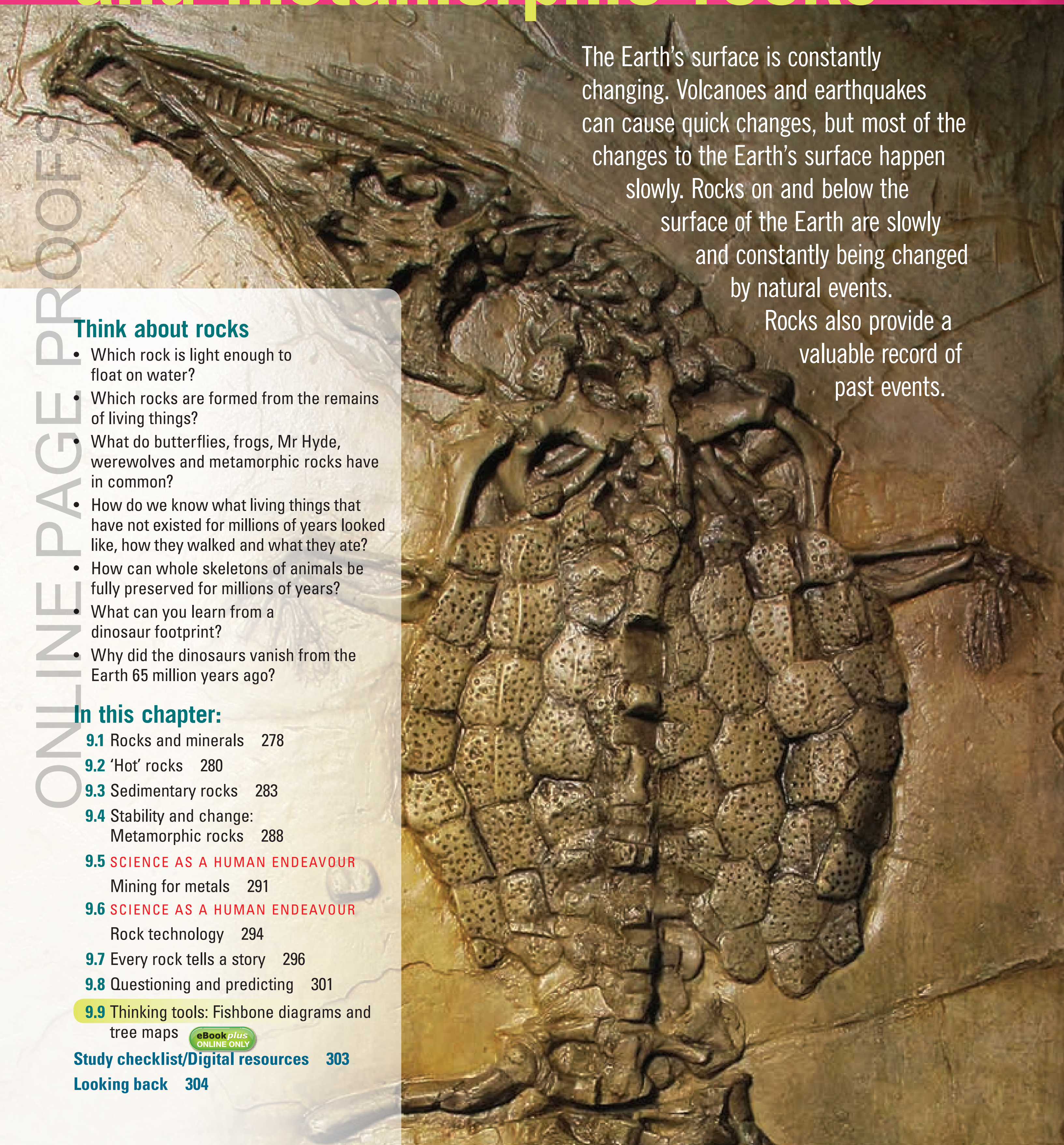
# 9 Sedimentary, igneous and metamorphic rocks



The Earth's surface is constantly changing. Volcanoes and earthquakes can cause quick changes, but most of the changes to the Earth's surface happen slowly. Rocks on and below the surface of the Earth are slowly and constantly being changed by natural events.

Rocks also provide a valuable record of past events.

## Think about rocks

- Which rock is light enough to float on water?
- Which rocks are formed from the remains of living things?
- What do butterflies, frogs, Mr Hyde, werewolves and metamorphic rocks have in common?
- How do we know what living things that have not existed for millions of years looked like, how they walked and what they ate?
- How can whole skeletons of animals be fully preserved for millions of years?
- What can you learn from a dinosaur footprint?
- Why did the dinosaurs vanish from the Earth 65 million years ago?

## In this chapter:

# YOUR QUEST

## Bathroom rocks

When you last used the bathroom, you probably weren't thinking about rocks. After all what does a bathroom have to do with rocks?

But where did the materials to make the shower recess come from? What about the taps and pipes that delivered the water? Where do the materials to make tiles come from? And what about the soap, talcum powder and toothpaste — where do they come from?

The answers to all of these questions lead back to rocks. For example, metals are extracted from rocks. Talcum powder is made from a mineral called talc, which comes from a rock. Some of the ingredients of toothpaste come from rocks.

Even food and clothes can be traced back to rocks. Plants grow in soil, which is made up mostly of weathered rock. Glass is made using sand, which is weathered rock.

**THINK**

Work in small groups to answer the following questions.

1 What materials are mirrors made from?
2 Where does the metal used to make bathroom taps come from?
3 What are bathroom tiles made from?
4 List some building materials that are:
   (a) made directly from rocks
   (b) not made directly from rocks but can be traced back to rocks.
5 The terms 'igneous', 'sedimentary' and 'metamorphic' are used to describe the three main groups of rocks. Just from looking at the words, suggest how each of these groups of rocks is formed.
6 Make a list of the names of rocks that you know. Attempt to classify them as igneous, sedimentary or metamorphic.

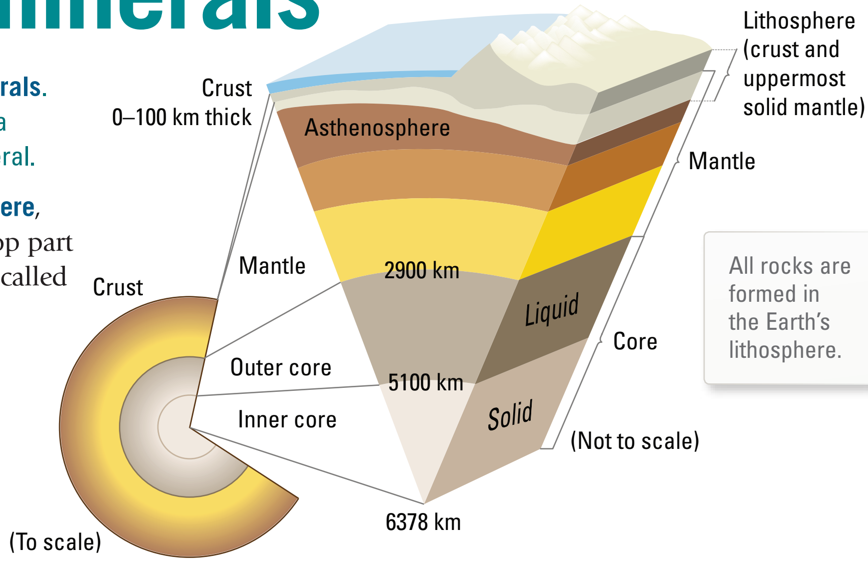


Taps, tiles, mirrors and even soap. Where do the materials needed to produce these come from?

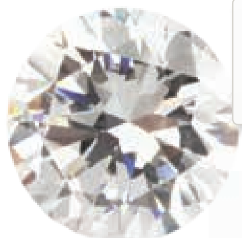
# Rocks and minerals

Rocks are made up of substances called **minerals**. Any naturally occurring solid substance with a definite chemical composition is called a mineral.

All rocks are formed in the Earth's **lithosphere**, which includes the Earth's crust and the top part of its mantle, where partially molten rock called **magma** flows very slowly under the crust. Some rocks are formed when magma gets close to the surface and slowly cools. Some of that red-hot magma breaks through the Earth's crust to form fiery volcanoes, releasing lava to cool quickly on the surface or even underwater. Other rocks form as a result of the weathering of older rocks and erosion, creating layers of **sediments**, which are eventually buried under more sediments and changed by heat and pressure. Some rocks are even formed from the remains of living things.




All rocks are formed in the Earth's lithosphere.



Native elements, such as the pure carbon that forms this diamond, are rare and valuable.

Quartz is one of the most common minerals in the Earth's crust.

## What's in a rock?

Elements found naturally in their uncombined form are also minerals. These elements, called **native elements**, include diamonds (pure carbon) and gold.

Most minerals in rocks are compounds with one or more metal elements together with the elements oxygen and silicon. The colours, shapes and textures of the minerals in rocks tell us what they are made of and how they were formed, as well as providing clues about the past.

Softest

| Mohs' scale of hardness | |
|---|---|
| Talc | 1 |
| Gypsum | 2 |
| Calcite | 3 |
| Fluorite | 4 |
| Apatite | 5 |
| Orthoclase | 6 |
| Quartz | 7 |
| Topaz | 8 |
| Corundum | 9 |
| Diamond | 10 |

Hardest

| Common materials |
|---|
| Soft grey lead pencil point |
| Fingernail |
| Copper coin |
| Iron nail |
| Sandpaper |

A scale for testing the hardness of minerals

## Cool shapes

The atoms that join together to form minerals make up regular geometric shapes in particles called **crystals**. The way crystals grow when a mineral is formed depends on the speed of the cooling process of the molten material from which they form and how much space is available. The quartz crystals shown below have cooled slowly and have had a lot of time and space to grow. Quartz, one of the most common minerals, consists of hexagonal-shaped crystals of silicon dioxide ($SiO_2$).

## Identifying minerals

Although colour might seem to be the quickest way to identify a mineral, it is not reliable. Many different minerals have similar colours. Some minerals, even though they have the same chemical composition, can have different colours. Quartz, for example, can be colourless like glass, or may be pink, violet, brown, black, yellow, white or green. Other properties can be used to identify minerals.

The **lustre** of a mineral describes the way that it reflects light. Minerals could be described, for example, as dull, pearly, waxy, silky, metallic, glassy or brilliant.

The **streak** is the powdery mark left by a mineral when it is scraped across a hard surface like an unglazed white ceramic tile.

The **hardness** of a mineral can be determined by trying to scratch one mineral with another. The harder mineral leaves a scratch on the softer mineral. Friedrich Mohs' scale of hardness is a numbered list of ten minerals ranked in order of hardness. Higher numbers correspond to harder minerals. The hardness of a mineral is determined by comparing it with the minerals in Mohs' scale. For example, a mineral that can be scratched by quartz but not by orthoclase has a hardness between 6 and 7.

The diagram at the bottom of the previous page shows that some more common materials can be used to determine the hardness of a mineral if the minerals in Mohs' scale are not available.



INVESTIGATION 9.1

## Which mineral is it?

**AIM** To observe the properties of a range of minerals

***Materials:***
*mineral kit*
*common materials to substitute for unavailable Mohs' scale minerals*
*hand lens*
*white ceramic tile*

### METHOD AND RESULTS

1. Construct a table like the one shown below and use it to record your observations as you work through the following steps for each mineral.
2. Describe the colour and lustre of the mineral.
3. Use the magnifying glass to look closely at the mineral, and describe the shape and size of its crystals.
4. Scrape the mineral across the unglazed side of a white ceramic tile. Record the colour of the streak.
5. Use Mohs' scale minerals or the common materials to estimate the hardness of the mineral by trying to scratch it. An approximate range, such as 5–6, is sufficiently accurate.

### DISCUSS AND EXPLAIN

6. Other than those already described, what additional properties of minerals could be used to identify them?
7. If two unlabelled mineral samples have the same colour and lustre, can you be sure that they are the same mineral? Explain how you would find out.

| Mineral | Colour | Lustre | Crystal shape and size | Streak | Hardness |
|---|---|---|---|---|---|
| | | | | | |

## UNDERSTANDING AND INQUIRING

### REMEMBER

1 Which parts of the Earth make up the lithosphere?
2 List three ways in which rocks can be formed in the Earth's lithosphere.
3 What is a mineral?
4 What is a native element? List two examples.
5 Which minerals are present in granite?
6 List at least five properties that you could observe to help you identify an unknown mineral.
7 What is the approximate hardness on Mohs' scale (to the nearest whole number) of a mineral that can be scratched by sandpaper but not by an iron nail?

### THINK

8 Explain the difference between a rock and a mineral.
9 You have two samples, each of a different mineral, but no other equipment to test them for hardness. How could you tell which mineral is harder?
10 A mineral can be scratched by a copper coin but not by a fingernail. You know that the mineral is quartz, fluorite or calcite. Which is it?
11 Is table salt a mineral? Think carefully about your answer and suggest reasons for and against classifying it as a mineral.

### CREATE

12 Find out how crystals can be artificially grown and then grow a crystal garden.

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work sheet 9.1 Identifying and classifying minerals

# ‘Hot’ rocks

Lava is released from erupting volcanoes at temperatures of 1000°C or more. At that temperature, it could take weeks for the lava to cool down to become solid rock. But lava surging violently into the air from explosive volcanoes cools much faster. The lava erupting from underwater volcanoes on the ocean floor also cools quickly.



## Extrusive rocks

Rocks that form from the cooling of magma below the Earth’s crust or lava are called **igneous rocks**. Igneous rocks that form from red-hot lava above the Earth’s surface are called **extrusive rocks**. Igneous rocks that form from the lava spilling from underwater volcanoes are also classified as extrusive rocks.

The appearance of all extrusive igneous rocks depends on two major factors:

- how quickly the lava or magma cooled
- what substances it contains.

### WHAT DOES IT MEAN?

The word *igneous* comes from the Latin word *ignis*, meaning ‘fire’. The words ignite and ignition also come from the same Latin word.

## Fast or slow?

The size of the crystals that make up extrusive igneous rocks depends on how quickly the lava cooled. When it cools quickly, there is not enough time for large crystals to form. The rocks formed from lava that cools more slowly have larger crystals.

## 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 this type of rock are **pumice** and **scoria**.

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## Pumice

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


## Scoria

Scoria is heavier than pumice, and darker because it contains more iron. It is usually found closer to the volcano’s crater than pumice. Scoria is a reddish-brown or grey rock that can be crushed and used in garden paths or as a drainage material around pipes.

## Basalt

**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. For example, basalt formed from lava cooling in cold ocean water has much smaller crystals than basalt formed by lava cooling on the ground. In fact, basalt that formed under water has crystals so small they are difficult to see.

The basalt in the photograph on the right has large crystals because it formed from lava on the ground. The crystals had time to grow before the rock became solid. It also has large bubble-like holes. That's because the lava was filled with gases when it began to cool. The gases have since escaped.

Basalt with bubbles

## 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.

Obsidian



**INVESTIGATION 9.2**

### Does fast cooling make a difference?

**AIM** **To investigate the effect of cooling rate on the size of crystals**

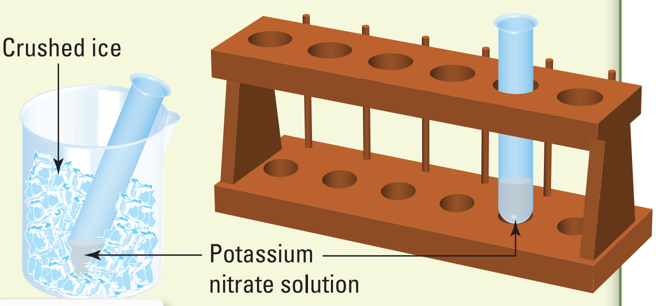
***Materials:***

*freshly made saturated solution of potassium nitrate*
*potassium nitrate*
*spatula*
*250 mL beaker*
*3 test tubes and test-tube rack*
*test-tube holder*
*Bunsen burner, heatproof mat and matches*
*crushed ice*
*safety glasses*
*hand lens*

**CAUTION** Safety glasses must be worn during this experiment.

#### METHOD AND RESULTS

- Half-fill a beaker with crushed ice.
- Quarter-fill a clean test tube with saturated potassium nitrate solution. Add a spatula of potassium nitrate.
- Gently heat the solution over a Bunsen burner flame until the added potassium nitrate has dissolved or until the solution starts to boil.
- Pour half the warm solution into each of two clean test tubes.
- Place one test tube in the beaker of crushed ice and the other test tube in the rack to cool.
- When crystals have formed in each test tube, examine them with a hand lens.




Cool one solution quickly and the other one slowly.

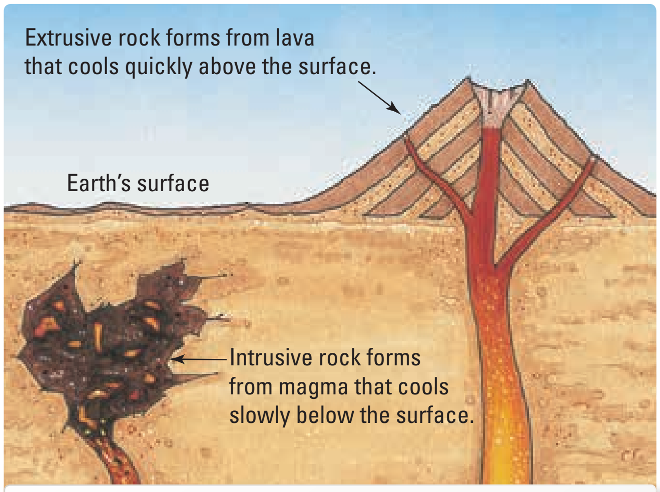
1. Draw a labelled diagram of some crystals in each test tube, concentrating on their shape and size.

**DISCUSS AND EXPLAIN**

2. Which test tube contained the larger crystals — the one that cooled quickly or the one that cooled slowly?
3. Which type of extrusive rock would you expect to have the larger crystals — those that cool slowly on the surface or those that cool quickly underwater?
4. Why do safety glasses need to be worn during this experiment?

## Cooling underground

Igneous rocks can form below the surface of the Earth. Those that form from magma that cooled below the surface are called **intrusive rocks**. They cool very slowly and become visible only when the rocks and soil above them erode. Large bodies of intrusive rock are called **batholiths**. They can stretch over distances of up to 1000 kilometres.



Igneous rocks can form below or above the Earth's surface.

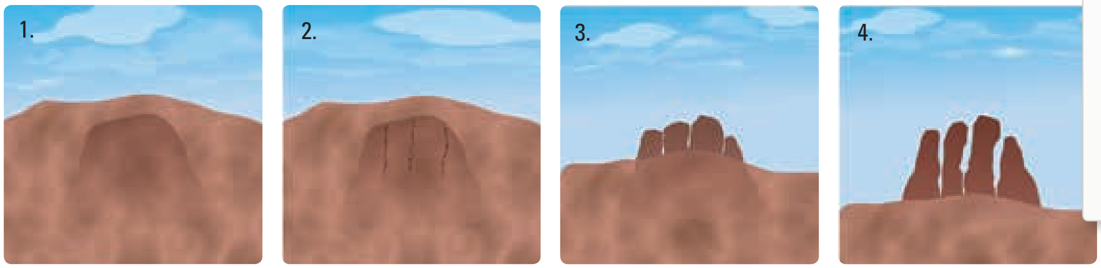
Intrusive rocks (sometimes called plutonic rocks) have larger crystals than extrusive rocks because the crystals had more time to grow.

### Granite

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


Granite

The crystals found in granite are a mixture of white, pink, grey, black and clear minerals. These are quartz (clear to grey), feldspar (white and pink) and mica (black). Feldspar is made of aluminium silicate, and black mica is aluminium silicate combined with potassium, magnesium and iron.



If a 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.

## UNDERSTANDING AND INQUIRING

### REMEMBER

1 What causes the frothy appearance of pumice and scoria?

2 Why are the crystals in basalt that formed under water smaller than those in basalt that formed on the ground?

3 Batholiths form well below the ground. Explain how they become visible on the Earth's surface.

4 Distinguish between the ways extrusive and intrusive igneous rocks are formed.

5 Describe two major differences between the appearance of granite and basalt.

6 List the three minerals found in granite.

### THINK

7 Explain how you would decide whether an igneous rock formed from a volcanic eruption.

8 Rhyolite is an extrusive rock that contains the same minerals as granite. In what ways would you expect it to be different from granite?

### INVESTIGATE

9 Locate a building, statue or memorial in your area that is made from granite. Describe the granite in the structure, and suggest why it was the chosen material.

10 Use the **Who am I?** weblink in your eBookPLUS to play the Rock Game and identify rocks from a series of clues.

work sheet 9.2 Igneous rocks

# Sedimentary rocks

Rocks that are formed from the particles of sediments are called **sedimentary rocks**.

Sediments are deposited when weathered rock is moved from one place to another by the wind, running water, the sea or glaciers. That process is called **erosion**. Deposits of dead plants and animals are also called sediments.

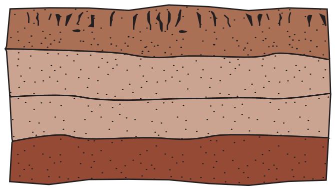
Sand deposited by the wind forms sand dunes, especially in coastal areas where sand is picked up and blown inland until it is stopped by obstacles such as rock or vegetation.

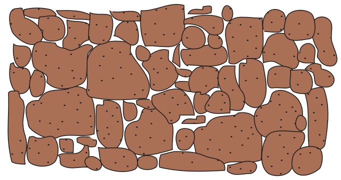
A fast-moving river is likely to carry with it sand, gravel and smaller particles. As it slows down on its path to the sea, the river loses energy and particles are deposited, forming sediments. The larger particles, such as gravel and sand, settle first. By the time the river reaches the sea, it is usually travelling so slowly that the very fine mud particles begin to settle.

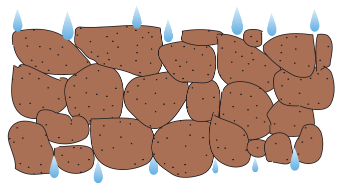
During floods when rivers break their banks, sediments are deposited on flat, open land beside the river. These plains are called **floodplains**.

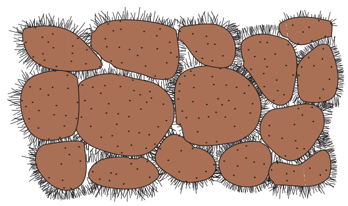
The water in fast-moving rivers, along with the weathered rock it takes with it, can carve out deep valleys in the Earth's surface. One of the most spectacular examples of this is the Grand Canyon in Arizona, USA.

In the coldest regions of the Earth, especially at high altitudes, bodies of ice called **glaciers** slowly make their way down slopes. They generally move between several

1

Sediments are laid down by ice, wind or water, in horizontal layers called beds.

2

Within each bed, the sediment grains are squashed together so that they are in close contact.

3

Water seeps in between the grains, bringing with it many dissolved chemicals.

4

When the water evaporates, these chemicals are left behind as crystals around the edges of the grains. These crystals cement the grains of sediment together to form rock.

Many sedimentary rocks form in this way.



## HOW ABOUT THAT!

**Chalk is a sedimentary rock. It is similar to limestone, but not as hard. Chalk is formed from very fine grains of calcium carbonate that separate from sea water and settle to become a white, muddy sediment on the sea floor. The sediment hardens over time to form chalk. This process takes millions of years. The remains of shellfish and other sea animals are also found in the sediment that forms chalk, but most of these remains are microscopic.**

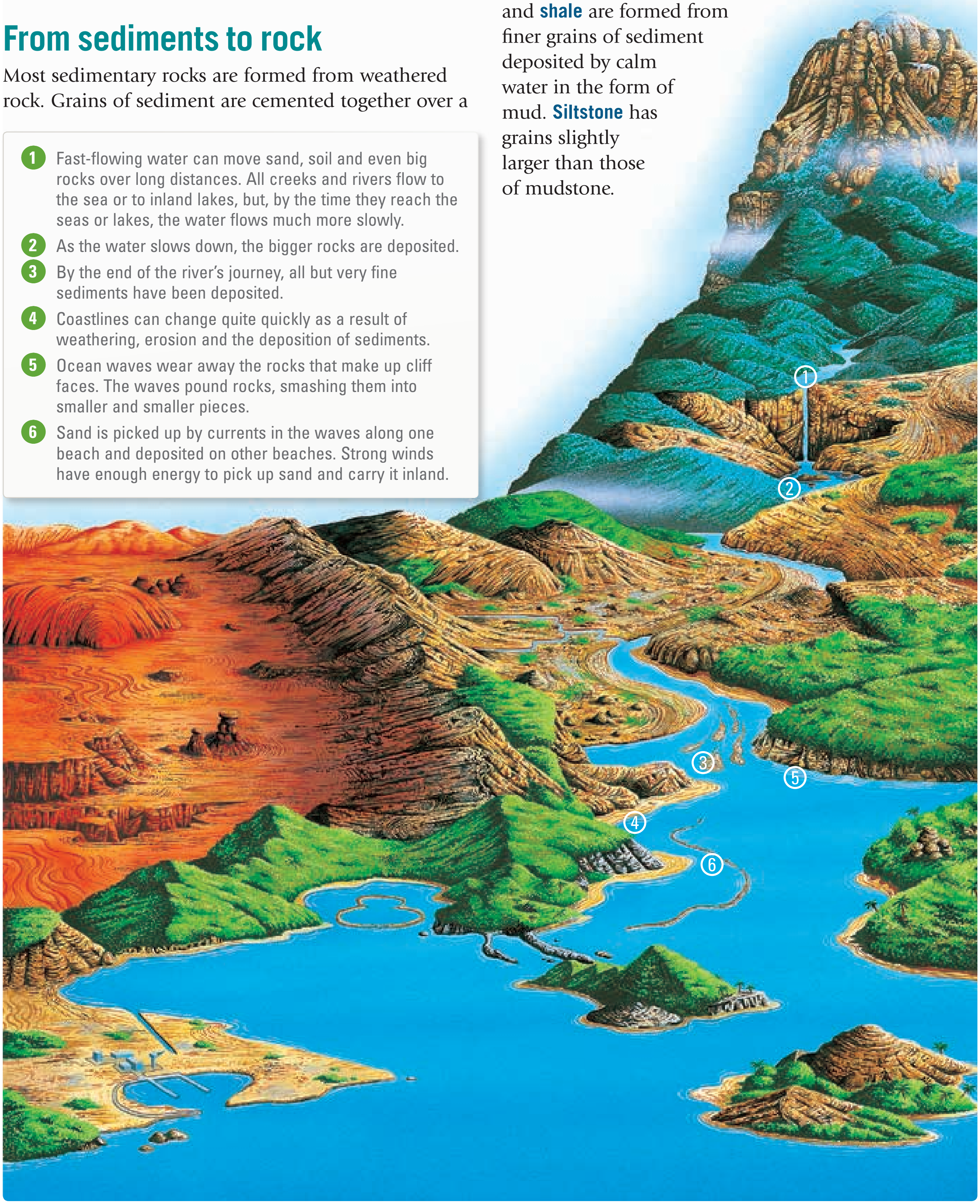
**The white cliffs of Dover that overlook the English Channel are composed of chalk.**

centimetres and several metres each day. Being solid, glaciers can push boulders, rocks, gravel and smaller particles down the slope, and deposit them on curves beside the glacier or at the end of the glacier. These deposits are called **moraines**.

## From sediments to rock

Most sedimentary rocks are formed from weathered rock. Grains of sediment are cemented together over a long period of time to form solid rock. The process is shown in the diagrams below.

**Sandstone** is formed from grains of sand that have been cemented together over a period of time. **Mudstone** and **shale** are formed from finer grains of sediment deposited by calm water in the form of mud. **Siltstone** has grains slightly larger than those of mudstone.




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 more slowly.
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 deposition of sediments.
5. Ocean waves wear away the rocks that make up cliff faces. The waves pound rocks, smashing them 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.

### WHAT DOES IT MEAN?

The word ***conglomerate*** comes from the Latin word *conglomerare*, meaning to 'roll together'.

**Conglomerate** contains grains of different sizes that have been cemented together.

Conglomerate is formed from sediments that might be deposited by a fast-flowing or flooded river.

The Grand Canyon is a spectacular example of erosion by a fast-flowing river.

## Rocks from living things

**Limestone** is a sedimentary rock that is formed from deposits of the remains of sea organisms such as shellfish and corals. The hard parts of these dead animals contain calcium carbonate. These deposits are cemented together over a period of time in very much the same way as other sedimentary rocks form from weathered rock.

**Coal** is formed from the remains of dead plants that are buried by other sediments. In dense forests, layers of dead trees and other plants build up on the forest floor. If these layers are covered with water before rotting is completed, they can become covered with other sediments. The weight of the sediments above compacts the partially decayed plant material. Over millions of years the compacting increases the temperature of the sediment and squeezes out the water, forming coal.

**INVESTIGATION 9.3**

### Sediments and water

**AIM** **To investigate the order in which different sediments are deposited**

***Materials:***
*mixture of garden soil, gravel, sand and clay*
*large jar with lid*
*watch or clock*

#### METHOD AND RESULTS

- Before commencing this experiment, form your own hypothesis about the order in which the different types of particles will settle. Give reasons for your hypothesis.

1 Draw a diagram to illustrate your hypothesis.

- Place enough of a mixture of garden soil, gravel, sand and clay in a large jar to quarter-fill it.
- Add enough water to three-quarters fill the jar and place the lid on firmly. Shake the jar vigorously.
- Put the jar down and watch carefully as particles begin to settle. Note the time taken for each layer of sediment to settle completely.
- Leave the jar for a day or two. Then compare your observations of the jar with your diagram.

2 Which type of sediment settled first?

3 Where are the other particles of sediment while the first layers are settling?

4 Draw a labelled diagram showing clearly any layers that form. Identify the layers if you can.

5 Which sediments settled after a day or two?

#### DISCUSS AND EXPLAIN

6 Why did the last sediments take so long to settle?

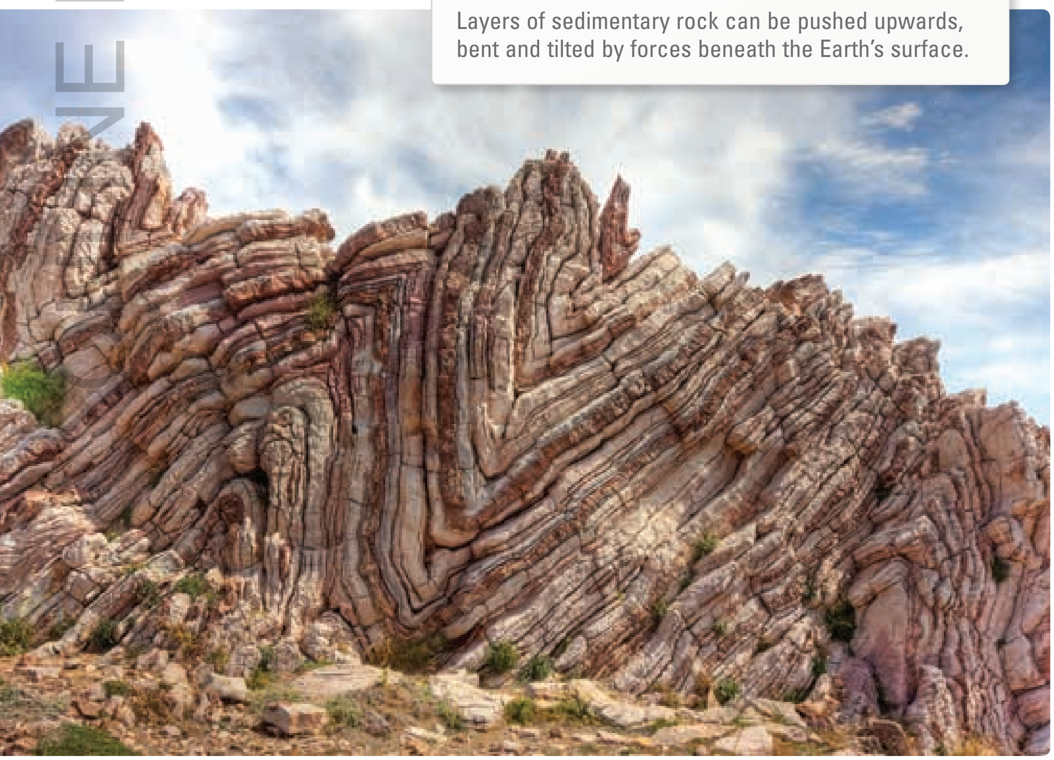
7 Was your hypothesis supported by your observations?

8 What is the relationship between the size of sediment particles and the time taken to settle?

## Rocks from chemicals

Some sedimentary rocks form when water evaporates from a substance, leaving a layer that is compressed after being buried by other sediments. **Rock salt** is an example of a rock formed in this way. It forms from residues of salt that remain after the evaporation of water from salt lakes or dried-up seabeds and can form beds that are hundreds of metres thick. Rock salt is used on roads and driveways in very cold areas to combat ice. Gypsum is another mineral that is formed in this way.

This limestone, rich in corals and shells, is many metres above sea level. How did it get there?



Layers of sedimentary rock can be pushed upwards, bent and tilted by forces beneath the Earth's surface.

## Rocks in layers

Layers of sedimentary rock are often clearly visible in road cuttings and the faces of cliffs. The limestone in the photograph at bottom left was formed on the ocean floor. Layers of sediments and sedimentary rocks can be pushed upwards by the same forces below the Earth's surface that form mountains. Those forces can also bend and tilt the rock layers.

When fossils are found in sedimentary rock, the layer they are found in can be used to figure out how old the fossil may be.

## Using sedimentary rocks

Sandstone and limestone are often used as external walls of buildings. These sedimentary rocks are well suited to carving into bricks of any shape. Shale can be broken up and crushed to make bricks.

Limestone is broken up to produce a chemical called lime. Lime is used to make mortar, cement and plaster, and is also used in the treatment of sewage and on gardens to neutralise acid in the soil.

Coal is another useful sedimentary rock. It is used as a fueland burned in electric power stations to boil water. The steam is then used to drive the turbines that produce electricity. In some countries, coal is burned in home heaters, although this can cause air quality problems.

INVESTIGATION 9.4

## Identifying sedimentary rocks

**AIM** To use a key to identify a variety of sedimentary rocks

***Materials:***

*several examples of unlabelled sedimentary rocks, including limestone*

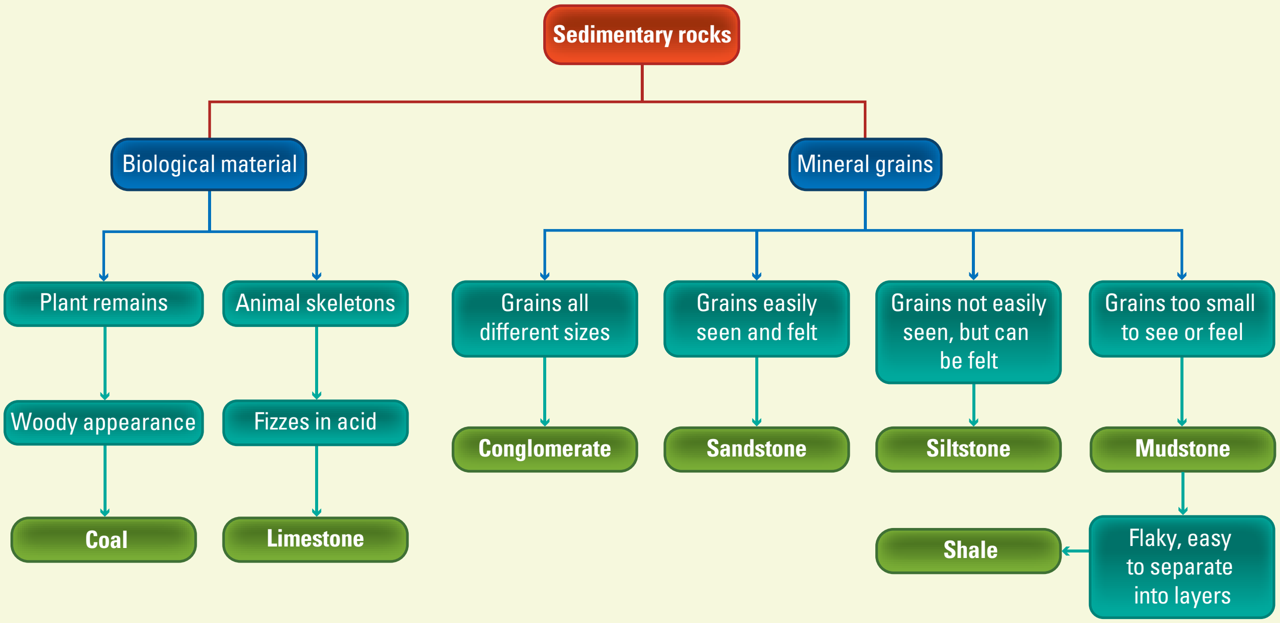
*dropping bottle of dilute hydrochloric acid*

### METHOD

- Use the key below to identify the samples of sedimentary rocks you have been given.
- To do the acid test, just add one drop of dilute hydrochloric acid onto the sample.

### DISCUSS AND EXPLAIN

1. How many of the unlabelled rocks did you identify?
2. Which of the rock samples were the most difficult to identify?




## UNDERSTANDING AND INQUIRING

### REMEMBER

1 What are most sediments composed of before they eventually form sedimentary rocks?

2 As a flooded river slows down, which particles are likely to settle first — gravel, sand or fine clay?

3 Explain how a floodplain is created.

4 From what are all sedimentary rocks formed?

5 Explain, with the aid of a diagram, how grains of sand can become part of a sedimentary rock.

6 Sedimentary rocks formed from the erosion of weathered rock cannot be identified by their colour. What feature allows you to identify them?

7 How is coal formed?

8 Explain why sedimentary rocks are found in layers.

### THINK

9 What type of sediment would you expect to find on the bed of the Yarra River in Melbourne?

10 A road cutting reveals a layer of sandstone beneath a layer of mudstone. Between them is a much thinner layer of conglomerate.
(a) Which layer would have formed from sediments beneath the sea?
(b) Which layer would have formed while the area was flooded by a swollen, fast-flowing river?
(c) Which layer would have formed while the land was the floor of a still lake?
(d) Which layer was formed most recently?

11 Explain why limestone and coal are sometimes referred to as biological rocks.

12 In which type of sedimentary rock would you be most likely to find embedded seashells?

### INVESTIGATE

13 What do peat, brown coal and black coal have in common? How are they different from each other?

eBook*plus* work sheet 9.3 Sedimentary rocks

# 9.4

# Stability and change: Metamorphic rocks

The thing that never changes about the Earth is that it never stops changing. Igneous rocks and sedimentary rocks are constantly undergoing change. If they are on the surface, they are weathered, cracked or even bent.

Igneous and sedimentary rocks deep below the Earth's surface are buried under the huge weight of the rocks, sediments and soil above them. They are also subjected to high temperatures. The temperature increases by about 25 °C for every kilometre below the surface. This heat and pressure can change the composition and appearance of the minerals in rocks.

The process of change in the rocks is called **metamorphism** and the rocks that are formed by these changes are called **metamorphic rocks**.

### WHAT DOES IT MEAN?

The word ***metamorphic*** comes from the Greek words *meta*, meaning 'change', and *morph*, meaning 'form'.

Shale (pictured below) 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**.

Shale

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

Marble

### HOW ABOUT THAT!

Have you ever tried to lift one end of a pool table and noticed how incredibly heavy it is? It's really heavy because the flat surface under the felt is not wood as you may have thought — it's actually made of slate. Because of its natural hardness and flat face, slate makes an ideal even surface!

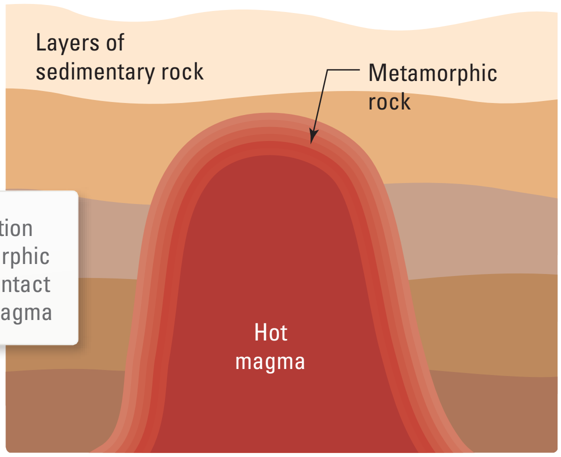
The changes that take place during the formation of metamorphic rocks depend on:

- the type of original rock
- the amount of heat to which the original rock is exposed
- the amount of pressure caused by the weight of the rocks above
- how quickly the changes take place.

Metamorphic rocks that are mainly the result of great pressure can often be identified by bands or flat, leaf-like layers. These bands are evident in the sample of **gneiss** (pronounced 'nice') pictured on the right.

Gneiss is formed mainly as a result of great pressure on granite.

The diagram on the right shows how rocks can be changed by the high temperatures that result from contact with hot magma.




The formation of metamorphic rock by contact with hot magma

Other common examples of the formation of metamorphic rocks are:

| | | |
|---|---|---|
| Shale (sedimentary) | mainly pressure ⇛ | Slate |
| Sandstone (sedimentary) | mainly heat ⇛ | Quartzite |
| Limestone (sedimentary) | mainly heat ⇛ | Marble |

## Clues from metamorphic rocks

The nature of metamorphic rocks above and below the ground can provide clues about the history of an area. Think about why the presence of quartzite or marble high in a mountain range would suggest that the area was once below the sea.

The presence of slate might suggest that the area was once the floor of a still lake or river mouth. The sediments were probably buried under many other sediments, and cemented together to form shale. The shale was transformed, or metamorphosed, into slate as a result of new rock formed above it.

## Uses of metamorphic rock

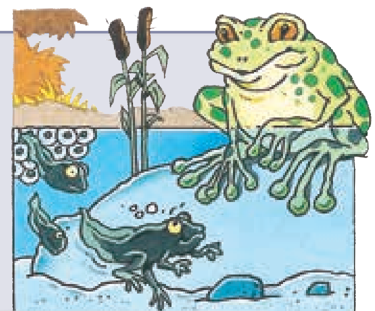
Marble's strength, appearance and resistance to weathering make it suitable for use in statues and the walls and floors of buildings (inside and outside). It is usually highly polished. The hardness, flat structure and strength of slate make it ideal for use in buildings, especially in roofing and floor tiles. The sedimentary rocks from which marble and slate are formed could not be used for these purposes.

## The rock cycle

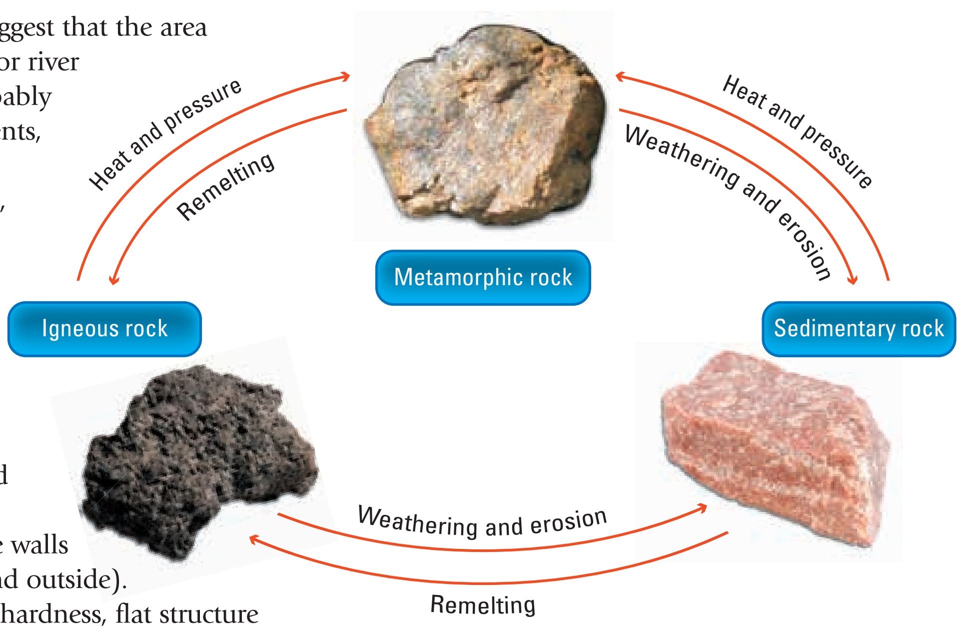
The rock cycle below describes how rocks can change from one type to another. Weathering, erosion, heat, pressure and remelting are processes that help change rocks. The rock cycle is different from other cycles because there is no particular order in which the changes happen. Some rocks have been unchanged 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.

### HOW ABOUT THAT!

A tadpole grows into a frog, female frogs lay eggs, and eventually more tadpoles emerge from the eggs. That's a life cycle. Some of the changes in rocks can be described as cycles too. Weathered rock is moved by erosion and the particles form sediments, which can be cemented together to form sedimentary rocks, which in turn may eventually change into metamorphic rocks. Once those rocks are exposed at the surface the weathering starts all over again. A complete cycle normally takes millions of years, but sometimes never takes place at all. Why?



There are many cycles in nature. Some happen faster than others.



## INVESTIGATION 9.5

### Rocks — the new generation

**AIM** To examine and compare a selection of metamorphic rocks and their corresponding 'parent' rocks

***Materials:***

*labelled samples of granite, gneiss, limestone, marble, sandstone, quartzite, shale and slate*

*hand lens*

#### METHOD AND RESULTS

- Try to sort the rocks into pairs of 'parent' rock and corresponding metamorphic rock. Use the descriptions and examples on the previous two pages if you have trouble pairing the rocks.
- Examine each pair of rocks with a hand lens. Take particular note of grain or crystal size and banding.
- If necessary, re-sort the rocks into different pairs.

1. Copy and complete the table below by noting the similarities and differences between the 'parent' and metamorphic rock of each pair.

#### DISCUSS AND EXPLAIN

2. Why is the term 'parent' rock used to describe the rock before metamorphosis?
3. Use the last column of your table to suggest whether the main cause of metamorphism was heat or pressure.

**Comparing 'parent' and metamorphic rocks**

| 'Parent' rock | Metamorphic rock | Similarities | Differences | Main cause of metamorphism |
|---|---|---|---|---|
| Shale | | | | |
| | Gneiss | | | |
| Sandstone | | | | |
| | Marble | | | |

## UNDERSTANDING AND INQUIRING

### REMEMBER

1 Rocks are classified into three groups. Metamorphic rocks are one of these. Identify two groups of rock from which metamorphic rocks are formed.

2 What can cause rocks to change form and become metamorphic rocks?

3 Describe the differences between gneiss and granite.

4 What causes granite to be transformed into gneiss?

5 Slate is commonly used in floor tiles. Why?

### THINK

6 If an igneous or sedimentary rock gets so hot that it melts completely, it does not become a metamorphic rock. Explain why.

7 Why is limestone referred to as the 'parent' rock of marble?

8 Metamorphic rocks are generally formed deep below the surface of the Earth. However, they are often found above the ground — even high in mountain ranges. How can this be so?

9 Devise a 'buildings trail' in your city or town to locate buildings made of different kinds of rock. Draw a map to show the location of the buildings and the type of rock used in constructing them.

### INVESTIGATE

10 Find out more about the uses of marble and slate. Where are they obtained? What are they used for? Why are they expensive?

### CREATE

11 Apply mainly heat or pressure to a series of rocks and watch them change with the **Metamorphic rocks** interactivity in your eBookPLUS. **int-0234**

eBook*plus*

12 Use the **Rock cycle** weblink in your eBookPLUS to watch an animation of how rocks undergo change.

work sheets
9.4 Metamorphic rocks
9.5 The rock cycle

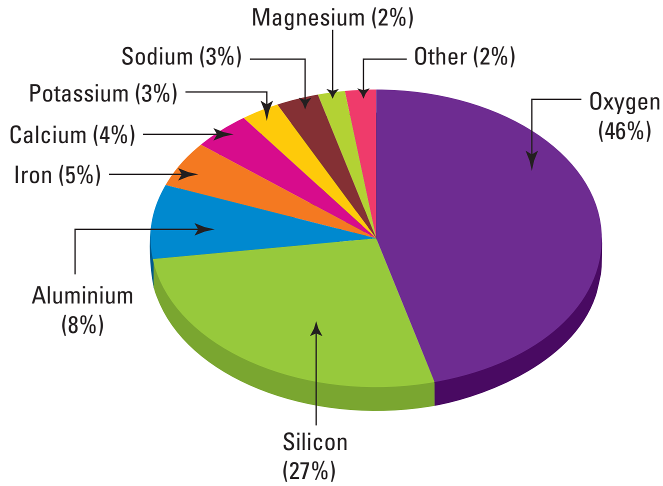
# Mining for metals

Metals play an important part in our lives every day. You probably slept on a mattress with metal inner springs. The alarm clock that woke you up has metal parts. You use metal cutlery to eat food. The bus, car or bike that you may have used to get to school is made from metal.

The metal elements used to make these things are all found in minerals within rocks in the Earth's crust. The pie chart below shows that almost three-quarters of the Earth's crust (by weight) is made up of the non-metals oxygen and silicon. Most of the metal elements are combined with other elements in compounds, usually with oxygen, silicon or other non-metals. It is these compounds that are the minerals.

Minerals containing metals of value are called **mineral ores**. It takes a lot of time, effort and money to get the rocks that contain the mineral ores out of the ground, separate the mineral ores from the rock and extract the metal element from the mineral ore. The **mining** of a mineral ore can take place only if enough of it is found at a single location.

The mining industry makes a major contribution to Australia's economy. Apart from the profits that go to shareholders in mining companies and to the government in taxes, the mining industry employs many thousands of Australians. Scientists and engineers are involved at every stage of the mining process.




The elements in the Earth's crust. The metal elements are relatively rare compared with oxygen and silicon.

## Mineral exploration

Finding minerals below the Earth's surface where you can't see them is an expensive business. Before any money or effort is spent on using helicopters and analysing samples, geologists have to know where to look. Their knowledge of sediments, rocks and minerals of all types, and the clues they provide, helps them to predict where precious mineral ores are likely to be found.

Geologists also make use of satellites equipped with cameras, radar and other sensors to search for geological features that are likely to contain high concentrations of minerals. Minerals in the crust dissolve in rain and running water and get washed into creeks and rivers. A chemical analysis of the sediments and surface water of lakes and streams, therefore, provides evidence of the presence of minerals in the area.

The magnetic properties of large bodies of rocks containing some minerals can be detected from aircraft or by geological surveyors on the ground. Samples of soil and rocks are taken using portable equipment. On average, only one in 1000 sites that are sampled is eventually mined.

If there is sufficient evidence of useful mineral deposits that might be worth mining, a licence must be obtained before any clearing is done or heavy drilling equipment is brought in. Helicopters are sometimes used to bring in heavy equipment to protect sensitive ecosystems. The drilling allows mining companies to have a detailed look at what lies beneath the surface. Mining companies are required by law to clean up exploration drill sites and ensure they are left as they were found.

## You can't start until …

In the past, mining was often carried out without considering its long-term effect on the environment and the people who live and work in the area. Today, however, an **environmental impact statement (EIS)** must be prepared before a mining operation can commence. An EIS outlines how the mining company intends to manage all environmental aspects of the proposed mine. It also outlines how the land will be **rehabilitated** or reconstructed, so that it can be used again after the mining is completed.

The environmental impact statement, along with any other relevant information, is studied by the government before permission to proceed is granted.

INVESTIGATION 9.6

### Searching without disturbing

**AIM** To model the search for minerals below the ground

***Materials:***

| | |
|---|---|
| *a tray of sand* | *10 paperclips* |
| *blindfold (optional)* | *compass* |
| *paper and clipboard* | *ruler* |

**METHOD**

- Find a partner. Each of you should then draw identical maps of the sand tray. Use a ruler to construct a grid on each map. Label the grids across the top and down the side (e.g. A–J across the top, 1–15 down the side). Each grid should consist of at least 100 equal-sized rectangles or squares.
- Without showing your partner, hide the paperclips in the tray of sand and mark the location of the ten clips on your map.
- Your partner's task is to locate the ten paperclips and mark them on the map without disturbing the sand. You might wish to set a time limit.
- Swap roles and repeat the steps above.

**DISCUSS AND EXPLAIN**

1. What property of the paperclips allowed them to be located?
2. How could your predictions of the location be checked with a pencil?
3. After checking, can the sand be restored to its initial condition?

The EIS reports on:

- existing flora, fauna and soils
- existing towns and roads in the area
- proposed new towns, roads and other developments
- how the new development might affect the local community and environment
- alternative plans to complete the development that might have less impact on the environment
- measures that will be put in place to monitor and control air, water and noise pollution during the project and while rehabilitation is undertaken
- rehabilitation proposals for the area.

## Taking out the mineral ore

To obtain mineral ore from the ground, it is often necessary to remove large amounts of rocks and soil. The way this is done depends on how close the mineral ore is to the surface. If it is close to the surface, first the vegetation and topsoil are removed. Then waste rock from beneath the topsoil, called **overburden**, is removed. The removed topsoil and overburden are used to fill areas that have already been mined, or are left in a pile to restore the newly mined area when mining is completed. This method of mining is called **open-cut mining**.

If the mineral ores are deep below the surface, miners use **underground mining**. This mining method is more dangerous and expensive than open-cut mining. Shafts and tunnels are dug up to four kilometres into the ground to reach the rocks containing the mineral ore. The development of open-cut and underground mining is overseen by mining engineers.

## Getting the metal

Obtaining the metal element takes place in two stages:

1. Mineral extraction separates the mineral ore from the rock taken from the ground. This involves crushing, grinding and washing the rock to separate the minerals from the unwanted rock.
2. Metal extraction separates the desired metal element from the mineral. This always involves chemical reactions. The nature of these reactions depends on a number of factors, including the chemical composition of the mineral ore. Chemical engineers are involved in the design of this process.

## Rehabilitation

Before mining of a new site begins, seeds of the natural vegetation of the area are collected so that seedlings can be cultivated at a later stage. The seedlings are grown in special nurseries until they are mature enough to return to the site of the mine.

During open-cut mining, the overburden (the material removed from the site to expose the mineral ore or coal) is used to fill holes left from earlier stages of the mining operation. Fresh topsoil is used to cover the overburden to ensure that new vegetation will grow. The soil surface is shaped to fit in with the surroundings, fertilised and sown with seeds or planted with seedlings. Care is taken to shape the new surface to prevent the newly sown soil from being eroded or washed away by wind or rain.

Prior to rehabilitation of the CSR Building Materials PGH mining site in Cooroy, Queensland (July 1994)

Six months into the rehabilitation process. The ongoing rehabilitation of this site earned CSR an environmental excellence award.

## UNDERSTANDING AND INQUIRING

### REMEMBER

1 Where are all mineral ores found?

2 In the Earth's crust, where are the metal elements found?

3 Describe the method of open-cut mining for removing mineral ores from the ground.

4 Outline the two stages involved in obtaining a metal element from rock.

5 What is an EIS?

6 Outline the information that is included in an EIS.

7 How do mining companies rehabilitate the land used for mining?

### THINK

8 The most common element in the Earth's crust is oxygen. This element is a gas except at extremely low temperatures. In what form is it found in the Earth's crust?

9 Explain why it is important to recycle metals as much as possible.

10 In a table like the one below, make a list of the benefits and disadvantages of mining.

| Benefits | Disadvantages |
|---|---|
| | |
| | |

11 Summarise the reasons for and against allowing mining to take place in Australia's national parks.

### BRAINSTORM

12 In a small group, discuss and list:
(a) the factors a mining company should consider when it decides whether to start a mining project
(b) the different tasks that scientists and engineers might perform from the beginning of mining exploration until mining rehabilitation is complete.
Compare the lists of your group with those of others in your class.

# Rock technology

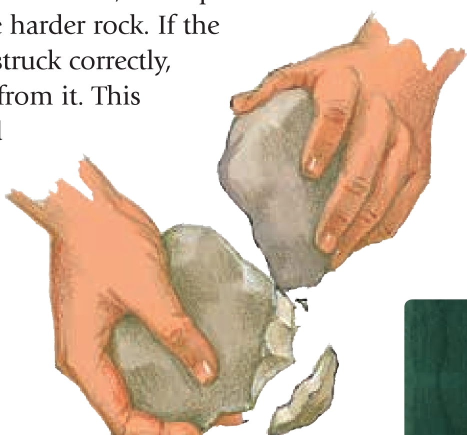
Rock technology began about two million years ago when early humans started using rocks to make simple chopping tools. This was the beginning of the period known as the **Stone Age**. For the great civilisations of Asia, Europe and North Africa, the Stone Age ended around 3000 BC with the discovery of bronze, an **alloy** of copper and tin.

Flint arrowheads were attached to wooden shafts with twine or animal sinews.

## Sharp edges

The most commonly used resource in the Stone Age was a fine-grained sedimentary rock called **flint**. When flint breaks, it leaves a razor-sharp edge, so it was ideal for making sharp tools like knives, axes and spearheads.

Small tools were made by striking tool stones like flint or the glass-like igneous rock obsidian with harder stones, such as quartzite, a metamorphic rock. To remove large flakes from the tool stone, a sharp blow was delivered by the harder rock. If the tool stone was struck correctly, a flake sheared from it. This process is called **percussion flaking**. The toolmaker continued to remove flakes from the stone until the desired shape was obtained. The flakes were then used to make tools such as knife blades, scrapers and engravers.



Larger items such as axeheads and spearheads were made with a combination of techniques, such as percussion flaking, grinding stones against each other and chiselling against the edge of a stone with tools made of bone or wood.

## Indigenous ingenuity

Aboriginals and Torres Strait Islanders were still using Stone Age tools when Europeans began to settle in Australia in 1788. They were highly skilled at working with stone. In fact, Indigenous Australians were the first people to use ground edges on cutting tools and to grind seed.

Their stone axes and other sharp tools were used to cut wood, shape canoes, chop plants for food, skin animals and make other tools out of stone or wood. The sharpened stones were often attached to wooden handles with twine from trees or with animal sinews.

Grinding stones are slabs of stone used with a smaller, harder top stone to grind seeds such as corn and wheat, berries, roots, insects and many other things

Hand axes made and used by the Ngadjonji people of the tropical rainforests of northern Queensland to prepare food for cooking. Leaves and bark were sometimes ground to make medicines. Aboriginals also used grinding stones to grind various types of soil and rock to make the powders used to paint shields and other wooden implements with traditional patterns.

Grinding stones were rough and usually made from sandstone, basalt with large crystals or quartzite. The smaller top stone was usually a hard, smooth river pebble.

A food grater made from stone by the Ngadjonji people of northern Queensland

An Aboriginal grinding stone with a top stone, or muller. The grinding stone is 40 cm long, 35 cm wide and 10 cm high. It is made from sandstone. The top stone is a hard, smooth river pebble.

The tools and the type of stone used to make them varied from group to group, depending on the location. Aboriginal people were skilled at making good use of the available resources. Apart from grinding stones, axes and other cutting tools, they made items such as bowls, cups and food graters out of stone.



## UNDERSTANDING AND INQUIRING

### REMEMBER

1 List one example of each of the following types of rock that were used in the Stone Age to make tools.
   (a) Igneous
   (b) Sedimentary
   (c) Metamorphic

2 Which alloy replaced stone as the substance chosen to make tools when the Stone Age ended?

3 What role did animal sinews play in toolmaking by Indigenous Australians?

4 List three different uses of grinding stones.

### THINK

5 What properties of flint made it so useful during the Stone Age?

6 List some properties that you would look for when selecting a suitable top stone for a grinding stone.

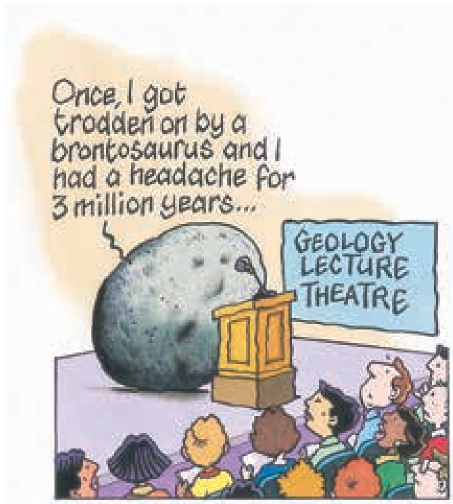
7 Suggest how the process of percussion flaking got its name.

### INVESTIGATE

8 Research and report on a range of tools, weapons and other devices made from rocks or other natural materials that Aboriginal and Torres Strait Islander peoples used in their daily lives.

# Every rock tells a story

If only rocks could talk! They would have so much to say. They would tell us about the Earth's history — about prehistoric creatures whose fossils lie within them, about explosive volcanoes, earthquakes, about flooded rivers that washed them away and about what it is like inside the Earth.




Although rocks can't talk, geologists are able to use them to answer questions such as:

- What did the first humans on Earth eat?
- How has the Earth's climate changed over millions of years?
- What caused the extinction of the dinosaurs?

The clues lie in the appearance of the rocks, how they feel and the different layers of rock beneath the Earth's surface. There are also clues in fossils. A **fossil** is evidence of living things preserved in rocks.

## Layers of clues

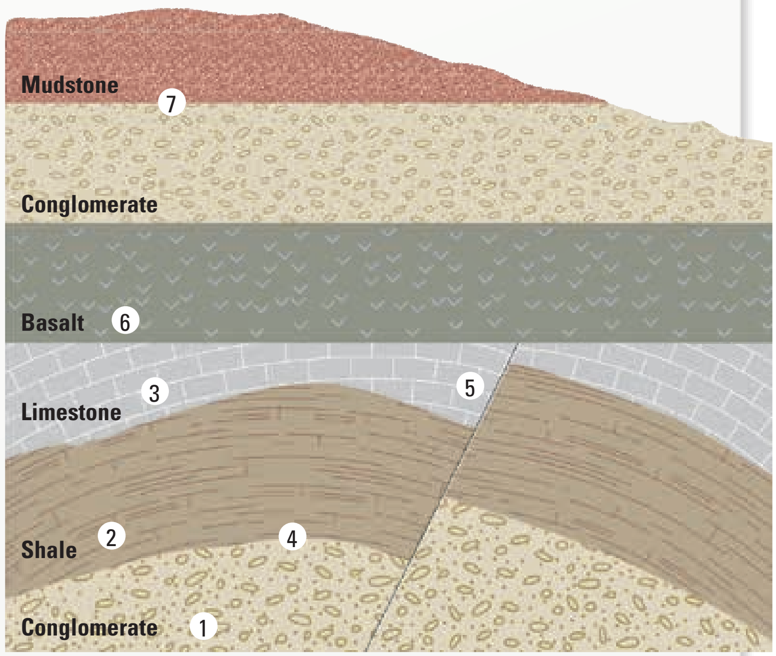
Over very long periods of time, rivers change their course, mountains form where seas once existed and the climate changes. As these changes take place, different layers of sediment can be deposited at the same location. Some layers will be thicker than others. Sedimentary rocks, which are formed by the different layers of sediments, provide many clues about the order in which events took place. Sudden events, such as erupting volcanoes or earthquakes, are also recorded in the layers.

Slow movements caused by the forces beneath the surface can tilt, curve and push up the layers. Weathering and erosion can expose some layers that were below the ground millions of years ago.

## It's all relative

Fossils provide a way of finding out how living things have changed over time. Evidence of the very oldest living things is buried within the deepest and oldest layers of rock. Scientists who study fossils are called **palaeontologists**.

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, such as 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 marine 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 — such as a very fast-flowing river.



Fossils provide clues about life in the past. This is a fossil of an ancient reptile.

By comparing fossils found in rocks in different areas, including different continents, it is possible to compare the **relative age** of rocks throughout the world. The relative age of a rock simply indicates whether it was formed before or after another rock. In any particular location it is almost certain that a layer of sedimentary rock is older than the rocks above it and younger than those below it. The relative ages of some igneous rocks and metamorphic rocks can be determined in the same way. It can also be assumed that the fossils in lower layers are older than those in the layers above.

## How fossils form

The remains of most animals and plants decay or are eaten by other organisms, leaving no trace behind. However, if the remains are buried in sediments before they disappear, they can be preserved, or fossilised. Fossils can take several forms.

### Hard parts

The hard parts of plants and animals are more likely to be preserved than the softer parts. Wood, shells, bones and teeth can be replaced or chemically changed by

These insects were trapped in the resin of a tree millions of years ago.

**INVESTIGATION 9.7**

### Making a fossil

**AIM** To model the formation of a fossil

***Materials:***
*small seashell*
*fine sand*
*small box (shoebox or milk carton)*
*plaster of Paris*

**CAUTION** Do not put plaster of Paris down the sink.

**METHOD**

- Half-fill the box with fine, damp sand.
- Make a clear imprint of a small seashell in the sand.
- Mix some plaster of Paris and pour it carefully into the imprint.
- Once the plaster has set, remove the plaster cast carefully from the sand.

You have two records of the seashell — the mould or imprint in the sand and the plaster cast.

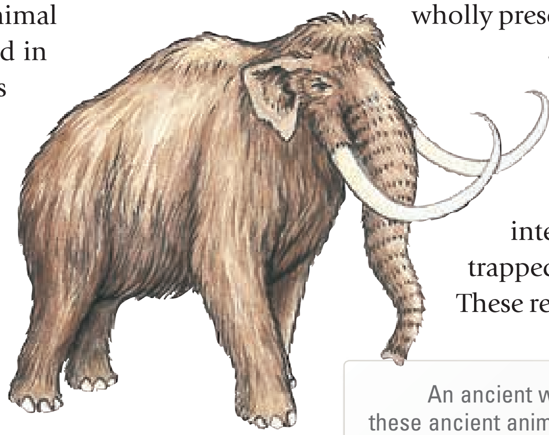
**DISCUSS AND EXPLAIN**

1. Which parts of animals are most likely to be preserved as casts?
2. Is the fossil of a fern leaf more likely to be found as a cast or a mould? Why?
3. Dinosaur fossils are found in casts and moulds. What evidence of dinosaurs is likely to be found as a mould?

minerals dissolved in the water that seeps into them. Fossils formed in this way are the same shape as the original remains but are made of different chemicals; petrified wood is an example. Animal bones and shells can be preserved in sediments or rock for many years without changing. The types of bones, shells and other remains found in the layers of sedimentary rock provide clues about the environment, behaviour and diets of ancient animals.

## Whole bodies

Sometimes, fossils of whole organisms, including the soft parts, are preserved. Such fossils are rare and valuable. Insects that became trapped in the resin of ancient trees (the fossilised resin is called amber) have sometimes been wholly preserved. Similarly, if the remains of animals or plants are frozen and buried in ice, they can be fully preserved. Whole bodies of ancient woolly mammoths (including skin, hair and internal organs) have been found trapped in the ice of Siberia and Alaska. These remains provide clues to the way in



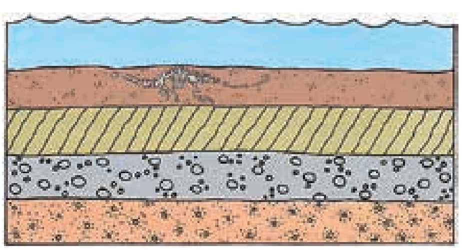
An ancient woolly mammoth. Whole bodies of these ancient animals have been discovered in the ice of Siberia and Alaska.



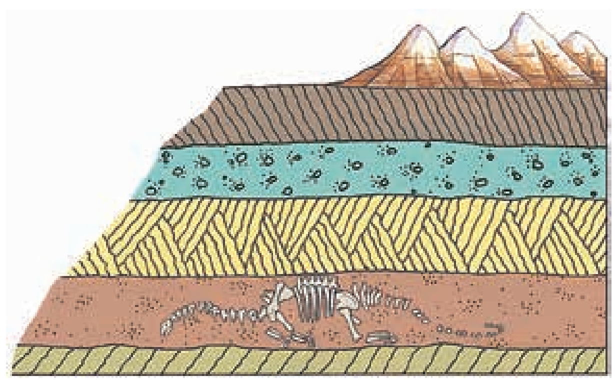
## DINOSAURS PRESERVED IN ROCK

1. After the death of a dinosaur, its body would usually be eaten by meat-eating animals (**carnivores** or **scavengers**). Its bones would be crushed or weathered, leaving no remains. If, however, the remains of a dinosaur were buried in sediment, the bones could be preserved.

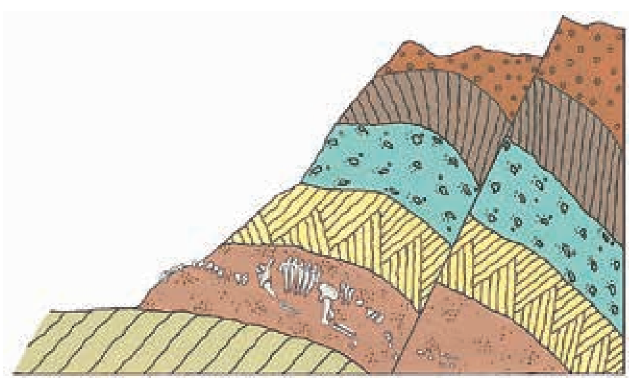
2. If a dinosaur died near a muddy swamp, shallow lake or riverbed, its remains sank in the mud or were washed into a river in a flood. The bones were quickly buried in sediment.



3. Over millions of years, more layers of sediment were deposited on top of the buried remains. Chemicals dissolved in the water that seeped into the remains changed their colour and chemical composition. The shape, however, was preserved. The sediments were gradually transformed into sedimentary rock.



4. The layers of rock containing the fossilised remains were pushed upwards, bent and tilted by forces beneath the Earth's surface. Weathering and erosion by the wind, sea, rivers or glaciers might expose one or more of the bones or teeth. If the exposed fossils were discovered before being buried again, palaeontologists might discover the remains.



which living things have changed since ancient times. Whole bodies and preserved skulls of animals can even reveal evidence of their last meal before death.

### Making an impression

The remains of animals or plants sometimes leave an impression, or imprint, in hardened sediments or newly formed rock. It is also possible for remains trapped in rock to be broken down by minerals in water, leaving a **mould** in the shape of the organism.

### Just a trace

Some fossils, called **trace fossils**, provide only signs of the presence of animals or plants. For example, footprints preserved in rock can provide clues about ancient animals, including dinosaurs, and how they lived. By studying the shape, size and depth of footprints, hypotheses can be made about the size and weight of **extinct** animals as well as how they walked or ran. Plant, leaf and root imprints, and feather impressions are other examples of trace fossils.

## Delving into dinosaurs

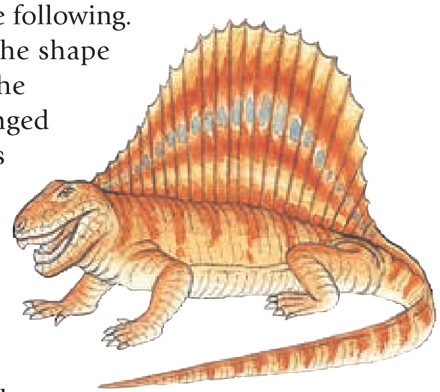
It is about 65 million years since the last non-flying dinosaurs existed on the Earth.

- What did they look like?
- What colour were they?
- How fast could they move?
- How did they behave?
- What did they eat?

Palaeontologists use fossils to try to answer all of these questions and more!

### Not just a pile of bones

Dinosaur fossils are not all bones. They may include the following.



- Fossilised teeth: The shape of the teeth and the way they are arranged provide vital clues about the diets of dinosaurs. Flat-surfaced grinding teeth would have belonged to a dinosaur with a plant diet. When fossilised teeth like these are examined under a microscope, scratches caused by the grinding of the teeth are sometimes visible. Sharp-pointed teeth suited to tearing flesh would have belonged to a meat-eating dinosaur.
- Footprints: Dinosaur footprints are often preserved in rock. Footprints from a single dinosaur provide clues about its size and weight. They also indicate whether the dinosaur walked on two legs or four, and how its weight was spread. The distance between footprints enables palaeontologists to estimate how fast the dinosaur moved. Footprints also provide clues about the behaviour of dinosaurs and whether they lived in herds or alone.
- Impressions of skin may be left in mud that has hardened.

The imprint of the leaf of an ancient fern left in stone is a trace fossil.

## UNDERSTANDING AND INQUIRING

### REMEMBER

1 A road cutting reveals the layers of rock shown in the diagram below. Which of the rocks in the cutting is:
(a) the oldest rock?
(b) the youngest rock?
(c) evidence of volcanic activity?

2 Explain why some layers of sedimentary rock are tilted, even though the sediments that formed them were laid in horizontal beds.

3 What does a palaeontologist study?

4 What clues about life in the past do fossils provide?

5 Under what circumstances can whole ancient living things be preserved as fossils?

6 Describe trace fossils and how are they useful.

7 What is the difference between a cast and a mould?

8 List the information about dinosaurs that can be obtained from fossils.

9 Fossils of dinosaurs form when their remains are buried under many layers of rock. Explain why fossils are often discovered in rocks and soil on the surface.

### THINK

10 In which rocks shown in the diagram below would you be most likely to find the fossil of:
(a) a seashell
(b) the leaf of a fern usually found in swamps?

11 Why are some layers in the diagram below thicker than others?

12 Explain why the hard parts of plants and animals are more likely to be preserved than the softer parts.

13 Explain how it is possible to use preserved dinosaur footprints to form hypotheses about:
(a) whether dinosaurs lived alone or in herds
(b) the way that dinosaurs walked
(c) the weight of different kinds of dinosaurs
(d) the walking or running speed of dinosaurs.

### CREATE AND EXPLORE

14 Use plasticine to construct a sample of sedimentary rocks. Apply a gentle force to the sides of the layers. Describe how the layers fold under gentle pressure.

### INVESTIGATE

15 Find out how the actual age of a rock in years is determined. This actual age is known as the absolute age.

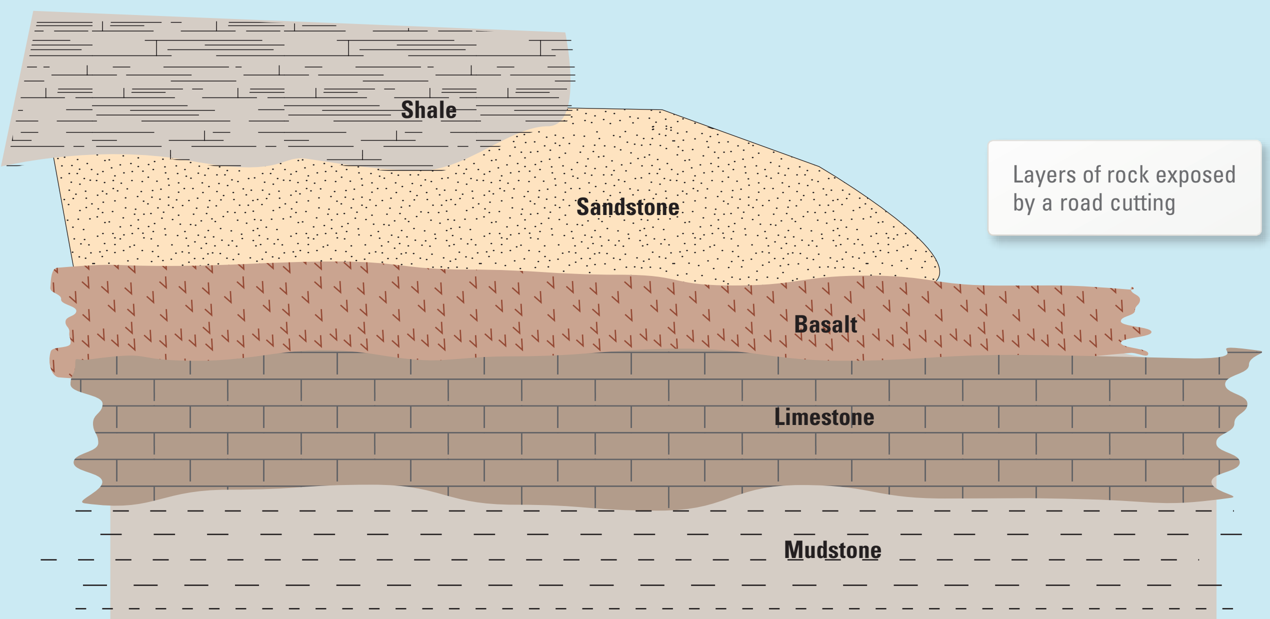
16 Even an animal's droppings can become fossilised. Use the internet or books to research and report on the following.
(a) Which animal was responsible for a huge fossilised dropping found in Canada in 1998?
(b) How long was the dropping?
(c) What can palaeontologists find out from it?

17 Use the **Australian Museum** weblink in your eBookPLUS or other resources to report on a major Australian fossil site where palaeontologists are working or have worked to increase our knowledge of ancient life.

eBook*plus*

18 Rate the rock formations in order from the oldest to the most recent with the **Relative age of rocks** interactivity in your eBookPLUS. **int-0233**

work sheet 9.6 Tracking changes in the rock




Layers of rock exposed by a road cutting

# Questioning and predicting

Two of the inquiry skills that geologists and other scientists use are questioning and predicting. The question of how the dinosaurs died out has intrigued scientists for many years. In answering this question, scientists use scientific knowledge to make 'predictions' about what happened many millions of years ago.



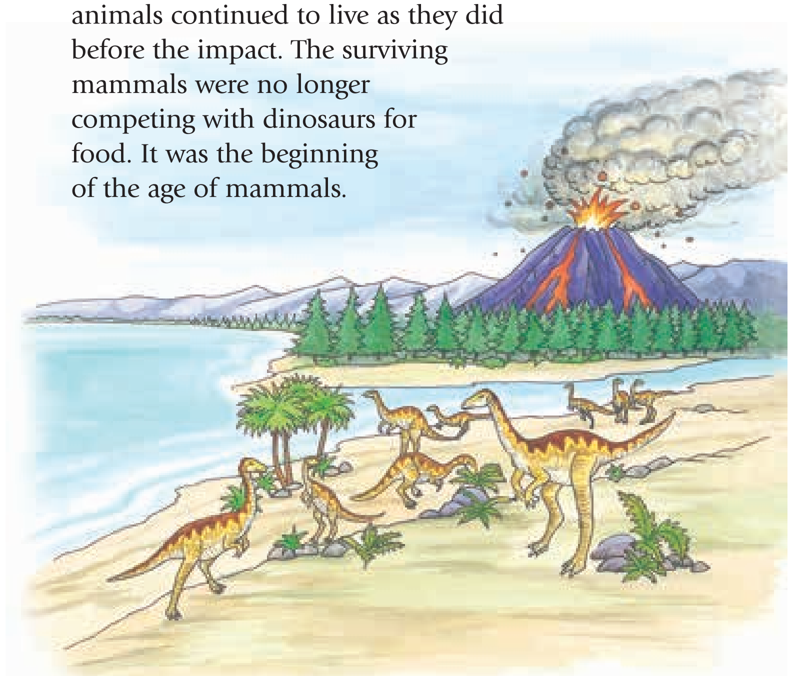
## Solving the dinosaur riddle

Between about 250 million and 65 million years ago, dinosaurs were the most successful animals on Earth. In fact, those years are known as 'the age of the dinosaurs'. Dinosaurs thrived and dominated the land while mammals lived in their shadow. Fossil evidence indicates that the last of the dinosaurs died about 63 million years ago. There are several theories about the extinction of the dinosaurs. Scientists and others argue about whether the end of the dinosaurs was sudden or gradual. Scientists do generally agree that the riddle of the dinosaur extinction remains unsolved. Palaeontologists and other scientists continue to look for clues that might provide the final solution.

### The asteroid theory

The most widely accepted solution to the dinosaur riddle is that an asteroid collided with the Earth around 65 million years ago. The asteroid's impact threw billions of tonnes of dust into the air, blocking out sunlight and plunging the Earth into darkness for two or three years. Plants stopped growing but their seeds remained intact. The temperature dropped. The large plant-eating dinosaurs would have died quickly of starvation. The meat-eating dinosaurs would probably have died next, having lost their main food supply but surviving for a while by eating smaller animals. Many smaller animals would have survived by eating seeds, nuts and rotting plants.

As the debris began to settle and sunlight filtered through the thinning dust clouds, many of the plants began to grow again. The surviving animals continued to live as they did before the impact. The surviving mammals were no longer competing with dinosaurs for food. It was the beginning of the age of mammals.



### The volcano theory

The eruption of Mount Pinatubo in the Philippines in June 1991 showed that ash and gases from volcanoes could reduce average temperatures all over the world. The average global temperatures during 1992 and 1993 were almost 0.2 °C less than expected. While this is not a large drop in temperature, the size of the eruption of Mount Pinatubo was very much smaller than those of many ancient volcanoes.

The ash from a large volcano could have the same effect on sunlight and the Earth's temperature as an asteroid impact. If there was an unusually large amount of volcanic activity about 65 million years ago, the extinction of the dinosaurs could be explained. The largest known volcanic eruption occurred about 250 million years ago in what is now Siberia. It is believed that many types of marine animals became extinct at about the same time.

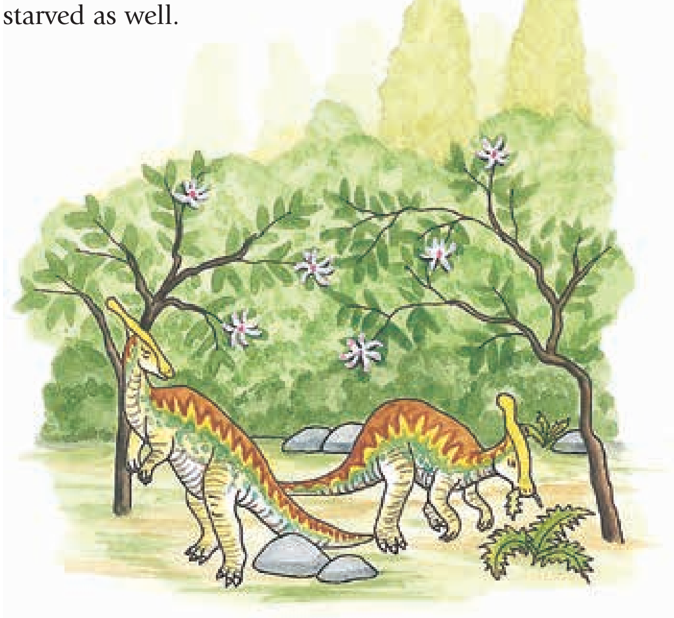
### The cooling climate theory

The gradual cooling of the Earth's climate due to changes in the sun's activity could have caused the extinction of the dinosaurs.

Dinosaurs, with no fur or feathers, had less protection from cold weather than mammals and birds. The larger dinosaurs would have found it very difficult to shelter from the cold conditions. Many smaller animals could burrow below the ground or shelter in the hollow trunks of trees or in caves. Many mammals and birds would have been able to migrate to warmer regions closer to the equator.

## The emerging plants theory

During the Cretaceous period (140 million to 65 million years ago), new types of plants began to appear. Flowering plants evolved, competing with the more primitive plants such as ferns for nutrients, water and sunlight. The plant-eating dinosaurs did not eat flowering plants. According to this theory, as their traditional food supply became more scarce, the plant-eating dinosaurs could not survive, and the meat-eating dinosaurs that preyed on them starved as well.



## Cold-blooded or warm-blooded?

Until recently, it was believed that dinosaurs were **ectothermic**. Ectothermic animals have body temperatures that depend on the temperature of their surroundings. As the surrounding temperature decreases, their body temperature decreases and they become less active.

Mammals are **endothermic**. Endothermic animals are able to maintain a constant body temperature that is usually above that of their surroundings. They are able to remain warm and active in lower surrounding temperatures.

If dinosaurs were in fact ectothermic, a cooler climate would have made it more difficult for them to compete with other animals for food. However, many scientists now believe that dinosaurs may have been endothermic.

The question of whether dinosaurs were cold-blooded or warm-blooded needs to be answered before the riddle of the dinosaurs can be solved.

### UNDERSTANDING AND INQUIRING

#### REMEMBER

1 What is the most widely accepted theory about the extinction of the dinosaurs?

2 Why would smaller animals be more likely to survive the effects of an asteroid impact or large volcanic eruption than larger animals?

3 What is the difference between an ectothermic animal and an endothermic animal?

#### THINK

4 In what ways were the dinosaurs different from mammals?

5 How could volcanic eruptions affect life throughout the whole world?

6 How could meat-eating dinosaurs be endangered by the evolution of new types of plants?

7 Which group of animals benefited the most as a result of the extinction of the dinosaurs?

8 List as many weaknesses as you can in each of the four theories about the dinosaur extinction presented.

9 Which theory of the extinction of the dinosaurs do you think is most likely to be correct? Explain your answer.

#### IMAGINE

10 Imagine what it would have been like 65 million years ago if an asteroid plunged into the Earth. Write a story about the first 24 hours after the impact.

11 Which animals and plants do you think would be most likely to survive if an asteroid struck central Australia now? Explain your answer.

# STUDY CHECKLIST

## CLASSIFYING ROCKS

- ☐ describe the formation of igneous rocks
- ☐ distinguish between extrusive and intrusive igneous rocks
- ☐ explain how cooling rate affects crystal size
- ☐ describe the formation of sedimentary rocks
- ☐ explain the role of water in the formation of many sedimentary rocks
- ☐ identify a range of sedimentary rocks using a key based on observing physical and chemical properties
- ☐ describe the roles of heat and pressure in the formation of metamorphic rocks
- ☐ identify the cyclic nature of the formation of igneous, sedimentary and metamorphic rocks
- ☐ outline the uses of igneous, sedimentary and metamorphic rocks, including as building materials

## MINERALS

- ☐ recall that all rocks are made of substances called minerals
- ☐ describe the physical properties of a variety of minerals
- ☐ recognise that the minerals in some rocks provide valuable resources
- ☐ describe the processes involved in mining mineralores

## READING THE EARTH'S HISTORY IN ROCKS

- ☐ explain how layers of sedimentary and other rocks, together with fossils, reveal information about past environments and life on Earth
- ☐ use geological cross-sections to interpret simple geological histories
- ☐ outline the use of fossil evidence for investigating dinosaurs and their behaviour

## SCIENCE INQUIRY SKILLS

- ☐ examine evidence in order to evaluate the theories about the extinction of the dinosaurs

## SCIENCE AS A HUMAN ENDEAVOUR

- ☐ explain how the expertise of scientists and engineers is used in mineral exploration, the extraction of mineral ores and metals, and the rehabilitation of mining sites
- ☐ describe some examples of the use of traditional rock technology in the daily lives of Aboriginal and Torres Strait Islander peoples
- ☐ discuss the environmental and community issues associated with the mining of mineral resources



# eBook*plus* DIGITAL RESOURCES

**ANSWERS** for this chapter can be found online in your eBookPLUS.

## Online section

This section of the chapter can be found online in your eBookPLUS.

9.9 Fishbone diagrams and tree maps (eBook*plus* ONLINE ONLY)

## Individual pathways

| Activity 9.1 | Activity 9.2 | Activity 9.3 |
|---|---|---|
| Investigating rocks and minerals<br>doc-6057 | Analysing rocks and minerals<br>doc-6058 | Investigating rocks and minerals further<br>doc-6059 |

**FOCUS activity**

**Access more details about focus activities for this chapter in your eBookPLUS.**

doc-10564

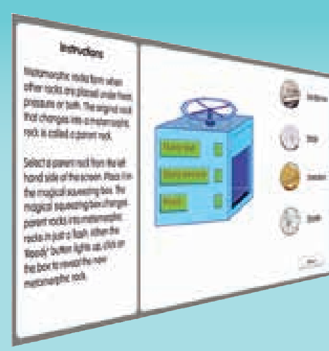
## eLesson

**Volcanoes**

In this eLesson you will learn how volcanoes are formed, what happens when they blow their tops and how volcanic eruptions change the face of the Earth.

**Searchlight ID: eles-0130**

## Interactivities



**Metamorphic rocks**

Metamorphic rocks form when other rocks are placed under heat, pressure or both. The original rock that changes into metamorphic rock is called a parent rock. This interactivity enables you to apply heat or pressure to a series of rocks and watch them change.

**Searchlight ID: int-0234**

**Relative age of rocks**

This interactivity tests your knowledge of how rocks are formed. Arrange a series of rock formations in order from the oldest to the most recent. Instant feedback is provided.

**Searchlight ID: int-0233**

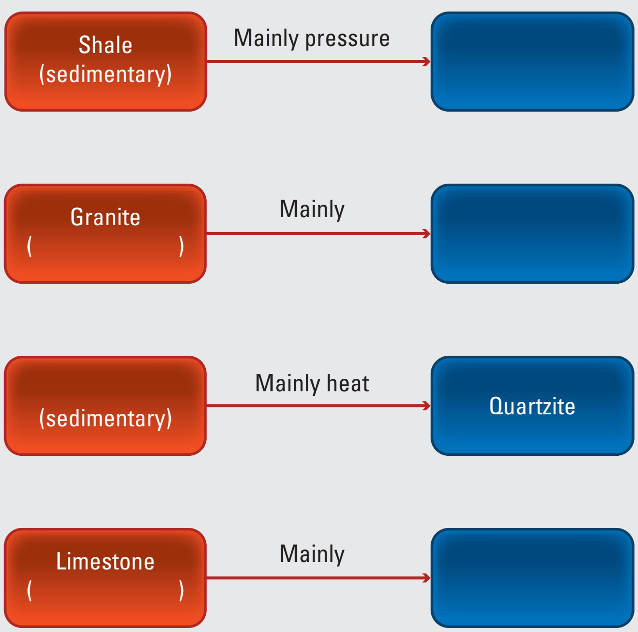
# LOOKING BACK



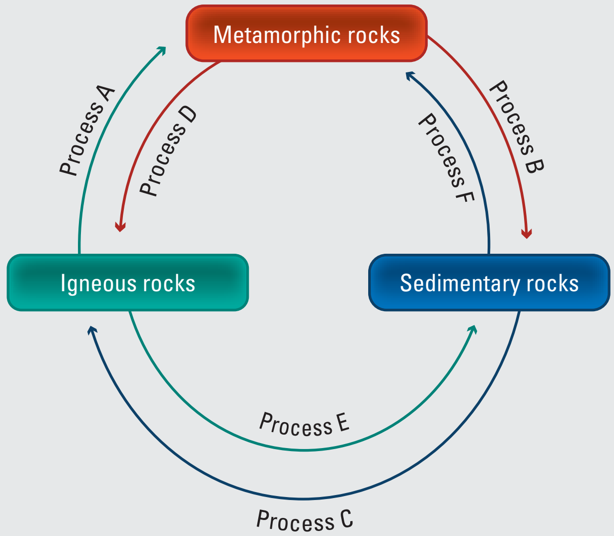
1. In which parts of the Earth are rocks formed?
2. How are all igneous rocks formed?
3. Explain the difference between the ways in which extrusive igneous rocks and intrusive rocks are formed.
4. List three examples of extrusive igneous rocks.
5. What clues does the size of the crystals in an igneous rock provide about how the rock was formed?
6. What are sediments?
7. Describe the three different ways in which sedimentary rocks can be formed.
8. Suggest a way of checking that a rock sample that appears to have seashells embedded in it is limestone.
9. Explain why some layers of sedimentary rocks are tilted or bent.
10. While studying sedimentary rocks in a railway cutting, a geologist discovers a bed of rock with ripple marks in its surface. How could the ripple marks have been made in the rock?
11. Describe two ways in which igneous and sedimentary rocks can be transformed into metamorphic rocks.
12. What is a parent rock?
13. Copy and complete the table below to summarise what you know about igneous, sedimentary and metamorphic rocks.

| Type of rock | How it is formed | Special features | Example | Uses |
|---|---|---|---|---|
| Igneous | | | | |
| Sedimentary | | | | |
| Metamorphic | | | | |

14. Copy and complete the diagram below to show how some common metamorphic rocks are formed.




15. The changes that lead to the formation of the three main groups of rocks can be drawn as a cycle, as shown below.




Which of processes A–F involve:
(a) weathering and erosion
(b) heat and pressure
(c) remelting?

16. Explain why the crystals in granite are larger than those in basalt.
17. What characteristic of minerals do the following terms describe?
(a) Lustre
(b) Streak
(c) Hardness
18. What property of minerals does Mohs' scale provide an approximate measure of?
19. If you were given a sample of each of two different minerals, how could you tell which one had the greater hardness?
20. Which sedimentary rock was the most important material for toolmaking in the Stone Age? What properties made it so useful?
21. In the Stone Age, tools were made by a process called percussion flaking.
(a) Describe the process of percussion flaking.
(b) Which property of the rock used to make the tool must be different from those of the stone from which the tool is formed?
22. What is the most common element in the Earth's crust and where is it found?
23. One factor that determines the way in which mineral ores are mined is their depth. Compare the mining processes used for mineral ores located near the Earth's surface with those used for mineral ores located deeper in the Earth's crust.

This dinosaur footprint has been preserved in rock for hundreds of millions of years at Gantheaume Point near Broome.



24 According to many geologists, parts of Antarctica are rich in mineral resources, similar to those found in Australia. Use a two-column table to list reasons why these mineral resources should be mined and why they should not be mined.

25 The mining industry provides employment for many Australians. Make a list of occupations that are involved in the mining industry. (*Hint*: Think about what happens before, during and after mining is undertaken.)

26 Imagine that the set of fossilised dinosaur footprints shown in the illustration below were found in a layer of sedimentary rock.
(a) Use the footprints to write a description of what might have happened millions of years ago.
(b) Compare your interpretation of the footprints with others.
(c) Does each person interpret the evidence in the same way?
(d) If there are differences of opinion about what happened, is there any way of knowing who is right?
(e) List as many differences as you can between the two types of dinosaurs making these footprints.

27 Not all fossils are the actual remains of living things. Name and describe two types of fossils that are not preserved remains.

28 Normally, old layers of rock are found below younger layers. Sometimes, however, younger layers are found beneath older layers. Explain how this could happen.

29 The photograph above is of dinosaur footprints that have been preserved in rock at Gantheaume Point near Broome
(a) What type of fossil is it?
(b) Why is it classified as a fossil even though it could be described as a dent in a rock?
(c) Have all dinosaur footprints been preserved? Why have these been preserved for hundreds of millions of years?
(d) What can be learned about the features of the dinosaur that left these footprints?
(e) What forms of evidence, apart from preserved footprints, can be used to gather knowledge about dinosaurs?

work sheet 9.7 Summing up