

PEARSON  
**Science**

STUDENT BOOK | VICTORIA

8



# TOPIC 5

## The rock cycle

Earth's surface is dynamic and has changed many times over the millennia. It has been shaped by the movement of the tectonic plates under Earth's surface and by the movement of wind and water. The rocks you see around you were once part of larger rock formations that have also changed in a continuous cycle over thousands of years.

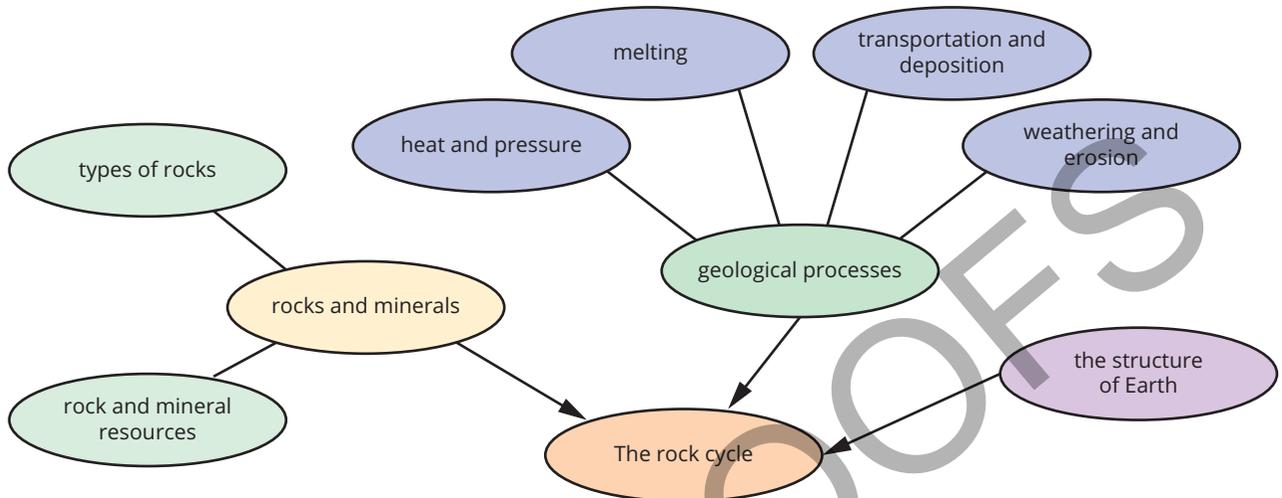
In this topic you will learn about the structure of Earth, the different types of rocks on Earth and how they are formed, how rocks change as part of the rock cycle and how the mining of mineral resources impacts Australian society.

### Learning intentions

- To understand the internal structure of Earth **xx**
- To understand how rocks on the surface of Earth can change **xx**
- To be able to investigate physical and chemical weathering **xx**
- To understand the formation of sedimentary rocks **xx**
- To be able to investigate how advances in deep Earth imaging has enabled identification of resources in sedimentary rock **xx**
- To understand the formation of igneous rocks **xx**
- To understand the formation of metamorphic rocks **xx**
- To be able to investigate the source of metamorphic rocks **xx**
- To understand how environmental changes affect the rock cycle **xx**
- To be able to explain how the mining of Australian mineral resources influences/impacts society **xx**

# The rock cycle

The key concepts that you will use in this topic:



The following prior knowledge questions will help to support your learning in the topic and can be attempted before the first lesson.

## Structure of Earth

- 1 List Earth's four main layers.
- 2 Describe how temperature and pressure change from Earth's surface to Earth's centre.

## Geological processes

- 3 Compare the processes of weathering and erosion.
- 4 Describe three types of weathering.
- 5 How do intrusive igneous rocks differ from extrusive igneous rocks?

## Rocks and minerals

- 6 There are three types of rocks. What type is formed by:
  - a melting and solidification of magma and lava
  - b deposition, compaction and cementation of eroded material
  - c high heat and/or high pressure conditions?
- 7 Name five rock and mineral resources that humans extract from Earth.

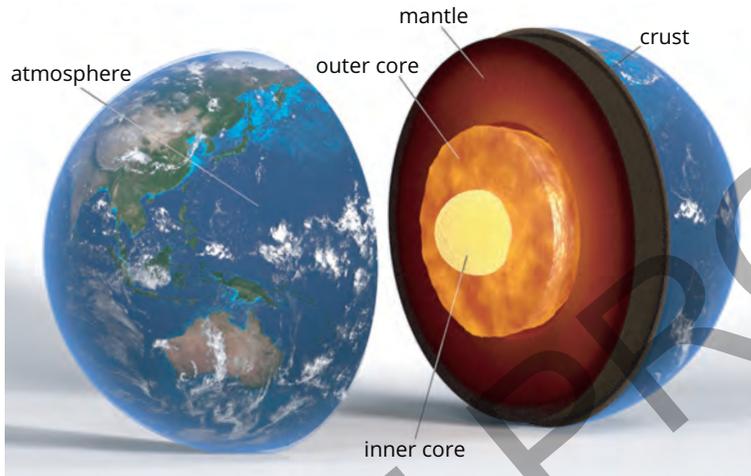
# 5.1 Structure of Earth

## Lesson overview

Earth is not a solid uniform mass. Instead, it is made up of different layers that have different properties. In this lesson you will learn about Earth's structure and its layers and how heat energy is distributed throughout Earth.

**SC 1** I can identify the different layers of Earth

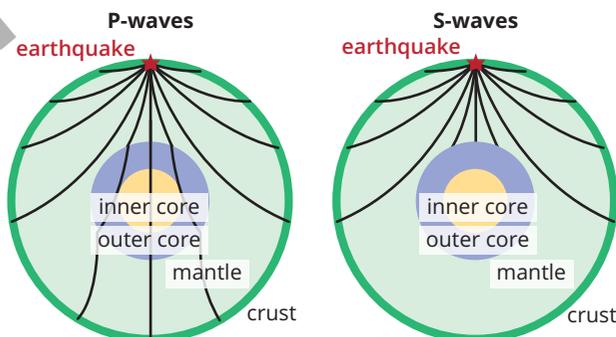
The structure of Earth consists of four main sections: the crust, the mantle, and the outer and inner core. Figure 5.1.1 shows how these layers are arranged.



**FIGURE 5.1.1** The four layers of Earth

Earth was formed approximately 4.5 billion years ago. Over time, the internal structure of Earth became made up of a solid inner core, a liquid outer core, a solid but fluid hot mantle, and a solid rock crust. The liquid outer core is responsible for Earth's magnetic field.

Scientists know about the composition of Earth's internal layers because of the behaviour of earthquake waves (P-waves and S-waves) as they travel through Earth. P-waves travel at different speeds through solids and liquids. S-waves are not able to travel through liquids at all (Figure 5.1.2).



**FIGURE 5.1.2** Earthquake P-wave and S-wave paths through Earth

### Learning intention

To understand the internal structure of Earth

### Success criteria

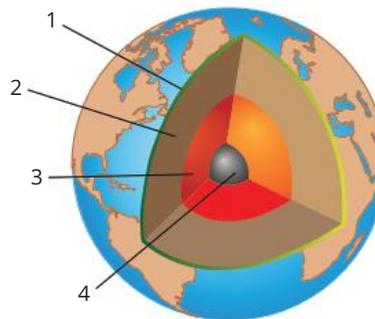
**SC 1:** I can identify the different layers of Earth.

**SC 2:** I can describe the layers of Earth's internal structure.

**SC 3:** I can describe the distribution of heat energy within the internal structure of Earth.

## SC 1 CHECK YOUR UNDERSTANDING

Refer to the diagram below showing the internal structure of Earth.



- Identify each of Earth's layers (numbered 1 to 4).
- For the two innermost layers, state whether they are solid or liquid.

## SC 2 I can describe the layers of Earth's internal structure

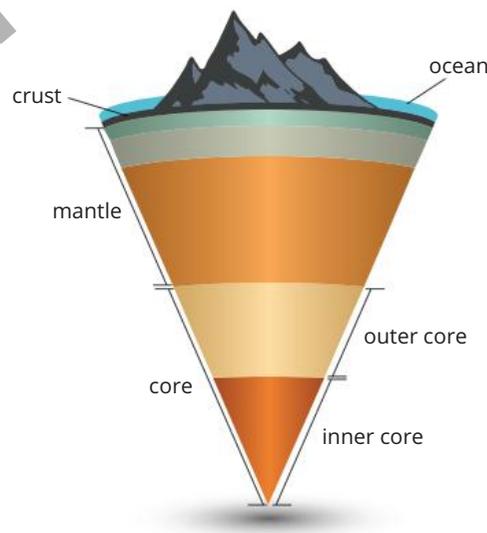
Each layer of Earth is different.

### Crust

The outermost layer of Earth is the **crust** (Figure 5.1.3). The crust is solid and very thin compared to the other layers. Its thickness varies from 7 kilometres beneath the oceans, to 30 or more kilometres beneath the continents. It is composed mostly of oxygen, silica and aluminium.

#### KEY TERMS

**crust** the outermost layer of Earth, composed of solid rock  
**mantle** solid layer of Earth between the crust and the outer core



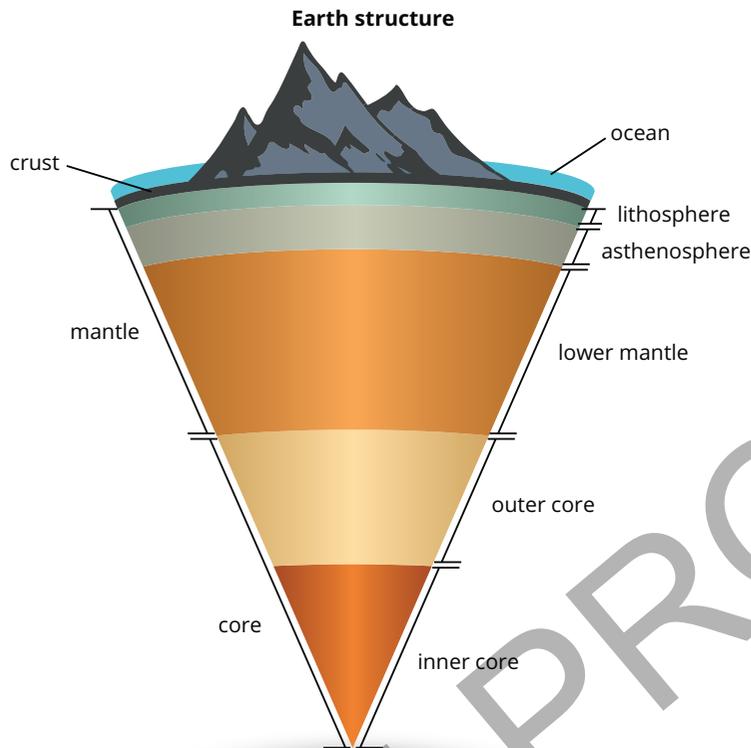
**FIGURE 5.1.3** Structure of Earth showing the crust, mantle, inner core and outer core

### Mantle

The **mantle** is the layer underneath the crust. It is much hotter than the crust, and the composition of this layer changes as it gets deeper. The mantle consists mainly of oxygen, silica and magnesium.

The uppermost solid layer of the mantle combines with the crust to create Earth's rigid outer shell called the **lithosphere** (Figure 5.1.4).

The **asthenosphere** is near the top of the mantle (Figure 5.1.4), just below the solid lithosphere, and it contains rock that can move very slowly. This rock is described as behaving plastically because it can bend or change shape under pressure, like plasticine, without breaking.



**FIGURE 5.1.4** The mantle is divided into the lithosphere, asthenosphere and lower mantle.

However, in the deepest part of the mantle (the lower mantle) the rock flow is also slow, but these rocks are rigid and break under pressure (Figure 5.1.4).

## Outer core

The **outer core** is liquid (Figure 5.1.4). It is believed to consist of iron and nickel.

## Inner core

The **inner core** of Earth (Figure 5.1.4) is also believed to consist of iron and nickel. It is so dense and the pressure so great inside the inner core that the iron and nickel do not melt.

### SC 2 CHECK YOUR UNDERSTANDING

How does Earth's outer core differ from:

- the inner core
- the mantle?

#### KEY TERMS

**lithosphere** name for the crust and the upper mantle together; Earth's tectonic plates

**asthenosphere** near the top of the mantle, just below the solid lithosphere, and it contains rock that can move very slowly

#### Scifile

##### Earth's deepest hole

The deepest hole ever drilled by humans is the Kola Superdeep Borehole in Russia. It is about 12 kilometres deep – that's not even halfway through Earth's crust! The attempt to reach the mantle had to stop after 20 years when the temperature in the crust reached 180°C – far too hot for the drilling equipment.

#### KEY TERMS

**outer core** a liquid layer of Earth's interior, primarily composed of liquid iron and nickel; located beneath the solid mantle and surrounds the inner core

**inner core** extremely hot, solid ball made of iron and nickel at the very centre of Earth

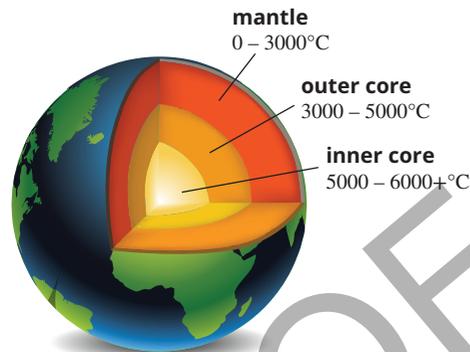
**SC 3** I can describe the distribution of heat energy within the internal structure of Earth

**KEY TERMS**

**primordial** something that originated during the planet's formation process a very long time ago

**geothermal energy** the heat energy that comes from within Earth

The inner core of Earth is very hot with a temperature ranging from 5000 to over 6000 degrees Celsius ( $^{\circ}\text{C}$ ) (Figure 5.1.5). The heat is generated from radioactive decay and **primordial** heat from when Earth was formed. The solid core is so dense, and the pressure inside the core so great, that it does not melt.



**FIGURE 5.1.5** Estimated temperatures within Earth's three interior layers

The outer core is liquid, and it is the movement of this liquid that helps distribute heat to the mantle and Earth's crust. Heat flows from warmer objects to cooler objects, so the heat from the warmer core is transferred to the cooler mantle and crust.

Heat energy that is generated within Earth is known as **geothermal energy**. It is geothermal energy that produces hot springs and geysers at Earth's surface (see Figure 5.1.6).



**FIGURE 5.1.6** Geothermal energy produces hot springs and geysers at the surface near volcanoes at El Tatio in Chile.

**SC 3 CHECK YOUR UNDERSTANDING**

Why does heat makes its way from the inner core to the mantle and crust?

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

- 1 Explain the location of Earth's mantle in relation to the other layers.
- 2 Describe how the behaviour of different types of earthquake waves have allowed scientists to determine Earth's internal structure.
- 3 If scientists discovered a new layer between the lower mantle and the outer core, what properties might you expect this layer to have?
- 4 Identify the layers of Earth which have the following characteristics.
  - a generates Earth's magnetic field
  - b contains the asthenosphere
  - c has the main elements of nickel and iron in a solid state
  - d does not allow the passage of earthquake S-waves
  - e composed of solid rock with thickness ranging from 7 to 50 kilometres
  - f contains material at the hottest temperature and highest pressure
  - g consists mostly of oxygen, silica and aluminium
  - h contributes to the rigid outer shell of Earth known as the lithosphere
- 5 Outline two sources of heat within Earth's internal structure.
- 6 Explain why geysers and hot springs are found near volcanoes.

## 5.2 Changes to rocks on the surface of Earth

### Lesson overview

When you look at a rock, you may not consider that the rock was originally part of a larger rock. The rocks you see in your garden, parks and at the beach were once part of a larger rock mass (Figure 5.2.1). These larger rock masses have changed over time, affecting their appearance and creating smaller rocks. In this lesson you will learn how and why rocks change and how this impacts the landscape.

**SC 1** I can describe different types of weathering

**Weathering** causes rocks to change and break down. There are three main categories of weathering.

### Physical weathering

**Physical weathering** (sometimes referred to as mechanical weathering) breaks rock into smaller pieces without changing its chemical composition. Physical weathering can happen in four ways.

- Wind can carry fine particles of rock which cause wear to the surface of other rocks as they blow past.
- If rocks expand and contract quickly due to a change in temperature, they may crack.
- Water entering rocks and expanding when it freezes can cause rocks to crack and break.
- When salt water evaporates, salts form crystals inside rocks. This process is called **crystallisation**. The crystals apply a force on the rocks which causes fractures and bits of rock to fall off.

Often, more than one of these processes can occur at the same time, contributing to the formation of unique landscape features, such as the fairy chimneys shown in Figure 5.2.2.



**FIGURE 5.2.2** Fairy chimneys, a unique landscape feature in Cappadocia (Türkiye), have been created through a combination of physical weathering processes.

### Learning intention

To understand how rocks on the surface of Earth can change

### Success criteria

**SC 1:** I can describe different types of weathering.

**SC 2:** I can describe, with examples from Australia, the difference between weathering and erosion.

**SC 3:** I can explain, with examples from Australia, the process of deposition and the land formations produced as a result.



**FIGURE 5.2.1** A large rock known as 'Eagle Rock' in Aireys Inlet, Victoria

### KEY TERMS

**weathering** the physical, chemical and biological processes that break rocks down into smaller pieces

**crystallisation** evaporation of a solvent from a solution, leaving solute behind as crystals



**FIGURE 5.2.3** The red colour of these rocks at Uluru is due to the presence of iron.



**FIGURE 5.2.4** These tree roots have pushed through cracks in the rocks and caused the rock to split.

#### KEY TERM

**erosion** the movement of weathered rock particles from the site of the weathering



**FIGURE 5.2.5** London Bridge, a natural arch limestone formation in coastal Victoria, has been formed by chemical weathering and erosion.



**FIGURE 5.2.6** Karlu Karlu (Devils Marbles) have formed as a result of rapid temperature changes (physical weathering) and erosion.

## Chemical weathering

**Chemical weathering** occurs when water dissolves chemicals from the surrounding soil and air. These chemicals may then react with a rock, causing it to crack or change.

Air contains oxygen and carbon dioxide. When these gases are dissolved in water, they can react with minerals in nearby rocks. These reactions may cause the rock to crumble or change colour on the surface.

Uluru is a well-known example of the process of chemical weathering. The original rock of Uluru is grey and called arkose. Water from the rain and oxygen in the air react with the iron in the rock to produce oxides of iron, which give Uluru its famous red colour (Figure 5.2.3).

## Biological weathering

**Biological weathering** is caused by moss, lichens, algae, and plant or tree roots forcing themselves through small cracks in rocks to create larger cracks (Figure 5.2.4). Biological weathering can even split the rock. Some plant roots can travel through rocks by releasing acids or an enzyme (a protein which speeds up chemical reactions) that softens the surrounding rocks.

### SC 1 CHECK YOUR UNDERSTANDING

Compare physical and chemical weathering in terms of their processes.

**SC 2** I can describe, with examples from Australia, the difference between weathering and erosion

Weathering weakens rocks and creates small rock particles, but **erosion** moves these particles elsewhere by the action or movement of gravity, ice, water or wind.

## London Bridge, Victoria

The limestone rock formation known as ‘London Bridge’ (Figure 5.2.5) is near the Great Ocean Road in south-west Victoria. It was originally connected to the mainland until the inner span collapsed in 1990. When it rains, limestone slowly dissolves due to a chemical reaction with the rainwater in a process of chemical weathering. The limestone is further weakened by physical weathering (action of wind and salt crystallisation). The movement of wind and water against rock, and gravity, causes small pieces of the rock to erode. Over time, this process has created natural arches or bridges, one of which has since collapsed.

## Karlu Karlu (Devils Marbles), Northern Territory

Karlu Karlu (or the Devils Marbles) (Figure 5.2.6) are giant granite boulders in the Northern Territory. They were formed by molten rock that became solid when it cooled underneath a layer of sandstone. Once this rock solidified, vertical and horizontal cracks appeared due to physical weathering, forming rectangular blocks. These blocks have since become rounded due to further rapid temperature changes. The ‘marbles’ appear to be stacked on top of each other as the sandstone surrounding the granite has been eroded.

## Tessellated Pavement, Tasmania

Tessellated Pavement in the Tasman Peninsula (Figure 5.2.7) is made of siltstone that was formed over 300 million years. The rocks fractured due to the movement of Earth. Over time, physical weathering from the crystallisation of salts inside the rock, and erosion by water (waves), have caused the pattern to deepen to form pans, contributing to its unique appearance.

### SC 2 CHECK YOUR UNDERSTANDING

Explain how weathering and erosion are different.

**SC 3** I can explain, with examples from Australia, the process of deposition and the land formations produced as a result

Erosion causes particles of rock to move to different places, and this movement ends when these particles are **deposited** and settle in an area. The particles settle in layers of materials called **sediments**. When the water, wind or ice that is transporting the particles of rock slows down, deposition occurs.

Examples of depositional landforms include coastal landforms such as beaches, deltas and sand dunes.

### Scifile

#### Fossil formation

Sediments that form sedimentary rocks often contain fossils. When plants and animals die, they can get buried by sediments. Eventually over millions of years, parts such as teeth, bones and leaves turn into body fossils. Trace fossils are those that are made by an organism or left behind, such as scat or footprints.

## Sand dunes

Sand dunes are formed as wind transports and then deposits individual grains of sand. Some grains are trapped by plants or are deposited in areas sheltered from the wind. As more and more sand accumulates, sand dunes are formed. Near beaches the dunes are held together by plants so they are fairly stable. In desert areas the dunes are constantly moving and changing (Figure 5.2.8).

## Spits

A **spit** is a depositional landform that forms along coastlines. Spits form when waves lose energy so that the material they carry (usually beach sand) is deposited. The deposited sediment builds up over time to form a long ridge connected to land at one end and jutting out into a water body (sea, ocean, river mouth) at the other.

Double Island Point in the Cooloola Region of Queensland is a rocky island connected to the mainland by the sand dunes of Teewah and Rainbow Beaches. On the northern side of Double Island Point is an extensive spit (Figure 5.2.9). The shape and size of the spit constantly changes depending on tides and ocean conditions. Large seas generated by cyclones can cause the spit to disappear entirely.



**FIGURE 5.2.7** Tessellated Pavement in Tasmania is a result of physical weathering (crystallisation) and water erosion.

#### KEY TERMS

**deposited** the settling of broken rock material to form sediment

**sediment** solid material that has broken down and moved because of erosion

**spit** stretch of beach material, connected to land and jutting out into the water



**FIGURE 5.2.8** Wind transports and deposits sand grains on Nappanerica (Big Red) on the edge of the Simpson Desert.

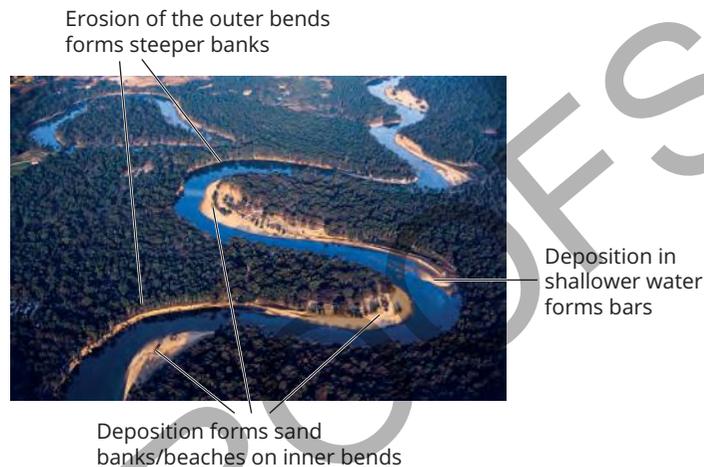


**FIGURE 5.2.9** The sand spit at Double Island Point with the extensive sand dune system of Rainbow Beach in the background

## Rivers

Rivers are shaped by both erosion and deposition. The Murray River meanders (follows a winding course) because it travels slowly across a plain (Figure 5.2.10). Sand and other sediments are deposited on the inside of its bends because that is where the river travels the slowest. On the outside of the bends, erosion can still occur as the water flows more rapidly.

Fast-flowing rivers can carry larger sediments, whereas slow-moving rivers can only carry smaller sediments. When the river stops flowing or water is very shallow, even the tiniest sediments settle on the riverbed and may form bars.



**FIGURE 5.2.10** Depositional and erosional features formed in the meanders of the Murray River

### SC 3 CHECK YOUR UNDERSTANDING

Describe how deposition occurs after erosion.

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

- 1 What are the three main types of weathering?
- 2 Compare physical and biological weathering in terms of their processes and effects on rocks.
- 3 In the desert regions of Australia, how might weathering and erosion work together to shape the landscape?
- 4 The Twelve Apostles are a famous limestone rock formation of sea stacks off the coast of Victoria. At the beginning of the 21st century there were nine. Two have since collapsed.
  - a Describe the role of weathering in the formation of the Twelve Apostles. Consider the type/s of weathering that has occurred.
  - b Explain how erosion has contributed to their current shape. Consider the main agents of erosion.
  - c Evaluate the long-term impacts of these processes on the remaining sea stacks.
- 5 Create a diagram to identify where one depositional feature and one erosional feature are likely to occur in the meanders of the Murray River.
- 6 Determine if erosion or deposition is the main factor contributing to the formation of each of the following landscape features:
  - a Fingal Spit off Fingal Beach in New South Wales
  - b Karlu Karlu (Devils Marbles) in Northern Territory
  - c Big Red sand dune in western Queensland
  - d Cottesloe Beach in Western Australia
  - e Tessellated Pavement in Tasmania
  - f London Bridge in Victoria
  - g Bunda Cliffs in South Australia

## 5.3 Weathering of rocks

### Introduction

Weathering is the process of rocks breaking down into smaller pieces. Weathering can occur because of physical, chemical and biological processes.

The rocks off the shore of Port Campbell National Park in Victoria (Figure 5.3.1) have been broken into separate rocks over thousands of years.

In this practical investigation you will investigate how chemicals and changes in temperature can cause the weathering of rocks.

### Background

Two types of weathering involve chemical or physical processes. Chemical reactions involve the creation of new substances. Physical processes involve changing the form of a substance and are easier to reverse than chemical processes.

### Aim

To investigate how ice and chemicals cause weathering

### Materials

- vinegar
- 2 small samples each of granite, limestone and sandstone (to fit in test tubes)
- 6 test tubes and a test-tube rack
- plaster of Paris
- 2 margarine containers or milk cartons
- small water balloon
- spoon or spatula
- rubber gloves

### Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

### Method

#### Part A: The effect of acid and water

- 1 Label your test tubes with numbers 1 to 6 (Figure 5.3.2).
- 2 Put small samples of granite into test tubes 1 and 2, limestone in test tubes 3 and 4, and sandstone in test tubes 5 and 6 as shown in the diagram.
- 3 Add water to test tubes 1, 3 and 5.
- 4 Add vinegar to test tubes 2, 4 and 6.

#### Learning intention

To be able to investigate physical and chemical weathering

#### Success criteria

**SC 1:** I can conduct a safe experiment to model and compare the weathering of rocks.

**SC 2:** I can use knowledge of weathering to explain observations.

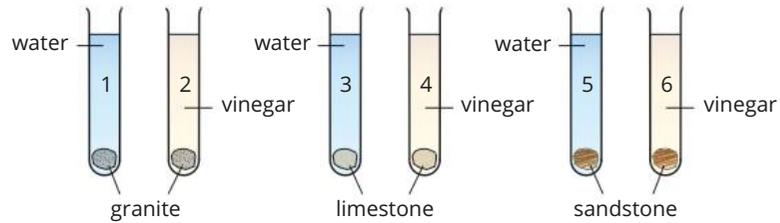
**SC 3:** I can analyse the effectiveness of an experiment as a representation of the weathering of rocks in the environment.



**FIGURE 5.3.1** Weathering and erosion have created the Twelve Apostles off the shore of Port Campbell National Park in Victoria

#### SAFETY NOTES

- ▶ Do not mix plaster with bare hands; mix with a spoon or spatula or use rubber gloves.
- ▶ Wear laboratory safety glasses and a dust mask when using dry plaster of Paris.



**FIGURE 5.3.2** Set-up of test tubes to investigate the effect of acid and water on three rock types

- 5 Leave the test tubes in the test-tube rack and record any observations. Leave them set up overnight or until your next science class.

## Part B: The effect of temperature

- 6 Mix up enough plaster with water to half-fill two margarine containers or cut-down milk cartons.
- 7 Fill a small balloon with water and tie it. Push the balloon into the plaster in one container and keep it below the surface so that it remains in the plaster after the plaster sets.
- 8 At the end of class, put both the margarine containers, or the cut-down milk cartons, in the freezer.

## Results

Copy the results tables below into your notebook and record your observations.

### Part A

Test tube	Rock	Liquid	Observations
1	granite	water	
2	granite	vinegar	
3	limestone	water	
4	limestone	vinegar	
5	sandstone	water	
6	sandstone	vinegar	

### Part B

Container	Observations
1 (without water balloon)	
2 (with water balloon)	

## Conclusion

- 1 Use the observations in Part A to explain the weathering of rocks by chemicals.
- 2 Use the observations in Part B to explain a possible effect of low temperatures on rocks.

## Evaluation

Evaluate how well this experiment models the weathering of rocks in the environment.

# 5.4 Sedimentary rocks

## Lesson overview

Sedimentary rocks are rocks made from sediments (Figure 5.4.1). Sediments are small particles of weathered rock or crystals that have been deposited and left behind by ice, water and wind. In this lesson you will learn how sedimentary rocks are formed, the observable features of sedimentary rocks, and how fossils preserved in sedimentary rocks can be used to predict how and when a rock was formed.

**SC 1** I can describe how and where sedimentary rocks are formed

## Sedimentary rocks

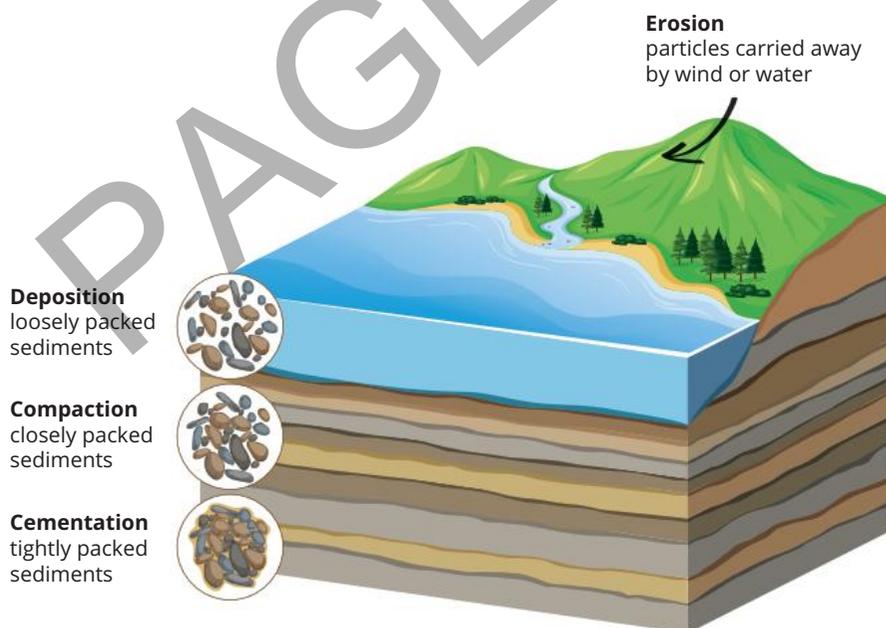
Sedimentary rocks are formed at the bottom of large bodies of water, including oceans and large lakes. Some also form in deserts and caves.

Sediments are small fragments of rocks that pile up over time. The laying down of these rock fragments is called deposition.

As sediments layer on top of one another, they push down on the underlying sediments. This squeezes out excess water, and a compact denser structure forms. This process is known as **compaction**.

Naturally occurring minerals in water, such as silica and lime, can bind or cement the sediments together and create a more solid rock structure in a process called **cementation**.

Sediments that have undergone compaction and cementation form **sedimentary rocks** (Figure 5.4.2).



**FIGURE 5.4.2** The three main stages of the formation of sedimentary rock

### Learning intention

To understand the formation of sedimentary rocks

### Success criteria

**SC 1:** I can describe how and where sedimentary rocks are formed.

**SC 2:** I can describe observable features of sedimentary rocks.

**SC 3:** I can explain how fossil evidence can be used to predict how and when a rock was formed.



**FIGURE 5.4.1** Sediment has been deposited in layers to form sedimentary rocks.

### KEY TERMS

**compaction** the squeezing of layers of sediments caused by pressure from layers above  
**cementation** the binding together of sediments as part of the formation of sedimentary rock

**sedimentary rock** rock made by sediments being compacted and cemented together

**KEY TERMS**

**clastic sedimentary rock** sedimentary rock formed mainly from small rock particles  
**chemical sedimentary rock** sedimentary rock that forms when dissolved materials precipitate from solution  
**biogenic sedimentary rock** sedimentary rock formed mainly from dead organisms



**FIGURE 5.4.4** Stalactites form when water, containing dissolved calcium carbonate, evaporates leaving behind a limestone precipitate.

**Scifile**

**Ancient oceans**

Many sedimentary rocks were formed in ancient oceans. The sediments that settled on the ocean floor millions of years ago underwent compaction and cementation to form rocks like limestone and shale. Many of these rocks also contain marine fossils such as turtles and trilobites that are now appearing in unexpected places like the Sahara Desert.



There are three types of sedimentary rocks.

**Clastic**

**Clastic sedimentary rocks** are formed from other rocks which have broken down through weathering and have then been compacted and cemented. Examples of clastic sedimentary rocks include conglomerate (Figure 5.4.3), mudstone, breccia and sandstone.



**FIGURE 5.4.3** This conglomerate is an example of a clastic sedimentary rock.

**Chemical**

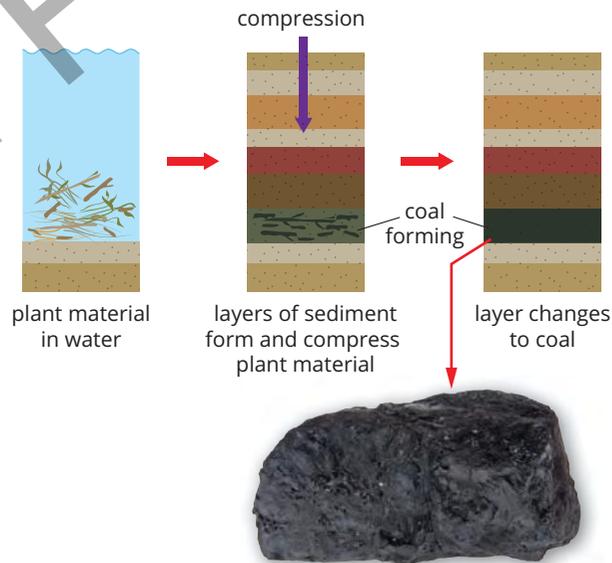
**Chemical sedimentary rocks** can be formed in two ways:

- when minerals that are dissolved in water crystallise within sediments
- when water evaporates leaving behind a build-up of sediment that forms a mass (Figure 5.4.4).

Examples of chemical sedimentary rocks include gypsum, halite and limestone.

**Biogenic**

**Biogenic sedimentary rocks** are formed by the compaction and cementation of dead plant or animal matter. While most of these sediments come from organisms, some sediment might come from weathered rock. Figure 5.4.5 shows the formation process of coal, a biogenic sedimentary rock.



**FIGURE 5.4.5** Coal is a biogenic sedimentary rock formed over millions of years.

**SC 1 CHECK YOUR UNDERSTANDING**

Outline the three main stages of the formation of sedimentary rock.

**SC 2** I can describe observable features of sedimentary rocks

Sedimentary rocks have observable features that will help you distinguish them from other types of rocks. There are three types of sedimentary rocks: clastic, chemical and biogenic. These types are classified based on how they are formed. Although they are formed in different ways, it is often difficult to distinguish between these three types of sedimentary rocks based solely on their appearance.

## Clastic sedimentary rocks

Clastic sedimentary rocks have a range of properties, but not all clastic rocks share all these properties. Many have the following characteristics.

- They are made of fragmented pieces of rocks, known as clasts.
- They may be formed in layers.
- The grains in clastic sedimentary rocks do not interlock as they are cemented together.
- They may contain **fossils** (the preserved remains of animals).

Clastic sedimentary rocks, such as those in Figure 5.4.6, are classified in terms of grain size and shape.

**KEY TERM**

**fossil** the preserved evidence in rocks or soils of organisms that were once alive



**conglomerate**  
large rounded rocks  
cemented between grains  
that are often microscopic



**shale/mudstone**  
particles often microscopic,  
very soft rock



**breccia**  
similar to conglomerate but  
lumps are sharp-edged



**sandstone**  
particles of sand, usually  
harder than mudstone

**FIGURE 5.4.6** Clastic sedimentary rocks are made of clasts cemented together and may contain fossils.

## Chemical sedimentary rocks

Chemical sedimentary rocks have the following characteristics.

- They do not often have interlocking crystals, so they are easier to break.
- They are soft compared to igneous rocks which are formed from the solidification of molten rock.
- Some are formed in salt water and may have a salty taste.

Four examples of chemical sedimentary rocks are shown in Figure 5.4.7.



**chalk** (a form of limestone)



**desert rose**



**gypsum**



**halite** (rock salt)

**FIGURE 5.4.7** Four examples of chemical sedimentary rocks

## Biogenic sedimentary rocks

Biogenic sedimentary rocks have the following characteristics.

- They are generally soft; although some (for example, chert and flint) are quite hard.
- They are formed in layers.
- They may contain fossils.

Limestone is normally formed as a biogenic sedimentary rock. It contains at least 50% calcium carbonate (commonly known as chalk) so its chalky appearance will help you to identify it. The original source of the calcium is the remains of corals and shells. Biogenic limestone may contain fossils (Figure 5.4.8). Note that a small amount of limestone on Earth is produced directly from calcium carbonate in water. Limestone formed in this way is classified as chemical sedimentary rock.



**FIGURE 5.4.8** Fossils can be clearly seen in this limestone formed as a biogenic sedimentary rock.

### SC 2 CHECK YOUR UNDERSTANDING

In which two sedimentary rock types can fossils be found?

**SC 3** I can explain how fossil evidence can be used to predict how and when a rock was formed

If the remains of an organism after it dies are quickly covered by sediment, then it may be preserved and become a fossil.

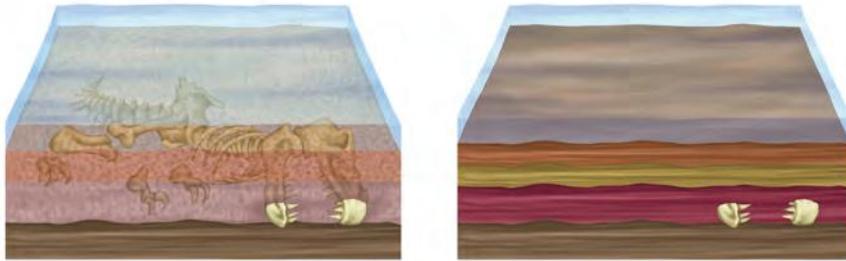
Fossils are often found where an organism's remains are located in sediments in water bodies such as in an ocean, lake or river (Figure 5.4.9). This means there is no oxygen in the sediment so there is little or no decomposition.

Organisms that die on land can also become fossilised when wind blows sediment to cover the remains.

The fleshy parts of the organism gradually decompose. The hard remains of the organism, such as bones, are replaced by minerals and so turn into rock, becoming fossilised. Over time, sediments continue to build up, compacting and cementing, and become sedimentary rock (Figure 5.4.10).



**FIGURE 5.4.9** An organism's remains become buried in sediments in a water body.



**FIGURE 5.4.10** Hard remains of the organism are replaced by minerals and become compacted in the surrounding sedimentary rock.

Changes to Earth's surface such as movements in Earth's crust, weathering and erosion can expose the fossil at Earth's surface (Figure 5.4.11).



**FIGURE 5.4.11** Fossilised remains of an organism become exposed at Earth's surface.

## Index fossils

As layers of sedimentary rock are built up over time, deeper layers will generally be older than those closer to the surface. It is possible to compare the relative ages of rocks from different places using **index fossils**. A fossil must meet the following requirements to be an index fossil:

- It must have been found across a large area such as on different continents.
- The organism must have lived within a short period of time.
- The organism must also have been a part of a large population; that is, there were many of that organism living at the time.

Index fossils within layers can mark where layers were formed around the same time but at different locations. Index fossils can be used to check the order of the layers and to check the age of the rock strata that housed the fossils.

### KEY TERM

**index fossil** a fossil that can be used to compare the relative age of rock strata in different locations



## SCIENCE IN SOCIETY

### Morocco's fossil trade

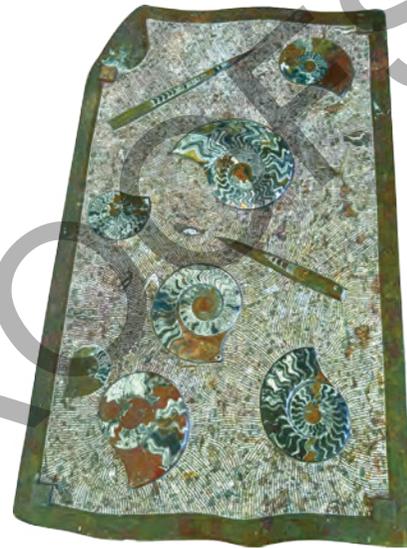
Morocco contains some of the world's richest fossil sites. Fossils date from the pre-Cambrian to recent geological time. Millions of years ago, the Sahara Desert in Morocco would have been a shallow sea. Prehistoric marine organisms such as ammonites, trilobites, orthocones and sharks lived in these waters in great numbers. When they died, their bodies were buried in the sediments on the sea floor, and over millions of years were turned into stone. Dinosaur teeth, mainly from the river-dwelling theropod dinosaur *Spinosaurus* are also abundant. The arid environment of Morocco has made it easy to find fossils on the surface. Other large finds are in marble quarries.



**FIGURE 5.4.12** Roadside stall selling fossils in Morocco

The rich abundance of fossils in Morocco has created a dilemma for Moroccans and palaeontologists (scientists who study fossils). For many Moroccans, the fossils provide their only source of income. Thousands of Amazigh, the ethnic peoples of Morocco, excavate by hand to collect fossils to sell. Small roadside stalls sell specimens directly to tourists. Larger scale operations create furniture and other pieces from the fossils. However, there are scientific concerns that excavations by non-scientists may damage important specimens.

The Moroccan fossil trade's focus is commercial, so specimens may be discarded that are not seen as valuable. These ignored specimens could be very significant to palaeontologists. With a ready market selling fossils to collectors worldwide, rare specimens may disappear into private collections and so would not be available for scientific study.



**FIGURE 5.4.13** A coffee table created from a slab of black marble with ammonite and orthocones fossils

Despite these scientific concerns, Morocco's fossil trade has allowed palaeontologists to make some very significant scientific discoveries. Many new species from the past have been discovered. Hundreds of trilobite species from 570 to 245 million years ago, many not found elsewhere in the world, have been found in Morocco. The methods of retrieving the fossils are, in so many cases, not conducted according to palaeontology protocols. Yet, without the fossil trade, many new fossil species would never have been uncovered. The science community's knowledge of the geological record has greatly improved because of the fossils that have been unearthed. In the future, conservation of the fossil sites and more sustainable management approaches to the trade should see further growth in scientific knowledge.

**SC 3 CHECK YOUR UNDERSTANDING**

Explain how fossils are preserved in sedimentary rocks.

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

- 1 Identify the type of environment in which sedimentary rocks are typically formed.
- 2 There are three types of sedimentary rocks.
  - a Which of the three is classified based on grain size and shape?
  - b Name a biogenic sedimentary rock.
  - c Halite, desert roses and gypsum are examples of which type of sedimentary rock?
- 3 Two students are arguing over the name of a clastic sedimentary rock. One student thinks it is breccia and the other thinks it is conglomerate. To help these two students, describe the size and shape of the clasts (grains) you would expect to see in each rock type.
- 4 Compare the processes involved in the formation of clastic sedimentary rocks and chemical sedimentary rocks. Give specific examples for each type of rock in your answer.
- 5 Explain why limestone can be classified as both a chemical sedimentary rock and a biogenic sedimentary rock.
- 6 *Paradoxides* is a type of marine trilobite that lived about 500 million years ago. Outline two reasons that would make this trilobite a useful index fossil.

PAGE PROOFES

# 5.5 Resources in sedimentary rock

## Learning intention

To be able to investigate how advances in deep Earth imaging has enabled identification of resources in sedimentary rock

## Success criteria

**SC 1:** I can describe recent advancements in deep Earth imaging techniques.

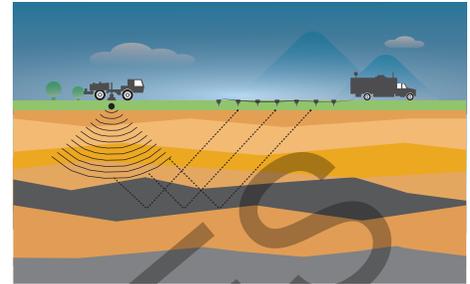
**SC 2:** I can describe the various resources that can be found in sedimentary rock.

**SC 3:** I can create an animation to explain how imaging techniques can be used to identify different resources.

## Introduction

Deep Earth imaging has played a significant role in the identification of resources in sedimentary rocks. Some of the valuable resources that have been found include hydrocarbons, minerals, groundwater, geothermal energy and rare earth elements (Figure 5.5.1).

In this inquiry activity you will investigate how advances in deep Earth imaging have enabled the identification of these resources in sedimentary rock.



**FIGURE 5.5.1** Deep Earth imaging is used to explore for hydrocarbon resources such as oil.

## Background

Deep Earth imaging is a scientific technique used to take pictures of what is happening deep beneath Earth's surface. Its special tools and instruments are used to gather data about the properties of rocks, minerals and fluids within Earth. Scientists analyse this data to create images of what is happening deep below the surface, including the underground rock and the location of underground resources like oil and gas (Figure 5.5.2). Deep Earth imaging has played a significant role in the identification of resources in sedimentary rocks.



**FIGURE 5.5.2** Seismic-vibrator vehicles are used in land-based exploration for oil resources.

## Aim

To create an animation explaining how deep Earth imaging technology can be used to identify resources in sedimentary rock

## Plan

- 1 Investigate some of the recent advancements in deep Earth imaging techniques and take notes about these.
- 2 Explore the resources that can be found in sedimentary rock.

## Design

Answer the following questions to guide the design of your animation.

- 1 What tools will you use to create your animation?
- 2 What makes an animation informative and engaging?
- 3 What information will you include in your animation? Refer to the notes you took during the planning stage of the inquiry activity.
- 4 What will your key headings be?

## HINT

Useful search terms include 'deep Earth imaging technology' and 'geophysical survey techniques'.

## Conduct

Create your animation using all the information you gathered during the Plan and Design stages.

## Improve

- 1 What were you proud of in your animation?
- 2 How might you change the look and feel of your animation to make it more engaging?
- 3 How might you change the information to make it more informative?
- 4 Would you do anything differently next time?

## Evaluate

- 1 What aspect of rocks were you investigating in this inquiry activity?
- 2 In this inquiry activity, you planned and conducted an inquiry into recent advancements in deep Earth imaging techniques. What skills did you use during this activity?

### HINT

Check with your teacher what animation platforms are available for use at your school.

### GO TO

Toolkit sections 5.1, Methods for presenting scientific ideas, 5.2, Using scientific language and 5.3, Using Artificial Intelligence (AI) in science writing

PAGE PROOFS

## 5.6 Igneous rocks

### Learning intention

To understand the formation of igneous rocks

### Success criteria

**SC 1:** I can describe how and where igneous rocks are formed.

**SC 2:** I can describe observable features of igneous rocks.

**SC 3:** I can explain the role of heat energy in the formation of igneous rocks and compare how quickly or slowly processes can occur.



**FIGURE 5.6.2** Volcano Fuego (Antigua, Guatemala) erupts bringing molten lava to Earth's surface.

### Lesson overview

Earth's crust was originally formed when molten rock cooled to form igneous rock. The word igneous means 'born of fire'. Molten magma and lava crystallise to form these rocks (Figure 5.6.1).



**FIGURE 5.6.1** Lava cools on Earth's surface to form igneous rock.

In this lesson you will learn how and where igneous rocks are formed, the observable features of igneous rocks and the role of heat energy in the formation of igneous rocks.

### KEY TERMS

**volcano** a place where extremely hot material from inside Earth erupts at the surface

**magma** molten rock below Earth's surface

**lava** molten rock that reaches Earth's surface

**igneous rock** rock formed by the cooling of molten rock, for example basalt

**extrusive igneous rock** igneous rock that forms on the surface of Earth

**intrusive igneous rock** igneous rock that forms below the surface of Earth

### SC 1 I can describe how and where igneous rocks are formed

A **volcano** is a formation that allows extremely hot material from inside Earth to erupt at Earth's surface (Figure 5.6.2). The molten rock below Earth's surface is called **magma**, and magma reaching Earth's surface is called **lava**.

**Igneous rock** is formed when magma or lava cools and hardens into rock.

This can happen in different ways:

- Magma may cool on the surface of Earth, in the air, underwater or underground.
- Igneous rocks that form above the ground are called **extrusive igneous rocks**.
- Igneous rocks that form when magma gets trapped underground and cools are called **intrusive igneous rocks**.



## SCIENCE IN SOCIETY

### Unusual types of lava

The viscosity (thickness) of lava influences the type of volcanic eruption that will occur. Lava with high viscosity will cause explosive eruptions. Less viscous, more runny lava will generally produce eruptions that are much less explosive.

The volcanoes in Hawai'i have less viscous basaltic lava. This less viscous lava can produce a very unusual form of volcanic glass if conditions are right. Sometimes the lava erupts fountain-like from the volcano. At other times the lava spatters over the surrounding landscape. The lava may also flow over a cliff like a waterfall into the ocean. In each of these situations, fine strands of volcanic glass are formed from stretching globules of lava, much like thin strands form when a piece of chewing gum is stretched in two. The strands cool very rapidly and solidify into hair-like volcanic glass. These strands are called 'Pele's Hair' (Figure 5.6.3), named after Pelehonuamea, the Hawai'ian goddess of volcanoes and fire. The globules form small tear-shaped pieces of volcanic glass called 'Pele's Tears'.

Pele's Hair can be carried by wind some distance from the eruption site. If produced in large quantities, it can form mats on the ground. Pele's Tears tend to fall closer to the volcano's vent as

they are heavier. Pele's Hair can be so fine, sharp and brittle that slivers can easily penetrate skin and cause eye injuries. It can also cause respiratory injuries if inhaled.

Hawai'i is not the only volcanic region producing Pele's Hair. Volcanoes in Nicaragua, Italy and Ethiopia also produce this type of volcanic glass. In Iceland, it is known as 'Witches' Hair'.



**FIGURE 5.6.3** Strands of Pele's Hair - fine, volcanic glass fibres formed from molten lava ejected into the air

### SC 1 CHECK YOUR UNDERSTANDING

Where are intrusive igneous rocks formed? Compare this to extrusive igneous rocks.

### SC 2 I can describe observable features of igneous rocks

As the molten rock cools into an igneous rock, it forms crystals that grow together. This causes the crystals to interlock, so the rock is hard.

### Extrusive igneous rocks

Extrusive igneous rocks cool very quickly when lava is exposed to air or water. They have specific observable features.

- Large crystals do not have time to grow, so the crystals are tiny and are only visible under a microscope.
- They might have a bubbly texture as can be seen in Figure 5.6.4. This is due to trapped bubbles of gas within the lava as it cooled rapidly.



**FIGURE 5.6.4** Pumice is an example of an extrusive igneous rock that trapped gas as it cooled rapidly.



**FIGURE 5.6.5** Granite is an example of an intrusive igneous rock.

#### KEY TERMS

**porphyritic** describes the texture of intrusive and extrusive igneous rocks that have large crystals surrounded by finer crystals or grains

**mineral** a naturally occurring solid substance that is inorganic, has a characteristic crystalline structure and a fairly constant chemical composition



**FIGURE 5.6.6** Andesite has a porphyritic texture with crystals of varying size.



**FIGURE 5.6.7** Obsidian (volcanic glass) is an extrusive igneous rock with very few crystals as it cooled very rapidly.

Some examples of extrusive igneous rocks are basalt, obsidian (volcanic glass), scoria and pumice.

## Intrusive igneous rocks

Intrusive igneous rocks cool slowly because they cool underground. They tend to have large crystals that can be seen without the help of a microscope. The large crystals form because the slow cooling time means that large crystals have time to grow. Some examples of intrusive igneous rocks are dolerite, gabbro and granite (Figure 5.6.5).

## Porphyritic igneous rocks

The term **porphyritic** is used to describe the texture of igneous rocks that contain crystals of very different sizes. Some are microscopic due to fast cooling while some are large due to slow cooling. Both intrusive and extrusive igneous rocks can be described as porphyritic.

Porphyritic igneous rocks are formed from rising magma. The larger crystals develop first as the magma cools slowly beneath the ground, then, as it erupts, it creates small, non-visible grains. An example of a porphyritic igneous rock, andesite, is shown in Figure 5.6.6.

## Making observations

When describing igneous rocks, you will observe their texture and colour. For example, their texture could be rough or smooth and the varying size of the crystals should be noted. The colour of the rock indicates what **minerals** it may contain.

### SC 2 CHECK YOUR UNDERSTANDING

An igneous rock sample has been identified as being porphyritic. What does this tell you about:

- where it formed?
- the size of its crystals?

### SC 3 I can explain the role of heat energy in the formation of igneous rocks and compare how quickly or slowly processes can occur

Heat energy plays an important role in how igneous rocks are formed.

When magma reaches the surface to become lava, it cools very rapidly as it loses heat energy to the surrounding environment, especially if the eruption happens underwater. This produces extrusive igneous rocks. When lava cools quickly it forms either very small crystals, or no crystals at all (Figure 5.6.7). This is because the crystals have not had enough time to grow during the rapid cooling.

Magma that does not reach the surface cools much more slowly and forms intrusive igneous rocks. In this case, the heat energy is absorbed slowly by the surrounding rock in Earth's crust. Larger crystals form in rocks when cooling occurs more slowly (Figure 5.6.8). This happens because particles within the magma can move around in a liquid state and keep adding to nearby crystals giving them time to grow.

### SC 3 CHECK YOUR UNDERSTANDING

Describe what happens to heat energy in lava when it reaches Earth's surface.



**FIGURE 5.6.8** Diorite's large crystals formed when magma beneath Earth's surface cooled very slowly.

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

- 1 Explain the difference between intrusive igneous and extrusive igneous rocks.
- 2 If you find an igneous rock with large, visible crystals, what can you infer about its formation?
- 3 You are examining igneous rock samples to identify their features.
  - a List the observable features you would look for in igneous rocks.
  - b Explain how the cooling rate affects the texture of igneous rocks.
  - c Compare the textures of intrusive and extrusive igneous rocks.
  - d Evaluate the importance of colour in identifying igneous rocks.
  - e One of the rock samples has crystals of varying sizes – some are visible to the naked eye and others are microscopic. What type of igneous rock is this likely to be?
- 4 Explain how heat energy affects the formation of igneous rocks.
- 5 A fine-grained igneous rock with a bubbly texture has been found on the beach.
  - a Which type of igneous rock is this specimen most likely to be?
  - b Is the molten material from which it formed likely to be lava or magma?
  - c Describe the rate at which heat energy would have been lost as this rock cooled.
  - d What is the likely cause of the bubbly texture?
  - e Suggest the name of the igneous rock.

## 5.7 Metamorphic rocks

### Learning intention

To understand the formation of metamorphic rocks

### Success criteria

**SC 1:** I can describe how and where metamorphic rocks are formed.

**SC 2:** I can describe examples of specific metamorphic rocks and their parent rock.

**SC 3:** I can explain the role of heat energy and force in the formation of metamorphic rocks and compare how quickly or slowly processes can occur.

### Lesson overview

All rocks can be altered by heat and/or pressure to form metamorphic rocks. Even metamorphic rocks can be metamorphosed. This process turns ordinary limestone into beautiful marble (Figure 5.7.1), and soft sandstone into hard quartzite.

In this lesson you will learn about the formation of metamorphic rocks, what a parent rock is, and the role of pressure and heat energy in the formation of metamorphic rocks.

#### SC 1 I can describe how and where metamorphic rocks are formed

When large amounts of heat energy or pressure are applied to rocks, the properties of the rock can change. This is how **metamorphic rocks** are formed.

Both physical and chemical changes can occur when rocks are metamorphosed. Crystals can transform into crystals of new minerals (recrystallisation). Crystals can grow into flattened sheets. Bands of different minerals form when crystals are squashed flat by forces within Earth while they are hot.



**FIGURE 5.7.1** The Marble Caves in Chile have been formed from metamorphosed limestone.

#### KEY TERM

**metamorphic rock** rock formed when temperature and/or pressure alter existing rock

### Scifile Gemstones

Many gemstones, like emerald and garnet, form in metamorphic rocks through the process of recrystallisation. The intense heat and pressure create the perfect conditions for these beautiful minerals to grow.

Trace elements give the gemstones their different colours. For example, sapphire and ruby are varieties of the same mineral corundum, but ruby's red colour is due to traces of chromium in its structure. Sapphire's colours come from traces of elements such as iron, nickel and titanium.



There are three types of metamorphism.

## Regional metamorphism

In **regional metamorphism**, the rock is affected by both heat and pressure. Most often, regional metamorphism occurs over large areas due to the collision of tectonic plates (Figure 5.7.2).



**FIGURE 5.7.2** Slate, when affected by regional metamorphism, becomes schist.

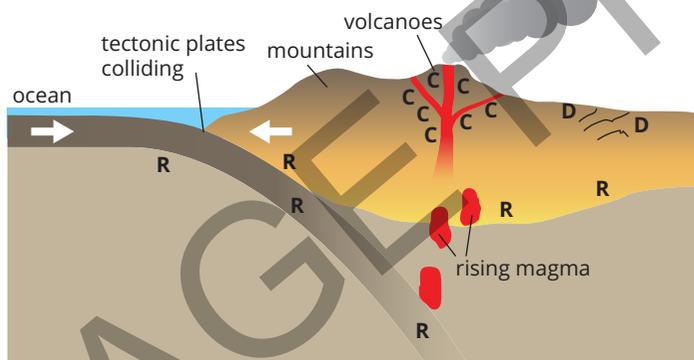
## Contact metamorphism

In **contact metamorphism**, the rock is mainly affected by heat. Most often, contact metamorphism occurs due to magma cutting through surrounding rock (Figure 5.7.3).

## Dynamic metamorphism

In **dynamic metamorphism**, the rock is mainly affected by pressure. Most often, dynamic metamorphism occurs in areas where the movement of the crust causes rocks to drag past each other. For example, this might occur near faults (Figure 5.7.4).

Figure 5.7.5 shows the areas in Earth's crust where the three types of metamorphic rock are formed.



- R regional metamorphism (heat and pressure)
- C contact metamorphism (mainly heat)
- D dynamic metamorphism (mainly pressure)

**FIGURE 5.7.5** Areas in Earth's crust where the three types of metamorphism occur

### SC 1 CHECK YOUR UNDERSTANDING

Name the three types of metamorphism. For each, state whether it is mainly heat, mainly pressure or both heat and pressure that causes rocks to metamorphose.

#### KEY TERMS

**regional metamorphism** a type of metamorphism where rock is altered by both heat and pressure over a wide area  
**contact metamorphism** a type of metamorphism where rock is altered mostly by heat  
**dynamic metamorphism** a type of metamorphism where rock is altered mostly by pressure



**FIGURE 5.7.3** Limestone, when affected by contact metamorphism, becomes marble.



**FIGURE 5.7.4** Schist, when affected by dynamic metamorphism, becomes gneiss.

**SC 2** I can describe examples of specific metamorphic rocks and their parent rock

### KEY TERMS

**parent rock** a rock that experiences metamorphism, or changes form, to become a new kind of rock

**foliated** a process where minerals under pressure realign and the rock develops layers or bands

## Parent rocks

Metamorphism changes the original rock or **parent rock** into a completely new rock. The parent rock can be sedimentary, igneous or metamorphic.

When the minerals in a rock are forced into layers, the rock is said to be **foliated**. These bands of minerals can also have a wavy pattern when pressure is applied and squeezes the layers. Metamorphic rocks are either foliated or non-foliated.

Foliated metamorphic rocks will split along lines (known as cleavages) that are parallel to the minerals that make up the rock.

Non-foliated rocks have no cleavage or banding and are typically harder rocks. Non-foliated rocks occur when heat is high, but pressure is low or equal on all sides.

## Foliated metamorphic rocks

The following are examples of metamorphic rocks that are foliated.

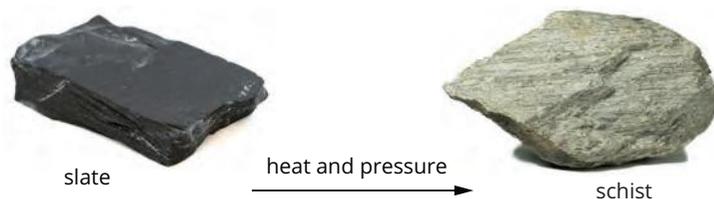
Shale (mudstone) is the sedimentary parent rock that forms slate under pressure and heat.

Slate is a foliated metamorphic rock. Note the cleavage lines through the rock shown in Figure 5.7.6. Slate is still fine-grained like its parent rock.



**FIGURE 5.7.6** Shale is metamorphosed to foliated slate.

If slate is subject to more pressure and higher temperatures, it will change again to form schist (Figure 5.7.7). New minerals are formed, the crystals are larger, and the rock remains a foliate.



**FIGURE 5.7.7** Slate is metamorphosed to form schist.

With even greater pressure and temperature, schist will change again into gneiss and the crystals may form into bands (Figure 5.7.8). The rock remains a foliate.

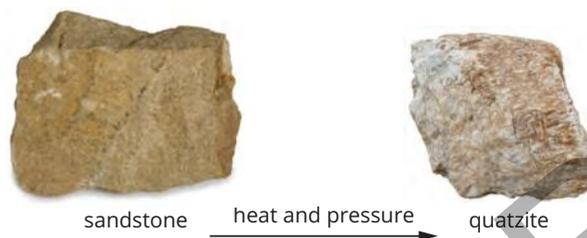


**FIGURE 5.7.8** Schist is metamorphosed to form gneiss.

## Non-foliated metamorphic rocks

The following are examples of metamorphic rocks that are non-foliated.

Quartzite is much harder than its parent rock sandstone (Figure 5.7.9). Sandstone will shatter into many individual grains of sand while quartzite will break across the grains. Quartzite is non-foliated.



**FIGURE 5.7.9** Sandstone is metamorphosed to form quartzite.

Marble is formed from metamorphosed limestone or dolomite. Marble has many colour variations including white (Figure 5.7.10), red, black, grey, pink, mottled and banded. Marble is non-foliated.



**FIGURE 5.7.10** Marble is metamorphosed from limestone, one of its parent rocks.

### SC 2 CHECK YOUR UNDERSTANDING

Shale can undergo several stages of metamorphism to form the metamorphic rock gneiss.

- Identify the parent rock in this process.
- Sketch a flow chart to show the stages of metamorphism of gneiss from the parent rock.
- Is gneiss an example of a foliated or a non-foliated metamorphic rock?

**SC 3** I can explain the role of heat energy and force in the formation of metamorphic rocks and compare how quickly or slowly processes can occur

Metamorphic rocks are formed by heat and pressure. The amount of heat and pressure placed on a rock changes its final appearance and characteristics.

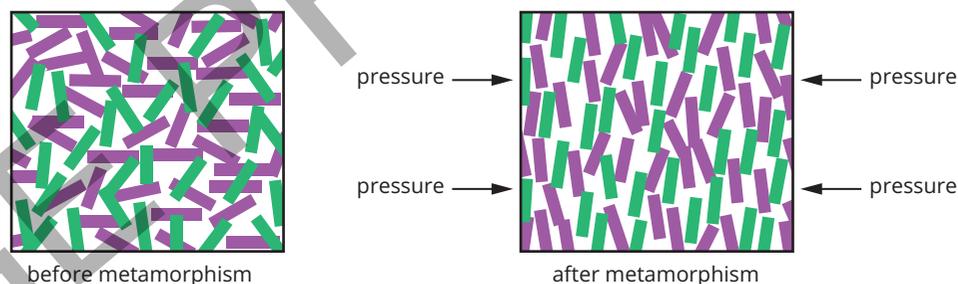
The heat energy applied to the rocks does not melt them but causes changes to the mineral composition and crystal structure. The temperatures required for these chemical changes are greater than 150°C. If the amount of heat energy becomes too great, then the rock may melt and thus become magma, creating new igneous rock instead. The application of force during movements in Earth's crust increases the pressure on the rocks, which also causes chemical changes in existing rock.

The chemical changes caused by the applied heat energy and pressure include:

- the recrystallisation and realignment of minerals
- a change in the mineral composition and texture of the rock
- the formation of new minerals.

### Forces and foliation

When the minerals in a rock are forced into alignment, the rock is said to be foliated (Figure 5.7.11).



**FIGURE 5.7.11** Pressure applied in the crust forces minerals to align to form foliated rocks.

Foliated metamorphic rocks are formed under high pressures from shearing forces. Shear forces describe forces that act in opposite directions. These forces cause parallel layers or cleaves to form in the rock.

### Heat energy and non-foliation

Non-foliated rocks are formed under high heat but low or equal pressure. This prevents the mineral crystals from forming cleaves or splits, and the overall density and strength of the rock are increased.

Contact metamorphism occurs when rock is heated up by an intrusion of hot magma. Contact metamorphism does not involve the squashing of rock layers, so these rocks do not have foliated textures.

Figure 5.7.12 shows a vein of non-foliated quartzite surrounded by gabbro, the intrusive igneous rock that caused the contact metamorphism.



**FIGURE 5.7.12** A non-foliated quartzite vein is surrounded by solidified igneous gabbro.

## Heat energy impacts the speed of metamorphism

Metamorphic processes work on very long timescales. Rocks experiencing lower heat and pressure will metamorphose more slowly than those exposed to higher heat and pressure. Regional metamorphism will occur more quickly than contact or dynamic metamorphism because the combination of high heat and high pressure will increase the rate of transformation.

### SC 3 CHECK YOUR UNDERSTANDING

Identify the type of metamorphic rock most likely to form when strong shear forces are applied to rock in Earth's crust.

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

- 1 Describe how metamorphic rocks typically form.
- 2 Compare the formation environments of contact metamorphism and regional metamorphism.
- 3 If you find a rock that has been subjected to high pressure but low temperature, what type of metamorphic rock might it be?
- 4 Compare the parent rocks and resulting metamorphic rock types for quartzite and schist.
- 5 You are studying the formation of metamorphic rocks under different conditions of heat and pressure.
  - a Describe the role of heat energy in the metamorphic process.
  - b Explain how pressure influences the texture of metamorphic rocks.
  - c Compare the formation processes of non-foliated and foliated metamorphic rocks.
  - d A metamorphic rock is foliated but the crystals are small. Identify the type of metamorphism this rock has most likely undergone.
- 6 Slate is a metamorphic rock that has been used for centuries as roof, floor and wall tiles, and as the base for billiard tables. Outline the characteristics of slate that make it suitable for these purposes. Consider grain size, foliation and hardness in your response.

# 5.8 The source of metamorphic rocks

## Learning intention

To be able to investigate the source of metamorphic rocks

## Success criteria

**SC 1:** I can use a dichotomous key to identify igneous, sedimentary and metamorphic rocks.

**SC 2:** I can use observations and secondary data to match the metamorphic rocks to their parent rocks.

**SC 3:** I can describe changes that have occurred to the properties of rocks because of the production of the metamorphic rock.

### KEY TERM

**dichotomous key** a key with two choices at each stage

## Introduction

Metamorphic rocks, such as the marble shown in Figure 5.8.1, are formed from other rocks when placed under pressure and/or heat. In this practical investigation you will investigate the source of metamorphic rocks by using an identification tool called a dichotomous key.



**FIGURE 5.8.1** Marble formed from the parent rock of limestone.

## Background

**Dichotomous keys** are used in classification processes. They give the user two choices at each point in the procedure. Dichotomous keys can be used to classify rocks.

## SkillBuilder

### Classifying rocks

#### Using dichotomous keys to classify rocks

Do the following when observing and classifying rocks.

- 1 Spray the rock with water to make it easier to see any contrasting colours.
- 2 View the rock through a magnifier.
- 3 Use a ruler to estimate the size of any clasts or crystals.

Note that very fine-grained rocks may be difficult to classify without extra techniques such as taking a thin slice of the rock to observe under a microscope.

#### Dichotomous key for classifying rocks

1	Rocks have crystals – go to 2. Rocks do not have crystals – go to 6.
2	Rocks are made entirely of interlocking crystals. <i>Igneous</i> – go to 3. Rocks are not made entirely of interlocking crystals. <i>Metamorphic</i> – go to 10.
3	Rocks have crystals large enough to see using a hand lens. <i>Igneous intrusive</i> – go to 4. Rocks are crystalline but their crystals are difficult to see using a hand lens. <i>Igneous extrusive</i> – go to 5.
4	Rocks are dark and dense. <i>Igneous, intrusive and mafic</i> (rich in magnesium and iron), e.g. gabbro Rocks are neither dark nor dense. <i>Igneous, intrusive and felsic</i> (rich in feldspar and silicon), e.g. granite, pegmatite

5	Rocks are dark and dense. <i>Igneous, extrusive and mafic</i> (rich in magnesium and iron), e.g. basalt Rocks are neither dark nor dense. <i>Igneous, extrusive and felsic</i> (rich in feldspar and silicon), e.g. rhyolite
6	Rocks are non-crystalline and are made of clasts (pieces or chunks). <i>Sedimentary, clastic</i> – go to 7. Rocks are non-crystalline but are not made of clasts. <i>Sedimentary, biogenic</i> , e.g. limestone, chalk, coal
7	Rocks have large clasts – go to 8. Rocks do not have large clasts – go to 9.
8	Rocks have large clasts that are rounded. <i>Sedimentary, clastic large grained</i> , e.g. conglomerate Rocks have large clasts that are not rounded. <i>Sedimentary, clastic large grained</i> , e.g. breccia
9	Rocks have medium rounded clasts. <i>Sedimentary, clastic medium grained</i> , e.g. sandstone Rocks have clasts that are less than medium size. <i>Sedimentary, clastic fine grained</i> , e.g. siltstone, mudstone
10	Rocks are foliated (or banded). <i>Metamorphic, foliated</i> , e.g. slate, schist and gneiss Rocks are not foliated (or banded). <i>Metamorphic, non-foliated</i> , e.g. quartzite and marble

## Worked example

### Classifying rocks

This worked example uses the dichotomous key from the SkillBuilder to classify a rock sample.

#### Problem

Use the dichotomous key to classify the unknown rock sample to the right. Note that each bar on the scale is 1 cm.

#### Solution

Thinking	Working
Does the rock have crystals?	Yes, go to 2.
Are the crystals interlocking?	Yes, go to 3.
Can you see the crystals using a hand lens?	Yes, go to 4.
Is the rock dark and dense?	The rock is neither dark nor dense – it is light in colour. This means it is an igneous, intrusive and felsic rock (rich in feldspar and silicon), such as granite or pegmatite. (Note: The sample is granite.)



**Try yourself****Classifying rocks**

Use the dichotomous key to classify this rock. Note that each bar on the scale is 3 cm.

**Aims**

To classify unknown rock samples as igneous, sedimentary or metamorphic

To compare metamorphic rocks with their parent igneous, sedimentary and metamorphic rocks

**Materials****Task 1**

- numbered but unlabelled rock samples
- stereo microscope and/or hand lens

**Task 2**

- labelled rock samples in containers: gneiss, granite, limestone, marble, quartzite, sandstone, schist, shale, slate
- stereo microscope and/or hand lens

**Method****Task 1**

- 1 Choose a numbered rock sample. Your first task is to describe the characteristics of the rock.
- 2 Use your microscope and/or hand lens to take a closer look. Then, using the dichotomous key, decide whether it is igneous, sedimentary or metamorphic. Record your reasons in your results table. If you feel confident, try to name the rock.
- 3 Repeat step 2 for each rock.
- 4 Record all observations in your results table.

**Task 2**

- 1 Use the microscope and/or hand lens to examine the rock samples.
- 2 Use the information in the 'Metamorphic rocks' lesson, and any other information available to you, to match each metamorphic rock to its parent rock.

**HINTS**

It is possible that a particular rock is the parent rock for more than one metamorphic rock.

It is also possible that a metamorphic rock may have more than one parent rock.

- 3 For each pair of rocks, write the name of the parent rock first and describe its characteristics, including its rock type. Then, do the same for the metamorphic rock.
- 4 For each metamorphic rock, describe the characteristics that enable you to decide it is metamorphic.
- 5 Describe changes that have occurred in each metamorphic rock as it altered from its parent rock.

## Results

Copy the results tables below into your notebook and record your observations.

### Task 1

Rock number	Description	Classification	Rock name

### Task 2

	Parent rock	Description	Metamorphic rock	Description
Pair 1				
Pair 2				
Pair 3				
Pair 4				
Pair 5				

Rock name	Reasons you have decided it is metamorphic	What changes occurred to make it metamorphic?

## Conclusion

Summarise how you were able to classify rock samples (Task 1) and determine the parent/metamorphic rock relationships (Task 2).

## Evaluation

Evaluate your practical investigation by considering how you could improve the process of classification.

## 5.9 The rock cycle in action

### Learning intention

To understand how environmental changes affect the rock cycle

### Success criteria

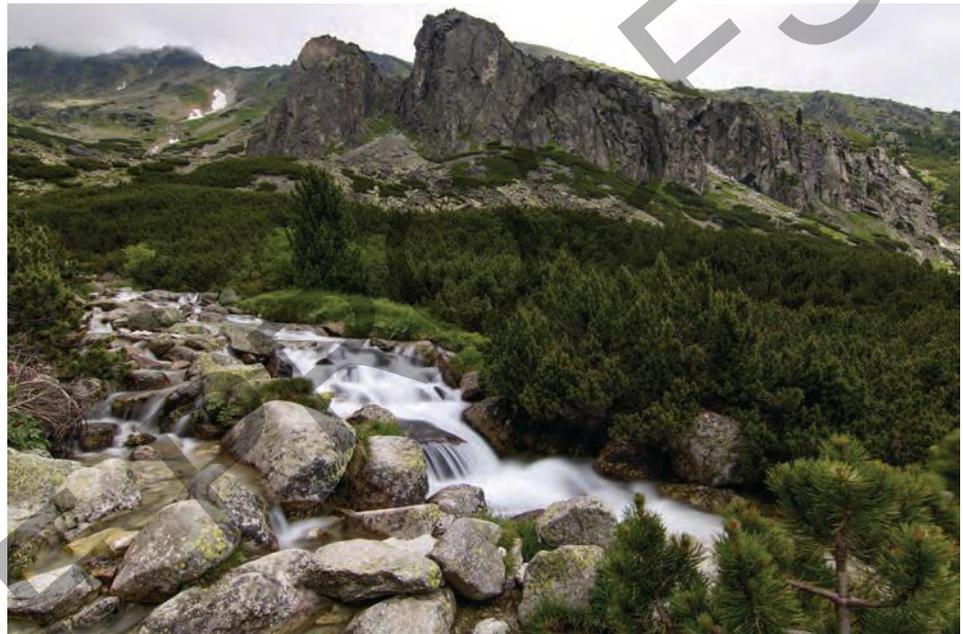
**SC 1:** I can compare the formation of different types of rock within the rock cycle.

**SC 2:** I can predict how environmental changes will affect a rock's structure based on the rock cycle.

**SC 3:** I can predict and explain locations where specific types of rocks are found.

### Lesson overview

Rocks are not alive, but they have been constantly changing since Earth formed. All landscapes, and the rocks in them, are the result of processes that include weathering and erosion (Figure 5.9.1), formation of new rocks, and changes brought about by heat and pressure. The rock cycle is a model that outlines these processes and the resultant changes to rock types. In this lesson you will learn about the formation of different types of rock within the rock cycle and the impact of environmental factors on the structure of rocks.



**FIGURE 5.9.1** Water is one of the most important agents of weathering and erosion in landscapes.

**SC 1** I can compare the formation of different types of rock within the rock cycle

### The rock cycle

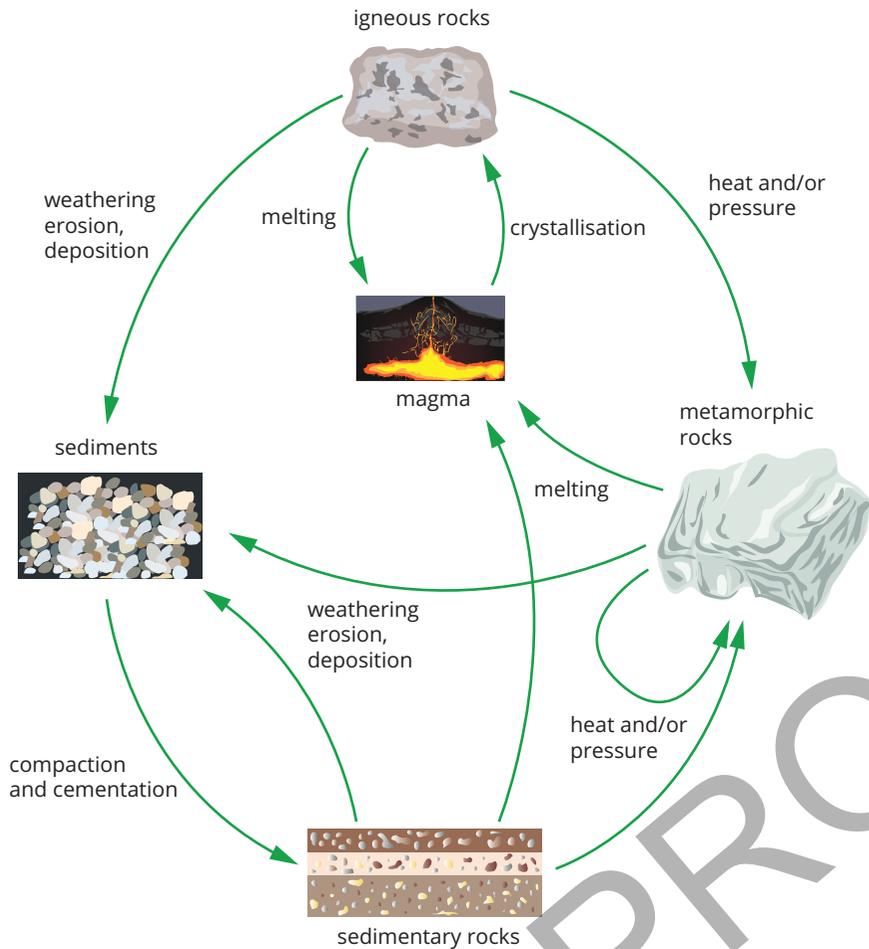
Since Earth was formed, **rocks** have been continually changing. The **rock cycle** is a model used by scientists to explain the endless cycling of rocks and rock types.

Changes constantly occur throughout the rock cycle, which affect the structure of rocks and assists in the formation of new rocks. The rock cycle diagram in Figure 5.9.2 shows that a range of processes such as erosion, deposition, melting, heat and/or pressure, and crystallisation cause changes to the structure of rocks. Some of these occur deep in Earth's lithosphere where there are higher levels of heat and pressure. Others are the result of environmental changes on Earth's surface itself.

### KEY TERMS

**rock** a solid mass of one or more minerals

**rock cycle** a model geologists use to explain the endless cycle of change that rocks undergo



**FIGURE 5.9.2** A more detailed version of the rock cycle showing geological processes and changes to rock type

The processes that form sedimentary, igneous and metamorphic rocks are a continuous cycle that began when Earth was first formed. It is important to note that the cycle does not occur in one direction, nor include all three rock types as is often depicted in images of the rock cycle. It is possible for igneous rocks to melt and cool, forming new igneous rocks. A metamorphic rock may undergo further heat and/or pressure to form a new type of metamorphic rock. Sedimentary rocks may undergo weathering, erosion, compaction and cementation, and so form a new sedimentary rock. A sedimentary rock may metamorphose when subjected to high levels of heat and/or pressure, then go through uplift and erosion to form a new sedimentary rock.

## Scifile

### Climate impact

Climate changes can speed up or slow down the rock cycle. For example, more rainfall can increase weathering and erosion, while a dry climate can slow these processes down. Higher temperatures speed up chemical weathering reactions. More extremes in temperature also accelerate physical weathering.

## SC 1 CHECK YOUR UNDERSTANDING

Identify the geological processes that can change:

- a an igneous rock into a sedimentary rock
- b a sedimentary rock into an igneous rock
- c a metamorphic rock into an igneous rock
- d a sedimentary rock into a metamorphic rock
- e a metamorphic rock into a metamorphic rock
- f a metamorphic rock into a sedimentary rock.

## SC 2 I can predict how environmental changes will affect a rock's structure based on the rock cycle

Environmental changes on Earth's surface can impact igneous, metamorphic and sedimentary rocks. The processes influenced by environmental changes include rates of weathering, erosion and deposition.

### Weathering

The term weathering describes the processes that affect the structure of rocks and breaks them down into smaller pieces.

#### Physical weathering

Agents of physical weathering include wind, rapid changes in temperature, water, ice and salt crystallisation. Figure 5.9.3 shows the effects of rapid temperature changes causing onion skin weathering of rock. This occurs in arid regions where temperatures can drop below zero at night causing water to freeze in cracks in the rock forcing particles apart.

#### Chemical weathering

Chemical weathering occurs when water with dissolved chemicals from the soil and air reacts with the rock, causing it to change colour or weaken. Figure 5.9.4 shows the effects of carbonic acid (carbon dioxide dissolved in water) on limestone. Chemical weathering of rocks also occurs when high levels of pollutants from the burning of fossil fuels, such as sulfur dioxide and nitrogen oxides, combine with water in the atmosphere to form acid rain.

#### Biological weathering

Biological weathering is commonly caused by the actions of plants and animals. For example, plant roots grow through cracks and split rocks, while plant enzymes and acids from **humus** can dissolve rocks. Deforestation reduces the rates of biological weathering by plants. Trampling by animals can also impact rock structure. As more land is occupied by hard-hooved livestock, weathering of the surface increases (Figure 5.9.5). Burrowing by animals such as rabbits into rocks can also break them down.



**FIGURE 5.9.3** Onion skin weathering is a type of physical weathering caused by rapid temperature changes.



**FIGURE 5.9.4** Chemical weathering of limestone



**FIGURE 5.9.5** Trampling by hard-hooved animals like cattle causes weathering of the ground surface.

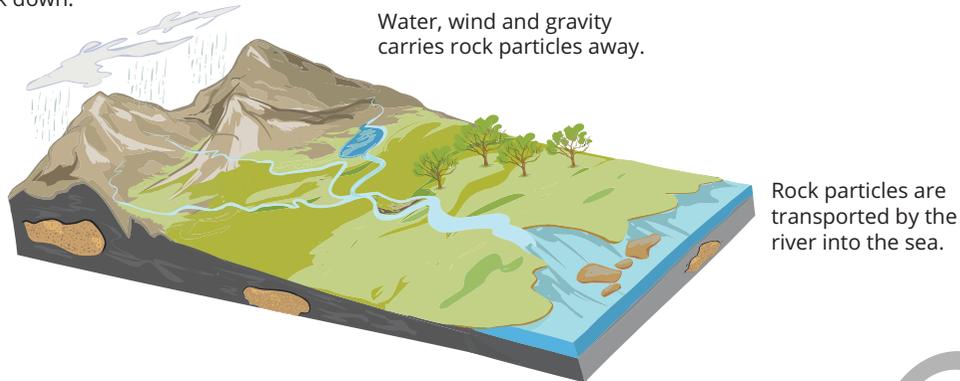
#### KEY TERM

**humus** dark material in soils produced by the decomposition of plant or animal remains

## Erosion

Erosion is the transportation of small rock particles created by weathering. Water, wind, gravity and ice (agents of erosion) move the particles away from the site of weathering (Figure 5.9.6).

Weathering causes rocks to break down.



**FIGURE 5.9.6** Erosion transports particles from the site of weathering to where they are deposited.

Rates of erosion are influenced by weather and climate. For example, episodes of high wind and rainfall such as with cyclones increase the rate at which weathered material is moved. Increased rainfall increases the incidence of landslides. In regions where conditions are becoming drier, high winds result in the transportation of more weathered material. Climate change causing glaciers to melt increases the erosion rate of meltwater and reduces erosion by ice.

## Deposition

The rock particles transported through erosion are deposited when the agents of erosion (water, wind, gravity or ice) lose energy and slow. This forms a layer of sediments. For example, when water slowed in the Colorado River, sand and rocks were deposited in the riverbed (Figure 5.9.7).



**FIGURE 5.9.7** Deposits of rock and sand in the Colorado River, USA

### SC 2 CHECK YOUR UNDERSTANDING

Australia's climate is expected to dry with climate change. Predict two impacts this might have on the rock cycle in Australia.

**SC 3** I can predict and explain locations where specific types of rocks are found

## Where specific types of rocks are found

Most of the rocks found in Australia are either igneous or sedimentary rocks. However, metamorphic rocks can be found in some regions of Australia, particularly in the Pilbara and Yilgarn in Western Australia where ancient gneiss rock formations are common. Igneous rocks formed during volcanic activity and mountain building, for example those on the east coast when the Great Dividing Range formed. Sedimentary rocks formed when large parts of Australia's interior were a shallow sea. Some of Australia's well-known landmarks are the result of environmental changes to these rock types.



**FIGURE 5.9.8** Mount Kosciuszko is part of a mountain range formed when igneous granite was uplifted.



**FIGURE 5.9.9** Wave Rock is a landmark formed from porphyritic igneous granite.



**FIGURE 5.9.10** Uluru is the remnants of the sedimentary rock arkose.



**FIGURE 5.9.11** Sedimentary limestone forms the Twelve Apostles.

## Igneous landmarks

Mount Kosciuszko in New South Wales is formed of igneous granite rocks. Igneous rocks are often found at mountain ranges where volcanic activity has occurred, or where there has been large-scale uplift of igneous rock formed deep in the crust, as occurred in the Australian Alps. The craggy appearance of the rocks in the Mount Kosciuszko landscape (Figure 5.9.8) is due to cracks that formed by weathering from water and ice. The scattered rocks are due to the erosive action of melting snow and gravity transporting some boulders downhill.

Western Australia's Wave Rock (Figure 5.9.9) is formed from porphyritic igneous granite with embedded crystals. Most of the stripes of colour on the rock are due to chemical weathering, but the black and brown stripes are due to discolouration from algae that lives on the rock. Water erosion has undercut the base.

## Sedimentary landmarks

Uluru in the Northern Territory is the remnant of sediments eroded from an ancient mountain range (Figure 5.9.10). The sediments were buried and compressed to form harder rock, resulting in the sedimentary arkose rock of Uluru. Arkose is made from sandstone and feldspar.

Figure 5.9.11 shows some of Victoria's Twelve Apostles, sea stacks made of sedimentary limestone. The rocks began forming hundreds of millions of years ago when pieces of sediment such as shells, coral and animal skeletons settled at the bottom of the ocean, layer upon layer. These sediments gradually compressed together to turn into limestone. Weathering and erosion have created the sea stacks.

## Metamorphic landmark

Trephina Gorge is in the East MacDonnell Ranges of the Northern Territory (Figure 5.9.12). This gorge has sheer cliffs made of metamorphic quartzite. The quartzite was once sandstone, but heat and pressure metamorphosed the sandstone to quartzite, which later uplifted to form the MacDonnell Ranges. Weathering and erosion have created the gorge.



**FIGURE 5.9.12** The MacDonnell Ranges formed when metamorphic quartzite was uplifted.

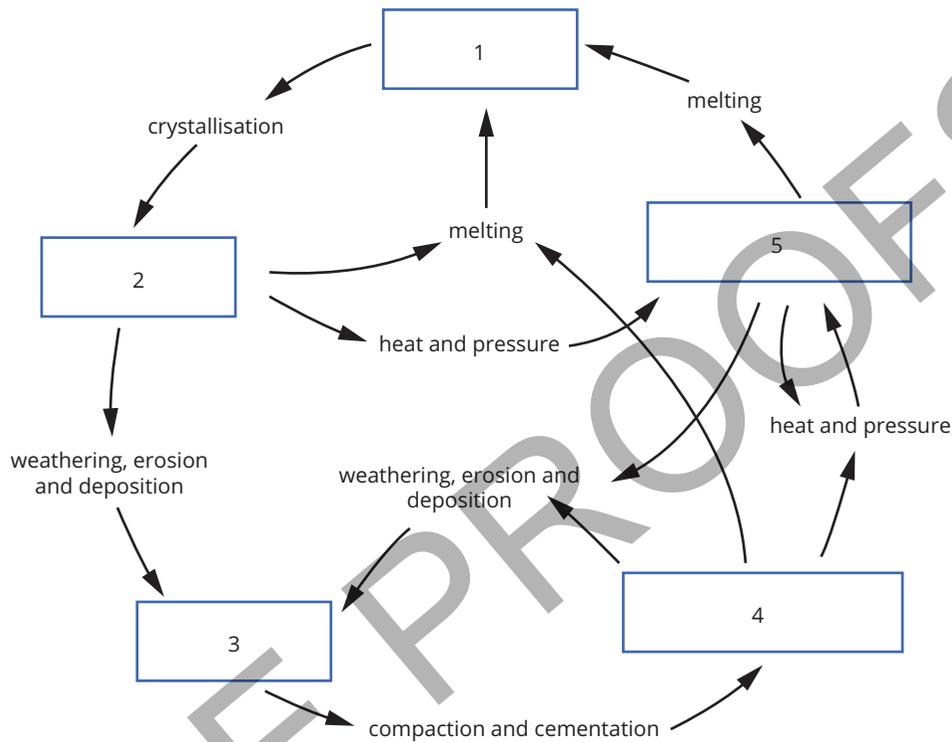
### SC 3 CHECK YOUR UNDERSTANDING

Identify the rock type or types that are the most abundant in Australia.

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

- Outline the five stages involved in the formation of sedimentary rocks.
- Compare the role of heat in the formation processes of igneous and metamorphic rocks.
- Identify the stages of the rock cycle labelled 1 to 5.
- Compare the effects of weathering and erosion on igneous rocks in a tropical climate versus a desert climate.



- You are mapping the distribution of different rock types in various geological settings.
  - Identify the types of rocks you would expect to find in a volcanic region.
  - Explain the processes that lead to the formation of these rocks.
  - Predict the types of rocks found in a river delta and explain their formation.
  - Evaluate the role of uplift on the distribution of all three rock types.
- 'Australia has the best sand beaches in the world because the landscape is so old.'  
Evaluate this statement, considering the role of the rock cycle in creating these beaches.

## 5.10 Mineral resources in Australia

### Learning intention

To be able to explain how the mining of Australian mineral resources influences/impacts society

### Success criteria

**SC 1:** I can describe how groups of First Nations Australians use quarrying to access rocks and minerals.

**SC 2:** I can describe the impacts of the Australian mining industry on Australian society.

**SC 3:** I can explain the impacts of Australian society on the Australian mining industry.



**FIGURE 5.10.1** The Ochre Pits in Tjoritja/West MacDonnell National Park in the Northern Territory are utilised by the Arrernte people.

### Introduction

Australia is rich in valuable mineral resources, including iron ore, gold and alumina. Australia's mineral resources have played, and continue to play, a major role in Australia's economy. Traditional mining has also been carried out by First Nations Australians over thousands of years (Figure 5.10.1).

Understanding the differing aims and processes of modern mining compared to traditional methods helps highlight the historical and cultural significance of First Nations Australians' mining. This knowledge also supports ongoing dialogue between First Nations Australians and the commercial mining industry.

Australian society influences the country's mining practices through social expectations and values, environmental awareness, activism and advances in technology.

In this inquiry activity, you will investigate the impacts of mining practices on Australian society, and vice versa.

### Background

First Nations Australians have engaged in mining for many generations, extracting resources like ochre and the minerals needed for tools, artwork and cultural practices. First Nations mining operations are generally localised, small-scale and deeply embedded in their cultural and spiritual traditions. Their practices are guided by a deep understanding of the local ecosystem.

In contrast, commercial mining companies operate on a much larger scale and are driven by profit, targeting valuable building, mineral and hydrocarbon resources such as sandstone, iron ore, gold and coal. These operations can have significant environmental impacts, including water pollution, habitat destruction and the potential displacement of First Nations communities from their traditional lands.

Commercial mining operates under the legal framework of the *Native Title Act 1993*, which requires negotiation and agreement with First Nations communities who hold native title rights over the land.

Commercial mining in Australia began in the late eighteenth century and focused on extracting precious minerals like gold and silver, often in small-scale, manually intensive operations. The mid-nineteenth-century Gold Rush in regions including Victoria and New South Wales resulted in large-scale commercial gold mining, causing population growth and the establishment of mining towns.

In the late nineteenth century, advances in mining technology led to the expansion of commercial operations to include other valuable minerals such as copper and iron ore. Commercial mining of mineral resources today continues to be shaped by changing societal expectations and environmental awareness.

## Aim

The aim of this activity is to explore how mineral resources have been extracted in Australia. Once your area of research has been identified, you may need to access information relating to methods used, how mining impacts people and the environment, and how the ideas and needs of society at the time have influenced different approaches to mineral extraction in Australia.

Possible areas for investigation are:

- how (at least two) groups of First Nations Australians use quarrying to access rocks and minerals
- how the commercial mining industry has evolved over time, and the impact of this industry on the development of Australian society
- how Australian society has influenced the commercial mining industry.

Your teacher will allocate your group a research topic. You will then present the findings of your inquiry to your class.

## Plan

Working in your groups, discuss the research task you have been allocated and what you will need to find out. For example, depending on your topic, it may help to consider which First Nations groups to research based on the availability of relevant information, why rocks and minerals are mined, how mining is carried out and why attitudes towards mining may have changed. Take notes on your discussion.

## Design

- 1 Identify the research questions that will help you complete your task, as well as possible sources of information and who is responsible for them. Record this information in a table. An example has been provided to get you started.

Research question	Sources of information	Who will research this?
Why do First Nation Australians quarry for rocks and minerals?	Internet, textbooks, other reference books	Jessie

- 2 Agree on how the research will be conducted and when it should be completed.

## HINTS

You will need to carry out research for this inquiry activity. When sourcing information from the internet, you must make decisions about whether the content you find is helpful and accurate. Consider the following questions when undertaking internet research:

- 1 Does it answer my question? Only record information that links directly to your research question.
- 2 Is this a credible author or source? Factual information is more credible from official organisations, government sites and authors with relevant qualifications and experience.
- 3 Can I find other sources to support the information I have found? If multiple sources provide the same answers, the information is more likely to be reliable.

### GO TO

Toolkit sections 2.3, Sites on Country/Place and 5.3, Using Artificial Intelligence (AI) in science writing

## Conduct

- 1 State your assigned research question/s.
- 2 Use a table like the one below to summarise your research. Be sure to include details about the sources of your information such as website addresses or book titles.

Research notes	Source information

### HINTS

To answer the Improve questions, consider the following.

Group collaboration: Was everyone clear on their role? Did everyone contribute?

Responding to your research question: Were there any gaps in your response that needed further research? Did you make a note of these in your presentation?

Mode of communication: How did you choose to communicate your findings? For example, did you use a poster or a slideshow presentation when showing it to the class? Discuss whether you believe extra visual aids would have been useful in your presentation.

References and acknowledgements: Did you include references.

- 3 Review your findings and refine them to ensure they answer your assigned research question/s. Record the key points, ensuring your research includes examples.
- 4 Return to your group to discuss your topic as a whole. Does everyone agree that all the research questions have been answered?
- 5 Collate the group's information into a report or presentation and deliver it to your class.

## Improve

- 1 What worked well during your group task?
- 2 What needed improvement?
- 3 What would you change about how your group approached the task?

## Evaluate

- 1 What was the most important thing you learnt from your research?
- 2 What did you learn from the information presented by other groups? Write down three main points.
- 3 How did your attitudes towards mining change because of the research?

# 5 The rock cycle

## Topic summary

The key concepts included in this topic are:

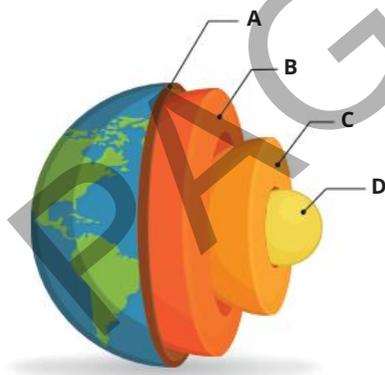
- Earth's internal structure is made up of four main layers.
- Rocks on the surface of Earth undergo constant change.
- Weathering of rocks can be physical (mechanical), chemical and biological.
- Sedimentary rocks form when rocks are weathered, eroded and deposited as sediments, with the sediments then undergoing the geological processes of compaction and cementation.
- Resources in rocks can be identified using deep Earth imaging techniques.
- Intrusive igneous rocks form when rocks melt to form magma and then solidify below Earth's surface. Extrusive rocks form when lava solidifies on Earth's surface.
- Metamorphic rocks form when rocks are exposed to high heat and/or pressure.
- Environmental changes affect the processes and rock types in the rock cycle.
- The mining of Australian mineral resources influences and impacts society, with societal expectations in return influencing the mining industry.

## Review questions

The following questions will assess your success in achieving the learning intentions for this topic.

### Remember

- 1 Use the diagram of the layers of Earth to complete the following questions.



- a Identify the layers of Earth shown on the diagram.
  - b Which layer is liquid?
  - c How do scientists know about the composition of Earth's internal layers?
- 2 Compare the processes of erosion and deposition.

- 3 Identify the common features of sedimentary rocks.
- 4 First Nations Peoples in Australia have been long involved in the extraction of mineral resources. State one example that outlines where mineral extraction occurs or has occurred, and the First Nations Peoples who value the resource.

### Understand

- 5 Describe the difference between the lithosphere and the asthenosphere.
- 6 A dichotomous key is a useful tool to classify rocks.
  - a Describe the features of a dichotomous key.
  - b State the characteristics that would help you to distinguish an intrusive igneous rock from a clastic sedimentary rock while using a dichotomous key.
- 7 If a granite rock is exposed to acid rain, which type of weathering will occur, and what will be the result?

- 8** Describe the three types of metamorphism that transform parent rocks into metamorphic rocks.

## Apply

- 9** Australia has a very extensive coastline with a variety of landforms.
- Name three landforms you might see on the coast.
  - List two environmental factors that contribute to the weathering of rocks in a coastal area.
  - Explain how weathering and erosion work together to shape the coastal landscape.
- 10** In August 2019 a volcano erupted under the surface of the Pacific Ocean near Tonga. The only sign of the undersea eruption was a large 150 square kilometre raft of bubbly igneous pumice floating on the ocean surface.



- What type of igneous rock is pumice?
- Explain the processes of igneous rock formation that results in a raft of pumice on the ocean surface.
- Lots of pumice ended up on the east Australian coastline after some months. It was covered in algae, barnacles, corals and worms. Propose why the pumice rocks had become much smaller in this time.
- Name the stage in the rock cycle reached by the pumice once it arrived on Australia's beaches.

- 11** Consider a crystal of quartz. Draw a rock cycle diagram to show the geological processes required for quartz to form:

- the extrusive igneous rock rhyolite, then
- the sedimentary rock sandstone, then
- metamorphic quartzite.

## Analyse

- 12** A species of marine trilobite has been discovered for the first time in sedimentary rock in the Sahara Desert in Algeria.
- Describe the sedimentary rock's formation environment.
  - Outline the geological processes that would bring the trilobite fossil from the environment of its formation to the sands of the Sahara Desert.
  - Assess the usefulness of this species of trilobite as an index fossil.
- 13** You have found this igneous rock. It is about 4 cm wide. What can you infer about its formation?



- 14** You have been given a number of metamorphic rocks that have been organised into three metamorphic sequences (A, B and C). Some of the rock's labels are missing.

A:  → slate →  → gneiss

B: limestone →

C: sandstone →

- Identify the unlabelled rocks numbered 1 to 4 that belong to the metamorphic sequences.
- Identify the parent rock in each sequence.
- Describe a feature you would expect gneiss to have that Rock 1 would not have.

## Extension: Research task

- 15** 'Diamonds are formed from the metamorphism of coal.'

Conduct research to evaluate the validity of this statement. In your research, determine how diamonds found at or near Earth's surface are formed. Is coal involved in this process, and if so, how?

Present a short report of 200–300 words outlining the diamond formation processes. Conclude your report with an evaluation of the validity of the statement.

## Topic reflection

The learning intentions for this topic are given in each lesson and at the beginning of the topic. Consider how well you have achieved them. Note down any particular areas that you are confident in, and others where you are not so sure.

# 5 Glossary

**asthenosphere** near the top of the mantle, just below the solid lithosphere, and it contains rock that can move very slowly

**biogenic sedimentary rock** sedimentary rock formed mainly from dead organisms

**biological weathering** living things and their products breaking down rock

**cementation** the binding together of sediments as part of the formation of sedimentary rock

**chemical sedimentary rock** sedimentary rock that forms when dissolved materials precipitate from solution

**chemical weathering** chemicals in minerals or air reacting with water, resulting in the breaking down of rocks

**clastic sedimentary rock** sedimentary rock formed mainly from small rock particles

**compaction** the squeezing of layers of sediments caused by pressure from layers above

**contact metamorphism** a type of metamorphism where rock is altered mostly by heat

**crust** the outermost layer of Earth, composed of solid rock

**crystallisation** evaporation of a solvent from a solution, leaving solute behind as crystals

**deposited** the settling of broken rock material to form sediment

**dichotomous key** a key with two choices at each stage

**dynamic metamorphism** a type of metamorphism where rock is altered mostly by pressure

**erosion** the movement of weathered rock particles from the site of the weathering

**extrusive igneous rock** igneous rock that forms on the surface of Earth

**foliated** a process where minerals under pressure realign and the rock develops layers or bands

**fossil** the preserved evidence in rocks or soils of organisms that were once alive

**geothermal energy** the heat energy that comes from within Earth

**humus** dark material in soils produced by the decomposition of plant or animal remains

**igneous rock** rock formed by the cooling of molten rock, for example basalt

**index fossil** a fossil that can be used to compare the relative age of rock strata in different locations

**inner core** extremely hot, solid ball made of iron and nickel at the very centre of Earth

**intrusive igneous rock** igneous rock that forms below the surface of Earth

**lava** molten rock that reaches Earth's surface

**lithosphere** name for the crust and the upper mantle together; Earth's tectonic plates

**magma** molten rock below Earth's surface

**mantle** solid layer of Earth between the crust and the outer core

**metamorphic rock** rock formed when heat and/or pressure alter existing rock

**mineral** a naturally occurring solid substance that is inorganic, has a characteristic crystalline structure and a fairly constant chemical composition

**outer core** a liquid layer of Earth's interior, primarily composed of liquid iron and nickel; located beneath the solid mantle and surrounds the inner core

**parent rock** a rock that experiences metamorphism, or changes form, to become a new kind of rock

**physical weathering** the breaking down of rocks by physical processes

**porphyritic** describes the texture of intrusive and extrusive igneous rocks that have large crystals surrounded by finer crystals or grains

**primordial** something that originated during the planet's formation process a very long time ago

**regional metamorphism** a type of metamorphism where rock is altered by both heat and pressure over a wide area

**rock cycle** a model geologists use to explain the endless cycle of change that rocks undergo

**rock** a solid mass of one or more minerals

**sediment** solid material that has broken down and moved because of erosion

**sedimentary rock** rock made by sediments being compacted and cemented together

**spit** stretch of beach material, connected to land and jutting out into the water

**volcano** a place where extremely hot material from inside Earth erupts at the surface

**weathering** the physical, chemical and biological processes that break rocks down into smaller pieces

PAGE PROOFS



## ATTRIBUTIONS – Pearson Science Victoria Student Book 8

The following abbreviations are used in this list: t = top, b = bottom, l = left, r = right, c = centre.

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