UNIT 1 LANDFORMS AND LANDSCAPES

TOPIC 5
Mountain landscapes

5.1 Overview
Numerous videos and interactivities are embedded just where you need them, at the point of learning, in your learnON title at www.jacplus.com.au. They will help you to learn the content and concepts covered in this topic.

5.1.1 Introduction
Mountains occupy 24 per cent of the Earth’s landscape, and are characterised by many different landforms. The forces that form and shape mountains come from deep within the Earth, and have been shaping landscapes for millions of years. The Earth is a very active planet — every day, many volcanoes are erupting somewhere on the planet, and even more tremors are occurring.

Landscape of the Dolomites, Italy
Starter questions

1. What is the highest mountain you have visited? What did you do there?
2. Have you ever seen a volcano? Where was it?
3. Is there a mountain or mountain range you would like to visit? Why?
4. Have you ever felt an earthquake or earth tremor? Where were you when it happened? How did you react?

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5.2 Where are the world’s mountains?

5.2.1 The world’s mountains and ranges

A mountain is a landform that rises high above the surrounding land. Most mountains have certain characteristics in common, although not all mountains have all these features. Many have steep sides and form a peak at the top, called a summit. Some mountains located close together have steep valleys between them known as gorges.

Mountains make up a quarter of the world’s landscape. They are found on every continent and in three-quarters of all the world’s countries. Only 46 countries have no mountains or high plateaus, and most of these are small island nations.

Some of the highest mountains are found beneath the sea. Some islands are actually mountain peaks emerging out of the water. Even though the world’s highest peak (from sea level) is Mount Everest in the Himalayas (8850 metres high), Mauna Loa in Hawaii is actually higher when measured from its base on the ocean floor. Long chains or groups of mountains located close together are called a mountain range.
1. The Himalayas
Located in Asia, the Himalayas are the highest mountain range in the world. They extend from Bhutan and southern China in the east, through northern India, Nepal and Pakistan, and to Afghanistan in the west. The Himalayas is one of the youngest mountain ranges in the world and the name translates as ‘land of snow’. The fourteen highest mountains in the world — all over 8000 metres above sea level — are all in the Himalayas.

2. The Alps
The Alps, located in south central Europe, are one of the largest and highest mountain ranges in the world. They extend 1200 kilometres from Austria and Slovenia in the east, through Italy, Switzerland, Liechtenstein and Germany, to France in the west. The highest mountain in the Alps is Mont Blanc in France, which is 4808 metres high.

3. The Andes
The Andes are located in South America, extending north to south along the western coast of the continent. The Andes is the second highest mountain range in the world, with many mountains over 6000 metres. At 7200 kilometres long, it is also the longest mountain range in the world.

4. The Rocky Mountains
The Rocky Mountains in western North America extend north–south from Canada to New Mexico, a distance of around 4800 kilometres. The highest peak is Mount Elbert, in Colorado, which is 4401 metres above

FIGURE 1 The world’s main mountains and mountain ranges.
sea level. The other large mountain range in North America is the Appalachian Mountains, which extends 2400 kilometres from Alabama in the south to Canada in the north.

5.2.2 Mountain climate and weather

It is usually colder at the top of a mountain than at the bottom, because air gets colder with altitude. Air becomes thinner and is less able to hold heat. For every 1000 metres you climb, the temperature drops by 6 °C.

**FIGURE 2** Ecosystems change with altitude on mountains.

High alpine environment. Snow and ice all year. Shallowest soils and high wind exposure. Average temperatures can drop to −15 °C (to −40 °C at 8000 metres). Air lacks oxygen — “thin air”.

Tundra environment. Shallow soils and wind exposure. Average temperatures are between 3 °C and −3 °C.

Coniferous forest environment. Shallow, slightly acidic soils. Average temperatures are around 5 °C to 9 °C.

Cool temperature deciduous forest environment. Soils with moderate humus. Average temperatures are around 10 °C to 15 °C.

Rainforest — evergreen forests with deep, relatively poor, leached soils. Base average temperature of around 20 °C to 25 °C.

### 5.2 Activities

To answer questions online and to receive immediate feedback and sample responses for every question, go to your learnON title at www.jacplus.com.au. **Note:** Question numbers may vary slightly.

**Remember**

1. What percentage of the Earth’s surface is covered by mountains?
2. Name the:
   - (a) highest mountain range in the world
   - (b) longest mountain range in the world
   - (c) highest mountain in Western Europe
   - (d) second-highest mountain range in North America.
3. Refer to **figure 2**. How does vegetation change on a mountain?

**Discover**

4. Locate and name the highest mountain closest to where you live in your state or territory.
5. Name the mountain range located closest to where you live. Name two other mountain ranges in your state or territory. Where are they located in relation to your school or home?
6. Work in groups of 4 to 6 to investigate some of the following mountain ranges.
   - Antarctica — Antarctic Peninsula, Transantarctic Mountains
   - Africa — Atlas Mountains, Eastern African Highlands, Ethiopian Highlands
   - Asia — Hindu Kush, Himalayas, Taurus, Elburz, Japanese Mountains
5.3 How do people use mountains?

5.3.1 Mountain people and cultures

People have moved through and lived in mountain areas for centuries. But few people live in the world’s highest mountain ranges, where it can be very cold and difficult to grow food and make a living. Thousands of people visit mountains, often in remote areas, for recreation and to see the spectacular scenery, plants and animals, historic and spiritual sites, and different cultures. Mountains are also vital for global water supply.

Around 12 per cent of the world’s people live in mountain regions. About half of those live in the Andes, the Himalayas and the various African mountains.

Usually, population density is very low in these areas. One reason for this is that mountains are very difficult to cross, as they are often rugged and covered with forests and wild animals. They can also be hard to climb and may have ice, snow or glaciers that make travel dangerous.

As a result of these difficulties, mountains have long provided a safe place for indigenous peoples and ethnic minorities. People live as nomads, hunters, foragers, traders, small farmers, herders, loggers and miners.
5.3.2 Mountain landscapes in the Dreamings

There are many Aboriginal and Torres Strait Islander Dreaming Stories that are linked to mountain landscapes. These teachings from the Dreamings help explain the formation and importance of each landscape and landform.

Indigenous Australian peoples are guided by Elders who know the local Dreaming Stories and customs. Dreaming Stories are passed on through the generations and explain the origin of the world around them.

The Three Sisters in the Blue Mountains

There is a story, thought to be an Indigenous Creation Story, about the formation of the Three Sisters in the Blue Mountains in New South Wales (see figure 2). It tells of three sisters, Meehni, Wimlah and Gunnedoo, who lived in the Jamison Valley as members of the Gundungurra nations. These young women had fallen in love with three brothers from the Dharruk nation, yet tribal law forbade them to marry. The brothers were not happy with this law and so decided to use force to capture the three sisters, which caused a major battle.

As the lives of the three sisters were seriously in danger, a clever man from the Kedoombar took it upon himself to turn the three sisters into stone to protect them from any harm. He intended to reverse the spell when the battle was over, but the clever man himself was killed. As only he could reverse the spell and bring the sisters back to life, they remain in their rock formation.

The Glasshouse Mountains

The Glasshouse Mountains in south-east Queensland are of great historical, cultural and geological significance (see figure 3). Their names—Beerwah, Tibrogargan, Coonowrin, Tunbubudla, Beerburrum, Ngungun, Tibberoowuccum and Coochin—reflect the culture of the Gubbi Gubbi people.

The story of these mountains goes something like this:

Tibrogargan was the father of all the nations. He and his wife, Beerwah, had many children, including Coonowrin, Tunbubudla, Miketeebumulgrai, Elimbah, Ngungun, Beerburrum and Coochin.

One day, Tibrogargan was looking out to sea when he saw the sea rising in a great swell. He became worried for Beerwah, who was pregnant. He quickly told his eldest child, Coonowrin, to take his mother to the mountains. ‘I’ll get the other children together and will meet you there.’
But when Tibrogargan checked to see if Coonowrin had done as he had asked, he was angered to see that he was running off alone, like a coward, and had not fetched his mother. This made Tibrogargan angry. He chased Coonowrin and hit him so hard on the head with his nulla nulla (war club) that he dislocated his neck. It has been crooked ever since.

When the flood receded, the family went back to their lands. But when the others saw Coonowrin, they teased him about his crooked neck and how he came by it, making him ashamed of his cowardice. He asked his father to forgive him, but the law would not allow this. Tibrogargan cried many tears for the shame Coonowrin had brought upon them, and his tears formed a stream that went all the way to the sea. Beerwah and all Coonowrin’s brothers and sisters cried too.

Coonowrin tried to explain that he had left his mother to fend for herself because she was so big. He did not know his mother was pregnant. Tibrogargan swore he would never look at his son again, and to this day he looks at the sea and not at Coonowrin, whose head is bowed and whose tears flow into the sea. As for Beerwah — she is still pregnant.

5.3.3 Sacred and special places

Mountain landscapes often have special meaning to certain groups of people. This might be because the location includes sacred sites or religious symbols; it might also be because people want to be close to nature or to feel spiritually inspired or renewed.

Mountaineers who take great risks, climbing alone or in small groups, often find a special meaning in mountain environments. They may hold deep spiritual, cultural and aesthetic (relating to beauty) values and ideas, and these will often inspire such people to care for and protect mountain environments.

The following list gives examples of mountains that are connected to various beliefs and religions.

- Hindus and Buddhists have beliefs about Mount Kailash in the Himalayas.
- Hindus in Bali, Indonesia, have a special connection with Mount Gunung Agung.
- Tibetan Buddhists revere Chomolungma (Mount Everest).
- The landscape of Demojong in the Himalayas is sacred to Tibetan Buddhists.
- Nanda Devi in the Himalayas is a sacred site for both Sikh and Hindu communities, and is a UNESCO World Heritage site.
- Mount Fuji, in Japan, is a place of spiritual and cultural symbolism to Japanese people.
- Saint Katherine Protectorate in South Sinai, Egypt, is in an area holy to Jews, Christians and Muslims.
- Jabal La’lam is a mountain that is sacred to the people of northern Morocco.

For the indigenous groups of the north-eastern American plains, the Sioux, or Dakota as they are sometimes referred to, and the indigenous Scandinavian people, the Sami, nature was recognized as sacred. The sacred places were not man-made temples or churches, but particularly spectacular or prominent features of the natural landscape. For the Sami these sacred places tended to be large rocks (called sieidi), the sides of lakes, rocky crevasses or caverns or mountaintops. These sacred mountains were somewhat isolated and had a jutting tall peak. A sacred mountain named Haldi, which rests among a group of mountains near Alta, and an 814-metre tall conical sacred hill named Tunnsjøguden in central Norway are examples. In general, the word saivu is applied to sacred mountains in the south while the terms bassi, ailigas and haldi are used for sacred mountains by northern Sami. Similarly, mountaintops were also of spiritual importance to Sioux groups who lived in their regions; for instance, the sacred mountain Harney Peak in modern-day South Dakota.

**Source:** [www.utexas.edu/courses/sami/diehtu/siida/religion/paralellism.htm](http://www.utexas.edu/courses/sami/diehtu/siida/religion/paralellism.htm)

5.3.4 Skills to survive

It can be hard to make a living in mountain regions. People living in small, isolated mountain communities have learned to use the land and resources sustainably. Many practise shifting cultivation, migrate with grazing herds, and have terraced fields.
Some of the world’s oldest rice terraces (see figure 1) are over 2000 years old. Rice and vegetables could be grown quite densely on the terraces. This enabled people to survive in a region with very steep slopes and high altitude.

On very high ranges, below the snowline is a treeless zone of alpine pastures that can be used in summer to graze animals. Elsewhere, in the valleys and foothills, agriculture often occurs, with fruit orchards and even vineyards on some sunny slopes.

Mountains supply 60 to 80 per cent of the world’s fresh water. This is due to orographic rainfall (caused by warm, moist air rising and cooling when passing over high ground, such as a mountain; as the air cools, the water vapour condenses and falls as rain). Where precipitation falls as snow, water is stored in snowfields and glaciers. When these melt, they provide water to people when they need it most.

5.3 Activities
To answer questions online and to receive immediate feedback and sample responses for every question, go to your learnON title at www.jacplus.com.au. Note: Question numbers may vary slightly.

Remember
1. List the geographical characteristics of mountains that limit the number of people who live there.
2. What type of work and recreation can people undertake in mountain regions? Present this information in words or in a diagram.

Explain
3. Think of a mountain you have visited or seen. Do you feel inspired by mountain environments? How can spiritual or religious beliefs linked to mountain landscapes help in protecting them?
4. How has the natural mountain environment in figure 1 been changed by people? Sketch the photo and make notes to show the changes.
5. Imagine you work as a park ranger in the Blue Mountains or Glasshouse Mountains. How can the Dreamtime legends of the region help other people understand this environment?
6. Describe how different groups of people value mountainous places.

Discover
7. Use the internet to locate the Jamison Valley in the Blue Mountains. Describe its location.
8. Use the Great Dividing Range legend weblink and the How the Hills Came to Be weblink in the Resources tab to read two Dreamtime legends. How are each of these connected to mountain landscapes?
9. From this subtopic, choose one of the mountains linked to Hindu or Buddhist beliefs. Use the internet to find out details of this connection. Present your information as a print or electronic brochure.
10. Research where your water supply comes from. Which mountains, if any, are located near your water supply?

Think
11. Draw a consequence chart to show how and why mountains are important for water supply. Now add information to your chart about what might happen if this was reduced for some reason; for example, through climate change.

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- Explore more with this weblink: Great Dividing Range legend
- Explore more with this weblink: How the Hills Came to Be
5.4 What are the forces that form mountains?

5.4.1 Continental plates

Mountains and mountain ranges have formed over billions of years from tectonic activity; that is, movement in the Earth’s crust. The Earth’s surface is always changing — sometimes very slowly and sometimes dramatically.

The Earth’s crust is cracked, and is made up of many individual moving pieces called continental plates, which fit together like a jigsaw puzzle. These plates float on the semi-molten rocks, or magma, of the Earth’s mantle. Enormous heat from the Earth’s core, combined with the cooler surface temperature, creates convection currents in the magma. These currents can move the plates by up to 15 centimetres per year. Plates beneath the oceans move more quickly than plates beneath the continents.

5.4.2 Continental drift

Scientific evidence shows that, about 225 million years ago, all the continents were joined.

1 Convergent plates

When two continental plates of similar density collide, the pressure of the converging plates can push up land to form mountains. The Himalayas were formed by the collision of the Indian subcontinent and Asia (see figure 1). The European Alps were formed by the collision of Africa and Europe.

When an oceanic and a continental plate collide, they are different densities, and the thinner oceanic plate is subducted, meaning it is forced down into the mantle. Heat melts the plate and pressure forces the molten material back to the surface. This can produce volcanoes and mountain ranges. The Andes in South America were formed this way.

Subduction can also occur when two oceanic plates collide. This forms a line of volcanic islands in the ocean about 70–100 kilometres past the subduction line. The islands of Japan have been formed in this way. Deep oceanic trenches are also formed when this occurs. The Mariana Trench in the Pacific Ocean is
2519 kilometres long and 71 kilometres wide, and is the deepest point on Earth — 10.911 kilometres deep.
If you could put Mount Everest on the ocean floor in the Mariana Trench, its summit would lie 1.6 kilometres below the ocean surface.

2 **Lateral plate slippage**
Convection currents can sometimes cause plates to slide, or slip, past one another, forming fault lines. The San Andreas Fault, in California in the western United States, is an example of this.

3 **Divergent plates**
In some areas, plates are moving apart, or diverging, from each other (for example, the Pacific Plate and Nazca Plate; see figure 1). As the divergent plates separate, magma can rise up into the opening, forming new land. Underwater volcanoes and islands are formed in this way.

4 **Hotspots**
There are places where volcanic eruptions occur away from plate boundaries. This occurs when there is a weakness in the oceanic plate, allowing magma to be forced to the surface, forming a volcano. As the plate drifts over the hotspot, a line of volcanoes is formed.

5 **The Pacific Ring of Fire**
The most active region in the world is the Pacific Ring of Fire. It is located on the edges of the Pacific Ocean and is shaped like a horseshoe. The Ring of Fire is a result of the movement of tectonic plates. For example, the Nazca and Cocos plates are being subducted beneath the South American Plate, while the Pacific and Juan de Fuca plates are being subducted beneath the North American Plate. The Pacific Plate is being subducted under the North American Plate on its east and north sides, and under the Philippine and Australian plates on its west side. The Ring of Fire is an almost continuous line of volcanoes and earthquakes. Most of the world’s earthquakes occur here, and 75 per cent of the world’s volcanoes are located along the edge of the Pacific Plate.

### 5.4 Activities
To answer questions online and to receive immediate feedback and sample responses for every question, go to your learnON title at www.jacplus.com.au. *Note: Question numbers may vary slightly.*

**Remember**
1. Look at figure 2. How do convection currents help explain plate tectonics?
5.5 How do different types of mountains form?

5.5.1 Types of mountains
The different movements and interactions of the lithosphere plates result in many different mountain landforms. Mountains can be classified into five different types, based on what they look like and how they were formed. These are fold, fault-block, dome, plateau and volcanic mountains. (Volcanic mountains are discussed in subtopic 5.8.)

5.5.2 Fold mountains
The most common type of mountain, and the world’s largest mountain ranges, are fold mountains. The process of folding occurs when two continental plates collide, and rocks in the Earth’s crust buckle, fold and lift up. The upturned folds are called anticlines, and the downturned folds are synclines (see figure 2). These mountains usually have pointed peaks.
Use the **Anticline and syncline** weblink in the Resources tab to see the formation of fold mountains.

Examples of fold mountains include:
- the Himalayas in Asia
- the Alps in Europe
- the Andes in South America
- the Rocky Mountains in North America
- the Urals in Russia

### 5.5.3 Fault-block mountains

Fault-block mountains form when faults (or cracks) in the Earth’s crust force some parts of rock up and other parts to collapse down. Instead of folding, the crust fractures (pulls apart) and breaks into blocks. The exposed parts then begin to erode and shape mountains and valleys (see figure 3).

Fault-block mountains usually have a steep front side and then a sloping back. The Sierra Nevada and Grand Tetons in North America, the Great Rift Valley in Africa, and the Harz Mountains in Germany are examples of fault-block mountains. Another name for the uplifted blocks is *horst*, and the collapsed blocks are *graben*.
5.5.4 Dome mountains

Dome mountains are named after their shape, and are formed when molten magma in the Earth’s crust pushes its way towards the surface. The magma cools before it can erupt, and it then becomes very hard. The rock layers over the hardened magma are warped upwards to form the dome. Over time, these erode, leaving behind the hard granite rock underneath (see figure 5).

Ben Nevis in Scotland is an example of a dome mountain (see figure 6).
5.5.5 The Himalayas

**CASE STUDY**

How were the Himalayas formed?

Before the theory of tectonic plate movement, scientists were puzzled by findings of fossilised remains of ancient sea creatures near the Himalayan peaks. Surely these huge mountains could not once have been under water?

Since understanding plate movements, the mystery has been solved. About 220 million years ago, India was part of the ancient supercontinent we call **Pangaea**. When Pangaea broke apart, India began to move northwards at a rate of about 15 centimetres per year. About 200 million years ago, India was an island separated from the Asian continent by a huge ocean.

When the plate carrying India collided with Asia 40 to 50 million years ago, the oceanic crust (carrying fossilised sea creatures) slowly crumpled and was uplifted, forming the high mountains we know today. It also caused the uplift of the Tibetan Plateau to its current position. The Bay of Bengal was also formed at this time.

The Himalayas were therefore formed when India crashed into Asia and pushed up the tallest mountain range on the continents.

Old mountains are those that have stopped growing and are being worn down by the process of erosion.

**FIGURE 7** The movement of the Indian landmass to its current location.
5.5.6 The Sierra Nevada Range, United States

CASE STUDY

Formation of the Sierra Nevada Range
The Sierra Nevada Range began to rise about five million years ago. As the western part of the block tilted up, the eastern part dropped down. As a result there is a long, gentle slope towards the west and a steep slope to the east.

FIGURE 8 The Sierra Nevada Range was formed by fault-block tilting.

FIGURE 9 Yosemite Valley in the Sierra Nevada mountains

5.5.7 Plateau mountains

Plateaus are high areas of land that are large and flat. They have been pushed above sea level by tectonic forces or have been formed by layers of lava. Over billions of years, streams and rivers cause erosion, leaving mountains standing between valleys. Plateau mountains are sometimes known as erosion mountains.

Examples of plateau mountains include Table Mountain in South Africa (see figure 10), the Colorado Plateau (see figure 11) in the United States and parts of the Great Dividing Range in Australia.

FIGURE 10 The plateau of Table Mountain towers over the city of Cape Town in South Africa.

FIGURE 11 The Colorado Plateau in the United States was raised as a single block by tectonic forces. As it was uplifted, streams and rivers cut deep channels into the rock, forming the features of the Grand Canyon.
5.5 Activities

To answer questions online and to receive immediate feedback and sample responses for every question, go to your learnON title at www.jacplus.com.au. Note: Question numbers may vary slightly.

Remember

1. List one example of fold, fault, dome and plateau mountains. Where is each located?
2. State whether the following statements are true or false.
   (a) Fold mountains are the most common type of mountain in the world.
   (b) The Sierra Nevada Range was formed by the eastern part of a fault-block tilting up.

Explain

3. Use the Fold mountains weblink in the Resources tab to explain the formation of fold mountains.
4. Use the video to explain the formation of fault-block mountains.
5. How does the shape of each of the mountains shown in this subtopic provide clues as to how they were formed? How have the effects of erosion changed these mountains?
6. Use figures 5 and 6 to explain the formation of dome mountains.

Discover

7. Sketch figure 6 and annotate it to show where erosion has taken place. Label places that have hard and weak rocks.
8. Draw a sketch of figure 11, noting the plateau and areas of erosion and weathering.
9. Use an atlas to locate the Sierra Nevada Range. Describe where it is. Name two national parks in this mountain range. Choose one, and investigate some of its geographical characteristics. Present this as a PowerPoint, Keynote or Prezi presentation.

Predict

10. Refer to the case study in this subtopic which describes the formation of the Himalayas.
   (a) Provide an explanation for why scientists found ancient sea fossils on top of the Himalayas.
   (b) Describe how the Himalayas were formed. How long did it take for the plate carrying India to crash into Asia? Explain why these mountains are described as ‘young’ mountains.
   (c) Based on the movements occurring, predict what might happen to the Himalayas in the future.

5.6 How do earthquakes and tsunamis occur?

5.6.1 Earthquakes and tsunamis

Earthquakes and tsunamis are frightening events and they often strike with little or no warning. An earthquake can shake the ground so violently that buildings and other structures collapse, crushing people to death. If an earthquake occurs at sea, it may cause a tsunami, which produces waves of water that move to the coast and further inland, sometimes with devastating effects.
5.6.2 Earthquakes

Earthquakes occur every day somewhere on the planet, usually on or near the boundaries of tectonic plates. The map in subtopic 5.4, figure 1, shows a strong relationship between the location of plate boundaries and the occurrence of earthquakes. Weaknesses and cracks in the Earth’s crust near these plate boundaries are called faults. An earthquake is usually a sudden movement of the layers of rock at these faults.

The point where this earthquake movement begins is called the focus (see figure 1). Earthquakes can occur near the surface or up to 700 kilometres below. The shallower the focus, the more powerful the earthquake will be. Energy travels quickly from the focus point in powerful seismic waves, radiating out like ripples in a pond. The seismic waves decrease in strength as they travel away from the epicentre. The strength of an earthquake is measured on the Richter scale.

The energy released at the focus can be immense, and it travels in seismic waves through the mantle and crust of the Earth. Primary waves, or P-waves, are the first waves to arrive, and are felt as a sudden jolt. Depending on the type of rock or water in which they are moving, these waves travel at speeds of up to 30 000 kilometres an hour.

Secondary waves, or S-waves, arrive a few seconds later and travel at about half the speed of P-waves. These waves cause more sustained up-and-down movement.

Surface waves radiate out from the epicentre and arrive after the main P-waves and S-waves. These move the ground either from side-to-side, like a snake moving, or in a circular movement.

Even very strong buildings can collapse with these stresses. The energy that travels in waves across the Earth’s surface can destroy buildings many kilometres away from the epicentre.

Measuring earthquakes

Earthquakes are measured according to their magnitude (size) and intensity. Magnitude is measured on the Richter scale, which shows the amount of energy released by an earthquake. The scale is open-ended as there is no upper limit to the amount of energy an earthquake might release. An increase of one in the scale is 10 times greater than the previous level. For example, energy released at the magnitude of 7.0 is 10 times greater than the energy released at 6.0.

Earthquake intensity is measured on the Modified Mercalli scale, and indicates the amount of damage caused. Intensity depends on the nature of buildings, time of day and other factors.

5.6.3 Nepal earthquake, 2015

CASE STUDY

What caused the 2015 Nepal earthquake?

On 25 April 2015, a magnitude 7.8 earthquake struck Nepal at around midday. The epicentre of this earthquake was quite shallow — only 15 kilometres below the Earth’s surface. It occurred approximately 80 kilometres to the northwest of Kathmandu, Nepal’s capital.

At this location, the Indian Plate to the south is subducting under the Eurasian Plate to the north — see figure 1 in subtopic 5.4. This is occurring at a rate of approximately 45 millimetres per year and is causing the uplift of the Himalayas (see the case study in section 5.5.5).

During the Nepal earthquake event, nearly 9000 people were killed and nearly 18 000 were injured — see the case study in subtopic 5.7 for more details.
Figure 3 shows that the earthquake released a large amount of energy and caused large slips of up to four metres of the Earth’s surface. There were severe aftershocks immediately after the main earthquake and the aftershocks continued for many weeks — up to 100 in total. The shaking from this earthquake was felt in China, India, Bhutan and much of western Bangladesh.

On 12 May 2015, a huge aftershock with a magnitude of 7.3 occurred near the Chinese border with Nepal (between Kathmandu and Mount Everest). More than 160 people died and more than 2500 were injured as a result of this aftershock.
CASE STUDY

What caused the 2011 Christchurch earthquake?

A magnitude 6.3 earthquake struck Christchurch, New Zealand, on 22 February 2011. The city was badly damaged, 185 people were killed and several thousand were injured. The earthquake epicentre was 10 kilometres south-east of Christchurch’s central business district, and was quite shallow — only five kilometres deep. The earthquake is considered to be an aftershock of an earthquake that occurred five months earlier in September 2010.

New Zealand is located between two huge moving plates — the Australian Plate and the Pacific Plate — and it experiences thousands of earthquakes every year. Most are very small, but some have caused a lot of damage. These movements continue to shape and form New Zealand and its dramatic mountain landscapes.
5.6.5 Tsunamis

A tsunami is a large ocean wave that is caused by sudden motion on the ocean floor. The sudden motion could be caused by an earthquake, a volcanic eruption or an underwater landslide. About 90 per cent of tsunamis occur in the Pacific Ocean, and most are caused by earthquakes that are over 6.0 on the Richter scale (see figure 6).

A tsunami at sea will be almost undetectable to ships or boats. The reasons for this are that the waves travel extremely fast in the deep ocean (about 970 kilometres per hour — as fast as a large jet) and the wavelength is about 30 kilometres, yet the wave height is only one metre.

When tsunamis reach the continental slope, several things happen. The wave slows down and, as it does, the wave height increases and the wavelength decreases; in other words, the waves get higher and closer together. Sometimes, the sea may recede quickly, very far from shore, as though the tide has suddenly gone out. If this happens, the best course of action is to head to higher ground as quickly as possible.

A tsunami is not a single wave. There may be between five and 20 waves altogether. Sometimes the first waves are small and they become larger; at other times there is no apparent pattern. Tsunami waves will arrive at fixed periods between 10 minutes and two hours.

CASE STUDY

The Japanese tsunami, 2011

The region of Japan is seismically active because four plates meet there: the Eurasian, Philippine, Pacific and Okhotsk. Many landforms in this region are influenced by the collision of oceanic plates. Chains of volcanic islands called island arcs are formed, and an ocean trench is located parallel to the island arc (see figure 1 in subtopic 5.4).

On 11 March 2011, an 8.9-magnitude earthquake struck near the coast of Japan. The earthquake was caused by movement between the Pacific Plate and the North American Plate. It occurred about 27 kilometres below the Earth’s surface along the Japan Trench, where the Pacific Plate moves westwards at about eight centimetres each year. The sudden upward movement released an enormous amount of energy and caused huge displacement of the sea water, causing the tsunami. When the tsunami reached the Japanese coast, waves more than six metres high moved huge amounts of water inland. Strong aftershocks were felt for a number of days. Nearly 16 500 people were killed and 4800 were reported missing.

![Figure 6: The location and magnitude of the earthquake that caused the Japanese tsunami](source: Spatial Vision)
FIGURE 7 This map shows the ground motion and shaking intensity from the earthquake across Japan.

FIGURE 8 The tsunami caused by the 8.9-magnitude earthquake in March 2011 swept over the coastline at Sukuiso and inland, carrying debris with it.
5.6 Activities

To answer questions online and to receive immediate feedback and sample responses for every question, go to your learnON title at www.jacplus.com.au. Note: Question numbers may vary slightly.

Remember
1. What is the focus and epicentre of an earthquake?
2. How does an earthquake occur?
3. What does the Richter scale measure? How much more powerful is the magnitude of an earthquake at 7.0 than at 5.0?

Explain
4. Use the P- and S-waves weblink in the Resources tab to watch an animation of these waves. What is the difference between the waves? How fast do they travel? How is damage caused by the waves?
5. Study the Tsunami animation weblink in the Resources tab and figure 9. Use your own words to explain how a tsunami occurs.
6. Study figure 2.
   (a) In which direction is the Indian Plate moving? Is it moving under or over the Eurasian Plate?
   (b) Describe the location of the highest intensity shaking. How close was it to the epicentre? To the tectonic plate boundary?
7. Study figure 3. Are the following statements true or false? If they are false, rewrite them to make them true.
   (a) The earthquake and aftershocks were between 4.0 and 6.0 in magnitude.
   (b) The furthest earthquake and aftershocks were 100 km apart.
   (c) The earthquake on 12 May was the same intensity as the earthquake on 25 April.
   (d) Most of the aftershocks were felt to the east of the main earthquake on 25 April.
5.7 What are the impacts of earthquakes and tsunamis?

Access this subtopic at www.jacplus.com.au

5.8 How are volcanic mountains formed?

5.8.1 How are volcanoes formed?
A volcano is a cone-shaped hill or mountain formed when molten magma in the Earth’s mantle is forced through an opening or vent in the lithosphere. Almost all active volcanoes occur at or near plate boundaries. Some occur where two plates converge, and others occur where the plates are pulling apart, or diverging (see figure 1). There is another group of volcanoes that are formed when plates move over hotspots.

Subduction zones
Some volcanoes are formed when an oceanic plate is pulled underneath a continental plate (see subtopic 5.4). As the crust is forced down, it heats up and becomes magma. It can then rise to the Earth’s surface through a magma chamber.

Discover
9. Use an atlas or Google Earth to find the location of Lituya Bay. Draw a map to show the location. Use the World's biggest tsunami weblink in the Resources tab to listen to eyewitness accounts of the event. How does this help give you a sense of the scale of this event?
10. Study figure 6. Describe where the most violent shaking occurred as a result of the earthquake. How many plates meet in this region? What impact does this have?
11. Study figure 7.
   (a) Where in Japan was the greatest intensity felt?
   (b) What is the population density for Sendai, Tokyo and Niigata? How would this increase the impact of the earthquake?

Think
12. Study the photo of the Japanese tsunami in figure 8.
   (a) Imagine you are a radio news reporter. Describe what you see and what might be happening to people in the area.
   (b) Imagine you were a Sendai resident. Describe what you would have done to take care of yourself.
13. Why would most Australians not know what to do if an earthquake occurred?
Volcanoes in rift zones
The longest mountain range in the world is underwater between the African and American continents, and is 56,000 kilometres long. It is called the Mid-Atlantic Ridge, and it is made up of many volcanic mountains. The volcanoes are formed where two plates move away from each other in rift zones. The molten lava rises to the surface in the space between the plates, and the largest volcanoes appear above the water as islands. Examples of rift islands are Iceland, the Azores, Ascension Island, Gough Island and Bouvet Island. The rifting, or spreading apart, can occur on land or on the seabed.

The rifting of Iceland
The Mid-Atlantic Ridge passes through Iceland, where the island is splitting in two different areas (see figure 2). This can be seen where Iceland’s volcanoes are located, at the point where the North American Plate is drifting to the west and the Eurasian Plate is drifting to the east (see figure 3). New crust is being formed in a rift below the sea, and eventually water from the Atlantic Ocean will fill the widening and deepening gaps between the separated parcels of land.

The Great Rift Valley, Africa
The Great Rift Valley is in Africa (figure 4). It is about 5000 kilometres long, and stretches from Syria in the north to Mozambique in the south. The valley varies in width from 30 kilometres at its narrowest point to 100 kilometres at its widest. In some places it is a few hundred metres deep; in others it can be a few thousand metres deep.

The Great Rift Valley was created through separation that began 35 million years ago, when the African and Arabian plates began pulling apart in the northern region. About 15 million years ago, East Africa began to separate from the rest of Africa along the East African Rift. The volcanic activity in this region has produced many volcanic mountains, such as Mount Kilimanjaro, Mount Kenya and Mount Elgon.

As these rifts continue to grow, new ocean waters will flow into the valleys, separating the landmasses.

5.8.2 Volcano hotspots
Although most volcanoes are formed on plate boundaries, some are located in the middle of plates, a long way from plate boundaries. These volcanoes have formed above a hotspot — a single plume of rising mantle. Volcanoes form as the plates slowly move over the hotspot and, over time, a chain of volcanoes can form. Hotspots are found in the ocean and on continents. Examples include the Hawaiian Islands and many of Australia’s extinct volcanoes. In Hawaii, the location of the volcanoes gives a clue to the direction and speed of the plate movement.
5.8 Activities

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. Note: Question numbers may vary slightly.

**Explain**

1. Go to the **Hawaii’s hotspot** weblink in the Resources tab and explain how hotspot volcanoes form.
2. Refer to figures 2 and 3. Explain why a chain of volcanoes, like the one in the photograph, forms in Iceland. What is happening to the plates?

**Discover**

3. Use an atlas to find the Cotopaxi volcano. In which country is it located? How high is it?
4. Use an atlas or Google Earth to locate the islands on the Mid-Atlantic Ridge. Give the latitude and longitude for three locations. Describe the **interconnection** between the location of the ridge and the location of islands and volcanoes.

**Predict**

5. Draw what you imagine Iceland will look like many thousands of years in the future after further rifting. Provide new names for each of the smaller islands. In which direction, and towards which continent, will each island drift? Describe key **changes**.
6. Draw a series of sketches to show what you predict will happen to the African landmass as the Great Rift Valley continues to rift. Include a map of Africa showing the change in shape that might occur. You need to annotate your sketches to justify the predictions you have made.

Think
7. Refer to an atlas map of Africa and look at the shape of the island of Madagascar. Try to imagine fitting this island back into the mainland. Using plate tectonic terms, write a paragraph to describe how Madagascar’s location has changed over time.

8. Describe the changes that are occurring in
   (a) the Great Rift Valley
   (b) Iceland
   that are causing volcanoes to form.

9. How is the scale of the changes happening in Iceland different from the scale of change happening in the Great Rift Valley?

5.9 How did Mount Taranaki form?

5.9.1 Introducing Mount Taranaki, New Zealand

New Zealand’s Mount Taranaki is named after the Māori terms tara meaning ‘mountain peak’ and ngaki meaning ‘shining’ (because the mountain is covered with snow in winter).

Mount Taranaki is 2518 metres high and is the largest volcano on New Zealand’s mainland. It is located in the south-west of the North Island (see figure 1).

Mount Taranaki was formed 135 000 years ago by subduction of the Pacific Plate below the Australian Plate. It is a stratovolcano — a conical volcano consisting of layers of pumice, lava, ash and tephra. Mount Taranaki is symmetrical, looking the same on both sides of a central point. It is the only active volcano in a chain in this region. The other volcanoes were once very large but have been eroded over time.

The summit of Mount Taranaki is a lava dome in the middle of a crater that is filled with ice and snow. The mountain is considered likely to erupt again. There are significant potential hazards from lahars, avalanches and floods. A circular plain of volcanic material

![FIGURE 1 Location of Mount Taranaki on the North Island of New Zealand.](source: Spatial Vision)
surrounding the mountain was formed from lahars (see figure 1 in subtopic 5.11) and landslides. Some of these flows reached the coast in the past. The volcano’s lower flanks are covered in forest, and are part of the national park. There is a clear line between the park boundary and surrounding farmland.

FIGURE 2 Mount Taranaki has a near-perfect conical shape.

FIGURE 3 Aerial photo of Mount Taranaki
FIGURE 4  Topographic map of Mount Taranaki

Source: Topographic Map 273-09 Egmont. Crown Copyright Reserved. Map drawn by MAPgraphics Pty Ltd, Brisbane
5.9 Activities

To answer questions online and to receive immediate feedback and sample responses for every question, go to your learnON title at www.jacplus.com.au. Note: Question numbers may vary slightly.

Remember
1. Where is Mount Taranaki located?
2. What is a stratovolcano?
3. Refer to figure 4.
   (a) What is the grid reference for the spot height of Mount Taranaki?
   (b) Calculate the number of private huts and public huts.
   (c) Name the ski field.
   (d) How many ski tows and lifts are there at the ski field? Calculate the length of each.
   (e) Name and give the grid reference of a lodge in which skiers could stay.
   (f) Name the other two lodges on the map.
   (g) Bushwalking is a popular activity. How many huts are on the map?

Explain
4. Mount Taranaki receives between 3200 mm and 6400 mm of rainfall each year. How would this contribute to the shape of this landform?
5. Describe evidence from the aerial photo in figure 3 that the national park has protected forests around the volcano. (See the ‘Interpreting an aerial photo’ SkillBuilder in subtopic 5.12.)

Discover
6. Use the Mt Taranaki Live weblink in the Resources tab to view Mount Taranaki using the webcam.

Predict
7. Use figures 2, 3 and 4 to describe where you think lava would flow if Mount Taranaki erupted. Describe the potential changes to the human and natural environment.

5.10 SkillBuilder: Drawing simple cross-sections

WHAT ARE CROSS-SECTIONS?

A cross-section is a side-on, or cut-away view of the land, as if it had been sliced through by a knife. Cross-sections provide us with an idea of the shape of the land. We can use contour lines on topographic maps to draw a cross-section between any two points.

Go online to access:
- a clear step-by-step explanation to help you master the skill
- a model of what you are aiming for
- a checklist of key aspects of the skill
- a series of questions to help you apply the skill and to check your understanding.
5.11 What is the anatomy of a volcano?

5.11.1 Volcanic eruptions

Volcanic mountains are formed when magma pushes its way to the Earth’s surface and then erupts as lava, ash, rocks and volcanic gases. These erupting materials build up around the vent through which they erupted.

A volcanic eruption can be slow or spectacular, and can result in a number of different displays (see figure 1).

5.11.2 Volcanic shapes

Volcanoes come in a variety of shapes and sizes, forming different landforms. There are four main types and each depends on:

• the type of lava that erupts
• the amount and type of ash that erupts
• the combination of lava and ash.

Lava that is rich in silica (a mineral present in sand and quartz) is highly viscous and is thick and slow moving. If the lava is low in silica, it tends to be very runny and may flow for many kilometres before it cools and hardens to become rock. Volcanoes that erupt runny lava tend to have broad, flat sides (shield volcanoes). Those that erupt thick, treacle-like lava tend to have much steeper sides (dome volcanoes).

Heavy ash material, like volcanic bombs, settles close to the crater while lighter ash is carried further away. Volcanoes that are built up through falls of ash are steep-sided cinder cones.

The most common type of volcano is one built up of both ash and lava; this is called a composite volcano.
A. A fragment of lava greater than 64 millimetres in diameter is called a volcanic bomb. They are often solid pieces of lava from past eruptions that formed part of the cone.

B. A pyroclastic flow is a superheated avalanche of rock, ash and lava that rushes down the mountain with devastating effects. The flow can travel at up to 240 kilometres per hour and reach temperatures of 800 °C. When Mount Pelee erupted in 1902, on the island of Martinique in the Caribbean, a pyroclastic flow covered the town of Saint-Pierre, killing all but two of the town’s 30 000 inhabitants.

C. Lightning is often generated by the friction of swirling ash particles.

D. As rock is pulverised by the force of the eruption, it becomes very fine ash, and is carried by wind away from the crater as an ash cloud. Volcanic ash may blanket the ground to a depth of many metres. In the eruption of Mount Vesuvius in AD 79, volcanic ash completely covered two large towns: Pompeii and Herculaneum.

E. A volcanic cone is made up of layers of ash and lava from previous eruptions. If the volcano has not erupted for thousands of years (i.e. is dormant), these layers will be eroded away.

F. Lava may be either runny or viscous, and can flow for many kilometres before it solidifies, thereby building up the Earth’s surface.

G. Pressure may force magma through a branch pipe or side vent. In the eruption of Mount St Helens in 1980, in the United States, the side of the mountain collapsed and the side vent became the main vent.

H. Where two plates move apart, molten rock from the mantle flows upward into a magma chamber. More rock is melted and erupts violently upwards. Magma is generally within the temperature range of 700 °C to 1300 °C.

I. When pyroclastic flows melt snow and ice, and mix with rocks and stones, a very wet mixture called a lahar can form. Lahars can flow quickly down the sides of volcanoes and cause much damage. One lahar that formed in 1985 on Nevado del Ruiz volcano in Colombia travelled at up to 50 kilometres per hour and was up to 40 metres high in some places. A wall of mud, water and debris travelled 73 kilometres to the town of Armero, devastating it. More than 23 000 people died that night and 5000 homes were destroyed.
FIGURE 2 Four volcanic landforms.

A Shield volcano
Shape formed by thin lava that spreads widely before cooling and hardening.
Lava flows that have built up over time.

B Cinder cone
Layers made up of heavier rocks near the vent, and cinders and ash towards the edges.

C Dome volcano
Shape formed by thick lava that cools and hardens rapidly.

D Composite volcano
Bodies of igneous rock formed when former channels of magma have cooled.
Layers made up alternately of cooled lava and ash.
5.11 Activities
To answer questions online and to receive immediate feedback and sample responses for every question, go to your learnON title at www.jacplus.com.au. Note: Question numbers may vary slightly.

Remember
1. What are the three main factors that determine the shape of a volcano?

Explain
2. Explain how the different shapes of volcano shown in figure 2 are the results of different materials being ejected.
3. (a) Refer to figure 1. Describe, in detail, the changes to the environment that volcanic eruptions can cause.
   (b) Which changes would impact on a small scale and which would impact on a larger scale?

Think
3. Use the internet to find pictures of volcanic landforms and materials. These include crater lakes, geysers, calderas, fields of ash deposits, volcanic plugs, lava tubes, hummocks and pumice. You could also find pictures of the two types of lava: a’a and pahoehoe. Use your pictures to put together a field guide to volcanic landforms. Each page should contain a picture of the landform, a brief description and a place where it could be found — sometimes they are tourist attractions.

5.12 SkillBuilder: Interpreting an aerial photo

WHAT ARE AERIAL PHOTOS?
Aerial photographs are those that are taken from above the Earth from an aircraft. **Oblique aerial photos** are those taken from an angle from an aircraft. **Vertical aerial photos** are taken from directly above; that is, looking straight down onto objects. Aerial photos can reveal details that are not recorded on maps. It is easy to see landforms with distinct shapes, different landscapes, land uses, specific places and spatial patterns of the environment.

Go online to access:
- a clear step-by-step explanation to help you master the skill
- a model of what you are aiming for
- a checklist of key aspects of the skill
- a series of questions to help you apply the skill and to check your understanding.

FIGURE 1 Cartographers use different types of photographs.
5.13 How do volcanic eruptions affect people?

Access this subtopic at www.jacplus.com.au

5.14 Review

5.14.1 Review
The Review section contains a range of different questions and activities to help you revise and recall what you have learned, especially prior to a topic test.

5.14.2 Reflect
The Reflect section provides you with an opportunity to apply and extend your learning.
Access this subtopic at www.jacplus.com.au