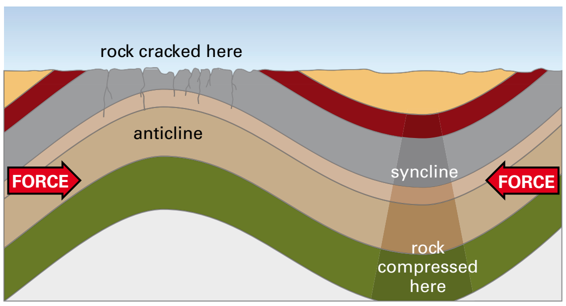


Fig 23 Folds are formed when rocks are squeezed by sideways forces.

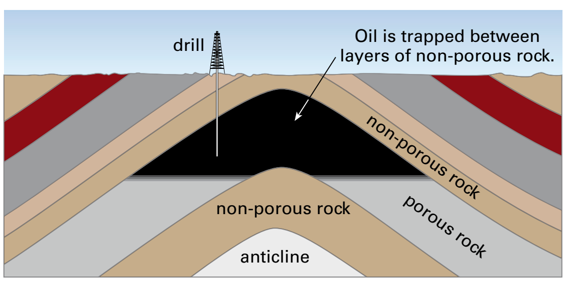


Fig 24 Oil is sometimes trapped in anticlines.

Hints and tips

- Find out which type of rocks and rock formations make up some of Australia's mountains. Are any of them extinct volcanoes? Organise an excursion to view some geological sites where folding or faulting of rocks is evident. If you have not already gone on an excursion to view fossil remains, you could combine the two.
- If it is possible, ask a geologist (specialising in an area of study from this chapter) to come to the school and give a presentation to the class. Universities, museums, and parks and wildlife centres are good places to find an appropriate person.

Learning experience

Ask students to brainstorm as many points as they can recall from previous studies of science or geography (eg *ScienceWorld 1* Chapter 13) about volcanoes, rocks and earthquakes, then write their points on an A4 sheet of paper. Either go around the room and ask each student to read out one point that is different from everyone else's, or collect the A4 sheets to view in your own time. This will allow you to get a feel for what they already know so you can avoid dwelling on topics that students already understand.

Learning experience

Using modelling clay, plasticine or artists' clay, students can demonstrate their own folding of rocks.

1. Roll out layers of clay and place the sheets on top of each other.
2. Have one end butting up against something hard, then slowly push the other end.
3. The clay will buckle, illustrating an anticline and syncline.

You may like to ask the class how they could adapt this demonstration to show how faults occur in rocks.

Hints and tips

- A normal fault is also called a tensional fault, gravity fault or normal-slip fault. The tension forces cause the rock to extend or stretch. Ask the students to look at the dark brown rock layer in Fig 25 and see how this layer appears to have lengthened (stretched) horizontally.
- A reverse fault is also called a compressional fault, thrust fault or reverse-slip fault. The fault motion is caused by compressional forces and results in a shortening of the formation. Again, ask the students to look at the dark-brown rock layer in Fig 26 and see how this layer has shortened horizontally.

Faults in rocks

If the pressures in the Earth's crust are very intense the rocks may break, especially if they are near the surface where they are more brittle than the deeper rocks. When this happens a crack appears and the rocks slide along the crack. A crack in the Earth's crust along which rocks move is called a **fault**. This movement can be vertical (Fig 25 and Fig 26), horizontal or both, and can be hundreds of metres or a few millimetres. Sometimes a huge amount of rock moves along a fault relative to the rock on the other side, forming mountains and valleys.

Geologists looking for minerals often look along fault lines. The reason for this is that mineral solutions can flow along a fault and crystallise to form minerals.

Oil can also be trapped against faults, as shown in Fig 27. It tends to move towards the surface through porous rocks and it sometimes becomes trapped under non-porous rocks.

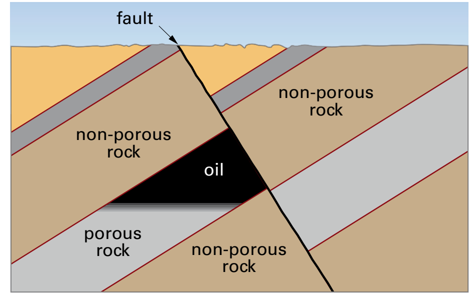


Fig 27 Oil can be trapped against a fault.

Fig 28 A normal fault in sedimentary rock layers in Canberra. Notice that the rock layers on the right have slipped downwards, as in Fig 25.

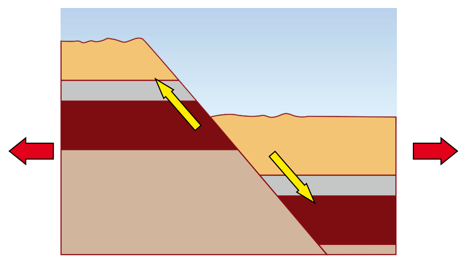


Fig 25 A normal fault caused by stretching forces

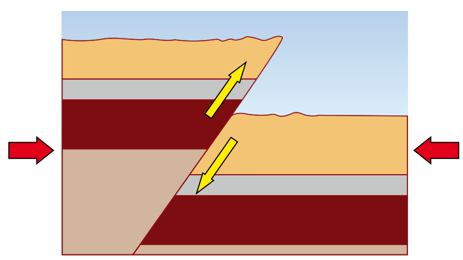


Fig 26 A reverse or thrust fault caused by pushing forces

WEBwatch

Go to www.scienceworld.net.au and follow the links to the websites below.

Savage Earth animations
Has many excellent animations, not just of faults.

Fault motion
Animations of four different types of faults.

Homework

Ask students to investigate strike faults and oblique faults. How do these occur?

Research

The students could do a mini-project on the formation and use of oil, and investigate questions such as:

- How is oil formed?
- Why is it called a 'fossil fuel'?
- Where in Australia do we drill for oil?
- What oil reserves are believed to be left?
- What makes oil so useful?
- What are its associated dangers?
- How was the oil found under the ocean formed?

Questions like these allow students to extend their thinking.

Learning experience

The internet has many interactive activities demonstrating folds and faults in rocks. It is worth booking the class into a computer room if the students do not have access to computers in the science rooms. Prepare a list of websites in advance for the class to view—you could start with those listed in the Webwatch—and put the list on the school intranet or email them to the class. If computer access is limited, prepare a PowerPoint slide show with downloaded applets or animations illustrating folding and faulting.

Activity

Modelling Earth changes

Suppose layers of sediments were laid down over millions of years in a shallow sea. During this time these layers changed into sedimentary rocks. The cross-section below shows a block of these rocks.

1 Your task in this activity is to draw models of what might have happened to the sedimentary layers in the block when it was subjected to a number of Earth changes that occurred one after the other over 300 million years.
2 Copy (or photocopy) the sedimentary layers in the block below. Colour the layers. Label this Step 1.
3 Read Step 2 opposite. Then underneath the Step 1 block, draw and colour a cross-section showing what you think might have happened to the block as a result of these events. Label this Step 2. Use arrows to indicate the forces that caused the changes.
4 Now read Steps 3–6. Do more cross-sections, each time making changes to the previous cross-section. You may need to do some cutting and pasting.

Teacher note: You may want to give each student a photocopied sheet with 6 cross-sections on it. They can then cut and paste to make the 6 steps.

Step 1 (400–300 million years ago): Layers of sediments have been changed to sedimentary rock.

Step 2 (300–250 million years ago): Enormous sideways forces squeezed the rocks, creating two complete synclines in the block.

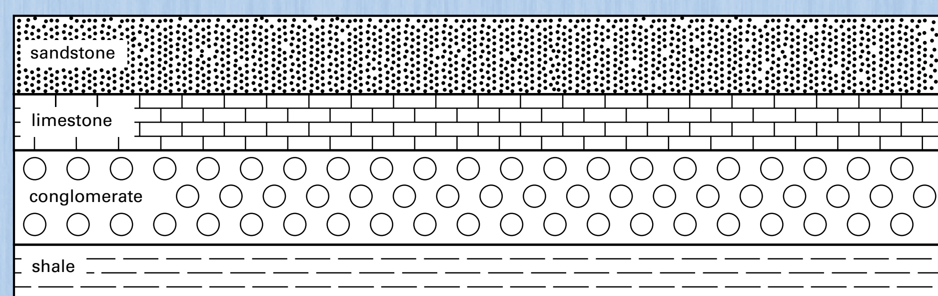
Step 3 (250–200 million years ago): The pushing forces continued. A reverse fault appeared through the left-hand syncline pushing up the left-hand side.

Step 4 (200–150 million years ago): The earth movements stopped for a period of time and erosion occurred, eroding the mountains (anticlines).

Step 5 (150–100 million years ago): The valleys filled up with water and sediment until the top surface of the block was fairly level.

Step 6 (100 million years ago to present): A river formed on the right-hand side of the block. Over millions of years the running water eroded the sedimentary rocks, forming a steep-sided canyon that reaches the bottom of the block.

What would the block in Step 6 look like viewed from above? Use your cross-section to sketch a plan view of the rock layers. Mark which rocks are the youngest and which are the oldest.



Activity notes

It is advisable to photocopy the cross-section for each student. Make one sheet with six cross-sections on it before photocopying a class set.

Homework

The activity could be completed as a homework exercise. This should ensure the students work individually and avoid copying each other. Emphasise that they need to follow the instructions carefully and read each step before they begin work.

Check!

1 Write in your own words the meanings of the following words. Then use the page numbers to check the meaning in the text. Change your answers if necessary.

a	mantle	page 146
b	anticline	page 147
c	fold	page 147
d	fault	page 148

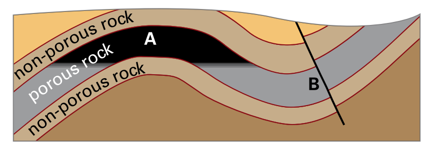
2 a How are sedimentary rocks formed?
b How is it that they are often found above sea level?

3 In which ways is the inferred structure of the Earth like a soft-boiled egg? (See page 146.) In which ways is it different?

4 The photo below shows part of the MacDonnell Ranges just south of Alice Springs. Suggest why the layers are almost vertical rather than horizontal.

5 Look at the photo above. Sketch the patterns in the layers and mark the position of an anticline and a syncline.

6 Oil was found at A but not at B. How could you explain this?



7 The photo below shows a fault.
a Suggest what happened to cause this.
b Suppose the land eroded away over a long period of time until it was once again flat. How could you tell where the fault line was?

Check! solutions

1 a The mantle is a layer on the Earth's crust which has a temperature of about 3000°C and is under great pressure and is in a semi-solid state.
b An anticline is an upward fold in rocks caused by huge forces in the Earth's crust.
c A fold is any upward or downward bending or layers of rocks caused by forces in the Earth's crust.
d A fault is when forces cause rocks in the Earth's crust to move along a line of weakness or crack in the Earth's crust.

2 a Sedimentary rocks are formed by the deposition of sediment. This deposition is usually in layers which are then compressed and compacted by materials above to form a solid rock.
b The sedimentary layers can be broken and faulted or bent or folded by forces in the Earth's crust. This movement may push rocks above the sea level. If the sea level falls for any reason this will also leave rocks exposed. Some of the biggest mountains in the world, like the Himalayas, were formed in this way.

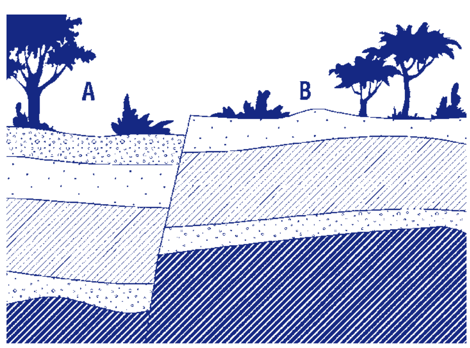
3 In a soft-boiled egg both the yolk and white part of the egg are distinct but are both thick, runny liquids. This is similar to the internal structure of the Earth. The differences are that the Earth is not the same shape as an egg, and in the Earth there are three layers which gradually blend into each other. In addition, scientists think that the inner core is solid whereas in the egg it is probably the least solid part.

4 There are many mountains in Australia that look like this. They were formed when sedimentary layers were forced into enormous folds and then partly worn away by water to leave what you see here.

5 On your diagram you should label an upward fold or anticline on the left side and a downward fold or syncline a bit towards the centre.

6 Oil will tend to float on any water and often be found in an anticline between two layers of non-porous rocks. If there is a fault, such as at point B, the oil could 'leak out'.

7 a What happened was that huge forces pushed in on either side of this area and a weakness or fault occurred in the rock layers. The forces caused the rocks on the right to move up and/or those on the left to move down. It is best to show this with a simple diagram:

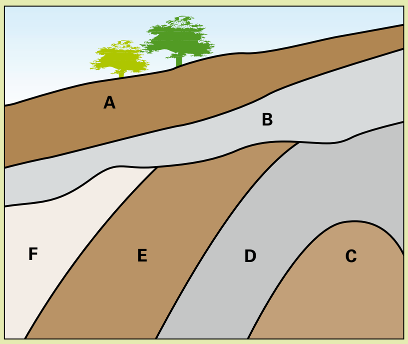


b The soil formed from the rocks at A will be different from the soil formed at B. This is often indicated by a change in the vegetation on the surface. A cutting across A and B will also show the fault line.

challenge

1 You and a friend are standing at a lookout overlooking a valley with a mountain in the middle of it. Your friend says that the mountain is actually an old volcano that has been eroded. You disagree and say that you think that the land around the mountain was formed under the sea and earth movements pushed the land up to form the mountain. How could you find out who was correct?

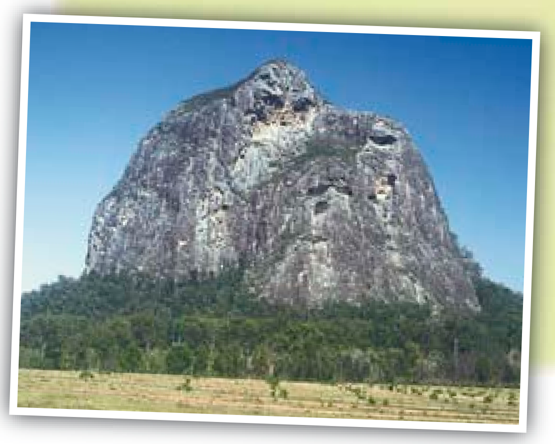
2 Infer how the sequence of rock layers in the diagram below was formed. List the rocks from youngest to oldest.



3 The photo below shows one of the Glasshouse Mountains in Queensland.

a What part of a volcano might this structure have been?

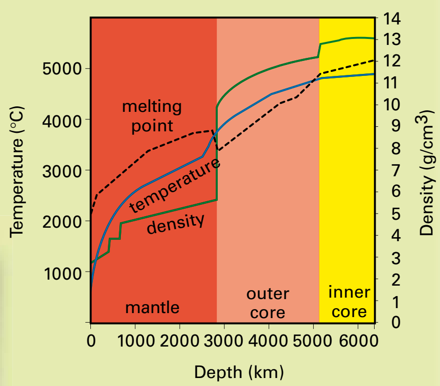
b Why did the outer parts of the volcano erode more easily than this structure?



4 The table shows the years from AD 79 to 1944 in which Mt Vesuvius has erupted. The dates marked in bold show the biggest eruptions. Can you tell when the volcano will erupt again? Write a brief report.

Years when Mt Vesuvius erupted			
79	1631	**1794**	1891
203	1660	1804	1895
472	1682	1805	1900
512	1689	**1822**	1903
685	**1694**	**1838**	1904
993	1707	**1850**	**1906**
1036	**1737**	1858	1913
1139	1760	1861	1926
1306	**1767**	**1871–72**	1929
1500	1779	1875	1944

5 The graph below shows the estimated temperature, density and melting point of the materials in the layers inside the Earth.



a What is the radius of the Earth?

b How thick is the mantle?

c Which layer has the highest average density?

d Make a generalisation about the temperature changes in the mantle.

e Which layer in the Earth's interior is liquid? Explain how you arrived at this answer.

Challenge solutions

1 You should look closely at the rocks in the mountain to see whether they are in layers (sedimentary) or consist of crystals (volcanic). If they are crystalline then the mountain was formed from a volcano. You may be able to show some of the rocks to a geologist or your teacher who could identify them.

2 A good inference is that layers C, D, E and F were deposited and then folded. They were then worn away and layers B and then A were deposited on top of them. From youngest to oldest the rocks are A, B, F, E, D and C.

3 a This structure is likely to have been the 'plug' of hard volcanic rock which formed when magma cooled in the central vent of the volcano.

b The outer parts of the volcano are formed when the ash and rocks are deposited in alternate layers with solidified lava to form a rock which has eroded much more easily than the volcanic rock in the plug.

4 No, we cannot be sure when Mt Vesuvius will erupt again but the data indicates that eruptions are becoming more frequent but less severe. It would be possible to draw a graph to display this data.

5 Using the given data:

a The radius of the Earth is about 6400 km.

b The mantle is about 2800 km thick.

c The inner core has the greatest average density.

d The temperature in the mantle increases with depth but the most rapid increase occurs just below the Earth's surface.

e The outer core is liquid because the temperature (green line) is higher than the melting point of the rock materials in it (dashed line).

Hints and tips

Earthquakes and earth tremors (small earthquakes) occur daily. Have a class discussion to see if any student can recall experiencing an earth tremor or an earthquake. What happened in Newcastle, New South Wales, in 1989? Find some articles about the Newcastle earthquake for the class to peruse (see also Webwatch on page 157).

Research

Ask the class to do an 'earthquake hunt' by scouring the daily news from the previous few weeks and for the next week or so for reports of earthquakes. Get the students to pin their reports onto a noticeboard in the science room and make a chart listing where, when and how big each earthquake was.

7.3 Earthquakes

So far in this chapter you have seen how forces caused by movements in the Earth's mantle can change the shape of the rocks in the crust. Generally these movements are very slow. Sometimes, however, there is a sudden movement that can result in large cracks in the ground, and can make buildings collapse and break water and gas pipes.

Earthquakes occur when intense pressures in the Earth's crust cause the rocks to break and move along a fault. The stored up energy in the rocks is released as shock waves which spread out in all directions, like the waves produced in a pond when a pebble is thrown in.

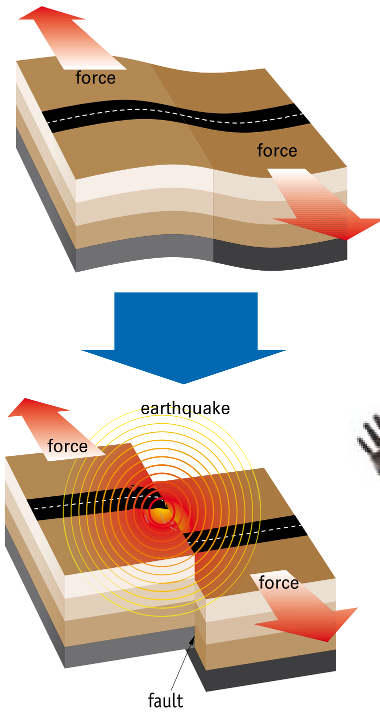


Fig 37 Crustal pressure causes the rocks to slide along each other at a fault, causing an earthquake.

Fig 38 The San Andreas fault appears as a scar running from left to right across the photo. The stream in the centre has been displaced 130 metres by the fault.

The earthquakes that have occurred in California have been caused by Earth movements along a very large fault called the San Andreas fault. It is about 800 km long, and the rocks to the west of it are being pushed northwards at about 5 cm a year. If this movement is slowed or stopped, the pressure builds up along the fault. When the rocks move again, the energy is released and an earthquake occurs.

Fig 39 Indonesian children at their school destroyed in an earthquake in Java in June 2006

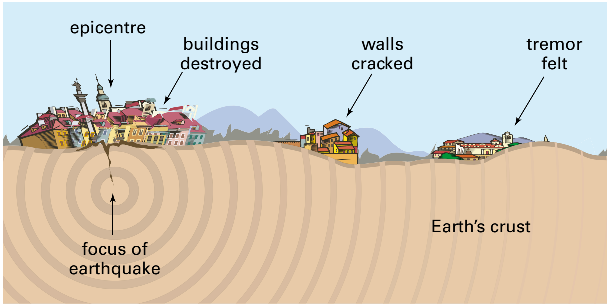


Fig 40 Cut-away view of the Earth's crust showing shock waves spreading out in all directions from the focus of an earthquake.

How are earthquakes recorded?

The vibrations or waves caused by an earthquake spread out in all directions. The place inside the Earth where the movement of the rocks occurs is called the *focus* of the earthquake. The **epicentre** is the point on the Earth's surface directly above the focus.

As the shock waves spread out from the focus they lose energy and the vibrations become smaller. On the surface, the damage is greatest at the epicentre since this is the closest point to the focus, and the damage decreases as you go further away from the epicentre.

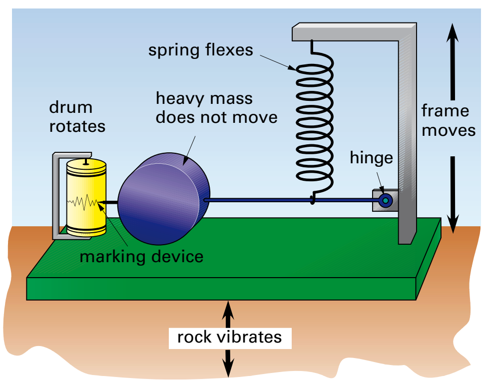


Fig 41 A simplified diagram of a seismograph

Earthquakes are recorded on instruments called **seismographs** (SIZE-mo-graphs). The frame of the seismograph is set on solid rock. In an earthquake the solid mass tends to remain motionless while the rest of the seismograph shakes, and a pen or laser beam makes marks on a rotating drum. Any movements of the solid rock show up as a series of troughs and peaks on the recording. The seismograph in Fig 41 measures vertical movements, while other types measure horizontal movement.

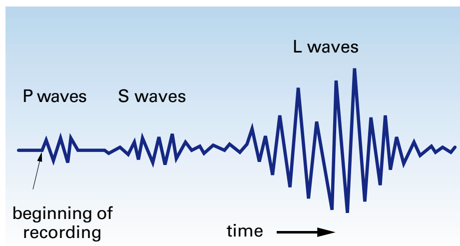


Fig 42 A seismogram

A record of the waves caused by an earthquake is called a *seismogram*. The diagram above shows a simplified seismogram. Notice there are three types of waves. The first to arrive at the recording station are the primary waves or P waves. These waves are also called *compression waves* and are formed when matter in the rocks is pushed together by the Earth's movement—in much the same way as sound waves form when air particles are compressed by a vibrating object. P waves can travel through solids and liquids.

The P waves are followed by secondary waves or S waves. These are also called *shear waves* and are due to the sideways motion of matter. S waves can travel only through solids.

L waves are the last waves to arrive at an earthquake recording station, but have the most impact. The energy in L waves causes the surface

Hints and tips

- What do the students know about the theory of tectonic plates from their geography classes? Why is it a theory and not fact? Find out what they already know. If they cannot remember, briefly revise it, as section 7.4 explains it in more detail.
- Students often confuse the instrument used to measure an earthquake and its magnitude scale. Make sure to clearly define the difference between a seismograph (instrument) and the Richter scale.

Learning experience

A way to explain how an earthquake's waves travel in all directions is by using the analogy of dropping a stone into a pond of water. It is very simple to demonstrate this by filling a wide (preferably flat) tray with water and dropping a pebble into it. A ripple tank tray from the physics department is ideal. When doing the demonstration, explain the difference between the *focus* and the *epicentre*. One way to do this may be to ask the class to simplify Fig 40 and draw it in their notebooks with correct labels.

Hints and tips

Show some commercial DVDs about earthquakes and tsunamis, or find some interactive computer applications (there are a lot on the internet) for the class to view. Try to obtain material that portrays how people's lives are affected by earthquakes and tsunamis. Encourage the students to listen with empathy and understanding. This will break up the theory components and make the topic feel more real.

of the Earth to vibrate like a shaken bowl of jelly. These waves produce the largest movement on a seismogram (see Fig 42). L waves, which are also called *surface waves*, cause the most damage to objects on the surface. Buildings, trees and other structures can be completely flattened.

The differences in the times taken by earthquake waves to travel certain distances are used by scientists to estimate the exact location of the epicentre.

The graph below shows the distance–time graph for P and S waves. Suppose the time between the arrival of P waves and S waves is 196 seconds. From the graph, the distance to the epicentre of the earthquake is 2000 kilometres.

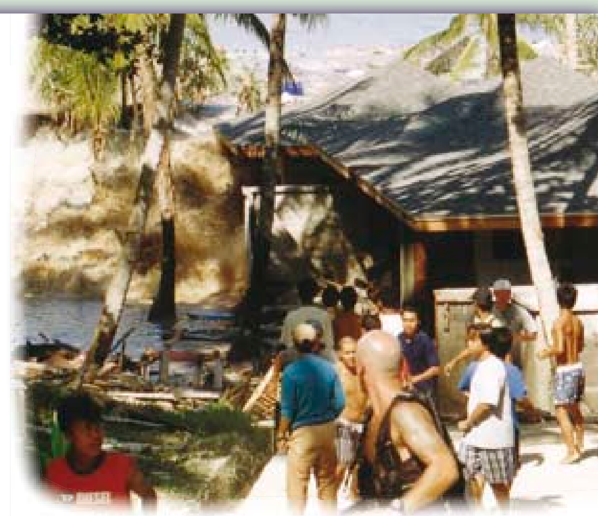


Fig 44 People running from the tsunami that devasted Indonesia, Thailand and Sri Lanka in 2004

Tsunamis

On 26 December 2004 an earthquake measuring 9.2 on the Richter scale occurred just off the western coast of northern Sumatra in Indonesia. It was the second largest earthquake ever recorded on a seismograph. The earthquake triggered a series of tsunamis that spread throughout the Indian ocean, killing almost 300 000 people.

A **tsunami** (tsoo-NAH-me) is a wave or series of waves in the ocean that can be hundreds of kilometres long. The word 'tsunami' is from the Japanese words *tsu* (harbour) and *nami* (waves).

Tsunamis have been known to reach heights of up to 10 metres. These 'walls of water' travel as fast or faster than a commercial jet. The Indonesian tsunami travelled at 480 km/h and caused enormous damage along the coasts of Indonesia, Thailand and Sri Lanka. Small waves (25 cm) were noticed in Western Australia.

The diagram below explains the Indonesian tsunami. Huge Earth forces from the left-hand side of a large fault caused the rocks on the right to move upwards about 5 metres. This is what caused the wave.

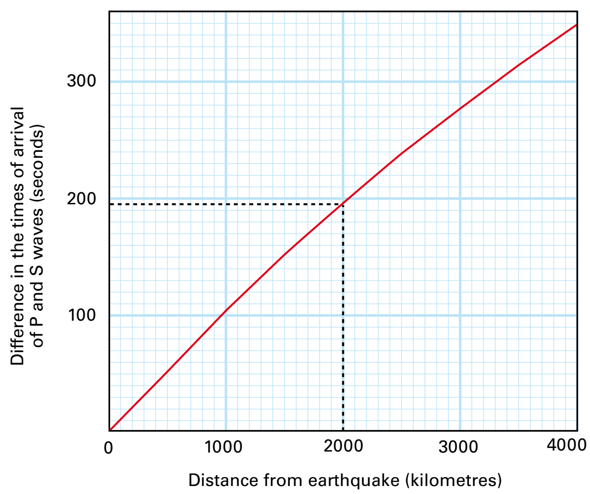
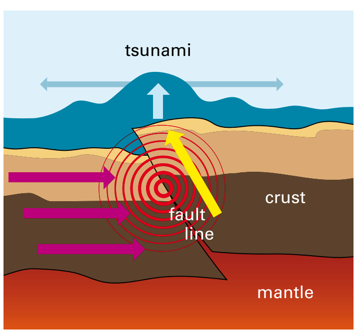


Fig 45 How the Indonesian tsunami formed



Homework

Ask students to create a concept map around the terms and ideas from this chapter. They should relate the map to at least two other areas of study in science (eg forces, ecology, environmental science). There should be a minimum of 10 words with sentences linking them. Some suggested words are force, waves, fault, habitat, energy, climate and fossils.

Learning experience

Set a creative writing task where students write about what they might experience if they were caught up in an earthquake or tsunami. They could write it from the point of view of a news reporter or as a diary entry. Award marks for creativity, accuracy and scientific information.

Learning experience

In small groups of mixed ability, ask the class to problem-solve and come up with a way to demonstrate a tsunami. Useful items may be sand, trays to hold water, an empty fish tank, etc. Students who prefer a less kinesthetic learning style could prepare a multimedia presentation instead.

Investigate

17 EARTHQUAKE WAVES

Aim

To model earthquake waves and to construct a simple seismograph.

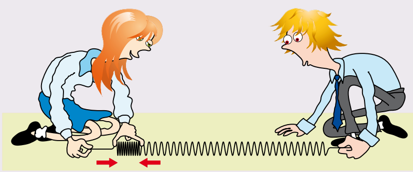
PART A Earthquake waves

Materials

spiral spring (slinky)

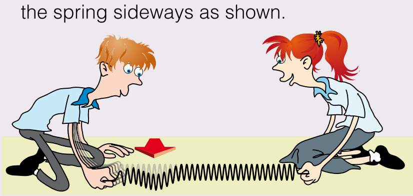
Method

1 To model primary or compression waves, stretch the spring on the floor between you and your partner. Bunch up 10 coils then let them go.



Record what happens as the pulse moves along the spring. In which direction do the coils move? In which direction does the wave move?

2 To model secondary or shear waves, stretch out the spring on the floor as before. This time flick the spring sideways as shown.



How do the coils move this time? In which direction does the wave move?

Discussion

1 How do the two types of waves differ?

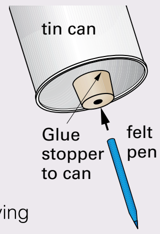
2 Which type of wave produces an up and down movement of the Earth? What type of movement would the other produce?

PART B Making a seismograph

Method

1 Use the diagram of the seismograph as a guide to make a model seismograph (as a class activity).

2 To attach the pen to the metal can, first glue the stopper to the base of the can. Then push the blunt end of the pen firmly into the hole in the stopper.



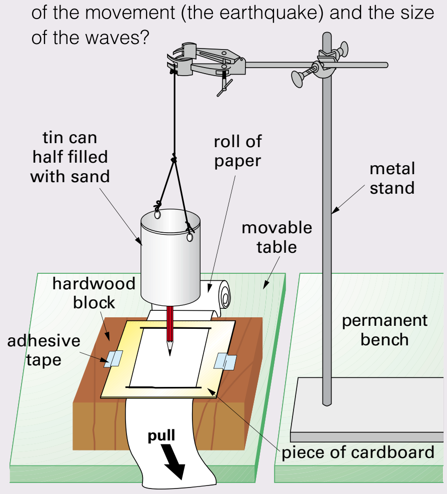
3 Test your seismograph by banging on the desk or giving it a shake.

4 Tear off your seismogram and test your seismograph again.

Discussion

1 Is your seismograph best at recording horizontal or vertical movement?

2 What is the relationship between the intensity of the movement (the earthquake) and the size of the waves?



Lab notes

Part A

- Make sure the floor is smooth. If possible, perform the investigation in a corridor.
- Remind the class that you do not want to see any slinky knotted up!

Part B

- This is best done as a group activity with three or four students per group. Discuss why it is important to make sure the can doesn't swing in a circle.
- Rolls of tracing paper cut into thirds works well for the roll of paper, otherwise a single sheet of A4 paper is OK.
- The students may like to do this part as a homework assignment or a group activity and bring their own equipment from home.

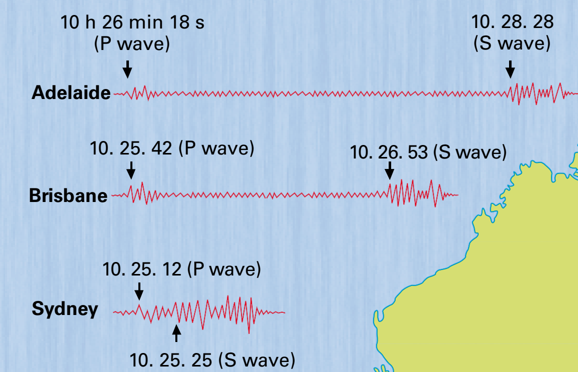
Activity notes

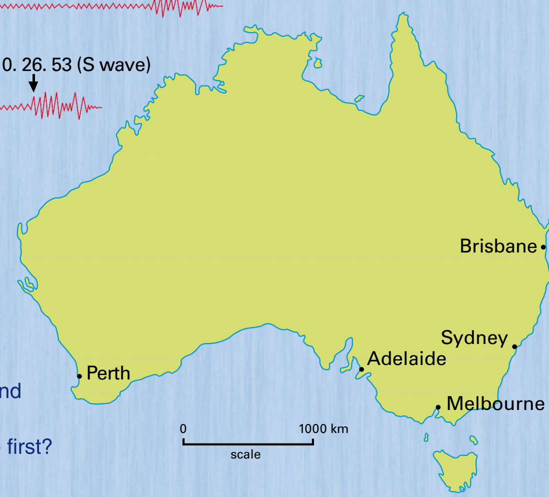
- If possible, do this activity using the online tool in the Webwatch.
- Prior to this lesson, ask the class to bring a pair of compasses to class, otherwise borrow some from the maths department.
- The students often find this task quite challenging so it is a good idea to do it together as a class exercise. Photocopy the map of Australia with its scale, and the graph from page 154, so each student has a copy.
- You will probably have to explain how to do simple ratios when converting the map distances to real-life distances. Do not assume they know how to do this.
- Students could print out the certificate showing they have successfully completed the task of locating the virtual earthquake.

Activity

WEBwatch

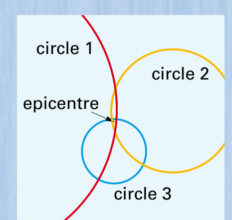
For animations of primary, secondary and surface waves, go to www.scienceworld.net.au and follow the links to **Savage Earth Animations**.





Finding an earthquake's epicentre

1. Look at the three seismograms recorded at Adelaide, Brisbane and Sydney.
   - Which city felt the earthquake first?
   - In which city were the waves strongest?
   - Which city can you infer was nearest to the epicentre of the earthquake?
2. Calculate the difference between the times of arrival of the P and S waves in each city, in seconds.
   - Record the three times.
3. Use the graph on page 154 to work out how far the earthquake waves travelled to each of the three seismographs.
   - Record the three distances.
4. Photocopy and enlarge the map of Australia. Then use the scale to convert the three distances to the distances on the map.
5. Select a city, say Adelaide first, open out a compass to the scale distance, place the point on Adelaide and draw a circle with this distance as the radius.
   Do the same for the other two cities.
6. The three circles should intersect at one point. In practice they rarely do, but instead enclose a small area as shown, whose central point can be taken as the epicentre of the earthquake.
   - Where was the epicentre?
   - Why are three seismograms needed for this calculation?



WEBwatch

You can do this activity by going to www.scienceworld.net.au and following the links to **Virtual earthquakes**.

The Richter scale

Scientists can use seismograms to work out the strength or *magnitude* of an earthquake. The magnitude of an earthquake is how much energy it has, and is measured on a scale from 0 to 10. This scale is called the **Richter** (RICK-ter) **scale** after its inventor, Charles Richter. A shock of magnitude 2 is the smallest normally felt by humans, and magnitudes of less than this can only be detected by seismographs.

On the Richter scale, the intensity or energy of an earthquake increases tenfold for a single increase in magnitude. For example, an earthquake of magnitude 6 causes ten times more ground motion (potential damage) than one of magnitude 5, and 100 times more than one of magnitude 4.

The table below compares the magnitudes of earthquakes and their effects at the epicentre.

Magnitude on Richter scale	Effects at the epicentre
2.5 to 2.9	detected only by instruments
3.0 to 3.9	suspended objects may swing, vibrations like passing trucks
4.0 to 4.9	wakes sleeping people, dishes and windows rattle
5.0 to 5.9	felt by all, furniture moves, walls crack and chimneys topple
6.0 to 6.9	most houses damaged
7.0 to 7.7	ground cracks, foundations damaged, pipes burst, landslides
7.8 to 8.6	disastrous, few structures remain, large cracks in ground
greater than 8.6	total destruction, waves seen on the ground, magnitude 9.5 most severe ever recorded (Iran 1972)

Fig 52 In September 1999 the strongest earthquake to hit Taiwan for more than 100 years had its focus 1.1 km below the middle of the island. The photo shows rescue workers searching for survivors in the ruins of this hotel which collapsed when the earthquake struck at 2 o'clock in the morning. It measured 7.6 on the Richter scale.

WEBwatch

Go to www.scienceworld.net.au and follow the links to the websites below.

Elastic rebound animation
Animation of an earthquake in an orchard.

How tsunamis work
Has dramatic before and after photos of the 2004 Indonesian tsunami.

The Newcastle earthquake
Details of the only recorded Australian earthquake to have claimed human lives.

Hints and tips

Australia has experienced earthquakes with greater magnitude than that of the Newcastle quake. Why have they not been so devastating? You may like to discuss the reasons with your class. (The areas where the earthquakes struck were not built-up or heavily populated.)

Homework

Have the students do the Webwatch as a homework exercise and present their findings to the class.

Learning experience

Print out some log paper (semi-log) from the internet, or ask the maths department to provide some, to illustrate how the Richter scale works. You may like to construct an earthquake magnitude and intensity graph. Gifted and talented students could do this as an extension task or for homework. With the class, work through a few earthquake magnitude calculations to clarify how the scale works.

Check!

1 How can a fault cause an earthquake?

2 What are P, S and L waves? Which type causes the most damage?

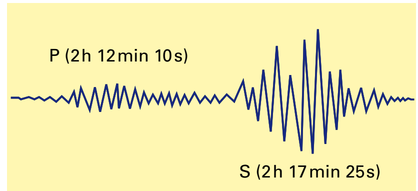
3 What is the Richter scale? What is the difference, in energy terms, between a magnitude 4 earthquake and a magnitude 5 one?

4 What is the smallest magnitude earthquake that can be felt by humans? An earthquake of which magnitude would cause trees to sway?

5 Explain in your own words how a seismograph works.

6 Use a diagram to explain the terms focus and epicentre of an earthquake.

7 The diagram below shows a seismogram recorded at a particular location. Use the graph on page 154 to find out how far away the recording station was from the epicentre of the earthquake.



challenge

1 Three seismograph stations in Brisbane, Adelaide and Perth recorded an earthquake. The times at which the P and S waves were detected are shown below.

Brisbane:	P wave 7 h 20 min 10 s
	S wave 7 h 24 min 10 s
Adelaide:	P wave 7 h 21 min 46 s
	S wave 7 h 26 min 34 s
Perth:	P wave 7 h 23 min 22 s
	S wave 7 h 28 min 59 s

a Which city first detected the earthquake?
b Which seismograph station detected the earthquake first? What does this tell you about the location of the earthquake?
c Using the map on page 156, find the epicentre of the earthquake.

2 P, S and L waves travel at different speeds depending on the composition of the rocks in the crust. P waves travel about 10 km/s, S waves at 5 km/s and L waves at 3 km/s. Suppose there was an earthquake 700 km north-west of Melbourne.
a How long will it take P, S and L waves to reach Melbourne?
b Calculate the difference in arrival times of the P and S waves.
c Use the graph on page 154 to find the difference between the arrival times of P and S waves after travelling 700 km. Does this agree with your answer from **b**? If it doesn't, suggest reasons for the difference.

3 California has had a number of very strong earthquakes, compared with Australia. Suggest why.

4 What patterns can you see in Fig 59 on page 161? It shows where major earthquakes have occurred around the world.

5 In 1968, one of the biggest earthquakes to have been recorded in Australia (magnitude 6.8) occurred at Meckering, east of Perth.
The photo below shows some of the damage caused by the earthquake. Suggest what sort of earth movement occurred here.

Check! solutions

1 When intense pressures act in the Earth's crust the forces can cause rocks to break and move along a fault. The energy which is released spreads out in all directions as vibrations or waves and is called an earthquake.

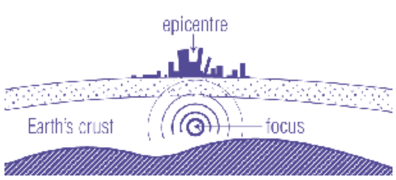
2 The three types of waves areas follow.
- P or primary waves travel quickly by compression of solids and liquids.
- S or secondary waves are shear waves which are due to the sideways movement of matter in solid rocks.
- L waves are surface waves which travel more slowly but cause most damage to objects on the Earth's surface.

3 The Richter scale is a scale from 1–10 which is used to work out the strength (or magnitude) of an earthquake. Each number is 10 times more powerful than the number before. An earthquake with a magnitude of 5 is 10 times as strong as one with a magnitude of 4.

4 An earthquake with a magnitude of 3 is the smallest that can be felt by humans. An earthquake with a magnitude of about 5–6 would probably cause trees to sway.

5 The seismograph on page 155 is designed to measure movement horizontally. A similar device can be built to measure movement vertically. This would be similar to Fig 41 on page 153.

6



The focus is the place where the rocks actually move, whereas the epicentre is the point on the surface of the Earth where there is maximum movement and damage.

7 The difference in the time of arrival is 5 min 15 s or 5.25 min. Using the graph on page 154 you can estimate that the distance from the earthquake is about 3500 km.

Challenge solutions

1 a The first earthquake waves were detected in Brisbane at 7.20 am (in the morning).
b The earthquake was first detected in Brisbane so it can be inferred that the epicentre is nearest to Brisbane.
c The technique is to find the difference in time between the P and S waves and use the graph to calculate the distances of each city from the epicentre. You can then use the given scale and a compass on a photocopy of the map on page 156 to find the point of intersection.

City	Time difference	Distance	Map distance
Brisbane	4 min	2500 km	5.0 cm
Adelaide	4.8 min	3100 km	6.2 cm
Perth	5.6 min	3800 km	7.6 cm

The epicentre is about 250 km north-west of Cape York in Queensland, although it is difficult to be accurate.

2 a The P waves will take about 70 s.
The S waves will take about 140 s.
The L waves will take about 230 s.
b The difference in time between P and S waves is about 70 seconds.
c From the graph, 700 km distance

7.4 Earth plates

During the late 1800s and early 1900s most geologists believed that the Earth was still in the process of cooling down because the crust was shrinking. They thought it was buckling like the skin of an old, dried-out apple. The continents were the raised parts of the skin and remained fixed in place.

However, a small number of geologists formed alternative ideas about the formation of continents. They suggested that the distribution of the continents is not fixed. Instead they suggested that some continents, such as Africa and South America, had been joined at some stage in the Earth's history. See Fig 55.

In 1915 a German scientist, Alfred Wegener, suggested that Africa, South America, Australia, Antarctica and India were joined about 200 million years ago. This supercontinent, called Gondwana, gradually broke apart and the continents separated. Wegener's hypothesis was called **continental drift**.

There was considerable evidence to support Wegener's ideas. Similar rocks are found in Australia, Antarctica and southern Africa. Fossils of an ancient plant called *Glossopteris* are widespread in all five continents and absent from Europe, Asia and North America. Fossils of *Mesosaurus*, a crocodile-like reptile, are found in southern Africa and in South America.

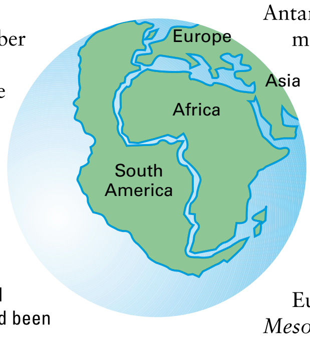


Fig 55 A map drawn in 1856 shows how some geologists thought Africa and South America had been joined.

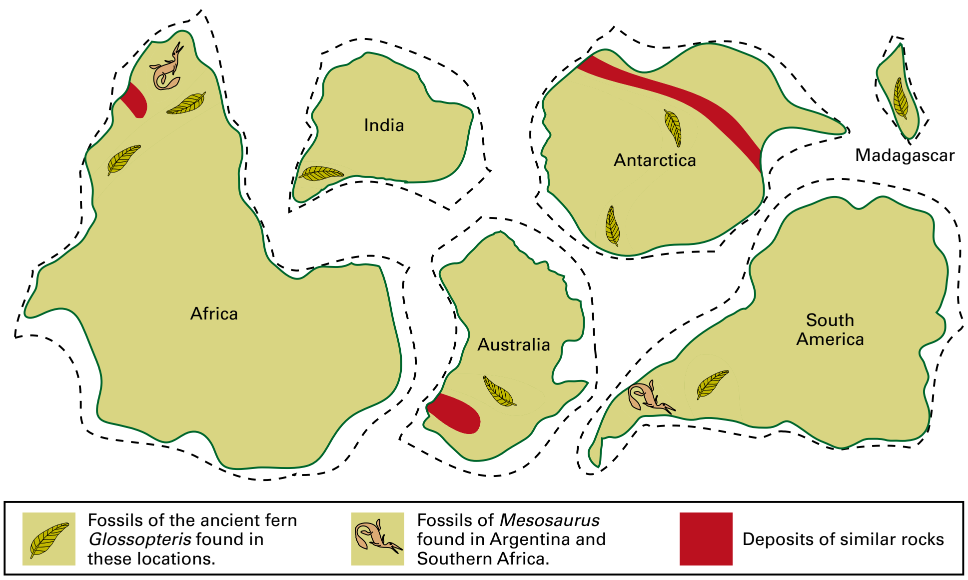


Fig 56 A collage of the southern continents showing the locations of similar fossils and rocks (for Activity on next page)

Hints and tips

Be sensitive to the religious and cultural beliefs some students may have in relation to this topic (and the formation of the world). Encourage the students to explore their ideas, experiences and feelings. Does science support all viewpoints? Can science explain everything? Make sure your students are not critical and judgmental toward their peers but remain open to new or different ideas.

means that the waves will be 1.2 min apart (about 72 s). This agrees with the answer in part **b**.

3 California is on the west coast of North America and on the edge of a continental plate (see page 161) whereas Australia has no plates running beneath it.

4 The pattern is that the distribution of earthquakes on the planet corresponds very closely to the boundaries where continental and oceanic plates meet. The reason is that the crust is relatively thin and weak at these points.

5 The damage in the photo was caused by a fault which moved the ground upwards and to the left in the foreground.

Learning experience

An interesting activity is to make a world jigsaw puzzle. Photocopy a map of the world and ask the students to systematically cut out and glue together the countries, islands and continents surrounded by sea. For example, New Zealand fits against the east coast of Australia, while Tasmania joins the coast of Victoria. When they glue the pieces together they need to make sure each piece is joining another land mass so eventually little sea exists. They will find most of the pieces fit together like a jigsaw puzzle. (This is similar to the activity on page 160.) The students will be quite amazed and it can lead into class discussion about our views of how the world was formed and how it has changed.

Activity notes

This would be a very good activity for the students to complete as a homework task. Photocopy Fig 56 on page 159 for them to use.

Activity

1. Photocopy (and enlarge if possible) the map of the southern continents at the bottom of the previous page.
2. Cut carefully around the dotted lines (the edges of the continental shelves).
3. Try to fit the six pieces together, leaving as few gaps as possible, to make the supercontinent of Gondwana. Try to match up the fossils and similar rocks.
4. When you are happy with the positions of the continents, glue them into your notebook.

Which continents did Australia touch?

You can try this activity by going to www.scienceworld.net.au and following the links to **Wegener: continental drift**.

Plate tectonics

Wegener's continental drift idea was not well accepted, because few scientists were convinced that there was enough evidence to support it. However, in the 1950s two American scientists, Maurice Ewing and Marie Tharp, used new technology called *echo-sounding* to map the depth of parts of the Atlantic Ocean. (Echo-sounding uses sound waves to find the depth of the ocean floor.)

In the middle of the ocean, a mountain range higher than any on the continents was mapped. This was called the Mid-Atlantic Ridge and it was later found to run from the Arctic, right down the middle of the Atlantic Ocean.

In the middle of the ridge, Tharp discovered a deep trench. When rock samples from this trench were taken and analysed, they were found to be very much younger than samples taken further away from the ridge. Another suprising piece of evidence was that the temperature of the ocean bed along the Mid-Atlantic Ridge was eight times higher than anywhere else. From these two observations, Ewing inferred that at the Mid-Atlantic Ridge new rocks are being made as hot material rises from the Earth's mantle and pushes the older rocks away from the ridge line.

This new idea created a dilemma. Scientists knew that the Earth is not expanding, but in fact getting smaller. How could this happen if new crustal rocks were being made along the ridge? In 1960, Professor Harry Hess, using echo-sounding data he had collected from the Pacific Ocean in the 1950s, suggested that as new crust is being made along the ocean ridges, older crust is slowly being pushed outwards towards the continents and then down into the mantle, as shown in Fig 57. The idea that giant sections or plates of crustal rock move over the Earth's surface became known as the theory of **plate tectonics**, a modification of the old continental drift hypothesis.

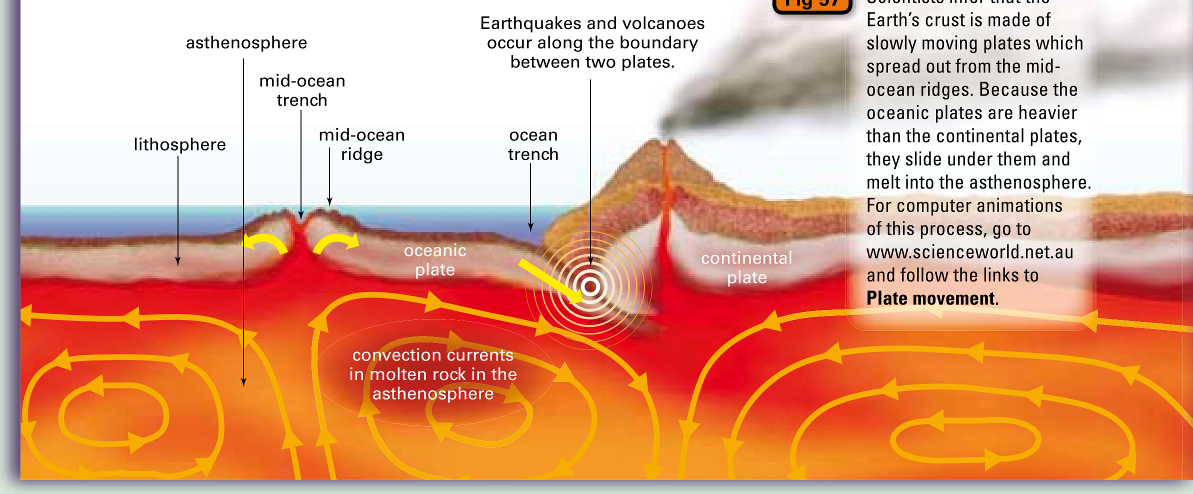


Fig 57 Scientists infer that the Earth's crust is made of slowly moving plates which spread out from the mid-ocean ridges. Because the oceanic plates are heavier than the continental plates, they slide under them and melt into the asthenosphere. For computer animations of this process, go to www.scienceworld.net.au and follow the links to **Plate movement**.

Hints and tips

Try to broaden the students' knowledge of the Earth by answering some interesting trivia questions, such as:

- What is the height of the tallest mountain?
- What is the length of the longest river?
- Which is the deepest part of the ocean?
- Which is the fastest moving glacier?
- Which are the most populated places and the least populated places in the world?
- What is the Gulf Stream?

Students love to go home and tell their parents something they think only they know!

Learning experience

Have a class discussion to come up with some possible reasons why the Mid-Atlantic Ridge is underwater. Was it always underwater? Turn it into a Think/Pair/Share activity (see page 34 of this book). Now ask them to come up with their own question for the class to investigate using the same method.

Learning experience

Colourful posters of Fig 57 could be made by the students and displayed on the science room's walls.

The theory of plate tectonics suggests that the Earth's crust is made up of separate plates that float on top of the semi-solid rocks in the mantle. Convection currents in the asthenosphere push the molten material to the surface along the mid-ocean ridges (Fig 57). The newly formed crustal rock becomes part of the oceanic plates, which are forced away from the ridges in the directions shown in Fig 58.

Fig 59 shows the world's major earthquake zones. Notice that they correspond to the plate boundaries in Fig 58. When an oceanic plate collides with a continental plate, earthquakes and volcanoes are produced along this line. Notice that where the 2004 Indonesian earthquake occurred is at the boundary of two Earth plates.

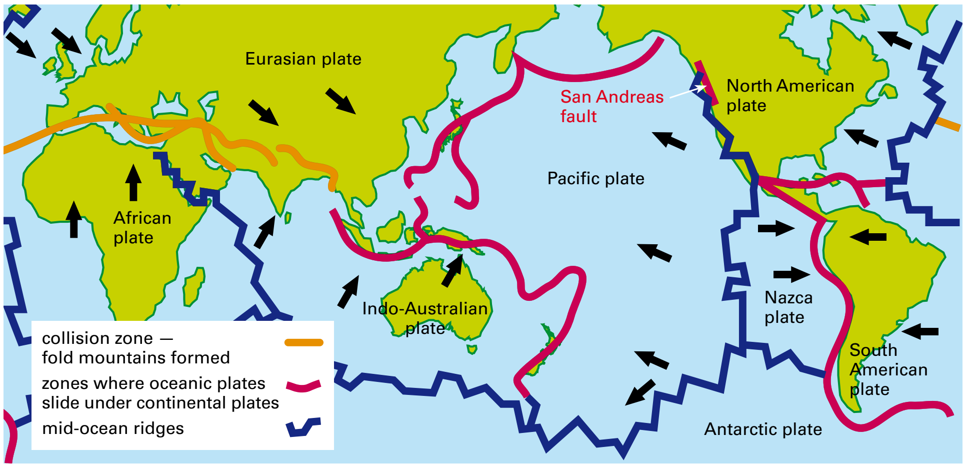


Fig 58 The Earth's crust is made up of large plates which move an average of 2 cm per year.

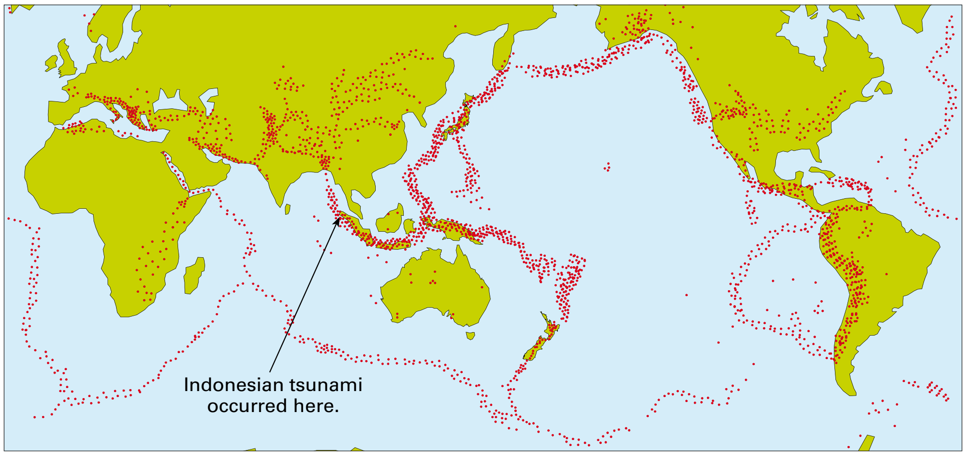


Fig 59 Each dot on this map shows where a major earthquake has been recorded.

Hints and tips

- Revise what is meant by convection currents. A simple demonstration using a drop of food colouring in hot water is all that is needed.
- A dot point summary of the chapter is a very useful tool for the students to develop here. It assists with reinforcing concepts, can be used as a revision tool and helps develop students' note-taking skills.

Learning experience

Ask the students to infer why there are a lot of earthquakes along the regions of the plate boundaries.

Check! solutions

1 At the start of the 20th century most geologists believed that the Earth was still in the process of cooling, and that the crust was shrinking and buckling to form the continents.

It is quite different to Wegener's theory, which proposes that there are movements of huge plates which collide with each other to form mountains, volcanoes and earthquakes.

2 The evidence includes similar rocks found in Australia, southern Africa and Antarctica, and similar plant and animal fossils found on several different continents.

3 Gondwana was thought to be the huge ('super') continent which broke up to form smaller continents like Australia.

4 Similar fossils to those found in Australia, India and Antarctica were not found in Europe or North America because these last two continents were never part of Gondwana.

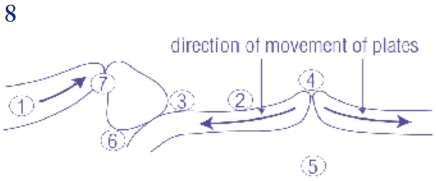
5 Important discoveries included finding younger rocks along the Mid-Atlantic Ridge, and finding out that the oceanic crusts were being pushed towards the continents on either side of the oceans.

6 If it moves 5 cm per year, in 200 years it will move 5 × 200 cm = 1000 cm = 10 m.

In 20 million years it will move 5 × 20 million = 100 million cm = 1000 km.

7 The dilemma for scientists was that if the rocks in the oceanic crust were being pushed outwards away from the ridge, how is it that the Earth is getting smaller and not larger?

8



Key:
1 continental plate
2 oceanic plate
3 region of colliding plates
4 mid-oceanic ridge
5 convection currents in mantle
6 regions of earthquake activity
7 region of volcanic activity

Check!

1 At the start of the 20th century most scientists accepted a theory about the formation of the continents. Describe this theory.
How is it different from the theory proposed by Alfred Wegener?

2 Describe the evidence used to support the theory of continental drift.

3 Why is Gondwana called a supercontinent?

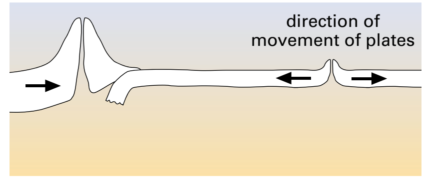
4 Suggest why certain fossils have been found in Australia, India and Antarctica but not in Europe or North America.

5 What discoveries during the mid 20th century added new evidence to the idea that the Earth's crust is not fixed in place?

6 Suppose a continental plate moves 5 cm a year. Predict how far it will move in 200 years, and in 20 million years.

7 Ewing and Tharp echo-sounded vast areas of the Atlantic Ocean during the 1950s. They concluded from their results that the seafloor was spreading. Why was this a dilemma for scientists at the time?

8 Copy the drawing below and label it with the following.
- continental plate
- oceanic plate
- region of colliding plates
- mid-oceanic ridge
- convection currents in the mantle
- regions of earthquake activity
- regions of volcanic activity



challenge

1 Some of the highest mountains in the Andes in South America are made mostly of sedimentary rocks containing marine fossils.
Use your knowledge of plate tectonics to explain how this mountain range might have formed.

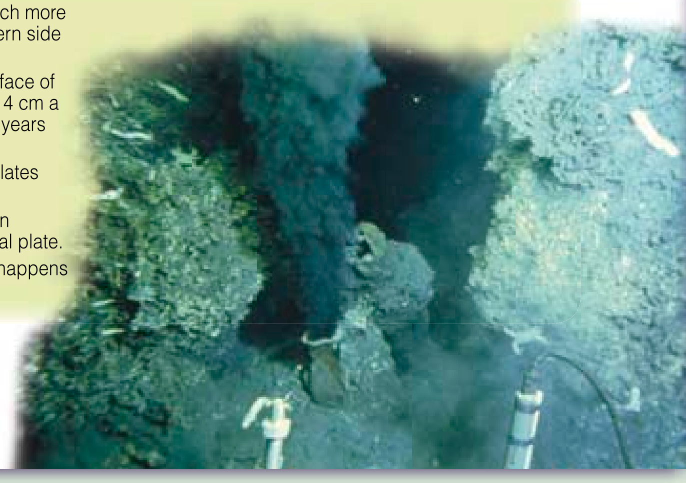
2 Use Fig 57 on page 160 and the maps on page 161 to explain why a deep-sea trench more than 10 000 m deep is found on the eastern side of Japan.

3 Which way is Australia moving on the surface of the Earth? If it is moving at an average of 4 cm a year, what is its likely position 100 million years from now?

4 There are two types of plates—oceanic plates and continental plates.
a Briefly describe what happens when an oceanic plate collides with a continental plate.
b Use library resources to find out what happens when two continental plates collide.

5 Use an atlas to locate the following volcanoes: Mt Fuji, Mt St Helens, Mt Vesuvius, Kilauea, Mt Pinatubo, Krakatoa.
Then use a pencil to mark them on a copy of the map of the Earth's plates on page 161. Why do you think they are found in these places?

6 The photo shows a hydrothermal vent or 'black smoker' on the ocean floor. Use the internet to find out what black smokers are, where they are found, and why they are important.



Challenge solutions

1 When plates collide, sedimentary rocks can be pushed up very high to form mountain ranges. In the case of the Andes mountains, the Nazca plate has collided with the South American plate. This is shown by Fig 57 on page 160.

2 This trench has formed because at this point the Pacific plate is colliding with the Eurasian plate and moving underneath it. This results in a deep trench as shown in Fig 57.

3 Australia is moving north-eastward towards the Pacific and Eurasian plates.

If this movement continues, 100 million years from now Australia will be 4000 km north-east of its present position in the northern hemisphere. This would be in the Pacific Ocean east of the Philippines on a current map.

4 a When an oceanic plate collides with a continental plate, the oceanic plate slides underneath the continental plate. This usually results in volcanoes and earthquakes.
b When two continental plates collide, again one slides under the other and often this results in a fold mountain being pushed up.

MAIN IDEAS

Copy and complete these statements to make a summary of this chapter. The missing words are on the right.

1 _____ are the preserved remains, impressions or traces of past life on Earth.

2 The _____ is a description of Earth's history which shows that many organisms found as fossils do not exist today.

3 Scientists infer that the Earth is made up of three main layers: the _____, the _____, and the core.

4 Movements in the mantle cause changes in rocks in the crust: rocks that bend slowly form _____ and those that break suddenly form _____.

5 _____ occur when large blocks of rock move suddenly and slide along each other at a fault.

6 Earthquakes produce three types of _____: P, S and L. These are detected by _____.

7 The magnitude of an earthquake is usually measured on the _____ (from 0 to 10).

8 According to the theory of _____, the Earth's crust is made up of a number of large plates which move slowly relative to one another. Earthquakes and volcanoes occur where these plates _____.

collide
crust
earthquakes
faults
folds
fossils
geological time scale
mantle
plate tectonics
Richter scale
seismographs
waves

Try doing the Chapter 7 crossword on the CD. Working with technology

REVIEW

1 Most fossils are found:
- **A** in rock layers which formed under water
- **B** in rocks which were formed from cooling lava from volcanoes
- **C** in sand on seashores
- **D** in the waters of seas and lakes

2 Which one of the following organisms has the best chance of becoming fossilised in the place in which it lives?
- **A** a bat
- **B** a crocodile
- **C** an emu
- **D** a dingo

3 Over millions of years, the original bone or shell of an organism has been replaced by minerals from the surrounding rock. The fossil is said to be:
- **A** petrified
- **B** carbonised
- **C** a mould
- **D** a cast

4 Read the descriptions below and decide what type of fossil is formed in each case. Justify your decisions.
- **a** A dragonfly lands on a tree and gets caught in sap. It dies and is covered in more sap. Over the years the sap hardens to form a pale, transparent solid.
- **b** A tree falls into the mud in a creek. More mud covers the tree and the creek dries up. The sediments surrounding the tree harden into rock. Over millions of years the fossil becomes harder than the surrounding rock.
- **c** A dead scallop becomes buried in the seabed. As the sand hardens to rock, the shell of the scallop slowly dissolves. This forms a cavity. After further time, minerals from the surrounding rock fill the cavity.

Main ideas solutions

1 fossils
2 geological time scale
3 crust, mantle
4 folds, faults
5 earthquakes
6 waves, seismographs
7 Richter scale
8 tectonic plates, collide

Review solutions

1 **A**—See Fig 5 on page 139.

2 **B**—Organisms that live in water have the best chance of being covered with sediment and preserved when they die.

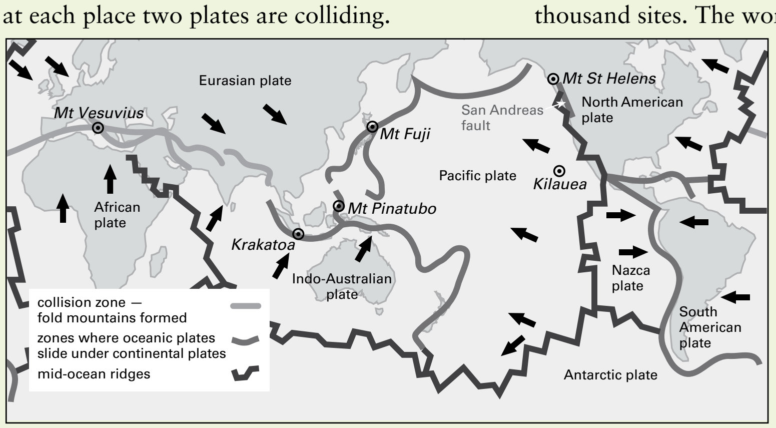
3 **A**

4 **a** The insect is an *unaltered fossil* because the sap preserves its body intact.

b The tree becomes a *petrified fossil* because the minerals from the surrounding rock replace the tree's materials and make it harder.

c The scallop forms a *mould* as the shell gradually dissolves. Then as the mould fills up with minerals it becomes a *cast* of the original shell.

5 The volcanoes are shown on the map below. They occur in these places because at each place two plates are colliding.



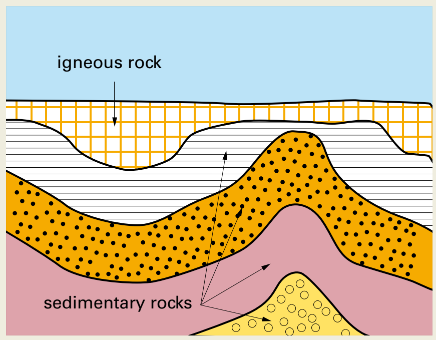
6 If you do an internet search for 'hydrothermal vent' you will find several thousand sites. The word *hydrothermal* means 'hot vents under water' and they are small cracks in the crust under the ocean through which extremely hot water is forced out. They occur along the boundaries of continental or oceanic plates. They are very interesting to scientists because some very unusual living organisms have been discovered, which may be useful in research. Hydrothermal vents may also provide some very useful mineral deposits (eg sulfur).

REVIEW

5 A fossil was discovered when a farmer noticed part of it sticking out from the surrounding rock.
  a What type of rock do you think surrounded the fossil?
  b Suggest why the surrounding rock eroded more easily than the fossil.

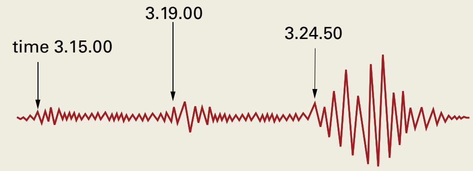
6 Use the maps of the world's earthquake zones and the earth plates on page 161 to explain why there is a greater chance of an earthquake occurring in Wellington, New Zealand than in Melbourne.

7 The diagram below shows a cross-section through an area of the Earth's crust.



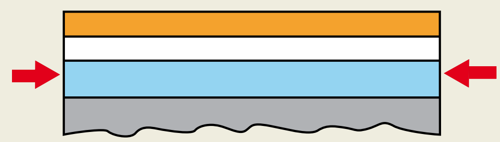
  a The shape of the sedimentary rocks is most likely the result of:
    A a fault
    B horizontal squeezing forces
    C the way in which the sediments were originally laid down
    D the pushing up of magma from below
  b Copy the diagram in your notebook. Mark the position of an anticline and a syncline on the diagram.
  c Account for the layer of igneous rock on top of the sedimentary rocks. Suggest why this layer is relatively flat on top.
  d Infer which of the rock layers is the oldest, and which is the youngest? Give reasons for your inferences.

8 The seismogram below is a record of an earthquake.



  a Which is the P wave and which is the L wave?
  b Which waves are due to the compression of matter in the crustal rocks?
  c Which type of wave has the most energy?
  d Which type of wave causes the most damage to structures on the Earth's surface?
  e What is the difference in the arrival times of the P and S waves?
  f Use the graph on page 154 to calculate how far away the earthquake was.
  g Can you use your answer in **f** to find the epicentre of the earthquake? Explain your answer.

9 Forces inside the Earth act on rocks in the crust as shown in the diagram below. As a result of these forces the rocks move. Draw labelled diagrams to show what the rock layers could look like after this movement. There are three possibilities.



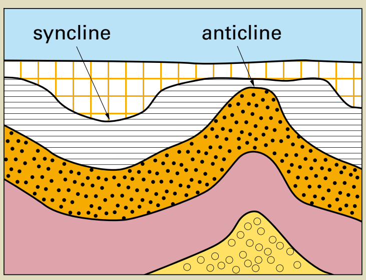
10 Scientists have calculated that the Mediterranean Sea between Africa and Europe is becoming narrower over time. Use the map on page 161 to suggest why.

Check your answers on page 321.

5 **a** The rock would have been sedimentary.
  b The fossil was probably petrified. In this process the minerals from the surrounding rock replace the fossil's materials and make it very hard—much harder than the surrounding rock.

6 Wellington is on a plate boundary. Here the relative movement of the two plates means that earthquakes are highly likely. Melbourne is well away from the edge of the plate, so the Earth there is less likely to move.

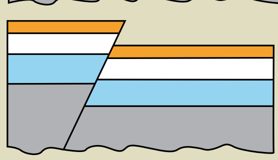
7 **a** B
  b



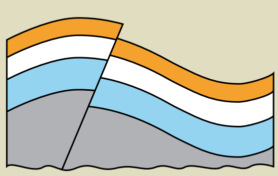
  c The igneous rock probably came from lava which flowed from a nearby volcano, then later hardened to form igneous rock. Being liquid, the top of the lava is flat.
  d The lowest layer of rock is the oldest because it was deposited first. The other sedimentary layers were deposited on top of this one. The youngest layer is the igneous layer which formed after the other layers had been folded and eroded.

8 **a** The P wave is the first wave to arrive (time 3.15.00) and the L wave is the last (3.24.50). See pages 153–154.
  b P waves
  c L waves have the most energy because they have the largest vibrations.
  d L waves
  e 4 minutes
  f The earthquake was about 2500 km away.
  g No. You know how far away the earthquake was, but not its location. To find the epicentre you need seismograms from *three* different locations.

9 The rocks may be folded or faulted:



Or they may be folded *and* faulted:



10 The African plate is moving north (upwards on the map), while the large Eurasian plate is moving south-east (downwards and to the right). The Mediterranean Sea is on the boundary of these two plates which are moving closer together. This movement is making the Mediterranean Sea narrower.