CHAPTER 4

The changing Earth

You will discover

That the Earth is constantly changing
How different types of rock form
How rocks can change from one type to another
Ways to estimate the age of rocks

Death of a city

Surveying the ruins of Pompeii a modern-day traveller observes, '... and to the left, to the right, wherever I look, grim reminders of the AD 79 disaster stare back at me. I am surrounded by the ruins of an ancient resort town that was once home to 15 000 people. Now all that remains are the plaster casts of the bodies caught in the mountains of hot ash that buried an entire city.'

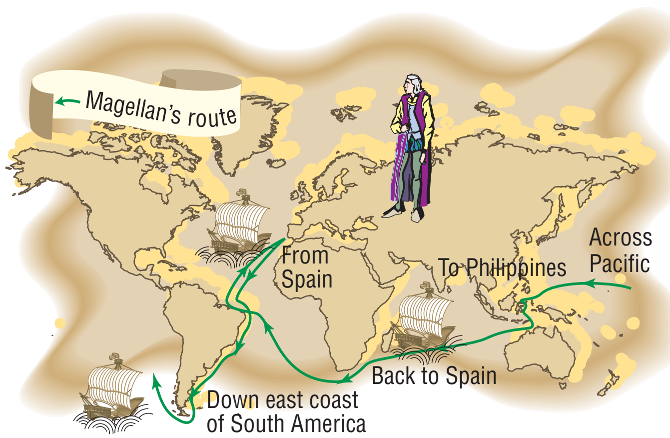
The citizens of Pompeii would have been taken by surprise by the exploding volcano. Mount Vesuvius had been asleep for centuries. In fact, only a few scholars would have known that the mountain in the distance was actually a volcano.

For over 100 years, excavations at Pompeii have been slowly uncovering more and more pieces of the past. Every day many tourists visit the site and walk the streets that the ancient residents of Pompeii once walked. And many of them glance at the distant mountain that last erupted in 1944, and which some scientists predict will erupt again soon.

1 Why are there now only plaster casts of the bodies that were caught in the disaster?
2 How long can volcanoes 'sleep' before they erupt again?
3 What can we learn from looking at fossils and the ruins of buried cities?

What's in the Earth?

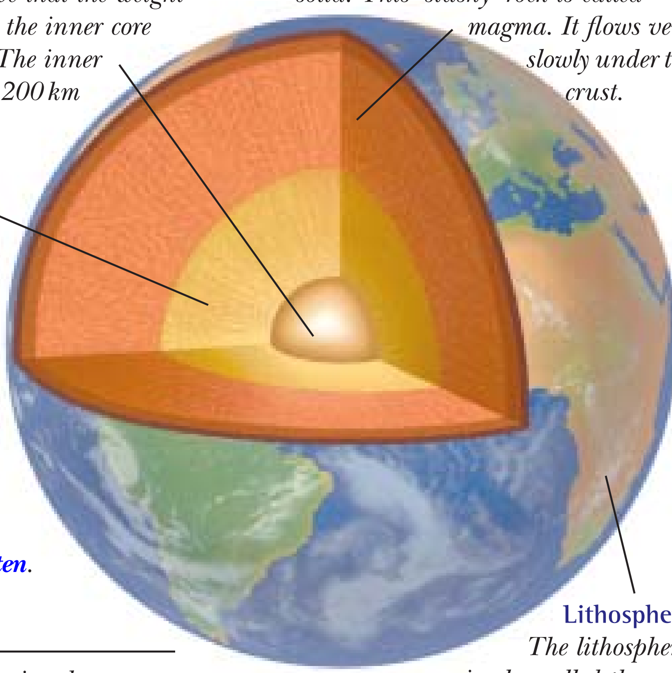
Until the sixteenth century, many people believed that the Earth was flat. In 1519, Ferdinand Magellan and his crew set off from Spain to the Spice Islands (Indonesia) in a westerly direction. Most people believed that eventually they would reach the end of the Earth and fall off. Instead, by continuing in the same direction, the crew arrived back in Spain and showed that the Earth could not be flat.



Inner core
The inner core is very hot. Its temperature is about 7000 °C. Even though it is hotter than the outer core, the inner core is solid. Scientists believe that the weight pushing in on the inner core keeps it solid. The inner core is about 1200 km thick.

Outer core
The outer core is about 2200 km thick and very hot. Temperatures from 4000 °C to 6000 °C make the rock in the outer core ***molten****.*

Mantle
The mantle is a 2900 km thick layer under the crust. It is made mostly of solid rock. But the upper part of the mantle, just under the crust, is not so solid. This 'slushy' rock is called magma. It flows very slowly under the crust.



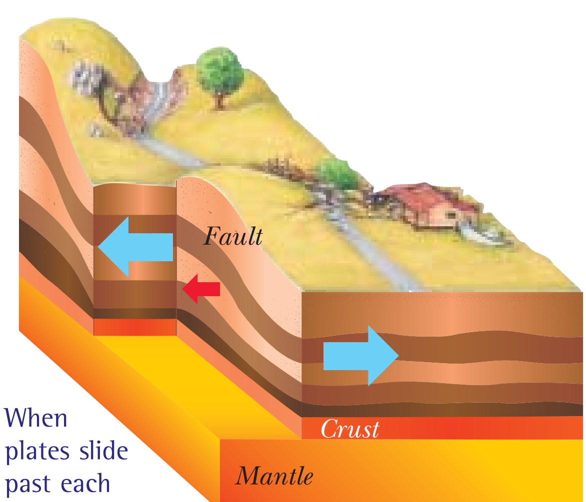
Atmosphere
The atmosphere is a layer around the surface of the Earth. It is over 80 km thick and made up of gases that are needed for life on Earth. The mixture of gases in the atmosphere is called ***air****. Most of the air mixture is made up of nitrogen. Oxygen makes up about one-fifth of the air.*

Lithosphere
The lithosphere is also called the crust. It is the layer that forms the hard surface of the Earth. The crust ranges in thickness from 8 km to about 40 km. The thinnest parts are under the oceans. The crust is mostly made up of soil, water and rocks.

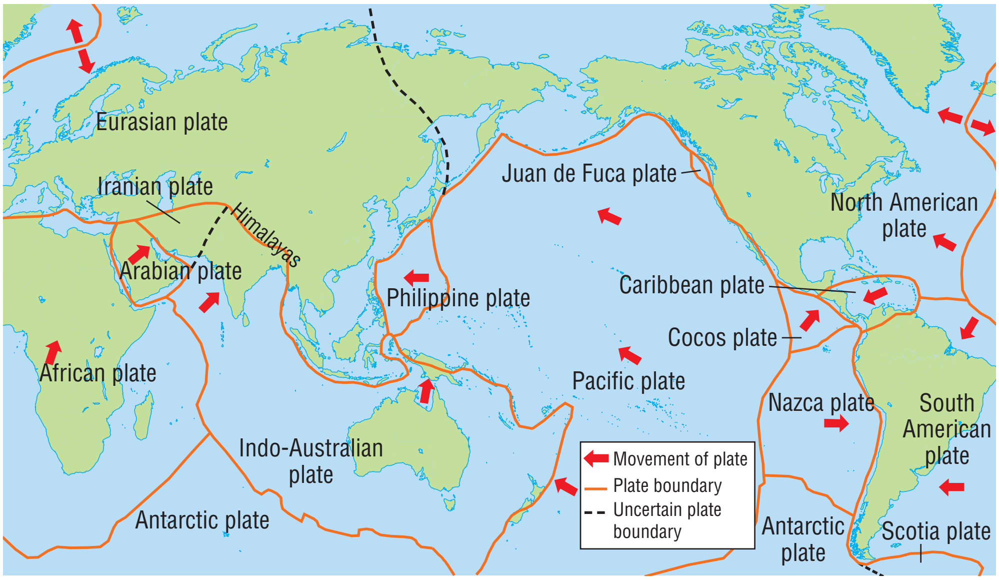
Floating on the mantle

The Earth's **crust** floats on semi-liquid **magma** at the top of the **mantle**. The crust is made up of large pieces called **plates**. The Earth's plates move very slowly over the top of the mantle.

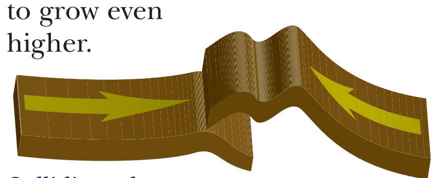
When plates slide past each other, earthquakes occur. Severe earthquakes happen when the sliding plates don't slide smoothly and get jammed together. This is happening in California. The **pressure** between the plates builds up. Suddenly the plates jolt past each other and the sliding starts again.



When plates slide past each other, they can get jammed and cause earthquakes.



Sometimes the Earth's plates crash into each other. When this happens, one plate can sink under the other. It's been happening between the Indo-Australian and Eurasian plates. The Indo-Australian plate is sinking under the Eurasian one. The world's highest mountain range, the Himalayas, is on the Eurasian plate. This plate buckles as the Indo-Australian plate slides under it and causes the Himalayas to grow even higher.



Colliding plates

Activities

REMEMBER

1. List the layers within the Earth from:
   (a) thinnest to thickest
   (b) the centre outward.
2. Where is magma found?
3. Why is the inner core solid even though it is hotter than the molten outer core?
4. How are the Himalayas being formed?
5. Describe one reason why severe earthquakes occur.

THINK

6. In 1961, geologists started a project that attempted to drill through the crust into the mantle. Where in the crust would the hole have been drilled? Explain your answer.

CREATE

7. Build a model of the Earth's layers using plasticine. When you have finished, cut a segment out of your model so that the different layers can be seen. Make sure that your model shows which layers are thickest and which are thinnest.

GRAPH

The deepest hole drilled into the Earth is only about 14 km deep. Even though this is a short distance compared with the distance to the centre of the Earth, the temperature increases dramatically. The distance to the centre of the Earth is about 6370 km. The table above shows the temperature at different depths in a drill hole.

Depth (km)	Temperature (°C)	Depth (km)	Temperature (°C)
0	15	5	158
1	44	6	187
2	73	7	215
3	102	8	242
4	130		

8. Use graph paper or a spreadsheet to plot a line graph of temperature against depth. Label the vertical axis 'Temperature' and the horizontal axis 'Depth'.
   (a) Use your graph to predict the temperature at 4.5 km.
   (b) At approximately what depth is the temperature of the Earth equal to 200 °C?
   (c) Estimate the temperature at the centre of the Earth.
   (d) How close is your estimate to the actual temperature (7000 °C)? Explain why your estimate might be different from the temperature that scientists have predicted.

checklist

I can:
- ☐ label and describe the layers of the Earth
- ☐ explain earthquakes and mountain building in terms of the movement of the plates that make up the Earth's crust.

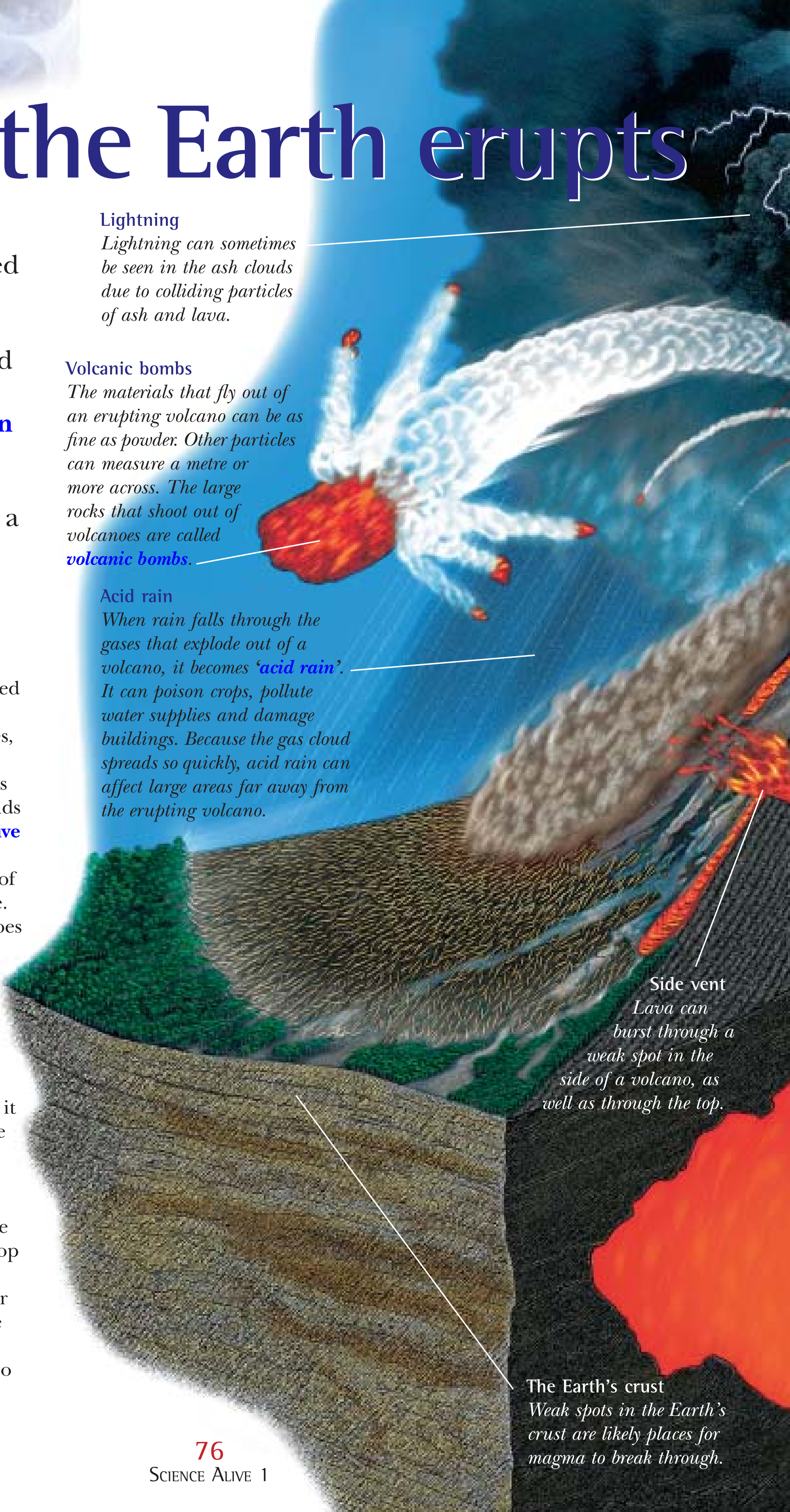
When the Earth erupts

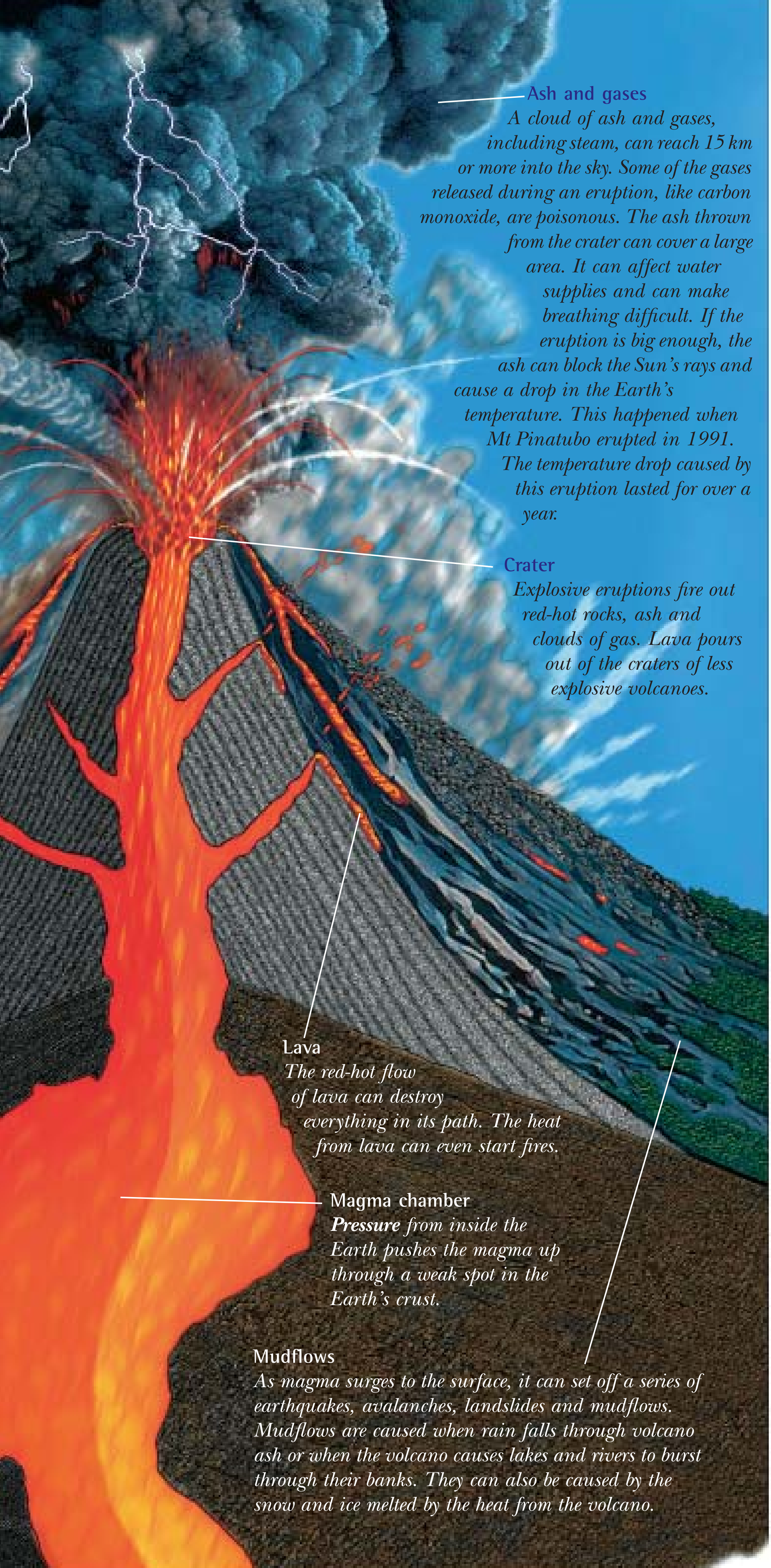
In 1943, a crack mysteriously appeared in the ground in a flat cornfield in Mexico. A week later the crack had become a 150 m high volcano. Red-hot **molten lava** spewed from deep inside the growing volcano. Ten years later, a 400 m high, rocky mass stood where a peaceful cornfield once lay.

This volcano is now described as **dormant** because it has not erupted for over 20 years. Dormant volcanoes are 'sleeping' volcanoes, but they can wake up at any time without much warning. Volcanoes that have not erupted for thousands of years are said to be **extinct**. **Active** volcanoes are those that have erupted recently and show signs of erupting again in the near future. There are about 500 active volcanoes around the world. None of these active volcanoes are in Australia.

What is a volcano anyway?

Magma can break through weak spots in the Earth's **crust**. When it does, a volcano is formed. As the magma reaches the Earth's surface, it releases some of its gases. The molten rock at the Earth's surface is called lava. The lava can ooze gently out of the top of a volcano or it can burst out explosively. Lava can be runny or really thick. The gases inside the volcano can explode out so violently that the top of a volcano can blow right off!





Go to worksheet 16

MI BODILY/KINAESTHETIC

Activities

REMEMBER

1. Describe the difference between a dormant and an active volcano.
2. When is a volcano extinct?
3. Where did the lava erupting from this volcano come from?

THINK

4. Explain how the eruption of a single volcano can affect the whole world.
5. How is lava different from magma?
6. How might people living in river valleys near a volcano be affected if the volcano erupted?

IMAGINE

7. Imagine that you live in a small town near a volcano. A warning has been issued that the volcano is about to erupt. What measures could be taken by the residents to protect the town and its people?

CREATE

8. Write a newspaper report that describes the eruption from one of these famous volcanoes:
   Mt Vesuvius
   Mt Pinatubo
   Mt St Helens
   Mt Krakatoa.

checklist

I can:
- ☐ describe how volcanoes form
- ☐ describe some of the hazards associated with volcanoes
- ☐ understand what can happen during a volcanic eruption.

When lava cools

Lava surges out onto the Earth's surface at temperatures of 1000 °C or more! At that temperature, **lava** could take weeks to cool down. But sometimes, when volcanoes erupt under water for instance, the lava cools much faster. When lava cools down it becomes solid rock. Looking closely at rocks that formed from red-hot lava tells a story about the way they cooled.

Frothy rocks

Some violent volcanic eruptions shoot out lava filled with gases. The lava cools quickly, while it is still in the **air**, and traps the gases inside. Rocks that form this way are full of holes. Two examples of these rocks are **pumice** and **scoria**. The substances in the **magma** affect the colour and hardness of the rock that is formed when lava cools. Scoria has more iron in it than pumice, so it is darker than pumice.

Growing crystals

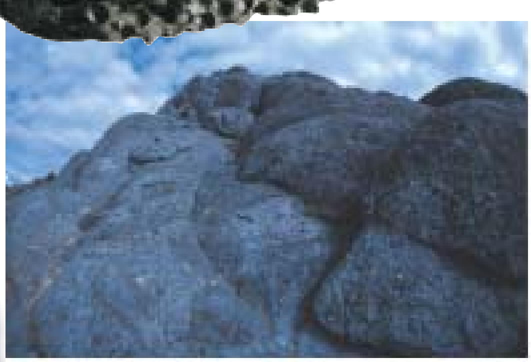
Rocks that form from lava cooling above the Earth's surface are called **extrusive rocks**.

Basalt is an extrusive rock that can take on many appearances. One big difference between samples of basalt is the size of the crystals that make up the rock. The size of the crystals gives us clues about how or where the rock formed. The longer it takes for the lava to cool down, the bigger the rock crystals grow.

Basalt with bubbles

The crystals in this basalt are large because they formed from lava on the ground. The crystals had time to grow before the rock became solid. Notice the holes. The lava was filled with gases when it began to cool. The gases have since escaped.

*Pumice is a pale-coloured rock. It is so full of holes that it is very light. It floats on water and sometimes washes up on beaches. Powdered pumice is used in some **abrasive** cleaning products.*



Pillow basalt

This rock formation came from a volcano that was once under water. The rocks formed from underwater volcanoes are smooth and round. The crystals in this basalt are so small that they are difficult to see.

Scoria is heavier than pumice. It is usually found closer to the volcano's crater than pumice. Scoria is a red-brown or grey rock that can be used in garden paths or around drainage pipes.

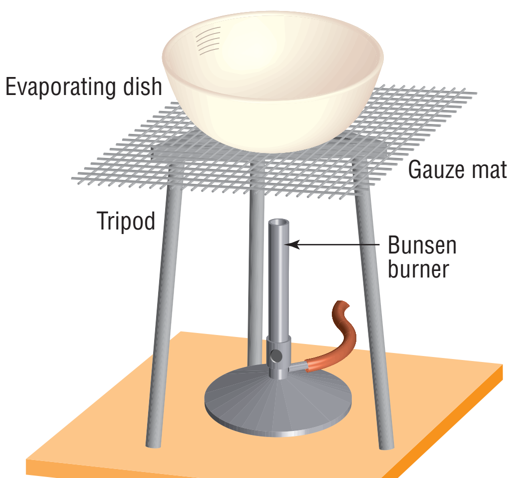
Obsidian

Obsidian is a smooth, black rock that looks like glass. It is formed when lava cools almost instantly. This rock is different from basalt because it cooled so quickly that no crystals formed. Sometimes very fine air bubbles are trapped in the rock, which give it a coloured sheen.

What affects crystal size?

You will need:
Bunsen burner, matches and heatproof mat
tripod and gauze mat
alum solution
2 Petri dishes
evaporating dish
safety glasses and lab coat.

- Pour roughly equal amounts of alum solution into the evaporating dish and the Petri dishes.
- Put one of the Petri dishes in the refrigerator.
- Put the other Petri dish on a windowsill.
- Place the evaporating dish on the gauze mat.



- Gently heat the evaporating dish without allowing the solution to boil rapidly.

!CAUTION: Rapid boiling may result in spitting. Wear safety glasses at all times.

- Continue heating the solution until nearly all of the water has evaporated.
- Observe the size of the crystals formed in the evaporating dish.
- After two days, observe the size of the crystals formed in the two Petri dishes.
- Observe the crystals formed in the refrigerator again after four or five days.

1. Draw a labelled diagram of the crystals formed in the evaporating dish and in the two Petri dishes. Your diagram needs to show the difference in size between the crystals.
2. Each of these crystals grew over a different time span. How does the time allowed for the crystal to form affect the size of the crystals?

Activities

REMEMBER

1. Where do extrusive rocks form?
2. Why are the crystals in pillow basalt smaller than the crystals in basalt which form on the ground?
3. Scoria and pumice are formed in a similar way. Why are their colours different?
4. What type of extrusive rock could easily be mistaken for glass?

THINK

5. In which of these two rocks did the lava cool fastest? Explain your answer.

6. What does the presence of ‘bubbles’ in rocks tell us about the lava?

IMAGINE

7. Imagine you are a mass of magma. Describe your journey from the depths of the Earth’s crust, through to its surface.

CONNECT

8. Go to www.jaconline.com.au/science/weblinks and click on the Guinness Book of Records link for this textbook. Mt Everest is said to be the highest mountain in the world, but there is a volcano that is higher.
   (a) What is the name of the volcano?
   (b) Where is the volcano?
   (c) Why do we call Mt Everest the highest peak, when this volcano is taller than Everest?

checklist

I can:
- ☐ compare crystal sizes in rocks
- ☐ explain why some rocks have air bubbles
- ☐ describe how extrusive rocks are formed.

Cooling under ground

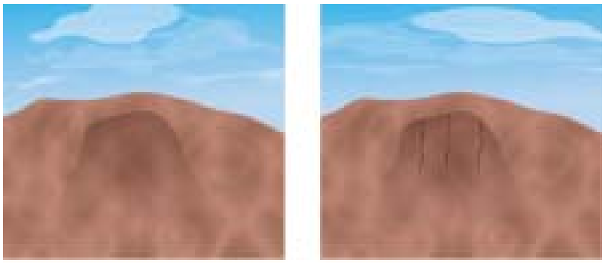
Trapped deep within the Earth lie bodies of **magma**. Far away from the cooling effects of **air** and water, magma can take millions of years to turn into solid rock.

Rocks that form when magma cools in the Earth's **crust** are called **intrusive rocks**. Many of these rocks are hidden beneath the surface and discovered only when the ground around them is blown or washed away. Intrusive rock bodies can be as small as a few centimetres across or larger than 100 kilometres across.

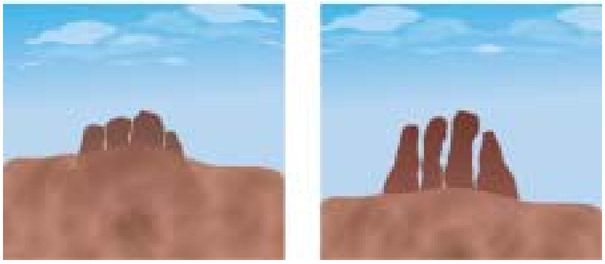
Intruding rocks

Batholiths are intrusive bodies of rock that measure more than 100 km across. If it weren't for the **weathering** process, many of these rocks would not ever be seen. **Granite** and other hard rocks often form batholiths.

The batholith forms under the Earth's surface when magma cools down.



Cracks form in the batholith while it cools down.

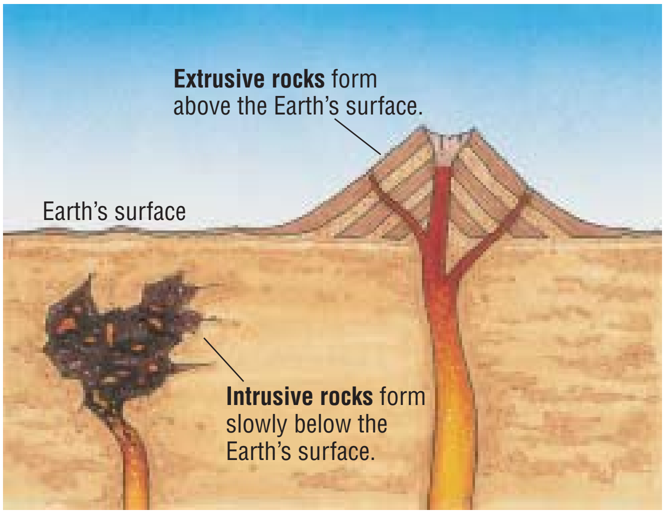


If the batholith is exposed to the environment, it will start to wear away along the cracks. Over time, the batholith may break down completely. The breakdown of rocks is called weathering.

The softer rocks and soil around the batholith may wear away.

Igneous rocks

Igneous rocks are those that form when magma or **lava** cools and turns into solid rock. **Extrusive** and intrusive rocks are both types of igneous rock. The word igneous comes from the Latin word for 'fire'.



A long walk to Tasmania?

Wilson's Promontory in Victoria is part of a huge granite batholith that measures about 300 km long and 50 km wide. The batholith links Tasmania to the rest of Australia and at one time created a land bridge between the two. About 15 000 years ago, rising sea levels covered the batholith and separated Tasmania from the rest of Australia.

Granite

Granite is a common intrusive rock. The crystals in granite form over long periods of time and grow large enough to make them easy to see with the naked eye. Granite is very hard and can be used for building. Headstones and other monuments can be made from granite that has been polished to give it a glossy finish.

*The crystals found in granite are a mixture of white, pink, grey, black and clear substances. The substances that make up rocks are called **minerals**. Granite is made up of a few minerals, such as quartz (clear to grey), feldspars (white and pink) and mica (black). Some rocks are made up of only one mineral.*

Activities

REMEMBER

1. Describe one way in which intrusive rocks can become visible on the Earth's surface.
2. Complete this sentence: Intrusive and extrusive rocks are both types of ___________ rock.
3. Complete these sentences: Intrusive rocks with large crystals form when ___________ cools ___________. Smaller crystals form in extrusive rocks when ___________ cools ___________.

THINK

4. True or false?
   (a) All intrusive rocks form batholiths.
   (b) Rocks are made up of substances called minerals.
   (c) All igneous rocks are extrusive rocks.
   (d) Intrusive rocks are more likely to have larger crystals than extrusive rocks.
   (e) Batholiths come from volcanoes.
5. Suggest reasons why granite has been chosen for this headstone.

6. Describe how granite and basalt are different from each other.

INVESTIGATE

7. Most towns and cities have buildings, or parts of buildings made from granite. Find out if there are any buildings or other structures such as statues or memorials in your area that are made from granite. You may find your local council helpful or you could try an Internet search. Describe the granite in one of the buildings or structures and explain why granite has been chosen. If a digital camera is available, you could present your findings in a multimedia report.

checklist

I can:
- ☐ describe how intrusive rocks form
- ☐ explain that all rocks are made up of minerals
- ☐ explain why the crystals in intrusive rocks are larger than those in extrusive rocks.

Wearing away

Volcanoes continue to erupt, leaving **igneous rocks** on the Earth's surface, yet the surface of the Earth's **crust** isn't a huge mass of solid rock. Wind, water, ice and other natural actions constantly break down rocks on the surface of the Earth.

The process of breaking down rocks is called **weathering**. Weathering is a slow process, but varies depending on the type of rock and the natural action involved. Hard rocks can take longer to break down than soft rocks. Winds that carry sand weather rocks more quickly than winds that don't carry sand. Some of the **minerals** found in rocks are easily dissolved by water, which speeds up the weathering process.

Wave Rock in Western Australia has been shaped by water and wind, which have also carried weathered rock away. The lines on the **granite** surface have been caused by water running down the face of the rock. The water has dissolved some of the minerals in the granite. This is an example of **chemical weathering**.

HOW IT WORKS

Cracking up

Some objects, like glass, crack if their temperature changes quickly. Rocks can do the same. The cracking occurs because the outer part of the rock cools more quickly than the inside of the rock after a hot day. Cracking can also occur when it rains on a hot day. The cracks gradually get larger, until large flakes begin to fall off. Granite often weathers this way.

Trees can begin to grow within cracks in rocks. As the trees grow, the cracks are forced apart, eventually splitting the rocks. This speeds up weathering.

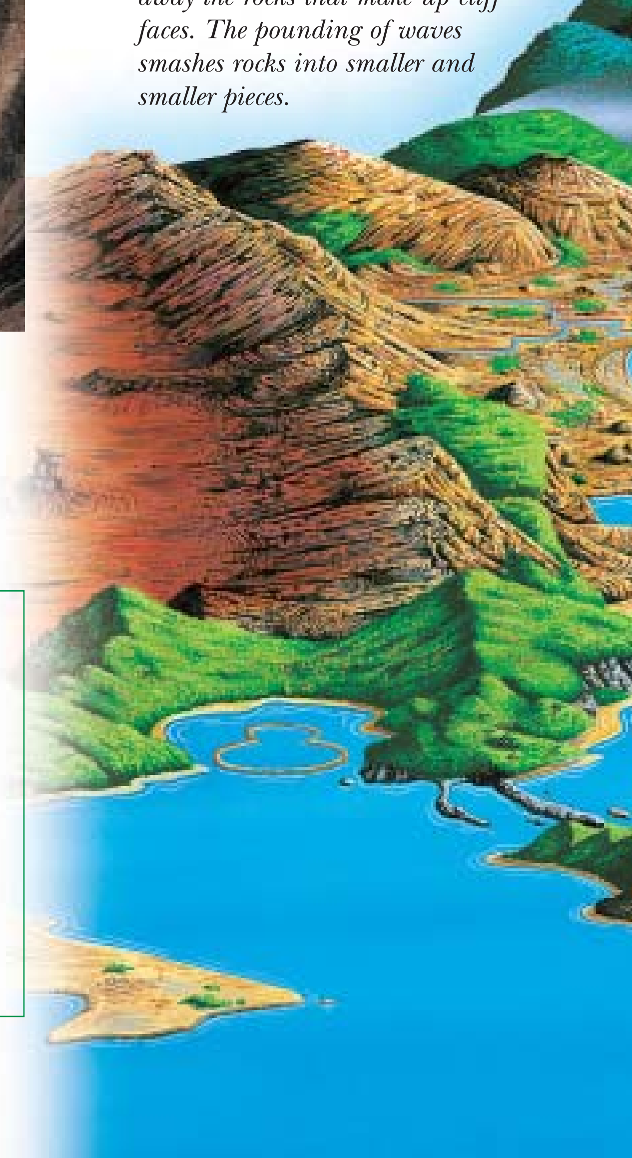
1 *Fast-flowing water can move sand, soil and even big rocks over long distances. All creeks and rivers flow to the sea or to inland lakes, but by the time they reach the seas or lakes, the water flows much slower.*

2 *As the water slows down, the bigger rocks are deposited.*

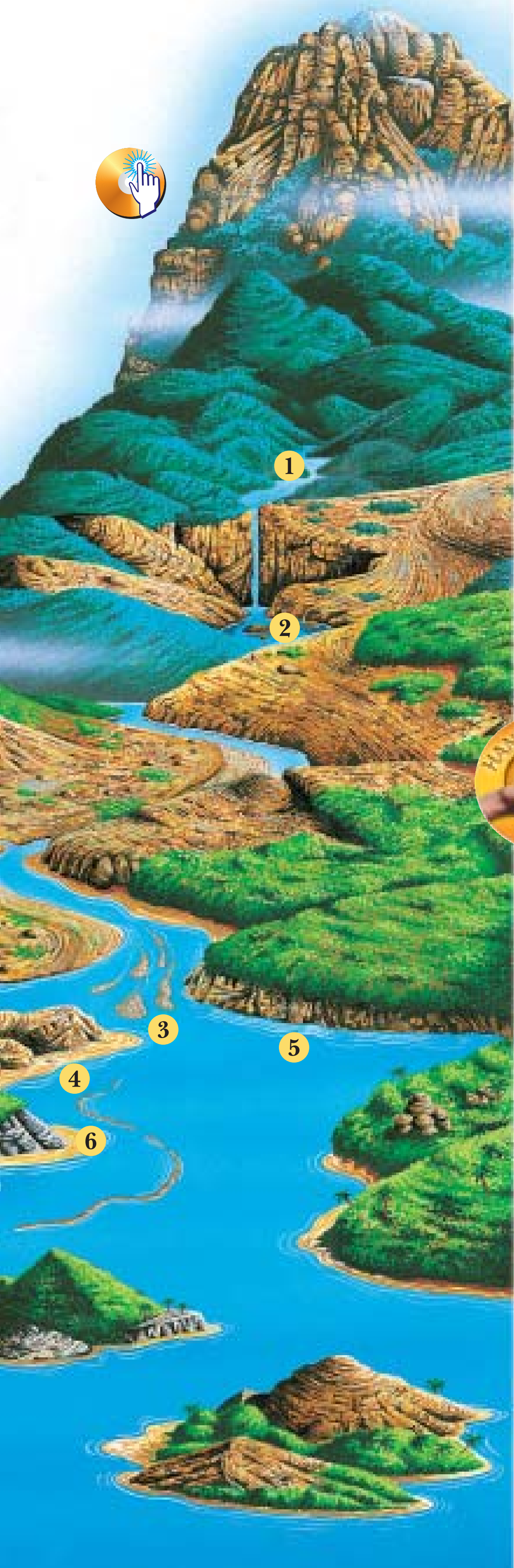
3 *By the end of the river's journey, all but very fine sediments have been deposited.*

4 *Coastlines can change quite quickly as a result of weathering, erosion and the depositing of sediments.*

5 *The waves from the oceans wear away the rocks that make up cliff faces. The pounding of waves smashes rocks into smaller and smaller pieces.*



6 *Sand is picked up by currents in the waves along one beach and deposited on other beaches. Strong winds have enough energy to pick up sand and carry it inland.*



Erosion

After weathering has broken down the rock, the wind, water or ice can then move it around. The process of moving weathered rocks and soil is called **erosion**. Eventually the wind, water or ice **deposits** the weathered material. The deposited materials are called **sediments**.

The wind is especially effective in wearing away rocks in dry, dusty areas. The wind can pick up tonnes of sand and soil and dump it many kilometres away. A dust storm is a very strong wind that carries huge amounts of weathered material. Dust storms are quite common in Australia.

Glaciers are large bodies of moving ice. They move very slowly compared to water and wind, but like these, collect weathered materials as they move. The difference between glacial erosion and other acts of erosion is that little of the sediment is dumped along the way. Glaciers deposit most of their sediment in one lot. That means that sediments of many different sizes are found in one place.

How ice speeds up weathering

You will need:
plastic bottle with a lid
water.

!CAUTION: Do not use a glass bottle.

- Fill the bottle with water right to the top.
- Freeze the bottle overnight.
- Observe what happens to the bottle.

1. What do your observations tell you about what happens to water as it freezes?
2. How do you think ice makes the breakdown of rocks happen faster?

Activities

REMEMBER

1. What is weathering?
2. What is erosion?
3. List three natural actions that break down rocks.

THINK

4. The Twelve Apostles, shown at right, were originally named because 12 'stacks' were close together along the western Victorian coast. Some of the stacks have since collapsed into the sea.
   (a) What is probably the main cause of the weathering of these stacks?
   (b) Which part of each stack is likely to weather most quickly? Give a reason for your answer.
   (c) Has this coastal feature been caused by weathering, erosion or both? Explain your answer.
5. Why are larger sediments deposited before finer ones in river systems?
6. How can you tell the difference between sediments deposited by a river and those deposited by a glacier after it melts?

INVESTIGATE

7. Find out if weathering and erosion occur on other planets or the Moon.

checklist

I can:
- ☐ describe the weathering process
- ☐ understand how rocks can crack
- ☐ describe the process of erosion.

The human contribution

Without **weathering** and **erosion**, the rocks that rise to the Earth's surface would keep building up. Both weathering and erosion are natural processes. But what happens when humans disturb the natural process?

Imagine a world where acid falls from the sky, a place where deserts replace fertile land and where the beaches are vanishing. These are some of the effects that humans have already had on the Earth.

Acid rain

Every day many harmful chemicals are pumped into the **air**. Some are naturally forming chemicals, but many are from cars, factories or from human activity. The chemicals in the air can dissolve in water, much like salt in hot water. The dissolved chemicals return to the ground in rainwater, snow or fog and the combination is called **acid rain.**

Acid rain can poison trees, soil and water supplies. It even eats away at rocks, including those used in buildings and statues.

Why save the trees?

The roots of trees help to hold the soil together. Removing trees exposes good, fertile soil to wind and water. The soil is blown or washed away, leaving the land destroyed. Early Australian settlers originally cut down trees to create farmland. As the population grew larger, more trees were cleared to provide space for industrial areas and housing. Since then, industrial areas have grown larger and the forests smaller. Trees are still being cleared for wood and wood products like paper.

Over the past 200 years, over two thirds of Australian forests have been cleared.

Deforestation is a worldwide problem.

Coasts under threat

Coastal areas can be badly affected by erosion. Bare sand is easily washed away by water and blown inland by the wind. Vegetation that binds the sand together has been torn up by recreational vehicles. Vegetation near beaches in tourist areas such as the Gold Coast has been removed and replaced with huge buildings. Barriers such as sea walls, mesh fences and **groynes** are built to hold sand on the beaches.

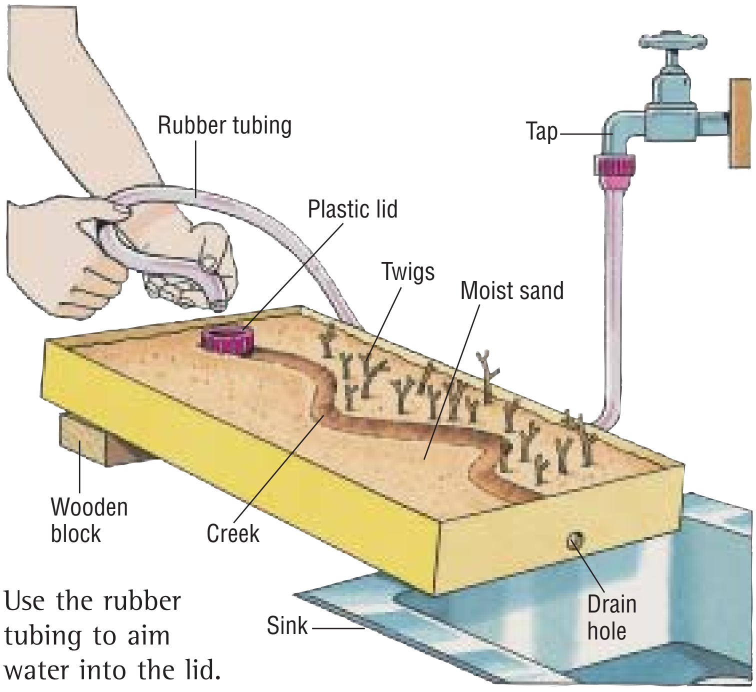
Go to worksheet 17

Why plant trees?

You will need:

stream tray or box
wooden block
plastic lid from a soft drink bottle
damp sand
rubber tubing
several small twigs.

- Pack the sand into the tray.
- Make a groove in the sand to represent a creek or river.
- Set up the equipment as shown in the diagram below. Make sure to 'plant trees' on one side of the 'creek' only.



- Use the rubber tubing to aim water into the lid.
- Allow water to flow slowly but steadily into the lid and then overflow into the 'creek'.

1. Where does most of the erosion occur along the 'creek'?
2. What effect do the 'trees' have on erosion?

On the mend

Scientists, conservation groups and government bodies play an important part in improving the environment. The aim is to reduce the impact of human activity and repair past damage. Some methods for reducing erosion and repairing the damage already caused by erosion include:

- farmers ploughing their fields around hills rather than up and down the slope. This prevents rain from washing soil down hills.
- sealing roads and gutters to direct water into proper drains
- controlling numbers of livestock
- replacing trees that have been removed
- fencing off large sections of beaches and banning recreational vehicles in many coastal areas
- reducing the impact of introduced animals, such as rabbits, on native vegetation.

Activities

REMEMBER

1. What is acid rain?
2. Give two reasons why forests have been cut down.
3. How does cutting down trees speed up erosion?
4. Describe two ways that farmers can reduce erosion.

THINK

5. Why has a barrier been placed at the back of the beach in the photo on page 84?
6. The photograph below shows an example of tunnel erosion. Suggest what has caused the erosion and how it may be stopped.

CREATE

7. Prepare a flow chart to show how deforestation can occur.

IMAGINE

8. Imagine you work for a local council in an area that has both national parks and coastlines. Your job is to educate people in the area about erosion and land care. Design a leaflet that gives the reasons for not using recreational vehicles in the area.

checklist

I can:

- ☐ describe how human activity can speed up erosion
- ☐ discuss ways to minimise erosion and improve the condition of the land.

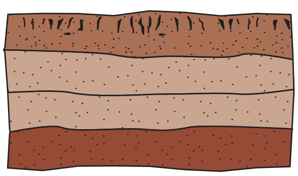
Sedimentary rocks

The Earth's **crust** is not made entirely of **igneous rocks** because these rocks break down. The process of **erosion deposits** broken-down rocks as **sediments**. But the Earth isn't full of sediment resulting from **weathering** either. It may take millions of years, but eventually sediments from weathering will form new rocks. Rocks formed from sediments are called **sedimentary rocks**.

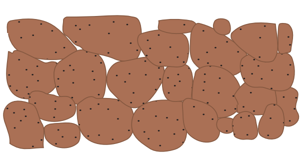
HOW IT WORKS

Sedimentary rocks

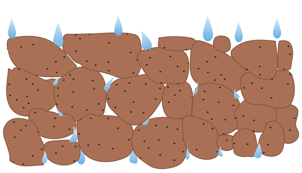
Many sedimentary rocks are made up of the grains of weathered rock. The grains cement together over time.



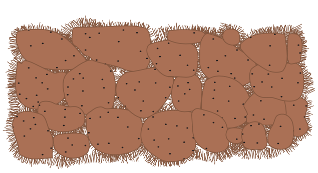
Sediments are deposited in layers called beds.



The grains of sediment in lower layers begin to squash together.



Chemicals that are dissolved in water can soak into the sediments.



The chemicals help cement the grains together once the water has evaporated.

Naming sedimentary rocks

Sandstone, mudstone and siltstone are types of sedimentary rock. Their names give us clues about the sediments they formed from. The types of sediment tell us what the environment was like when the sediments were deposited.

*Sandstone is made up of grains that are easy to see. Sand-sized grains are deposited in changing environments like deserts and beaches. The grains are carried by **air** in the deserts and by the surf at beaches.*

Siltstone has finer grains than sandstone. The grains are hard to see, but can be easily felt. Silt is deposited in quiet environments like slow flowing creeks and near the end of rivers. You are not likely to find silt on beaches, but it can be deposited out at sea.

Most of the grains in mudstone are too small to see or feel. Mud is deposited only in very still environments, like lakes and swamps.

Conglomerate rocks have grains in a wide range of sizes. Some grains are so small that they cannot be seen. Other grains are as big as pebbles. The sediments in conglomerate rocks are deposited in fast flowing rivers, during floods or by glaciers.

Go to worksheet 18

Biological rocks

Sedimentary rocks are not always formed from other rocks. Living things break down and are deposited as sediments too. Under special conditions, the remains of plants and animals form biological sedimentary rocks.

Limestone

The shells and hard parts of sea organisms break down in a similar way to rocks. Shells and shell fragments deposited in layers on the ocean floor can cement together to form limestone.

Coal

When plants and animals die, they break down and rot. **Coal** is formed from dead plants and animals that became buried before rotting completely. Even though the remains are squeezed together over millions of years, coal may still look like the trees it formed from.

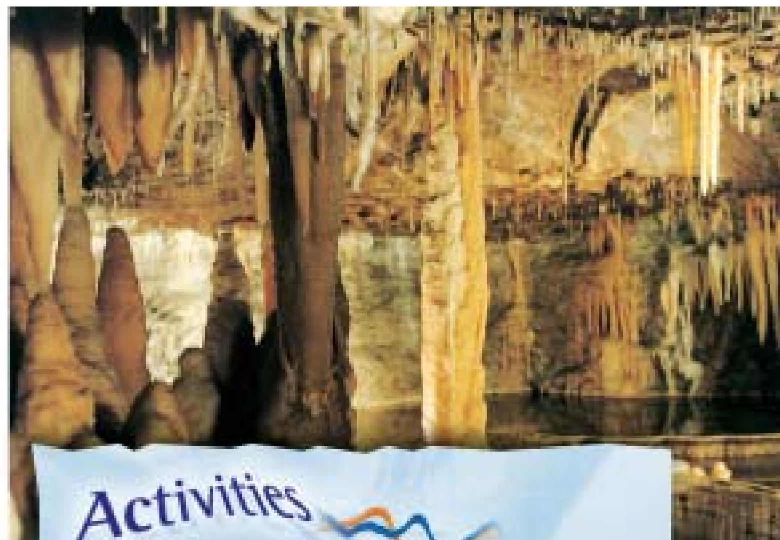
The chalk age?

You may have heard of the stone age, the bronze age and the iron age. But have you heard of the 'chalk age'? The period in history called the Cretaceous lasted from about 145 million years ago to about 65 million years ago. It was the time when flowering plants first existed on Earth. It was also the time when huge amounts of chalk were deposited on the ocean floors all around the world. Chalk, like other forms of limestone, is made from the remains of sea animals. The word cretaceous comes from the Latin word *creta* meaning chalk.

Chemical rocks

Chemical sedimentary rocks are those that form when water evaporates, leaving behind a solid substance. When salt lakes or seabeds dry up, they leave behind solid salt. If the layer of salt is squeezed under other sediments, it can eventually form **rock salt**.

When ground water or rainwater passes over limestone, it can pick up some of the chemicals from the limestone. When the water evaporates, it leaves behind the limestone chemicals again. Limestone re-forms like this in caves. It looks a bit different from the limestone formed from the remains of sea animals, but is made up of the same chemicals.



Activities

REMEMBER

1. What helps to cement the grains of sediments together to form sedimentary rocks?
2. How are the environments that form sandstone different from those that form mudstone?
3. Why are limestone and coal called biological sedimentary rocks?
4. How are chemical sedimentary rocks formed?

THINK

5. Explain why not all plant and animal remains form coal.
6. What role do weathering and erosion play in the formation of sedimentary rocks?

INVESTIGATE

7. Find out what coal and diamonds have in common.

checklist

I can:

- ☐ explain the formation of sedimentary rocks
- ☐ describe the environments in which sedimentary rocks may form and how this affects the appearance of the rock.

Metamorphic rocks

Searing hot **magma** can push through the Earth's **crust** wherever there is a weakness. To get through to the surface, it needs to push through layers of other rocks. When rocks are heated to extreme temperatures by magma pushing through, their appearance and structure can change. Changes can also occur in rocks that are under **pressure** from layers of rocks above them. **Metamorphic rocks** are those rocks that have been changed by heat, pressure or both.

Hot rocks

Hornfels looks similar to **basalt**, but it is much harder.

When **igneous** and **sedimentary rocks** come into direct contact with rising magma, they are heated to very high temperatures. **Hornfels** is one rock that forms under these conditions. It is sometimes hard to tell what rock hornfels came from because it forms under such high temperatures.

Under pressure

Bands can sometimes be seen in metamorphic rocks formed under high pressure. The bands tell us that crystals were squeezed together to form new crystals in the new rock. Sometimes, the crystals are squeezed together so tightly that they partially melt and form fewer, but larger crystals.

Gneiss can be formed when **granite** is exposed to high pressures. Notice the bands in the new rock.

Old and new

The types of rock that are exposed to heat and pressure determine what the metamorphic rock will be. When sandstone containing the **mineral** quartz is heated, the metamorphic rock formed also contains quartz. This metamorphic rock is called quartzite.

Marble forms from **limestone** under heat and pressure. It contains the same minerals as limestone.

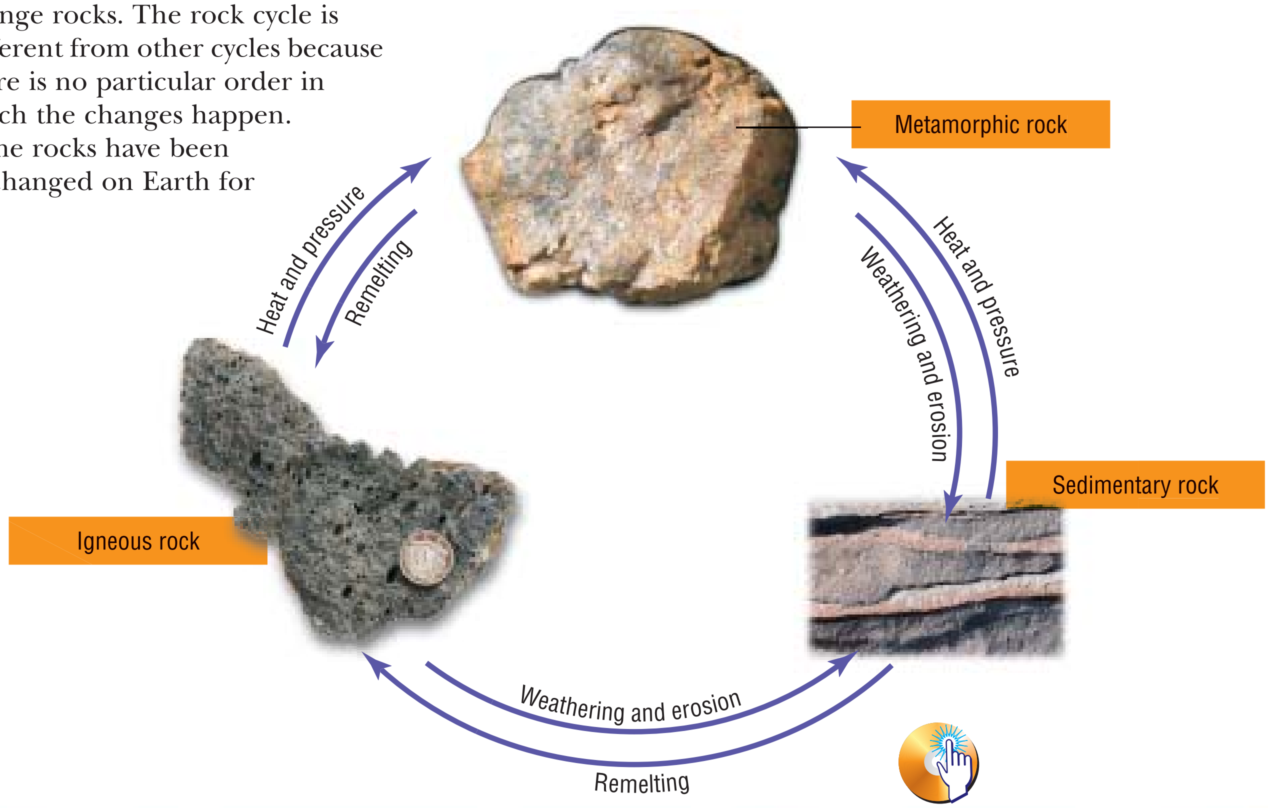
Shale is a common type of sedimentary rock. It has fine grains and crumbles easily along its layers. When shale is exposed to moderate heat and pressure, it forms slate.

Go to worksheet 19

VISUAL/SPATIAL

Recycling rocks

The **rock cycle** describes how rocks can change from one type to another. **Weathering**, **erosion**, heat, pressure and remelting are processes that help change rocks. The rock cycle is different from other cycles because there is no particular order in which the changes happen. Some rocks have been unchanged on Earth for millions of years and may not change for millions more. Some rocks change very quickly, especially near the edges of the plates that make up the Earth's crust.



Activities

REMEMBER

1. What do the bands in metamorphic rocks tell us about how the rocks were formed?
2. When sandstone is under heat and pressure, what metamorphic rock might it form?
3. From what rock has slate formed?

THINK

4. How could you tell the difference between basalt and hornfels?
5. Metamorphic rocks form only when the **parent rocks** do not melt completely from the heat and pressure. If the parent rocks do melt, the new rock is an igneous rock.
   (a) What do you think is meant by the term 'parent rock'?
   (b) Give an example of a metamorphic rock and its parent rock.
   (c) Why do metamorphic rocks form only when the parent rocks don't melt completely?
6. How are the bands in metamorphic rocks different from the layers in some sedimentary rocks?
7. Suggest why slate has been chosen for the surface (under the felt cover) of this billiard table.

checklist

I can:
- ☐ describe how metamorphic rocks form
- ☐ explain how the rock cycle works
- ☐ list some common metamorphic rocks and their parent rocks.

How old is that rock?

Scientists believe that the Earth is about 4600 million years old. The clues held in rocks have helped them to calculate the Earth's age. Rocks also give scientists an idea about how the climate on Earth has changed over millions of years. But what types of clue do scientists need to look for in rocks?

Layers of clues

Sedimentary rocks form in layers. Each new layer forms on top of the older layers below. Sedimentary rocks are therefore useful for giving scientists clues about the order in which events have happened.

Sudden events, like exploding volcanoes, are recorded in the layers. Slow movements beneath the surface can also be seen in the layers.

7 *These layers were deposited last. They have started to weather and erode.*

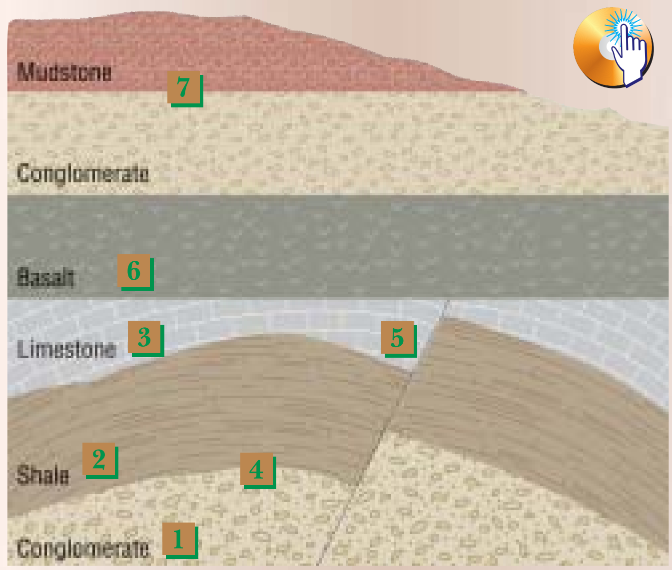
6 *A long period of **weathering** and **erosion** left the layer of **limestone** with a flat surface. When a volcano then erupted nearby, **lava** from the volcano cooled to form **basalt** on the flat surface.*

5 *A sudden event, like an earthquake, has occurred to break the layers of rocks like this. This event took place after the lower layers were folded. A break like this is called a **fault**.*

4 *A slow event has caused the lower levels to buckle. This is called **folding**. Folding can occur when rock layers are under **pressure** from both sides.*

3 *The third event to occur was the deposition of limestone. It tells us that there were probably sea **organisms** present in the area during this time.*

2 *This is the second layer deposited. Shale is a fine-grained rock that is deposited in a quiet environment such as a swamp, lake or the slow flowing part of a river.*



1 *Conglomerate was deposited first in this rock sample. This layer was deposited by a glacier or an active environment — like a very fast flowing river.*

Living in the past

The layers in rocks are useful for finding out about the order of events in a particular area. Finding out about the order of events, or comparing the ages of rocks without actually knowing their age in years is called **relative dating**.

Palaeontologists study **fossils**. A fossil is evidence of life in the past. Fossils can be used to compare the ages of rocks all around the world. Sedimentary rocks that contain the same fossils have usually formed at about the same time.

Fossil of a reptile

Go to worksheet 20

LOGICAL/MATHEMATICAL

Fossils can form from the remains of plants and animals that have been preserved before they could decay. They can also be impressions, or **imprints**, left by rotting animals as a rock forms. In fact, even dinosaur footprints are fossils because they provide evidence of their existence. Fossils are not created very often because of the special conditions needed, and many fossils are destroyed if rocks are remelted in the **rock cycle**. Scientists can rely on fossils and rock layers only to *compare* the ages of rocks.

Finding out the actual age of a rock in years is called **absolute dating**. Scientists use a technique called **radiometric dating** to work out how old a rock is. Rocks, like everything else on Earth, have a small amount of radioactivity. Some substances in the rock release tiny radioactive particles. Radiometric dating relies on knowing how quickly those substances lose these particles. By measuring how much of these radioactive substances is left in a rock, scientists can work out its age.

HOW ABOUT THAT!

A fatal fall . . . or was it murder?

In 1991, some German hikers found a body preserved in ice near the Italy–Austria border. Scientists used radiometric dating and found that the body was about 5300 years old! They thought that the person, known now as the Iceman, had died of hypothermia (extreme cold). Ten years later, another group of scientists using high-tech X-rays found the remains of an arrowhead lodged near his left lung. Specialists have not yet confirmed whether the Iceman fell back onto his arrow, or if he was murdered. And without any witnesses to question, the truth may never be known!

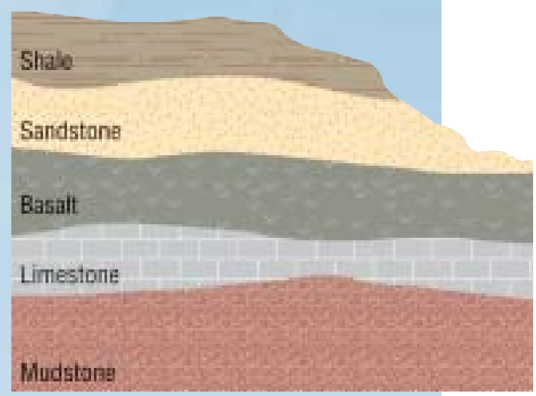
Activities

REMEMBER

1. Complete the following sentence:
   The buckling of rocks is called ____________.
   It occurs when rocks are under ____________.
2. What is a palaeontologist?
3. What is the difference between relative dating and absolute dating?

THINK

4. At right is a section of a rock face exposed in a quarry.



   (a) Make a list of the rocks in the cutting, from oldest to youngest.
   (b) Which rock is not a sedimentary rock? How did it form?
   (c) Describe the evidence for erosion in this rock face.
5. Why are fossils so rare?
6. How can fossil records help us to link rocks from different parts of the world?

CREATE

7. Use plasticine to create a sample of sedimentary rocks. Apply a gentle force to the sides of the layers. Observe how the layers fold under gentle pressure.

CONNECT

8. Even an animal's droppings can become a fossil. Go to www.jaconline.com.au/science/weblinks and click on the Fossilised Droppings link for this textbook to find out:
   (a) Which animal was responsible for a huge fossilised dropping found in Canada in 1998?
   (b) How long was the dropping?
   (c) What can palaeontologists find out from it?

✓ checklist

I can:
- ☐ understand that rocks provide clues to the past
- ☐ describe and compare ways to date rocks
- ☐ describe how folding occurs.

Checkpoint

THE INVERLOCH INVESTIGATOR

9 March 1997 — Weather: Perfect for the beach

Prehistoric mammal uncovered

Just yesterday, crowds of onlookers witnessed a most amazing find. A tiny 115 million-year-old jawbone, believed to be that of a placental mammal, was exposed. Until this find, scientists thought that placental mammals had reached Australia only 5 million years ago. The jawbone was found at the Dinosaur Dreaming site, a five-minute drive from the township of Inverloch on the Flat Rocks platform. A large group of volunteers is expected at the site tomorrow to search for more remains of the prehistoric mammal.

Every minute counts …

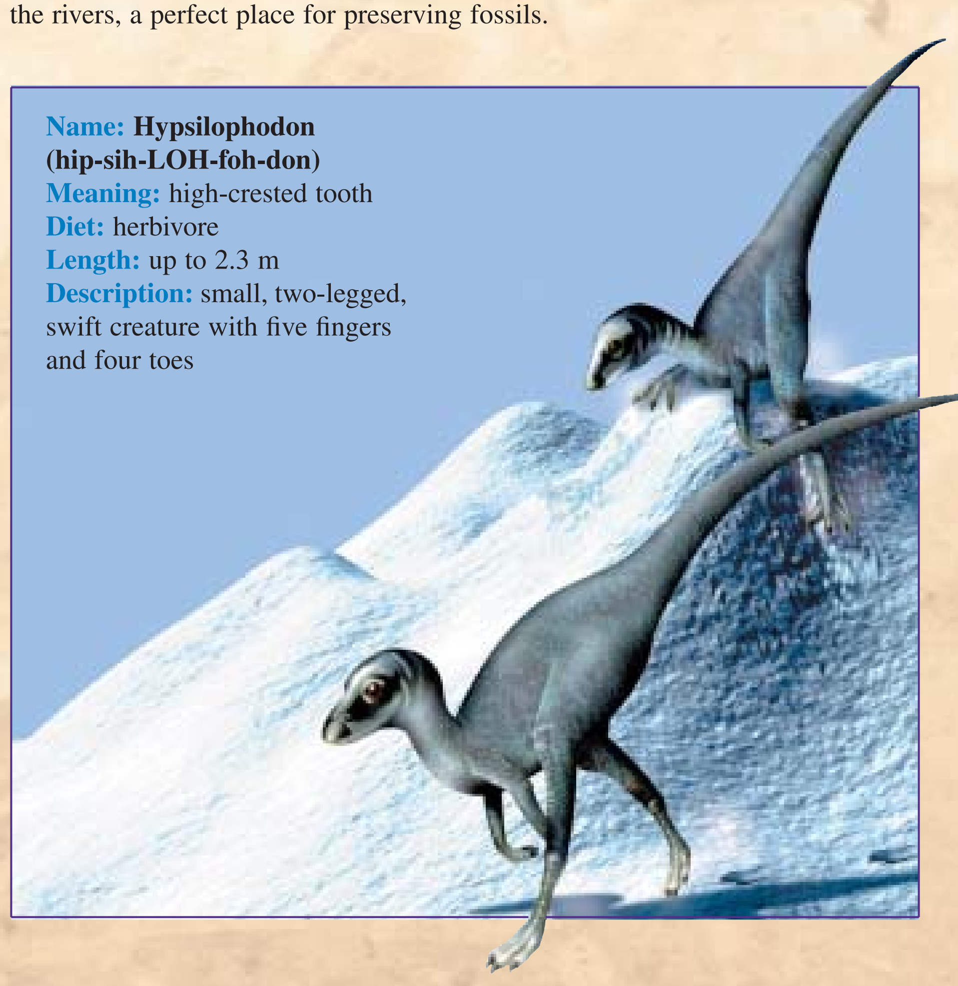
The site on the Flat Rocks platform is accessible for only three to four hours each day, when the tide is low. Removing the sand brought in at high tide can take a while, even though new mesh and tarpaulins have been installed to stop sand filling the diggings. With time so precious, a large team of volunteer diggers is expected at the site tomorrow.

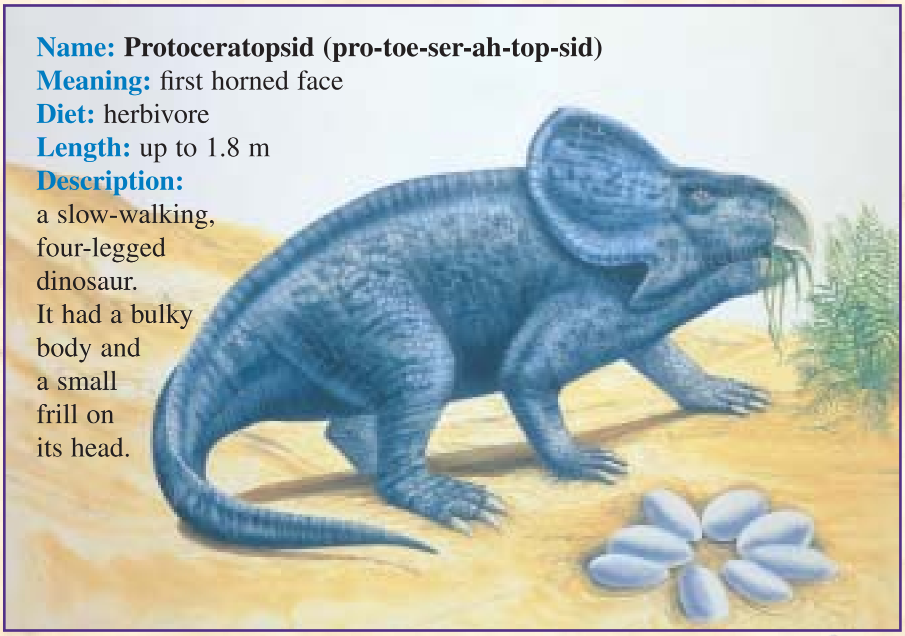
They will work with a small group of **palaeontologists**, who will ensure that the fragile **fossil** is not destroyed by an overenthusiastic digger. The fossils at Flat Rocks are embedded in sandstone and mudstone. These rocks are quite hard, so tools like rock saws, hammers and chisels have to be used to locate fossils without damaging them.

Looking back 115 million years

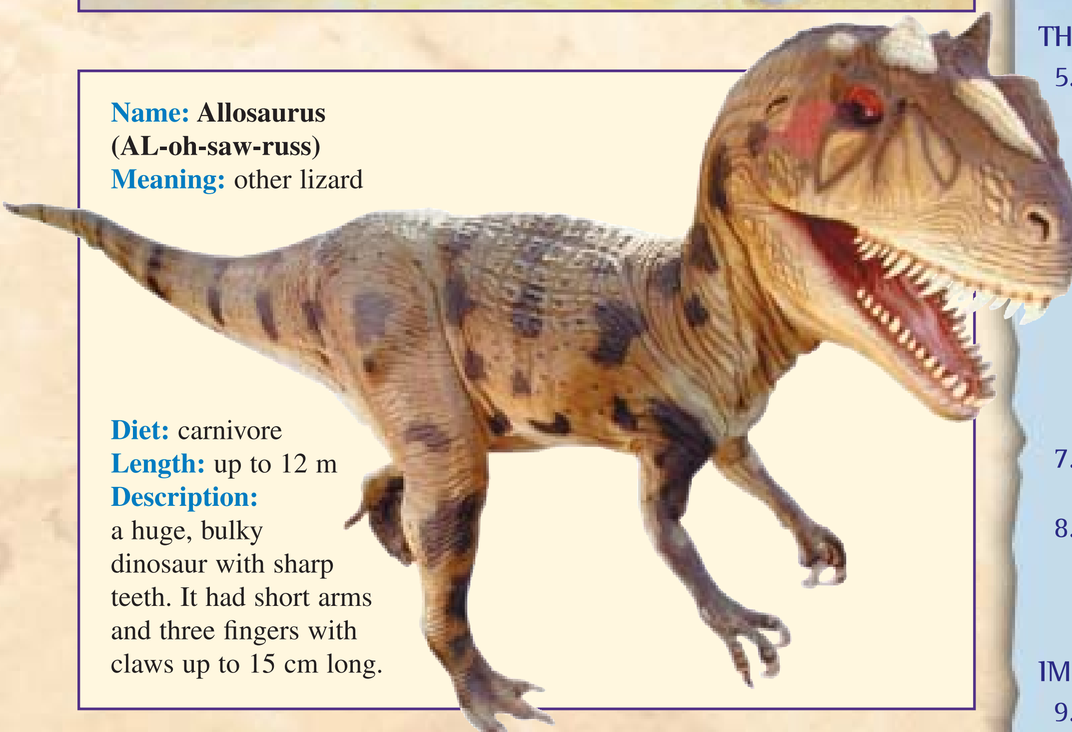
If palaeontologists are right about the jawbone uncovered yesterday, the mammal it belonged to lived in a world of dinosaurs. About 115 million years ago, a wide river valley was all that separated Australia from Antarctica. Hypsilophodons (shown below) ran between the trees, protoceratopsids grazed on the plains and labyrinthodonts lay in the water awaiting their prey. The distant roar of an allosaurus sent fear through to the core of every other dinosaur. Clouds of ash churned out of volcanoes that formed in the valley between Australia and Antarctica. The bones of dead dinosaurs lay scattered along the muddy banks of the rivers, a perfect place for preserving fossils.

Name: **Hypsilophodon (hip-sih-LOH-foh-don)**
Meaning: high-crested tooth
Diet: herbivore
Length: up to 2.3 m
Description: small, two-legged, swift creature with five fingers and four toes





Name: Protoceratopsid (pro-toe-ser-ah-top-sid)
Meaning: first horned face
Diet: herbivore
Length: up to 1.8 m
Description: a slow-walking, four-legged dinosaur. It had a bulky body and a small frill on its head.



Name: Allosaurus (AL-oh-saw-russ)
Meaning: other lizard
Diet: carnivore
Length: up to 12 m
Description: a huge, bulky dinosaur with sharp teeth. It had short arms and three fingers with claws up to 15 cm long.

Activities

REMEMBER

1. Why was the discovery of the jawbone so important?
2. Why is time precious when looking for fossils at Flat Rocks?
3. List two plant-eating animals whose fossils can be found in south-eastern Victoria.
4. Which dinosaur, found in Victoria, had a frill on its head?

THINK

5. The dinosaurs at Flat Rocks are found in mudstone and sandstone. What do these rocks tell us about the environment they formed in?
6. How might scientists have decided that the fossil layer of rock near Inverloch is about 115 million years old?
7. What would the claws of an allosaurus be used for?
8. Describe two ways in which fossils at Flat Rocks could become damaged or lost.

IMAGINE

9. Imagine you are a hypsilophodon. Write a short story that describes the environment you live in, what you eat and some of the dangers you face each day.

checklist

I can:
- ☐ appreciate the importance of the jawbone discovery
- ☐ understand how a palaeontologist works
- ☐ imagine what prehistoric Australia was like.

Check and challenge

THE CHANGING EARTH

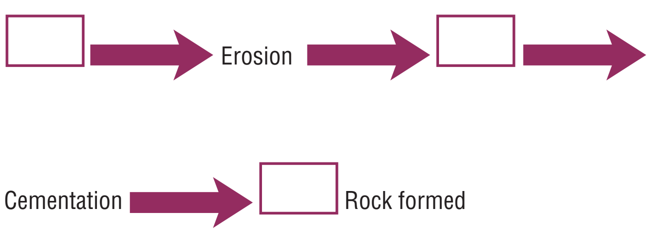
Check

Structure of the Earth

1. What is the name of the layer in the Earth where rocks are formed?
2. From where in the Earth does magma come?
3. Which layer in the Earth is the thickest?
4. Scientists believe that the Earth's crust is made up of plates that are constantly moving. Describe how the movement of plates can lead to the formation of mountains.
5. On which of the Earth's plates is Australia situated?

Sedimentary, igneous and metamorphic rocks

6. How are igneous rocks formed?
7. Fill in the blanks on this flow chart.

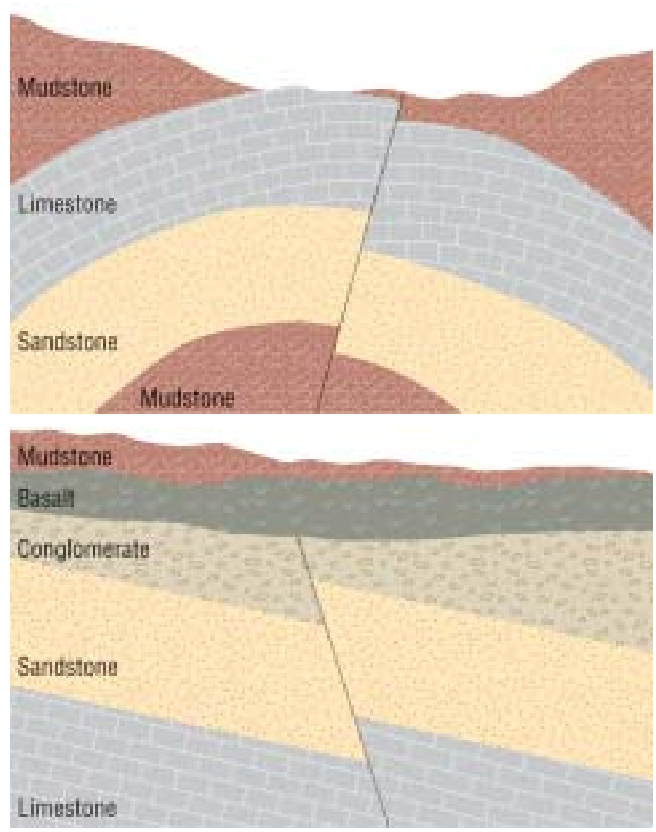


8. Why is limestone sometimes referred to as a biological sedimentary rock and at other times as a chemical sedimentary rock?
9. What two conditions can change an igneous or sedimentary rock into a metamorphic rock?
10. The parent rock of marble is:
    A sandstone?
    B mudstone?
    C limestone?
    D basalt?
11. Divide the following list into two columns. Label the columns 'extrusive igneous rocks' and 'intrusive igneous rocks'.
    Scoria
    Basalt
    Granite
    Obsidian
    Pumice
12. Decide if the word in *italic* makes the statement true or false. If the statement is false, replace the word in *italic* to make it true.
    (a) Extrusive rocks form *above* the Earth's surface.
    (b) The *faster* the cooling time, the larger the crystal size in igneous rocks.
    (c) *Weathering* is the process of moving broken-down rock or soil from one place to another.
13. Link the rock type with the environment it most likely formed in.

Mudstone (fine grains)	Very fast flowing river
Sandstone (sand-sized grains)	Swamp
Conglomerate (mixture of very large and small grains)	Desert

Dating rocks

14. Why can fossils be used to estimate the age of rocks around the world?
15. What information does radiometric dating give us that clues from fossils cannot?
16. Write a description of the order of events that occurred to form these rock samples.

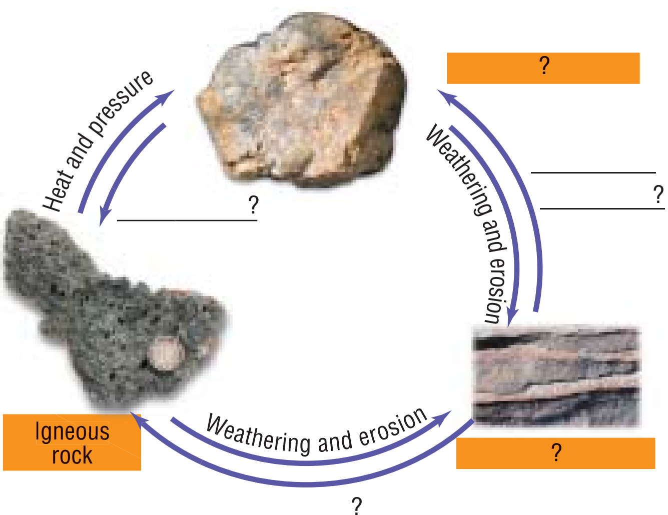


Volcanoes

17. Describe the difference between extinct, dormant and active volcanoes.
18. Describe how lava is different from magma.
19. When Mt Pinatubo erupted in 1991, it caused a drop in the Earth's temperature. Explain, in simple terms, how this could have happened.
20. Often, when lava cools, the rocks formed near the edge of the lava flow have different-sized crystals than the rocks formed in the middle of the flow.
    (a) Where in the flow would the rocks with the smallest crystals form?
    (b) Suggest a reason for this.

The rock cycle

21. Fill in the blanks on the following diagram.



Wearing away

22. Draw diagrams to explain the difference between weathering and erosion.
23. What most likely caused the rocks on this building to wear away?

24. Deforestation is a worldwide problem.
    (a) How does deforestation speed up the process of weathering and erosion?
    (b) List some measures that are being taken to reduce erosion and improve the environment.

Which rock?

1. Identify the rocks in the photos as igneous, sedimentary or metamorphic. If you are not certain, write down the types of rock they are most likely to be. In each case, state a reason for your answer.

(a)

(c)

(b)

(d)

2. When a weak acid is dropped onto limestone, the limestone fizzes. Would the same thing happen if the acid were dropped onto marble? Explain your answer.

Spanning time

3. Fossils can give us clues about the age of rocks. They can also tell us about the plants and animals that lived and the conditions they lived in. Suggest what type of information could be obtained from studying the following fossils:
    (a) fossilised teeth
    (b) footprints
    (c) impressions of leaves left in mud that formed a rock
    (d) fossilised droppings (called **coprolites**).
4. The Grand Canyon in Arizona has been forming over millions of years. It once formed the lower slopes of a mountain range that was twice as high as Mount Everest. Today, it is the largest gorge on Earth.
    (a) Find out how deep the gorge is.
    (b) Describe how the climate at the top differs from the climate at the bottom of the gorge.
    (c) By observing the picture below, make a list of the processes involved in creating this canyon. What types of weathering and erosion have occurred? What types of rock are found here?

Summary of key terms

abrasive: a property of a material or substance that easily scratches another

absolute dating: finding out the actual age of a rock

acid rain: rainwater, snow or fog that contains dissolved chemicals that make it acidic. Acid rain can cause rock to weather faster than pure rain.

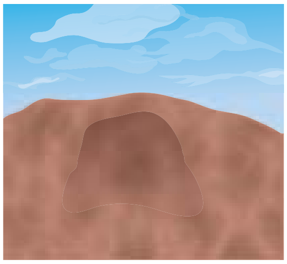
active: describes a volcano that has recently erupted and is likely to erupt again in the near future

air: the mixture of gases that surround the Earth

band: flat strip of differently coloured minerals that is sometimes found in metamorphic rocks formed under high pressure

basalt: a dark igneous rock with small crystals. It sometimes contains holes that once contained volcanic gases.

batholith: intrusive rock mass that measures more than 100 kilometres across



chemical weathering: the breakdown of rocks into small parts by the chemicals in water, air and other substances

coal: a sedimentary rock formed from dead plants and animals that became buried before rotting completely

coprolite: fossilised dropping

crust: the outermost layer of the Earth. The surface of the Earth is the very top part of the crust.

deposit: (*noun*) the sediment left as a result of erosion; (*verb*) to release and put down

dormant: not currently active, but not regarded as extinct. Dormant volcanoes show no signs of erupting in the near future.

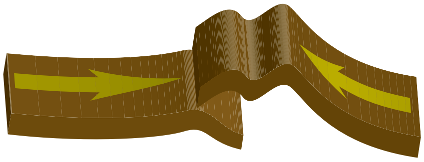
erosion: the process of moving weathered rock or soil from one place to another

extinct: no longer active. Extinct volcanoes have not erupted for thousands of years and show no signs of future eruption.

extrusive rock: igneous rock that forms when lava cools above the Earth's surface

fault: a break in a rock structure. The rock on either side of the break can move.

folding: the buckling of rocks. It is caused when rocks are under pressure from both sides



fossil: evidence of life in the past

granite: a hard igneous rock with crystals large enough to see. It forms below the Earth's surface.

groyne: a jetty built into the sea to prevent the erosion of the beach

hornfels: a dark metamorphic rock formed under extreme heat

igneous rock: rock that forms when magma or lava cools to a solid

imprint: the outline of an object, left as a record in a rock

intrusive rock: igneous rock that forms when magma cools below the Earth's surface

lava: a mixture of molten rock that loses gas as it erupts from a volcano

limestone: a sedimentary rock formed from the remains of sea organisms

magma: a mixture of molten rock and gases that comes from the top of the mantle

mantle: the thick layer in the Earth, below the crust. Most of the mantle is solid rock, although the upper part is molten rock called magma.

metamorphic rock: rock that forms from other rocks that are under great heat or pressure (or both)

minerals: the substances that make up rocks. Each mineral has its own chemical make-up.

molten: the liquid state of a substance that is usually a solid at room temperature

organism: living thing

palaeontologist: a scientist who studies fossils

parent rock: the original form of a rock before it was changed by heat, pressure, weathering, erosion or all of these

plates: the large pieces that make up the Earth's crust

pressure: a push or squeeze on an object

pumice: a pale rock that forms when frothy lava cools in the air. Pumice is very light and often floats on water.

radiometric dating: a technique in which radioactive substances are used to calculate the age of rocks or dead plants and animals

relative dating: comparing the age of rocks without actually knowing their age in years

rock cycle: a model that describes how a rock can change from one type to another

rock salt: a sedimentary deposit formed when a salt lake or seabed dries up

scoria: a dark igneous rock formed from gassy lava that cools quickly

sediment: substance deposited on land or in rivers, lakes or oceans

sedimentary rock: rock formed from sediments deposited by water, wind or ice. The sediments are cemented together in layers, under pressure.

volcanic bomb: large rock fragment that is blown out of erupting volcanoes

weathering: the process of breaking down rocks by elements of the weather