PEARSON

# Science

STUDENT BOOK | NEW SOUTH WALES

Stage 4

NSW SYLLABUS

# Topic 13 Geological change

## Prior knowledge

### Structure of Earth

**1** The two layers of the Earth closest to the surface are the crust and the mantle.

**2** Temperature increases on Earth's surface to extremely high temperatures in Earth's centre. Pressure also increases closer to the centre of Earth.

### Geological processes

**3** Weathering is the process of larger rocks being broken down into smaller rocks, transportation is the movement of weathered material.

### Rocks and minerals

**4** Minerals are pure elements or compounds, whereas rocks are mixtures of minerals. Possible examples:

Minerals; diamond, quartz, gold, gypsum

Rocks; limestone, granite, sandstone, basalt.

### Plate tectonics

**6** Two natural disasters caused by the movement of tectonic plates include earthquakes and volcanoes. Tsunamis can also occur after underwater earthquakes or the collapse of erupting underwater volcanoes.

**7** The Himalayas was created when processes in Earth's crust caused the rocks to rise. In this process, rock with marine fossils were uplifted, leaving the fossils high up in the mountains.

## 13.1 Structure of Earth

### Check your understanding

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

**a** The layers are:

1: crust

2: mantle

3: outer core (liquid)

4: inner core (solid)

**b** Outer core is liquid, inner core is solid.

**SC 2: I can describe the layers of Earth's internal structure and compare them to other planets in the Solar System.**

Earth's Core: Primarily composed of iron and nickel. It consists of a solid inner core and a liquid outer core.

Neptune's Core: Believed to be composed of rock and metal, surrounded by a layer of water, ammonia, and methane ices. The core is solid, but it is surrounded by a thick layer of highly pressurised and hot ices and fluids.

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

The movement of liquid in the outer core distributes heat from the very hot inner core to the cooler mantle and crust. This happens because heat moves from warmer areas to cooler areas.



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## Lesson review

1 Earth's mantle is located below the thinnest outermost layer, the crust. The mantle layer is above the liquid outer core.

2 Earth's core generates Earth's magnetic field.

3 Mercury, Venus, and Mars

4 The layers of Earth with the stated characteristics:

**a** outer core

**b** mantle

**c** inner core

**d** crust

**e** inner core

**f** crust

**g** crust and mantle

5 Two sources of heat within Earth's internal structure are primordial heat, retained from when Earth was formed, and the heat generated from radioactive decay.

6 Geothermal energy close to the surface can heat groundwater that escapes to the surface as hot springs.

# 13.2 Changes to rocks on the surface of Earth

## Check your understanding

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

Physical weathering breaks rocks into smaller pieces without changing their chemical composition, while chemical weathering involves chemical reactions which break down the rock.

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

Weathering involves the physical, chemical or biological breakdown of rocks, while erosion involves the movement of these weathered materials from one location to another.

## Lesson review

1 The three main types of weathering are physical (mechanical), chemical, and biological weathering.

2 Physical weathering involves the mechanical breakdown of rocks into smaller pieces without changing their chemical composition. Biological weathering involves living organisms, such as plant roots or lichens, breaking down rocks.

3 Physical weathering breaks down rocks into smaller particles. These particles are then carried away by wind or water in the process of erosion. These two processes can form landscape features such as sand dunes, canyons and gorges.

4 **a** Chemical weathering of the limestone, and physical weathering through the impacts of water and biological action have broken down the limestone rock into smaller pieces to help form the cave system.

**b** Erosion by water (Jenolan river and rain) have carried away weathered material, sculpting the cave system into their current shapes.

**c** Over time, continued weathering and erosion will likely cause the Carlotta Arch to become smaller, and more likely to collapse.



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# 13.3 Practical investigation: Weathering of rocks

## Results

**Part A**

| Test tube | Rock | Liquid | Observations |
|---|---|---|---|
| 1 | granite | water | no change |
| 2 | granite | vinegar | no reaction |
| 3 | limestone | water | no change |
| 4 | limestone | vinegar | chemical reaction – bubbles formed |
| 5 | sandstone | water | water becomes cloudy |
| 6 | sandstone | vinegar | slight reaction – a few bubbles formed |

**Part B**

| Container | Observations |
|---|---|
| 1 Plaster without water balloon | no change |
| 2 Plaster with water balloon | plaster cracked / broke up |

## Discussion

**Sample answer:**

Chemicals, such as the acid in vinegar, exist naturally in the environment. Temperatures often drop below 0°C, causing water to freeze. Rocks are weathered by these processes in the natural environment, in the same way as shown in this investigation. So, the experiment models the weathering of rocks reasonably well, although the concentrations and the time scales in this experiment are far too short to be realistic.

## Conclusion

1. The acids in the environment will react with some rocks, including limestone and sandstone. The products of the chemical reaction can then be blown or washed away via erosion. Over a long time, this will remove some parts of some rocks.
2. Water expands when it freezes. This expansion can push the rocks apart with enough force to break them.

# 13.4 Sedimentary rocks

## Check your understanding

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

The three main stages of the formation of sedimentary rocks are:

Stage 1: Weathered sediments carried by water, wind or ice are deposited at the bottom of large bodies of water.

Stage 2: Over time, the layers of sediments push down on lower layers, squeezing out excess water in the process of compaction.

Stage 3: Cementation is the third stage, where minerals in water, such as silica or lime, bind or cement the compacted sediments

**SC 2: I can explain how the law of superposition and fossil evidence can be used to predict how and when a rock was formed**

Fossils are preserved when organisms are buried rapidly by sediments, protecting them from decomposition. Over time, compaction and cementation of the sedimentary layers occur, and the organism's remains are replaced by minerals and so become fossils.



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## Lesson review

1 Sedimentary rocks are typically formed in environments such as deep rivers, lakes and oceans, where sediments are deposited over time. Some also form in deserts and caves.

2 Compaction occurs when layers of sediments are pressed together under the weight of overlying layers, reducing the space between sediment particles. Cementation happens when minerals precipitate from water and fill the spaces between the compacted sediment particles, binding them together to form solid rock.

3 The law of superposition states that in an undisturbed sequence of rock layers, the oldest layers are at the bottom and the youngest layers are at the top. This helps geologists determine the relative age of rock layers by examining their position in the sequence.

4 Fossil evidence can be used to determine the age of rock layers by identifying and dating the fossils found within them. Certain fossils, known as index fossils, are characteristic of specific geological time periods. By matching these fossils to known time periods, geologists can estimate the age of the rock layers in which they are found.

5 Water plays a crucial role in the formation of sedimentary rocks by transporting sediments to new locations, where they settle and accumulate in layers. Over time, the weight of the overlying layers compresses the sediments, and minerals dissolved in water act as a cement to bind the particles together, forming solid rock.

6 Student answers may vary but could include:

Determining the age of sedimentary rocks using the law of superposition involves examining the position of rock layers to establish a relative timeline, where the oldest layers are at the bottom and the youngest at the top. Fossil evidence is used to provide more precise age estimates by identifying and dating the fossils within the layers.

# 13.5 Igneous rocks

## Check your understanding

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

Intrusive igneous rocks form below the ground from cooling magma. Extrusive igneous rocks, in comparison, form above the surface from cooling lava.

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

**a** This intrusive igneous rock cooled beneath the ground.

**b** The rock will contain large crystals, as those that formed beneath the ground will be larger than the small or microscopic crystals formed if it had rapidly cooled above ground.

## Lesson review

1 Intrusive igneous rocks form from magma that cools slowly beneath Earth's surface, resulting in large crystals. Meanwhile, extrusive igneous rocks form from lava that cools quickly on the surface, resulting in small or no crystals.

2 A rock with large, visible crystals is likely an intrusive igneous rock, formed by cooling slowly beneath Earth's surface, allowing large crystals to develop.

3 **a** Observable features of igneous rocks include crystal size, texture and mineral composition.

**b** Slow cooling allows large crystals to form, resulting in a coarse-grained texture, while rapid cooling results in small crystals and a fine-grained texture.

**c** Intrusive igneous rocks have coarse-grained textures with large crystals, while extrusive igneous rocks have fine-grained textures with small or no crystals.



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**d** Colour is important for identifying igneous rocks as it provides information about the rock's mineral composition.

**e** As the rock contains crystals of varying sizes, it is likely to be a porphyritic igneous rock.

**4** As heat energy is lost slowly from magma below the ground larger crystals form. When this magma is exposed to cooler air it cools more rapidly, creating smaller crystals. This results in porphyritic rocks that contain both large and small crystal sizes.

**5** **a** This bubbly-textured rock specimen is most likely to be an extrusive igneous rock.

**b** The molten material from which it formed is most likely to be lava as the small grains indicate that it cooled rapidly on the surface.

**c** Heat energy would have been lost rapidly to the surrounding environment.

**d** The likely cause of the bubbly texture is bubbles of gas trapped as the lava cooled rapidly.

**e** The igneous rock is likely to be pumice.

# 13.6 Metamorphic rocks

## Check your understanding

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

The two effects of metamorphism are:

- a chemical change: to form a different mineral
- a physical change: to form a different shape.

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

**a** The parent rock of schist is shale (also known as mudstone).

**b** Schist is a foliated metamorphic rock.

## Lesson review

**1** Metamorphic rocks typically form deep within Earth's crust where high temperatures and pressures cause existing rocks to change.

**2** High pressure and temperature cause the minerals in the parent rock to recrystallise and form new mineral structures, leading to the formation of metamorphic rocks. These conditions can be found deep within Earth's crust.

**3** A rock subjected to high pressure but relatively low temperature might be a foliated metamorphic rock such as slate.

**4** Quartzite forms from the parent rock sandstone through high temperature and lower pressure conditions, resulting in a non-foliated rock type. Schist forms from the parent rock shale or mudstone through high levels of pressure and temperature, resulting in a foliated rock type with visible crystals.

**5** **a** Heat energy causes the recrystallisation of minerals, changing the mineral composition and texture of the rock.

**b** Pressure causes minerals to align, creating a foliated texture with parallel layers or bands or cleaves.

**6** Slate is suitable for these purposes as it is a hard foliated rock, has a fine grain, and has very strong cleavage lines that allow it to be split into flat and thin, but strong, sections.



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# 13.7 Practical investigation: The source of metamorphic rocks

## Try yourself

### CLASSIFYING ROCKS

| Thinking | Working |
|---|---|
| Does the rock have crystals? | No, go to 6. |
| Is the rock non-crystalline and is it made of pieces or chunks of smaller rock? | Yes, *Sedimentary, clastic* – go to 7. |
| Does the rock have large pieces or chunks of smaller rock? | Yes, go to 8. |
| Are the large pieces or chunks of smaller rock rounded? | Yes, the pieces or chunks of smaller rock are rounded. The rock is *Sedimentary, clastic, e.g. conglomerate* (Note: This rock is conglomerate.) |

## Results

**Task 1**

Task 1 results will depend on the rocks the students have been allocated.

**Sample results:**

| Rock number | Description | Classification | Rock name |
|---|---|---|---|
| 1 | Light colour<br>Interlocking crystals | Igneous intrusive<br>Felsic | Diorite |

**Task 2**

Task 2 results should show the parent/metamorphic rocks correctly matched with relevant descriptions and the metamorphic rocks correctly identified with correct reasoning.

**Sample results:**

| | Parent rock | Description | Metamorphic rock | Description |
|---|---|---|---|---|
| **Pair 1** | Limestone | Light colour<br>No interlocking grains<br>Sedimentary rock | Marble | Light colour<br>Interlocking grains<br>Crystalline |
| **Pair 2** | Shale | Dark colour<br>No interlocking grains<br>Soft<br>Sedimentary rock | Slate | Dark colour<br>Foliated<br>Hard<br>Feels smooth<br>Can't see crystals |
| **Pair 3** | Shale | Dark colour<br>No interlocking grains<br>Soft<br>Sedimentary rock | Schist | Dark colour<br>Foliated<br>Can see crystals without a magnifier |
| **Pair 4** | Granite | Light colour<br>Interlocking crystals<br>Igneous rock | Gneiss | Light colour<br>Foliated<br>Hard<br>Can see crystals without a magnifier |



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| | Parent rock | Description | Metamorphic rock | Description |
|---|---|---|---|---|
| **Pair 5** | Sandstone | Light colour<br>Gritty texture – very fine grains, can't see with a magnifier<br>Soft<br>Sedimentary rock | Quartzite | Light colour<br>Can see crystals without a magnifier<br>Feels gritty |

Note: It is also possible that students may have determined that shale is the parent rock for gneiss, depending on the colour of the gneiss sample.

| Rock name | Reasons you have decided it is metamorphic | What changes occurred to make it metamorphic? |
|---|---|---|
| Marble | Crystals had formed compared to its parent rock | Large amounts of heat will have been applied to produce the crystals |
| Slate | Appears to have some foliation and has cleaves | Pressure applied to create the banding |
| Schist | Appears to have some foliation and has crystals | Large amounts of heat and pressure |
| Gneiss | Appears to have some foliation and has crystals | Large amounts of heat and pressure |
| Quartzite | Crystals have formed | Large amounts of heat |

## Discussion

Student answers will vary but could include:

- modification to the dichotomous key
- visual sorting of rocks by their own classification criteria.

## Conclusion

The conclusion should discuss how the dichotomous key was used and the process for determining parent/metamorphic rock relationship.

**Exemplar response:**

**Task 1**

I was able to classify the rock samples by analysing the colour and texture of each of the rocks and using a dichotomous key to determine what type of rock it is. I recorded relevant observations to use the dichotomous key, such as whether the rock had interlocking crystals and the size and shape of the visible grains. I combined my observations with research on the internet to determine the names of some of the rocks by comparing the sample with online images.

**Task 2**

For each pair, I was able to determine the parent/metamorphic rock relationship by identifying key features of each rock. My observations included looking for crystallisation and any obvious foliation in either of the rocks which would suggest that the rock had undergone a period of high temperature and/or heat, which would result in a metamorphic rock. I paired this with identifying features in the parent rock which may make it sedimentary or igneous, for example, the fine grains in limestone.



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# 13.8 The rock cycle in action

## Check your understanding

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

**a** igneous to sedimentary: weathering, erosion, deposition, compaction and cementation

**b** sedimentary to igneous: melting to form magma then crystallisation/cooling

**c** metamorphic to igneous: melting to form magma then crystallisation/cooling

**SC 2: I can predict and explain locations where specific types of rocks are found**

The most abundant rock types in Australia are igneous and sedimentary.

## Lesson review

**1** The five stages involved in the formation of sedimentary rock are weathering, erosion, deposition, compaction and cementation.

**2** Heat can melt existing rock to form magma and lava. When these cool and become solid, igneous rocks are formed. When rocks are subjected to heat but do not melt, changes to the rock such as the formation of new crystals occur, producing metamorphic rocks.

**3** **1** magma
**2** igneous rocks
**3** sediments
**4** sedimentary rocks
**5** metamorphic rocks

**4** **a** In a volcanic region, you would expect to find igneous rocks like basalt and pumice.
**b** These rocks form from the cooling and solidification or crystallisation of magma or lava.
**c** At the mouth of a river, you would find sedimentary rocks like sandstone and shale, formed from the accumulation and compaction of sediments carried by the river.
**d** Uplift can bring igneous, sedimentary and metamorphic rocks to the surface where weathering and erosion can occur to create new sedimentary rocks.
Pressure created by the uplift can cause rocks to metamorphose.
Uplift may bring molten magma closer to the surface which may trigger volcanic eruptions and the formation of new igneous rock.

**5** Australia is an old landscape, meaning that there is little to no formation of new igneous or metamorphic rocks. Weathering, erosion and deposition are the major geological processes occurring in Australia. This means that the rock of the Australian landscape is being broken down and transported by rivers to the ocean where it ends up on our beaches as sand. So Australian beaches can be considered the best in the world because there is so much sand and less rocks on the beach.

# 13.9 The theory of plate tectonics

## Check your understanding

**SC 1: I can describe the formation of the Earth and the tectonic plates**

The lithosphere is a rigid but brittle layer on Earth's surface which includes the crust and the upper layer of the mantle. The asthenosphere is a layer of the mantle, below the lithosphere, that is solid but behaves plastically as the solid rock can bend and flow over long periods of time.

**SC 2: I can identify the tectonic plates**

The major plates are the African, Antarctic, Eurasian, North American, South American, Australian, and Pacific Plates.



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**SC 3: I can explain the forces of motion of tectonic plates**

A: mid-ocean ridge

B: newer oceanic crust

C: older and denser oceanic crust

D: ridge push

E: subduction and slab pull

## Lesson review

**1** **a** Scientists believe Earth started to form about 4.5 billion years ago.

**b** Gravitational forces acted on the molten material of early Earth, resulting in the formation of layers with heavy materials pulled towards the centre and lighter materials rising to the surface.

**c** The asthenosphere is described as plastic because the solid rock can bend and flow over very long periods of time. This allows the tectonic plates to slide over the asthenosphere at a rate of 1.5 cm per year.

**2** Oceanic crust forms the ocean floor and is more dense than continental crust. Continental crust is found where there are continents and is less dense than oceanic crust.

**3** Arranged from youngest to oldest: orange then yellow then brown then green.

**4** Convection in the mantle occurs due to hotter, less dense mantle material moving upwards while cooler, more dense mantle material moves downwards. This causes a convection current that will drag the overlying crust along. Slab pull involves a sinking or subducting plate margin pulling the rest of the plate below the neighbouring continental plate, while ridge push involves gravity pulling new crust down and away from the mid oceanic ridge to push the plates apart.

**5** **a** 1: North American Plate
2: African Plate
3: Antarctic Plate
4: Australian Plate
5: Philippine (or Philippine Sea) Plate

**b** A: slab pull
B: ridge push

**c** The oceanic crust will be younger and less dense at B, as this is where new crust will be forming at a mid-ocean ridge.

# 13.10 Plate boundaries

## Check your understanding

**SC 1: I can describe differences between convergent, divergent and transform plate boundaries**

**a** transform plate boundary

**b** convergent plate boundary

**c** divergent plate boundary

**SC 2: I can analyse the role of plate boundaries in the formation of geological features**

Older oceanic crust is most likely to subduct as it is denser than both continental crust and younger oceanic crust.



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## Lesson review

**1** A convergent boundary is a boundary at which plates are being pushed together, divergent boundaries are where two plates move away from each other, transform boundaries are where two plates move alongside each other, either in opposite or the same direction.

**2** Continental crusts are of similar density, so when they collide they are most likely to push upwards to form tall mountain ranges.

**3** Students' answers will vary but could include:

**a** a convergent boundary

**b** a divergent boundary in the ocean

**c** a transform boundary

**4** Ocean trenches are formed at convergent plate boundaries where one tectonic plate is forced beneath another in a process known as subduction. The descending plate bends and creates a deep trench in the ocean floor.

Mid-ocean ridges are formed at divergent plate boundaries where two tectonic plates are pushed upwards to form the ridge by the rising magma below.

**5** **a** Convergent: The Himalayas

Processes: The Himalayas were formed by the collision of the Indian Plate and the Eurasian Plate. As these two continental plates converged, the immense pressure and compression caused the crust to buckle and fold, leading to the uplift of the mountain range.

**b** Divergent: The East African Rift Valley

Processes: The East African Rift Valley is formed at a divergent plate boundary where the African Plate and the Arabian Plate are diverging. As these plates move apart, the crust thins and sinks, creating a rift valley. Magma from the mantle can also rise to fill the gap, leading to volcanic activity. This process results in the formation of a linear valley with steep sides, and the rift continues to widen over time.

**c** Transform: The San Andreas Fault

Processes: The San Andreas Fault is a transform plate boundary where the Pacific Plate and the North American Plate slide past each other horizontally. The movement of these plates causes friction and stress to build up along the fault line, which is eventually released in the form of earthquakes.

# 13.11 Inquiry activity: Modelling the different types of plate boundaries

## Plan

**1** Possible solutions:
Boundary type: convergent
Plate 1: continental (less dense)  Plate 2: oceanic (more dense)
Geological formation: ocean trench

Boundary type: divergent
Plate1: oceanic  Plate 2: oceanic
Geological formation: ridge

Boundary type: transform
Plate 1: continental  Plate 2: continental
Geological formation: fault



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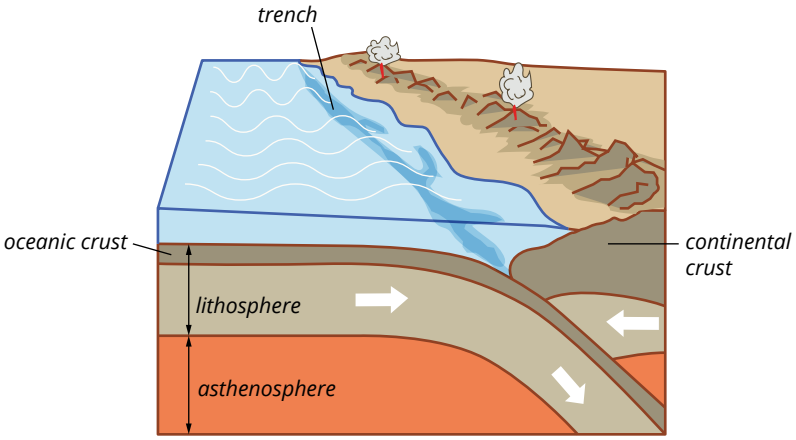
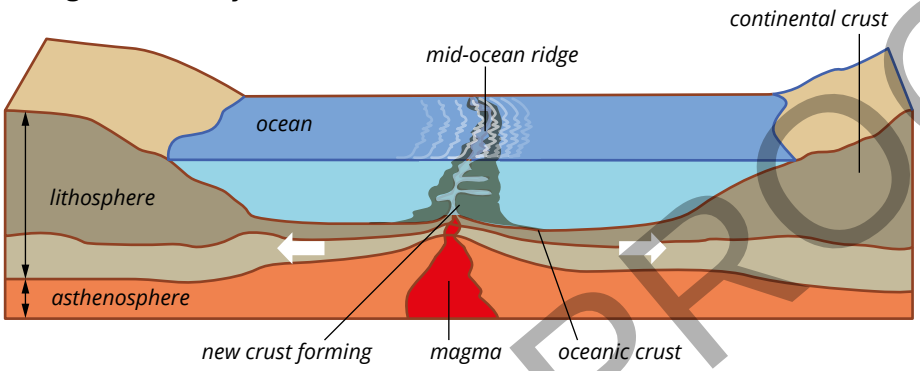
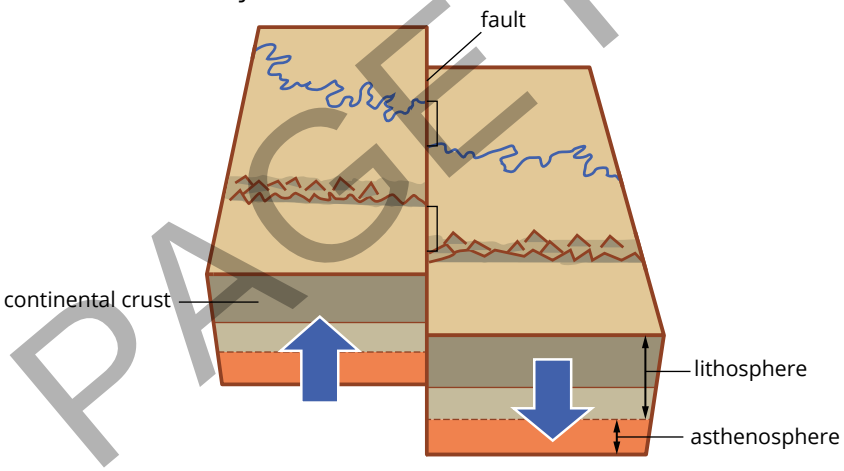
**2** Possible solutions:
Convergent boundary




**3** Divergent boundary




Transform boundary




**4** The lithosphere is solid and brittle. The asthenosphere is plastic and can flow.

## Design

**1** Sample responses:

Boundary: convergent, continental–oceanic
Lithosphere: biscuits (two types to signify the different crusts)
Asthenosphere: jam

Boundary: divergent, oceanic–oceanic
Lithosphere: biscuits
Asthenosphere: jam



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Boundary: transform, continental–continental
Lithosphere: deck of cards
Asthenosphere: layer of sand

**2** Sample responses:

For the convergent and divergent boundaries, jam has been used for the plastic asthenosphere because it can flow very slowly. The brittle lithosphere is shown by biscuits.

For the transform boundary, cards will slide alongside each other as the solid outer lithosphere, while the layer of sand will be the plastic asthenosphere.

**3** Strong features include identifying the difference in each material's properties to show that the asthenosphere can flow but the lithosphere is brittle. Other strong features may include identifying the difference in densities across oceanic and continental boundaries, if relevant.

**4** Sample response:

Boundary: convergent, continental–oceanic

Alternative design using an Oreo biscuit and a Mars bar

Lithosphere: biscuit of the Oreo shows the denser oceanic crust, while the fluffy/ chocolate part of the Mars bar shows the less dense continental crust

Asthenosphere: shown by the Oreo's centre and the caramel of the Mars bar, both of which can 'flow'

**5** Sample responses:

Photographs will be taken from directly above, with a group member recording each step after small changes are made to the model.

Photographs will be taken in bursts from the side after each small change is made to the model so that the best photograph of each stage can be selected for the stop-motion video.

## Improve

**1** Students may comment on the depiction of geological features in their video, such as mountains and the boundary; for example, the successful use of crumbling biscuits to model mountains and their properties, and whether the boundary clearly shows the direction of movement of the plates (convergent, divergent or transform). They may discuss the inclusion of a voiceover or other communication within the video to support the explanation of the model.

**2** A range of considerations could include the materials used, the modelling of the movement itself, how plastic versus brittle can best be modelled, and the suitability of the type of geological feature chosen to model.

## Discussion

**1** Student answers may differ, for example:

Biscuits:

Benefits: can be easily broken and moved to simulate the brittle nature of Earth's crust. They can be layered to represent different strata.

Limitations: may crumble too easily, making it difficult to control the model. They may not accurately represent the ductile behaviour of some geological materials.

Chocolate Bars:

Benefits: can be broken and moved to simulate tectonic plates. They can show the brittle fracture of the crust.

Limitations: can melt, especially under warm conditions, which may not be ideal for extended demonstrations. It may not accurately represent the plastic deformation of rocks.

Play Dough:

Benefits: Play dough is malleable and can be shaped to represent various geological features. It can show both brittle and ductile deformation.

Limitations: Play dough may dry out over time, losing its malleability. It may not accurately represent the rigidity of Earth's crust.



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**2** Software used or how the model is built: 2D or 3D digital model made with image editing software; animation built using Animaker, Blender or Adobe Animate

Format of communication examples: website, infographic, video

Annotations: lithosphere, asthenosphere, convergent boundary, divergent boundary, transform boundary, subduction, ridge, volcanoes, rift valley

Key impacts: earthquakes, volcanic eruptions, tsunamis

# 13.12 Earthquake and volcanic activity

## Check your understanding

**SC 1: I can describe patterns in the locations of earthquakes and volcanoes**

Most of Earth's active volcanoes are located on plate boundaries. Hot spot volcanoes form far from the boundaries when a tectonic plate moves across an area where hot material rises from the mantle.

**SC 2: I can describe how earthquakes are detected.**

The epicentre is the place on the surface directly above the focus of an earthquake.

## Lesson review

**1** **a** The earthquakes are distributed mainly on or near the tectonic plate boundaries.

**b** The earthquakes are located along the tectonic plate boundaries as this is where plates interact and collide with each other, resulting in sudden movements.

**c** The plates are the Australian Plate, Pacific Plate, Eurasian Plate and Philippine Sea / Philippine Plate.

**d** A natural feature that could be seen where earthquakes occur are volcanoes.

**2** The Galápagos Islands are forming over a hot spot in the Nazca Plate. This hot spot allows magma from the mantle to come to the surface to form volcanoes. As the Nazca Plate slowly moves, volcanoes move away from the hot spot and become extinct.

**3** **a** secondary waves (S-waves)

**b** surface waves

**c** primary waves (P-waves)

# 13.14 Inquiry activity: First Nations Australians' accounts of geological events

## Plan

Student answers will vary, sample answer:

I have chosen to research the Awabakal and Worimi Peoples' Dreaming story, 'The Kangaroo that lives inside Nobbys'. I plan to gather information from reliable sources such as the AIATSIS website, academic journals, and books on Indigenous knowledge. I will present my findings through a written report, ensuring that I address all the success criteria. My report will include images, maps, and quotes from my sources to make it engaging and informative.

## Design

Students' answers will vary. Sample answers could include:

**1** I have identified the Awabakal and Worimi Peoples and their Dreaming story, 'The Kangaroo that lives inside Nobbys'.

**2** I researched this account using reliable sources such as the AIATSIS website, academic articles, and books on Indigenous knowledge.



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**3** I found that the Dreaming story of 'The Kangaroo that lives inside Nobbys' is a significant cultural narrative for the Awabakal and Worimi Peoples. According to the story, a giant kangaroo once roamed the land and eventually laid down to rest, forming what is now known as Nobbys Head, a prominent geological feature in Newcastle, New South Wales. This event is remembered through oral traditions, passed down through generations, and serves as a powerful reminder of the connection between the land and its original inhabitants. The story is not only a cultural and spiritual touchstone but also provides an Indigenous perspective on the geological formation of the region. It underscores the importance of Dreaming stories in preserving Indigenous knowledge and offers a unique lens through which to understand Australia's natural history.

**4** I plan to present my findings in a written report, ensuring that I address all the success criteria.

**5** My outline includes: an introduction, a detailed account of the event, an explanation of how it was remembered, and its significance in understanding Australia's geology.

## Conduct

Students' answers will vary. Sample answers could include:

**1** I used the following websites to gather information:

- **a** Australian Institute of Aboriginal and Torres Strait Islander Studies (AIATSIS): https://aiatsis.gov.au
- **b** National Library of Australia: https://www.nla.gov.au
- **c** Indigenous Weather Knowledge: http://www.bom.gov.au/iwk/
- **d** The Conversation: https://theconversation.com/au

**2** I collected information from multiple sources to ensure accuracy and comprehensiveness. This involved cross-referencing details from various websites and academic articles to build a well-rounded understanding of the Dreaming story and its significance.

**3** I organised my notes and evidence logically, ensuring I covered all aspects of the success criteria. This included categorising information into sections such as the description of the Dreaming story, its cultural significance, and its geological implications.

**4** I began drafting my report, incorporating quotes and references from my sources to support my findings. For example, I included direct quotes from Indigenous elders and academic experts to provide authenticity and depth to my explanations.

Awabakal and Worimi Peoples have a Dreaming story known as 'The Kangaroo that lives inside Nobbys'. According to this story, Nobbys Head, a prominent headland at the entrance to Newcastle Harbour, is the resting place of a giant kangaroo. The kangaroo is said to be sleeping inside the hill, and its movements are believed to cause the tremors and shaking of the earth. This story is a way for the Awabakal and Worimi Peoples to remember and explain the occurrence of earthquakes in the region. The significance of this account lies in its ability to provide a cultural explanation for geological events, which can be valuable in understanding the history of seismic activity in the area. By preserving and sharing these stories, the Awabakal and Worimi Peoples contribute to our knowledge of Australia's geological past and the ways in which natural events have been interpreted and remembered by Indigenous communities.

## Improve

Students' answers will vary. Sample answers could include:

**1** I reviewed my draft thoroughly to ensure that all the success criteria were met. This involved cross-referencing my outline with the final content to confirm that each required element was addressed comprehensively.

**2** I meticulously checked for clarity and coherence in my explanations and descriptions. I read through my report multiple times, focusing on the logical flow of ideas and ensuring that each section transitioned smoothly to the next.



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3 I sought feedback from my teacher, who provided valuable insights and constructive criticism. Based on their suggestions, I made necessary revisions to improve the overall quality and accuracy of my report. This included refining certain sections for better clarity and adding more detailed explanations where needed.

4 I ensured that my written report was visually engaging and well-organised. I incorporated images, maps, and quotes to support my findings and break up the text, making it more appealing and easier to follow. I also used headings and subheadings to structure the content logically.

5 I practiced presenting my findings multiple times to ensure confidence and fluency. This practice helped me become more familiar with the material and allowed me to refine my delivery, ensuring that I could present my findings clearly and effectively to my audience.

## Discussion

1 Reflecting on the quality and depth of my research, I found it to be comprehensive and thorough. I utilised a variety of reliable sources, including the AIATSIS website, academic articles, and books on Indigenous knowledge, which provided a well-rounded perspective on the Dreaming story of 'The Kangaroo that lives inside Nobbys'.

2 Assessing how well I explained the significance of the Awabakal and Worimi Peoples' Dreaming story in understanding Australia's geology, I believe my explanation was clear and detailed. I effectively highlighted the cultural and spiritual importance of the story and its role in offering an Indigenous perspective on the geological formation of the region.

3 Considering how effectively I communicated my findings, I found my report to be engaging and informative. The use of images, maps, and quotes helped to support my findings and made the report visually appealing and easier to follow. The logical structure and smooth transitions between sections also contributed to the clarity of my communication.

4 Identifying areas for improvement in my research or presentation process, I recognised that seeking more diverse sources could have enriched my understanding further. Additionally, incorporating more direct quotes from Indigenous voices could have added authenticity and depth to my report.

5 Evaluating the overall impact of my work on my understanding of the topic, I found that it significantly enhanced my knowledge of the Dreaming story and its significance. The research process deepened my appreciation for Indigenous perspectives on Australia's natural history and underscored the importance of preserving and respecting these cultural narratives.

# 13.15 Evidence for the theory of plate tectonics

## Check your understanding

**SC 1: I can identify evidence to support the theory of plate tectonics**

**a** GPS monitoring

**b** magnetic striping

**c** seafloor spreading

**d** radiometric dating

**SC 2: I can analyse sources of data related to the theory of plate tectonics**

The distribution of Glossopteris fossils on continents that are now widely separated by oceans suggests that these continents were once connected, allowing the plants to spread across them. This supports the idea that the continents have moved over time.

## Lesson review

1 Magnetic striping shows symmetrical patterns of magnetic orientation in minerals either side of mid-ocean ridges. This indicates that new crust is continuously being formed and spreads outward, providing evidence for seafloor spreading.



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**2** The fit of the continents, such as the coastlines of South America and Africa, suggests that these continents were once connected and have since drifted apart. This supports the idea that the continents have moved over time due to the movement of tectonic plates.

**3** Students' answers will vary, but could include:

Evidence at a convergent plate boundary – formation of mountain ranges, GPS monitoring.

Evidence at a divergent plate boundary – magnetic striping, relative ages of rocks either side of a mid-ocean ridge to support sea floor spreading, radiometric dating of rocks, GPS monitoring.

**4** On the west coast of California, the speed of movement of the land is approximately 45 mm/year in a north-west (NW) direction. On the east side of California, the speed is slower at approximately 3 mm/year, with the direction mostly towards the north-west.

On the east side of California, the direction of movement is the same as the west coast of California, but it is considerable slower.

**5** **a** There are 4 episodes of normal polarity shown on the image (each of which is recorded on both sides of the mid-ocean ridge).

**b** Approximately 2 million years ago, the magnetic polarity flipped from reverse polarity to normal polarity. At approximately 1.9–1.8 million years ago, the polarity flipped to reverse polarity before changing to normal polarity again at approximately 1.5 million years ago.

**c** Earth's magnetic polarity is likely to switch to reverse polarity if it follows the trends of the past.

**d** Changes in the magnetic field recorded by minerals in the rock provides evidence that new oceanic crust is being formed at the mid-ocean ridges. The spread outwards is equivalent on either side of the ridge, supporting the theory of ridge push and seafloor spreading.

**6** Fossil distribution provides evidence for plate tectonics by showing that similar fossils are found on continents that are now widely separated, suggesting that these continents were once connected. Magnetic stripes on the seafloor provide evidence for seafloor spreading, as the symmetrical pattern of stripes records the history of Earth's magnetic field reversals. Both types of evidence support the theory of plate tectonics, but they do so in different ways: fossil distribution shows the movement of continents, while magnetic stripes show the formation of new oceanic crust.

# Topic review

## Remember

**1** Erosion involves the movement of weathered rock particles by agents of erosion (i.e. wind, water, gravity or ice). Deposition is the settling of weathered and eroded rock material to form sediment.

**2** Common features of sedimentary rocks include layers (strata), fossils and grain size variation.

**3** **a** The layers of Earth are:

A: crust, B: mantle, C: outer core, D: inner core

**b** The layer that is liquid is the outer core.

**c** Scientists know about the characteristics of Earth's internal layers because of the behaviour of earthquake waves. P-waves travel at different speeds through solids and liquids. S-waves are only able to travel through solids.

**4** **a** Subduction is the process when one plate sinks beneath another plate during a collision.

**b** Viscosity is the measure of a liquid's resistance to flow. For example, pitch is a highly viscous liquid that has a viscosity around 100 million times that of water at room temperature.

**c** Slab pull is the pulling force exerted by older, colder and denser oceanic plates sinking down into the asthenosphere due to gravity, dragging the rest of the plate with it.

**d** An epicentre is the point on Earth's surface directly above an earthquake focus (the place in the lithosphere where an earthquake starts).



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**5** Students' answers will vary but could include one of the following pieces of evidence.

The fossil record provides evidence in support of the theory of plate tectonics by showing:

- that the same species were present at the same time on continents that are now distant from each other, for example *Lystrosaurus* fossils are found on Africa, India and Antarctica
- how the continents were once joined in Pangaea, for example the distribution pattern of *Cynognathus* shows that South America fitted snugly against Africa
- that continents were once located in different climate zones, for example the presence of polar fossils in Victoria shows that Australia was once much further south, and the presence of *Glossopteris* in Antarctica where it is now too cold for plants to grow.

## Understand

**6** The lithosphere is a rigid layer made up of the crust and the very top layer of the mantle. The lithosphere is broken up into segments called tectonic plates. The asthenosphere is a layer in the mantle just below the lithosphere. It is also solid, but the rock can move very slowly.

**7** **a** A dichotomous key is a tool that has two choices at each stage to help with the identification of organisms or objects such as rocks.

**b** An intrusive igneous rock has crystals that are visible to the naked eye. A clastic sedimentary rock has clasts (particles) of various sizes, such as sand or mud, cemented together.

**8** Acid rain is a type of chemical, so chemical weathering of the outer parts of the limestone rock will occur. This will weaken the limestone and it will break down into smaller pieces.

**9** **a** The type of geographical evidence shown by this image is magnetic striping in oceanic crust on the sea floor.

**b** The youngest rocks are the inner bands closest to the rift (coloured red). Radiometric dating can be used to establish the age of rocks.

**c** The type of plate boundary shown in this image is a divergent plate boundary.

**d** Processes occurring as the oceanic crust moves away from the mid-ocean ridge in both directions include any two of ridge push, mantle convection and seafloor spreading.

**e** Earthquakes would not be expected to occur here as there is little to no build-up of stress as occurs at convergent and transform plate boundaries.

**f** Any two of the following geological features can form at a convergent plate boundary: fold mountains, volcanic island arcs, trenches, continental volcanic arcs.

## Apply

**10** Students' answers may vary but could include four of the following deep-Earth imaging techniques:

- seismology
- electromagnetic (EM) methods
- aeromagnetic surveys
- radiometrics
- ground penetrating radar.

**11** **a** Student answers may vary but could include beaches, sand dunes, spits, rocky headlands, rocks, cliffs, sea stacks, sea arches, caves, or wave cut platforms.

**b** Environmental factors in a coastal area that contribute to weathering include wind abrasion, wave action, rainfall, salt crystallisation, algal growth and extremes of temperature.



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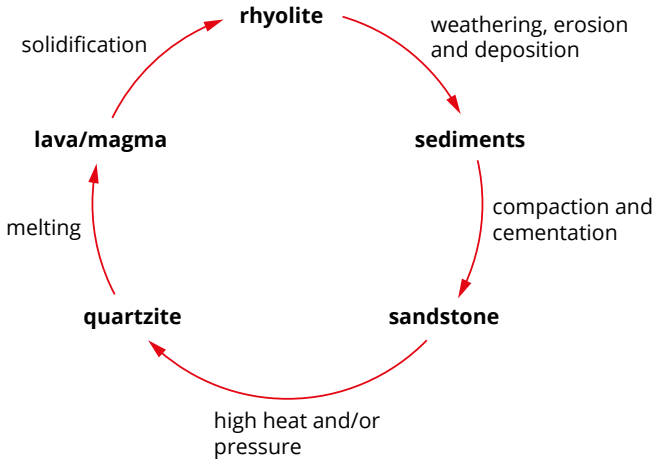
**12** Students' responses will vary but should be similar to the following diagram.




**13** The Himalayas are a fold mountain range that has formed with the convergence of two continental plates (Indian and Eurasian). The Mariana Trench has formed as a result of the convergence of the oceanic Pacific Plate which subducts under the oceanic Philippine Plate.

## Analyse

**14 a** The unlabelled rocks are:

1: shale/mudstone, 2: schist, 3: marble, 4: quartzite

**b** The parent rocks in each sequence are:

A: shale/mudstone, B: limestone, C: sandstone

**c** Rock 1 (shale/mudstone) is a soft sedimentary rock with fine grains. Gneiss is a metamorphic rock that has undergone extreme heat and pressure conditions. It will be very hard, has foliations, and the crystals have formed into bands which are visible.

**15 a** *Glossopteris* had the longest period of existence in Pangaea.

**b** *Cynognathus* had the shortest period of existence in Pangaea.

**c** The reptiles *Mesosaurus* and *Lystrosaurus* occurred at the same time as *Glossopteris*.

**d** The two reptiles *Cynognathus* and *Lystrosaurus* existed at the same time as each other at about 245 million years ago.

**e** The organisms *Glossopteris* and *Lystrosaurus* appear to have become extinct at, or shortly after, the Permian–Triassic extinction event about 252 million years ago.

## Extension: Research task

**16 a–d** Students' responses will vary depending on the live data they access. They should identify a strong correlation between the Great earthquakes and the occurrence of magnitude 4.5+ earthquakes in the previous 30 days around the Pacific Ring of Fire, and the convergence zone between the Australian Plate / Indian Plate and the Eurasian Plate.



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