Sphere 3: The Lithosphere

Photo: *Uluru at sunset, Brian Dean, ABC*

What do you see?	What do you think is happening?	What do you want to wonder or want to ask questions about?
The type of photograph above is: ground level, aerial (vertical), aerial (oblique) or satellite?		

Predict how Uluru was formed:

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This booklet belongs to: ____.

The Lithosphere

Term	Definition
Asthenosphere	A layer of partially molten material within the upper part of the mantle, upon which the lithospheric plates move.
Continental drift	A theory that proposes that all the continents were once joined together in a giant supercontinent, which subsequently split apart, with the continents drifting away from one another until they reached their present locations.
Desertification	The spread of desert-like conditions in arid and semi-arid regions resulting from a combination of climatic changes and increasing human pressures, such as overgrazing, removal of vegetation and the cultivation of marginal land.
Earthquakes	Vibrations and shock waves caused by the sudden movement of tectonic plates along fracture zones, or faults, in the earth's crust.
Erosion	The wearing away of land by running water, rainfall, wind, ice or other geological agents.
Geomorphology	The study of landforms, including their origin, evolution, form and distribution.
Gradational processes	Those processes that result from gravity and the sun's radiant energy and which act upon the surface of the lithosphere and bring it to a common level. It includes the fragmentation of rocks by weathering, their mass movement downslope, and the detachment and removal of these materials by the agents of erosion and the deposition of debris at a lower elevation.
Land degradation	A decline in the quality of natural land resources, commonly caused by improper use by humans.
Landform	A specific physical feature of the earth's surface; for example, a plain, escarpment, valley, plateau, hill or mountain.
Land-use	The range of uses that humans make of the earth's surface.
Lithosphere	The outer shell of the earth, consisting of solid rock (100 –150 km thick), soil and geological formations.
Mass movement	The downslope movement of weathered rock material under the influence of gravity.
Soil	The loose material composed of both mineral and organic matter that covers the earth's land surface. Its thickness varies from place to place.
Tectonic forces	Disturbances in the earth's crust that result from the earth's internal energy and create physical features, such as mountains, on the earth's surface.
Tectonic plates	Sections of the earth's crust that move about as distinct units on the asthenosphere on which they rest.
Volcanism	A process resulting in the upward movement and expulsion of molten material from within the earth to the surface, where it cools and hardens.
Weathering	The in situ physical disintegration and chemical decomposition of rocks and minerals at or near the earth's surface by atmospheric and biological agents.

Forces that shape the earth's surface

The lithosphere is the solid, outer portion of the earth—its rigid upper mantle. The principal features of the lithosphere are the continental plates on which the ocean basins and continents are located.

Wave Rock at Hyden, Australia | Amusing Planet

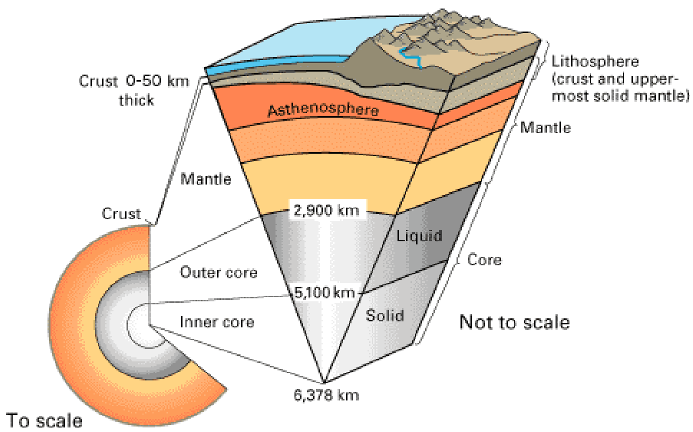
The presence of soaring mountains, deep gorges and rugged coastlines all tell of the ongoing battle between opposing forces: tectonic and gradational. The forces of gradation, which result from gravity and the radiant energy of the sun, wear down and smooth the earth's surface. Tectonic forces, the result of the earth's internal energy, upheave the land surface. These forces deep within the earth have pushed up and created new landforms. If it were not for tectonic forces, the earth's surface would have been reduced long ago to a flat, featureless plain by the relentless gradational processes of weathering, mass movement and erosion. The Snowy Mountains of south-eastern Australia were, for example, once 500m higher than they are today. Millions of years of gradation have lowered them to their current height and rounded form.

Catastrophic earthquakes and volcanic eruptions have been responsible for the formation of some of the earth's most spectacular scenery. Yet the majority of landform features associated with the earth's internal forces are the result of small, largely discrete movements that are constantly repeated over millions of years. Most of the rock masse seen at the earth's highest elevations were originally formed on ancient ocean floors. This is evidenced by the fossilised remains of marine organisms found on top of the lofty Himalayan Mountains.

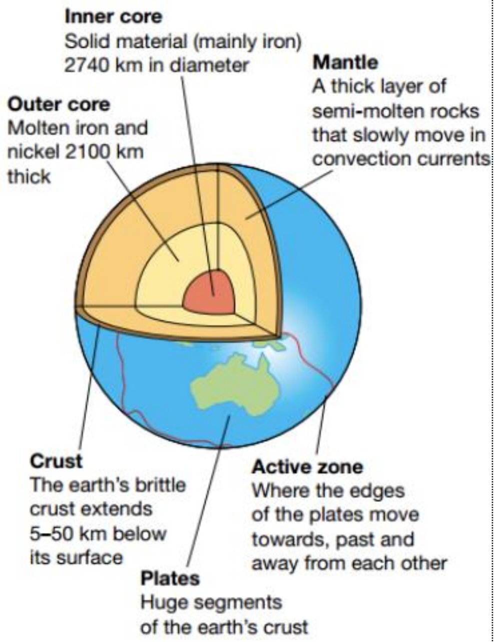
Looking inside the earth

Tectonic activity, whether it be sudden and violent or slow and unnoticeable, occurs within the outer shell of the earth known as the lithosphere. The lithosphere is the solid portion of the earth as opposed to the liquid hydrosphere and gaseous atmosphere. It encompasses all solid materials between the earth's surface and the overlying mantle of its core. As large amounts of these materials are inaccessible, their effects on the surface features of the earth are still not fully understood.

For many years, scientists have been aware that the earth's rumblings and joltings originated from movements deep within the earth. When an earthquake strikes, the earth reverberates with shock waves. These waves, called seismic waves, travel through the earth. The speed of seismic waves varies according to the properties of the material through



which they pass. From a study of thousands of seismographs, the depth, density, physical state and type of rock in each layer below the surface can be inferred. To understand the forces at work within the lithosphere it is necessary to know how this sphere relates to the internal structure of the earth.



4.1.3 The earth in cross-section. The tectonic movements that shape the earth's surface features take place in the lithosphere.

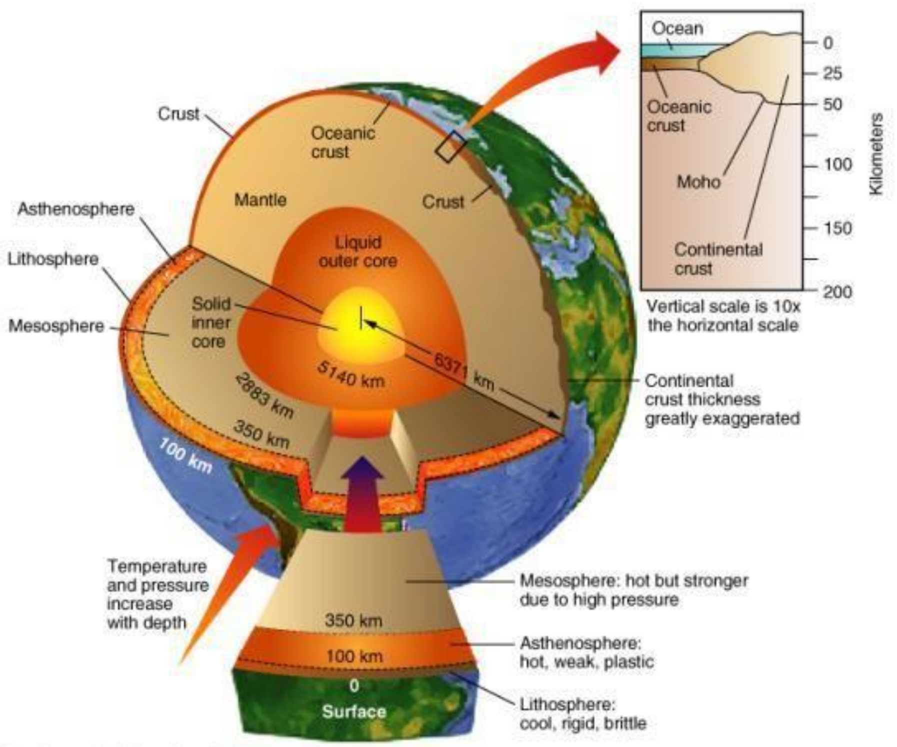
The core

Extending about halfway to the surface from the earth's centre is the core, which has a radius of 3400 km. Because of the intense heat at the centre of the earth, the core is thought to consist of molten rock. Scientists, however, are not certain of the physical state of this material, since the combination of high pressure and temperature at the centre of the earth cannot be duplicated in laboratories.

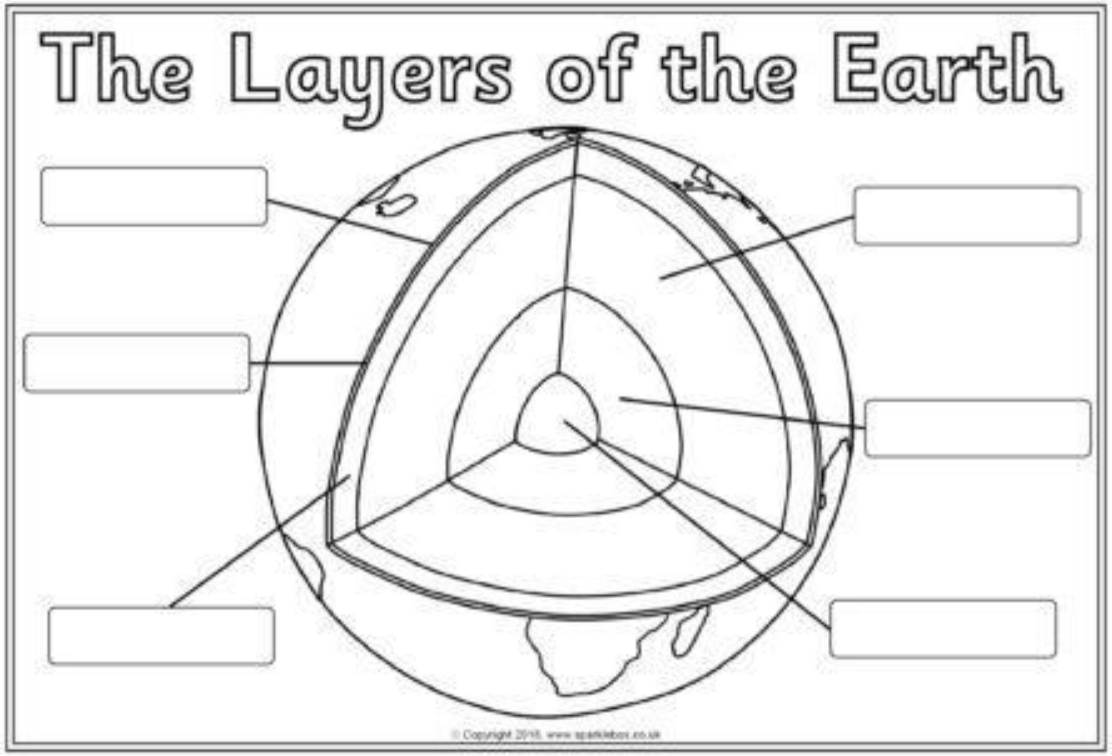
Surrounding the inner core is the mantle, believed to be about 2900 km thick. Temperatures in the mantle are high enough to melt rock material, but pressures are so intense at these depths that most of the mantle is rigid. However, within the upper mantle, there is a soft layer of partially molten rock known as the asthenosphere. Movement of material in the asthenosphere plays an important role in shaping the earth's surface. There is a distinct boundary between the mantle and the lithosphere. The surface of this separation is known as the Mohorovic Discontinuity, or Moho, a simplification of the name of the seismologist who discovered it.

The crust

The outermost and thinnest of the earth's layers is its crust. This uppermost part of the lithosphere is the most accessible part of the earth's structure. The depth of the crust varies from 40 km beneath the continents to 6 km beneath the deep ocean floors. This variation is a result of differences in rock density in the two areas. Rather than forming a single, continuous shell over the earth, the lithosphere is broken into a number of large units, called plates. These move over the partially molten material in the asthenosphere.



The layers of the Earth



1. Match the term to the definitions:

Asthenosphere	This is the third layer of the Earth. It is the only liquid layer, and is mainly made up of the metals iron and nickel, as well as small amounts of other substances.
Crust	This is the mostly-solid bulk of Earth's interior. It lies between Earth's dense, super-heated core and its thin outer layer, the crust and is about 2,900 kilometres thick.
Inner core	This is the very centre of the Earth, and the hottest part of the planet. It is a mainly a solid ball with a radius of about 1,220 km.
Mantle	This is the outermost layer of a planet. It is composed of a great variety of igneous, metamorphic, and sedimentary rocks.
Outer core	This is the upper layer of the earth's mantle, below the lithosphere.

2. Task: Complete the diagram using the words below:

Inner core	Asthenosphere
Rigid mantle	Outer core
Stiffer mantle	Crust

3. True or false:

1. What is true about the earth's crust?

T or F The Earth's crust is made of rock.

T or F The Earth's crust thick melted rock.

T or F The Earth's crust is thicker than the inner layers.

T or F The Earth's land forms are found on Earth's crust.

2. What is true about the mantle of the earth?

T or F The mantle is a solid piece of rock.

T or F The mantle is thick liquid rock.

T or F The mantle is the outside layer of the earth.

T or F The mantle is hotter than the crust.

Check your understanding:

1. Describe the two sets of forces that shape the earth's surface:

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2. Define the lithosphere and explain how it differs from the hydrosphere and the atmosphere:

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3. Identify, with the aid of the diagram, the layers that make up the internal structure of the earth:

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4. Explain why the depth of the crust varies:

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5. State what the lithospheric plates are:

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Continental drift and the origin of the continents

Task: Write five things you learnt from the YouTube Clip: https://www.youtube.com/watch?v=p-vNSqUy0l4

- ○
- ○
- ○
- ○
- ○

The publication of Alfred Wegener's theory of continental drift in 1915 provided an explanation for the striking similarity between the edges of the shoreline on the two sides of the Atlantic Ocean, especially between those of Africa and South America. These findings were based on the matching of fossils and rocks from the coastal regions of two continents. The supercontinent was named Pangaea and was believed to consist of two main parts: Laurasia (Asia, Europe, Greenland and North America) and Gondwana (Australia, Antarctica, Africa, India and South America). Laurasia and Gondwana began to move apart about 200 million years ago. Each part of the original land mass (today's continents) slowly drifted to its present location. The broken pieces of the supercontinent, it was argued, could all fit back together like the pieces of a giant jigsaw puzzle.

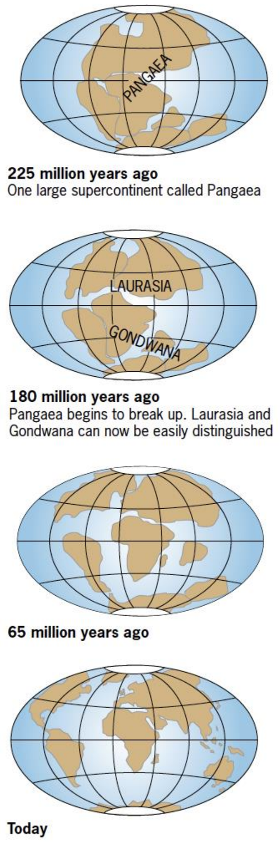
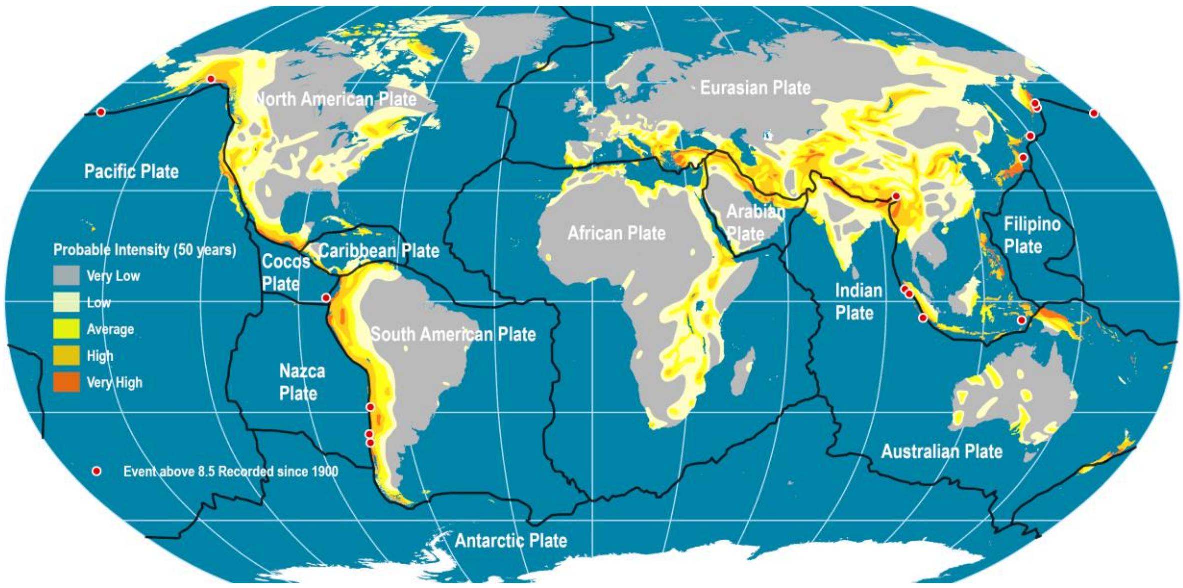


FIGURE 1.4.4

The movement of the continents. (Source: *Heinemann Atlas*)

Plate tectonics

There are **five major lithospheric plates**, as well as a number of minor ones. It is estimated that the earth's plates move at speeds of between 1.5 and 7 cm per year. Australia, for example, continues to drift north at a rate of 6.7 cm per year.



Causes of plate motion

Convection currents within the earth's mantle have long been regarded as the cause of plate motion. The rising magma at the diverging midocean ridges is believed to push the plates apart horizontally. The depth of mantle convection is still unknown. Some recent research suggests that it is shallow and largely confined to the asthenosphere, rather than extending further into the mantle.

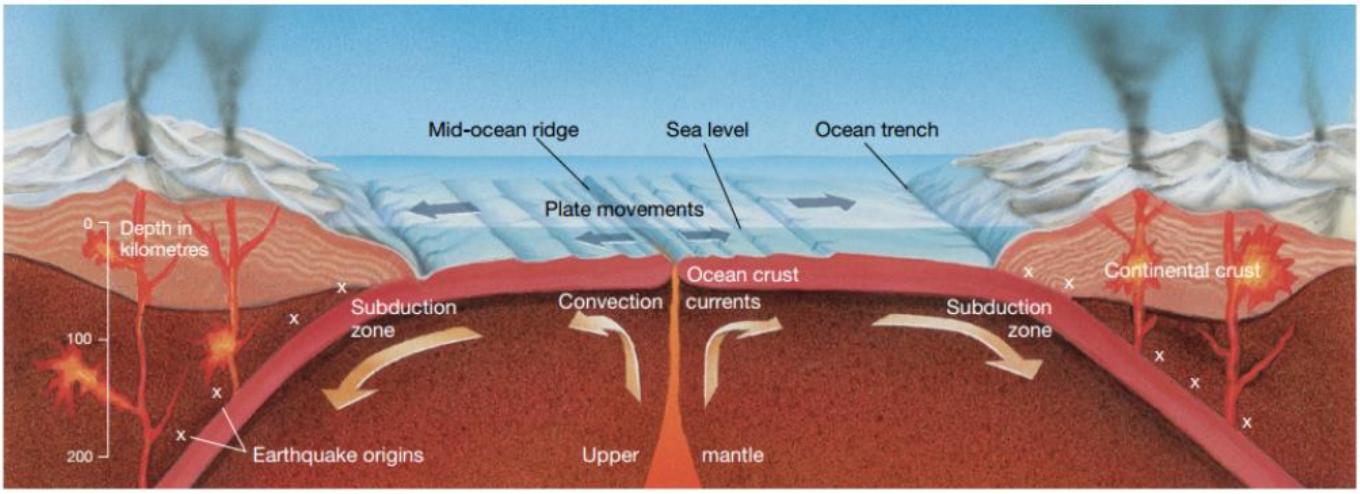


Plate movements

Almost all tectonic and volcanic activity on the earth's surface takes place at the boundaries of the plates. At the boundaries they diverge, converge or slide past one another. Each type of boundary produces distinctive and recognisable landform features.

- **Divergent plate boundaries:** the point where plates are pulled apart, allowing molten rock to emerge at the Earth's surface
- **Collision plate boundary:** the point where two plates of similar strength or speed collide
- **Convergent (subduction) plate boundary:** the point where two plates are moving towards each other and collide, with one plate being pushed beneath the other; the lower plate is the 'subducted' plate
- **Transform plate boundary:** the point where two plates

Complete the table below using the cut and paste activity provided:

Tectonic process	Description	What can occur	Example	Diagram
Divergent plate				
Collision plate				
Convergent (subduction) plate				
Transform plate				

The Result of Tectonic Plate Movements

Mountain-building

The world's great mountain ranges coincide with the advancing edges of the earth's continental plates. They are therefore a product of plate _________________. As the continental plates collide, the earth's _________________ thickens in an effort to absorb the impact. As it does so, pressure is exerted and layers of rock are compressed and forced upwards, folding and faulting as they go. Mountains are landform features composed mostly of _________________ slopes and large amounts of local relief within a specified area.

As continental movements tend to be very _________________, the mountain chains they produce are dominated by folded rock _________________ (layers of rock) and are therefore classified as fold mountains. Folds are wave-like patterns in the earth's crust. Mountains can also be the result of faulting and volcanic activity. Faults are fractures in the rock structure. Rift valleys and block mountains are large-scale landforms associated with faulting.

Earthquakes

Earthquakes are a series of rapid _________________ caused by sudden movements within the earth's crust. These movements are usually the result of the fracturing or faulting of rock strata that have been placed under great _________________. The energy released by these sudden movements travels through the earth in a series of waves that spread out from the focus and _________________ of the earthquake. When earthquakes occur in heavily populated areas they can cause widespread _________________. Most loss of life is caused by collapsing _________________, fires and _________________ (large earthquake-induced ocean waves). Tsunamis can devastate coastal communities.

Worst earthquakes 1900–2015			
Location	**Year**	**Magnitude scale**	**Deaths**
Sumatra–Andaman Islands	2004	9.3	295 000
Haiti	2010	7.0	222 000
Gansu, China	1920	8.6	200 000
Xining, China	1927	8.3	200 000
Japan	1923	8.3	143 000
Sichuan, China	2008	7.9	87 500
Kashmir, Pakistan	2005	7.6	86 000
Bam, Iran	2003	6.6	40 000
Iran	1990	7.7	35 000
Chillan, Chile	1939	8.3	28 000
Armenia	1988	6.9	25 500
Santiago, Chile	1906	8.6	20 000
Kangra, India	1905	8.6	19 000
Central Asia	1907	8.1	12 000
India/Nepal	1934	8.4	10 700
Mexico	1985	8.1	9 500
Nepal	2015	6.3	8 000
Java, Indonesia	2006	6.3	5 700
Chile	1960	9.5	4 485

Volcanic activity

Volcanic eruptions occur when _________________ rock reaches the earth's surface, through _________________ or faults in the underlying rock structures. Once it reaches the earth's surface, the molten material (lava) cools and _________________. Over time, successive layers of lava and volcanic ash may build up a volcanic cone. A caldera, or crater, forms when a particularly violent eruption blasts away the _________________ of an existing volcanic cone. The most active volcanoes lie in volcanic belts that coincide with zones where there is fracture of, and collision between, the earth's crustal plates.

Volcanic eruptions can produce landforms in a rapid and spectacular manner. Some of the world's largest _________________ and many of the islands that dot the world's _________________ are the result of past volcanic activity. Today there are 550 known _________________ volcanoes on earth. Large-scale eruptions may result in short-term climatic change as millions of tonnes of volcanic ash and _________________ are released into the atmosphere, reducing the amount of _________________ reaching the earth's surface.

Word bank:

hardens	*mountains*	*cracks*	*devastation*	*vibrations*
active	*top*	*tectonics*	*tsunamis*	*steep*
buildings	*slow*	*sunlight*	*epicentre*	*oceans*
strata	*molten*	*stress*	*smoke*	*crust*

Check your understanding:

1. Describe how mountains are formed:

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2. Describe why earthquakes occur:

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3. Explain the process of a volcanic eruption:

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4. Mountains are often part of a mountain range. Why do you think this is the case?

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5. Describe the relationship between the location of the world's great mountain ranges and continental plates (see map on the Google Slides)

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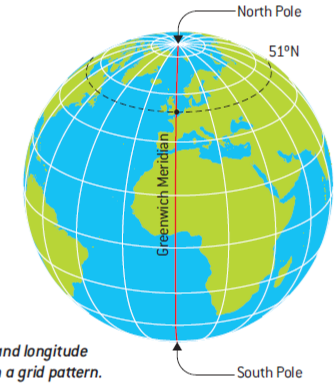
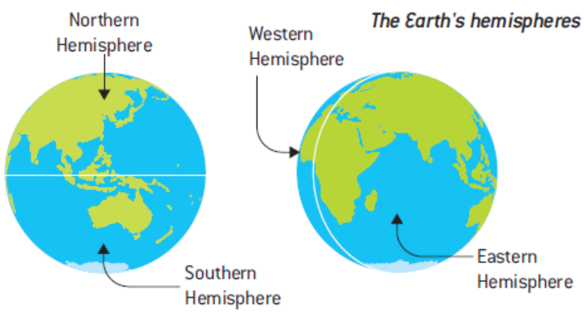
Geographical Skill: Latitude and Longitude (plotting and locating coordinates on a map)

Lines of latitude are imaginary lines drawn around the Earth in an _____________ direction. These lines are called _____________ of latitude because they run parallel to each other. They are measured in degrees ($^{\circ}$). The most important line of latitude is the _____________ (0°). Latitude lines are written using the letters N (north) and S (south). Lines of _____________ are imaginary lines that run in a _________________ direction from the North Pole to the South Pole. The lines are called _____________ of longitude and they are also measured in _____________ ($^{\circ}$). The most important line of longitude is the ________________ or Prime Meridian (0°). All other lines of longitude are given a number between 0° and 180°. Longitude lines are written using the letters E (east) and W (west).

The Equator divides the globe into the Northern and Southern ___________. Australia is located in the Southern Hemisphere, but most of the world's ___________ is found in the Northern Hemisphere. The Greenwich Meridian divides the globe into the Western and Eastern hemispheres. The Western Hemisphere contains North America and South America. The Eastern Hemisphere contains most of Africa, Europe, Asia and Australia. Parts of Antarctica are found in both hemispheres.



Latitude and longitude lines form a grid pattern.



The Earth's hemispheres

The _____________ of the lines of latitude and the lines of longitude can pinpoint any position on the Earth's _____________. The lines of latitude and longitude form a grid pattern on the Earth's surface (look at diagram). The Greenwich Observatory in London can be located at a latitude of approximately 51° north of the Equator and a longitude of 0°. Today the Global Positioning System (GPS) and Google Earth can calculate latitude and longitude anywhere on Earth.

To help pinpoint particular locations, each degree of longitude and latitude can be further divided into 60 small _____________ that are referred to as ______________. For example, the latitude of the town of Bathurst is 33 degrees ($^{\circ}$) and 27 minutes (') south of the Equator. Its longitude is 149 degrees ($^{\circ}$) and 35 minutes (') east of the Prime Meridian. When you look for the location of Bathurst in the index of an _______________, it will look something like this: **33° 27' S 149° 35' E.**

Word bank:

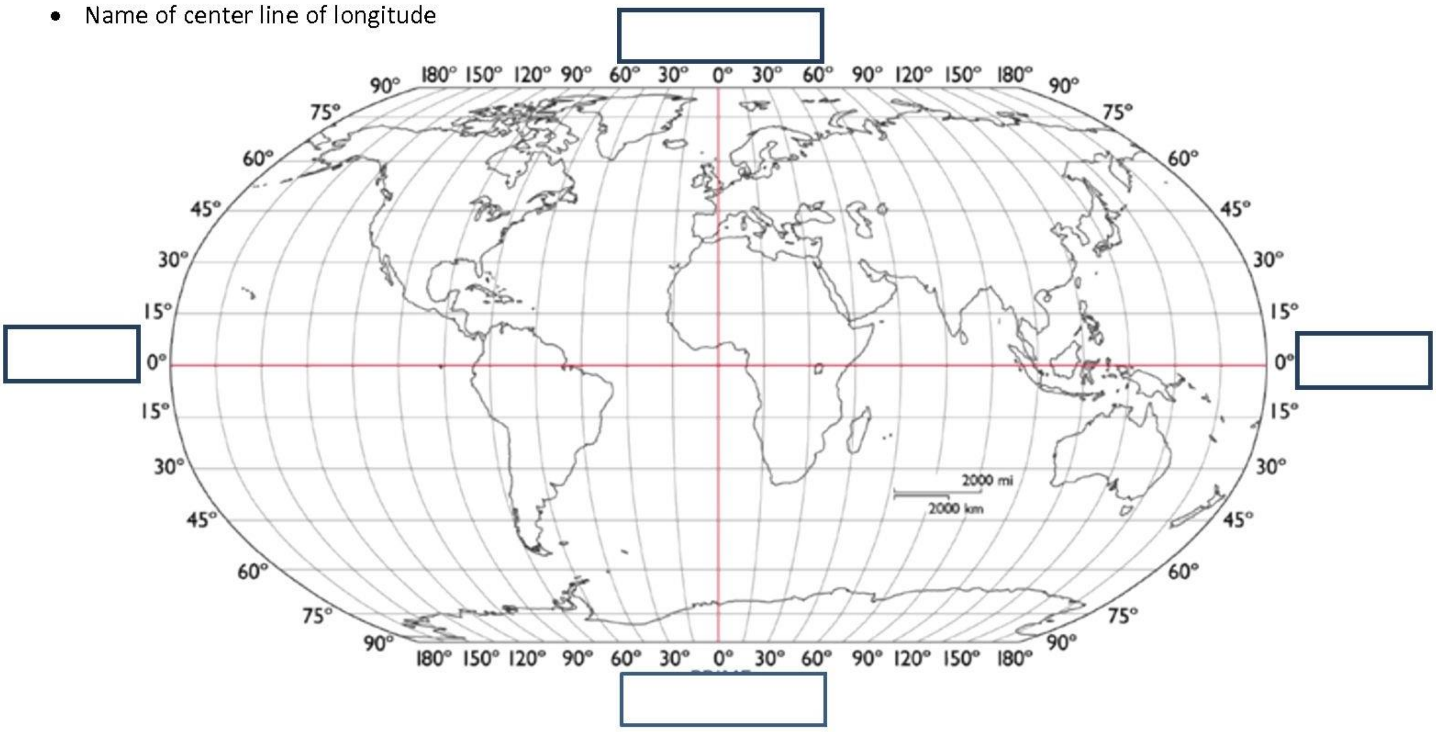
meridians	north–south	landmass	Equator	intersection
degrees	longitude	parallels	sections	minutes
east–west	surface	hemispheres	Greenwich	atlas

Test your knowledge:

World Map

Label the following:

- Continents
- Oceans
- Directions for latitude and longitude
- Name of center line of latitude
- Name of center line of longitude



Fill in the blanks using the words in the word bank:

- The world is divided into four ____________________
- There are seven ____________________and five ____________________
- Australia is located in the southern and ____________________ hemisphere
- The Prime Meridian is also called the ____________________ Meridian
- The Prime ____________________ divides the eastern and western hemisphere
- The ____________________ divides the northern and southern hemisphere
- The Equator is measured at 0° ____________________
- Parallels of latitude run ____________________ to west
- Lines of ____________________ run north to south
- The ____________________ Date Line sets the boundary between one day and the next
- The International Date Line is located ____________________ around the world from the Prime Meridian (0° longitude)

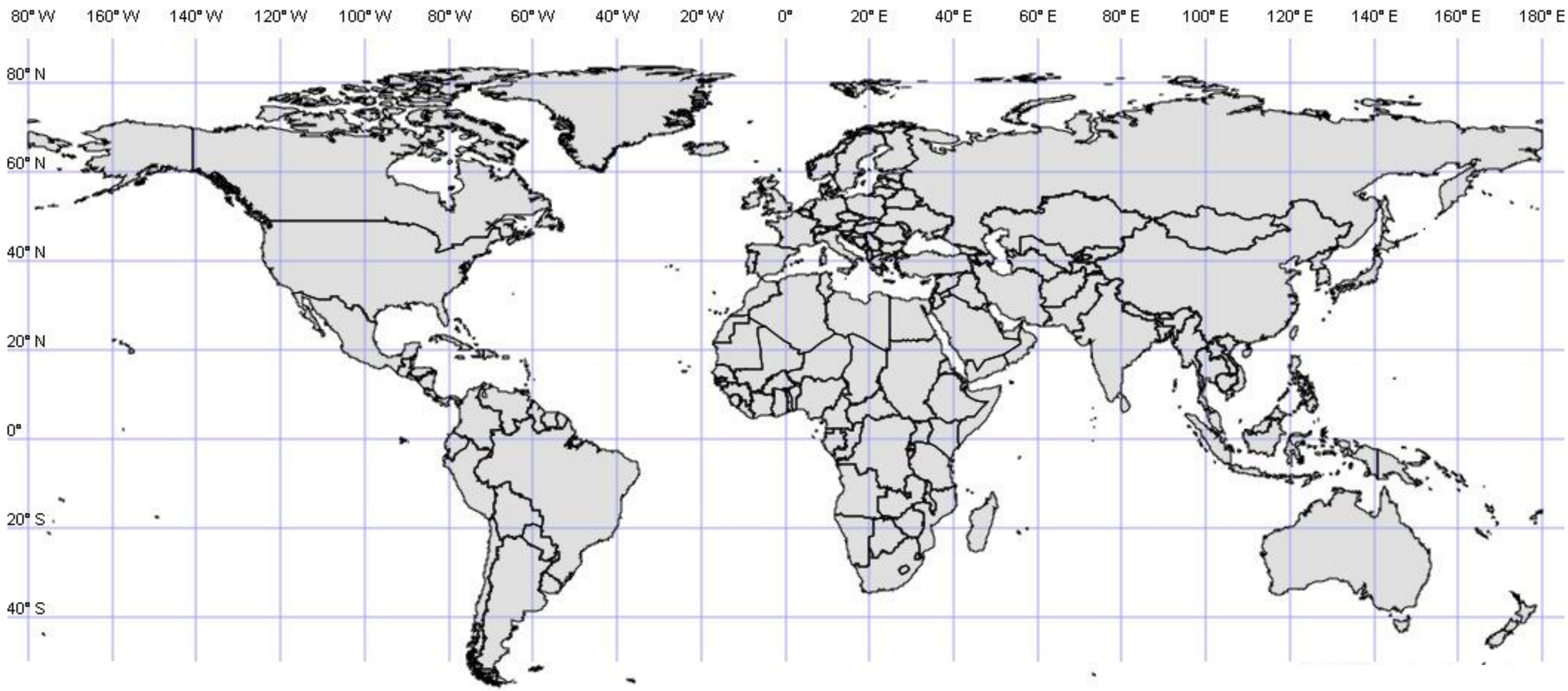
Word bank:

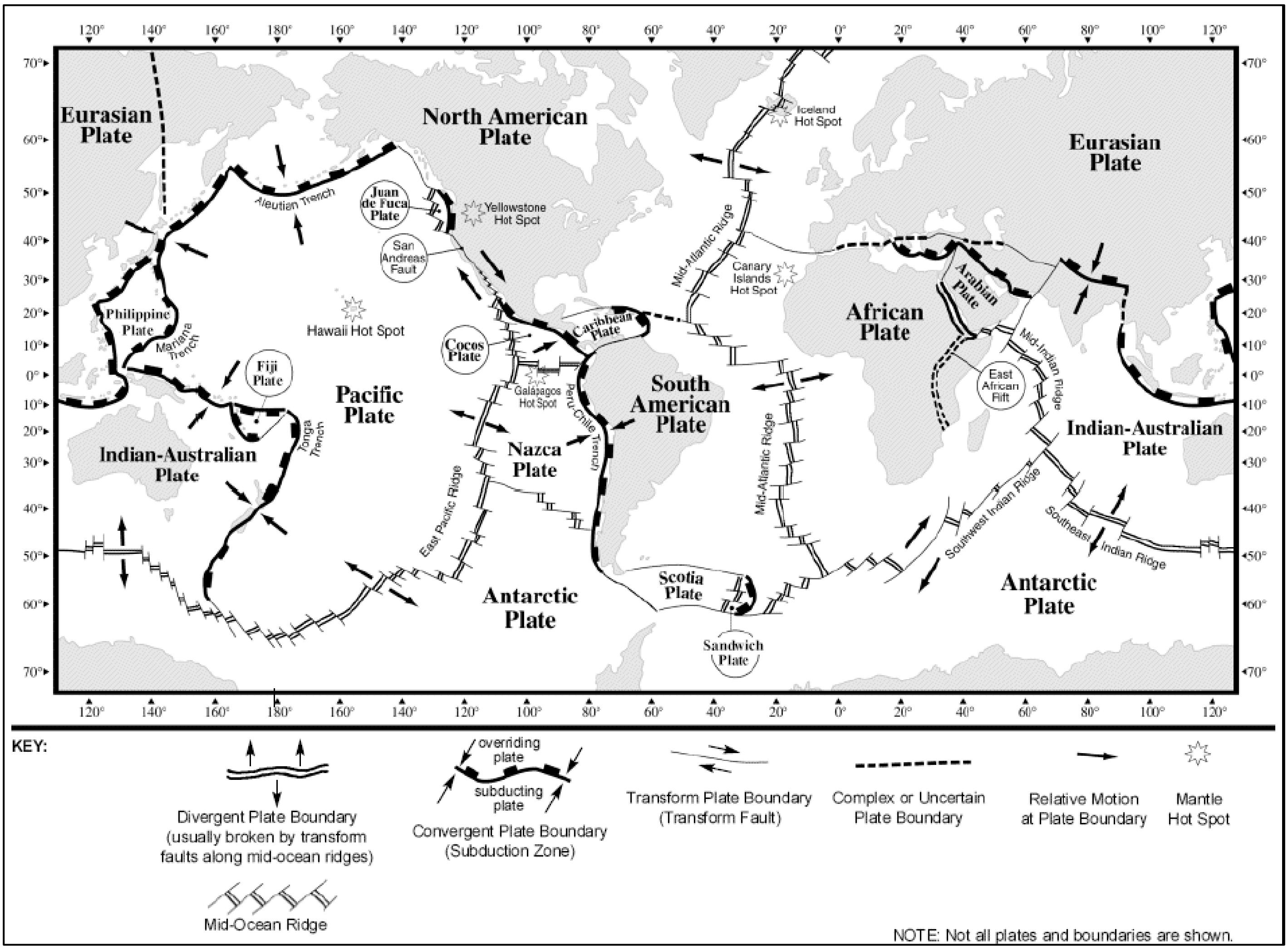
eastern	*east*	*Meridian*	*oceans*
Equator	*hemispheres*	*halfway*	*International*
Greenwich	*longitude*	*continents*	*latitude*

Plotting Latitude and Longitude

The table to the right shows 20 volcanoes by their latitude and longitude. Plot each location on the map above. Mark each volcano by writing its number where you have plotted it to be on the map. Then answer the six questions below.

VOLCANO	Latitude	Longitude	VOLCANO	Latitude	Longitude
1	60N	150W	**11**	55N	160E
2	45N	120W	**12**	40N	145E
3	20N	105W	**13**	5S	155E
4	0	75W	**14**	10S	120E
5	65N	15W	**15**	5S	105E
6	40N	30W	**16**	15S	60E
7	17N	25W	**17**	30S	70W
8	20N	120 E	**18**	55S	25W
9	50N	180	**19**	40S	175E
10	40S	75W	**20**	20N	160W





Map of the Plate boundaries

Check your understanding:

1. Which ocean has volcanoes that run north and south? …………………………………………………………………………..
2. Which ocean has a ring of volcanoes on the land surrounding that ocean? ……………………………………………….
3. Use the tectonic plate map above. What features on the tectonic map correspond with the plotted volcanic activity (name 5): ………

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4. What's the relationship between the volcanoes and the plate boundaries?

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5. Explain where volcanoes are most likely to occur:

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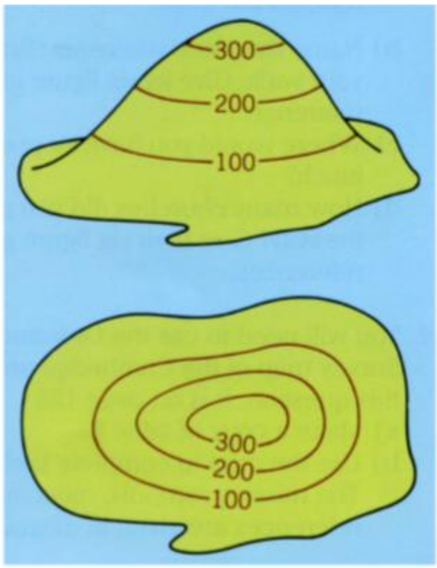
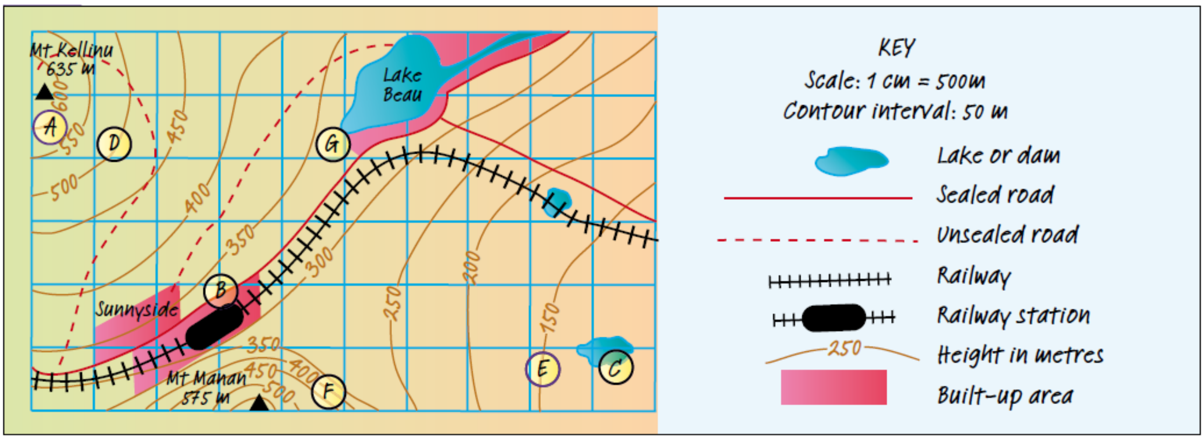
Geographical Skill: Topographic maps and cross sections (plotting and locating coordinates on a map)



Maps are useful tools for showing where places are located, but they don't usually show the height of the land. This is because they show a view from above (aerial), rather than from the side. Some maps show the **height of the land through contour lines**. These lines help us to visualise the shape of the land.

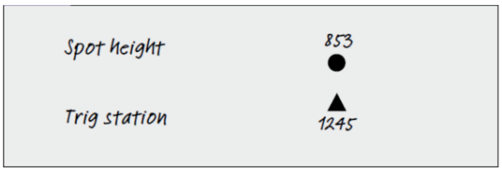
A topographic map shows the height of land on a 2D map. This is done by drawing lines that join place of the same height. These lines are called **contour lines** and can be used to show the shape of the land as well. They show landforms from above.

Each contour line **joins places of equal height above sea level**, so each point on a line has the same height. Not every metre above sea level is draw, because this will make the map too crowded and hard to read; they graph every 10, 20 or 50 metres. The difference in height between each contour line is called the **contour interval** and will always be the same distance apart on the map.



Features of topographic maps

- **Spot heights**



A *spot height* is indicated by a dot point and a number. If a *trig* (short for triangulation) station is present, the spot height is shown by a triangle and a number. A trig station is a point in an area that has been accurately measured. It is usually marked by a concrete block and provides the real-life link between the topographic map and the site.

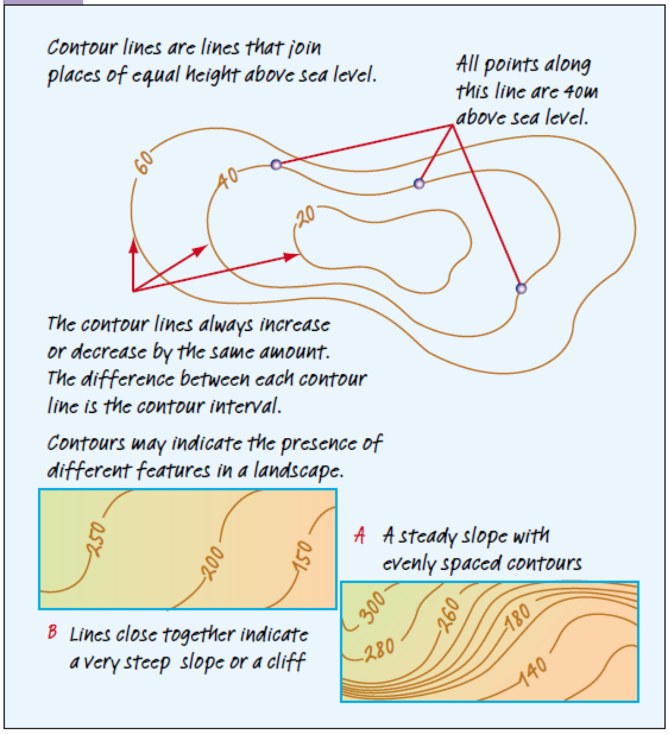
- **Contour lines**

Curved *contour lines* are easily identifiable on a topographic map. But they are not drawn for every metre of height. A map would become far too cluttered so a suitable contour interval is chosen. The *contour interval* is expressed in words near the key. The contour interval is **always the same on a single map**. For example, if the contour interval is 20 metres then the height will increase or decrease in 20-metre sections.

Two general rules of topographic maps are:

1. Where contour lines are far apart it means that the change in height over a given distance is small—it is a gentle slope [2.3A].
2. Where contour lines are close together it means that the change in height over a given distance is large—it is a steep slope [2.3B].

2.3 Contour lines join places of the same height. Lines close together indicate a steep slope. Lines further apart indicate a gentle slope.



Check your understanding:

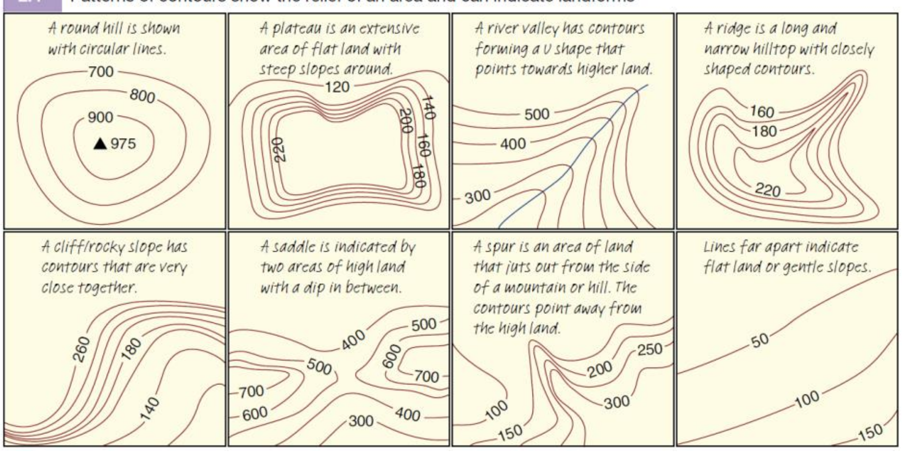
Use the words below to fill in the blanks:

- A topographic map features the earth's ______________.
- The distinguishing feature is topography, which is shown by different ______________ over the map.
- Natural ______________ such as rivers and vegetation, and ______________ features such as settlement and roads are also plotted.
- A ______________ height is a single point on a map that represents the actual height (usually in metres) above sea level.
- A contour line is an isoline on a map ______________ all places of ______________ height above or below sea level.
- A contour interval is the ______________ in height between any two contour ______________ on a map.
- The contour interval is always the ______________ on a single map.
- The closer the contour line, the ______________ the slope.
- The farther apart the contour line, the ______________ the slope.

Word bank:

heights	difference	gentler	lines	human	equal
spot	features	same	surface	joining	steeper

2.4 Patterns of contours show the relief of an area and can indicate landforms



Relief, sight lines, gradient and aspect

Two important features of the natural environment can be read from a topographic map—relief and gradient (or slope).

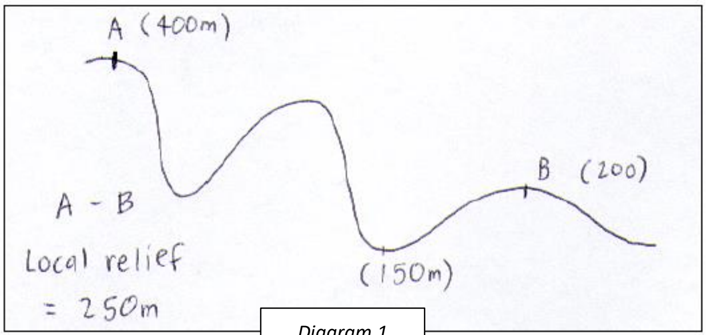
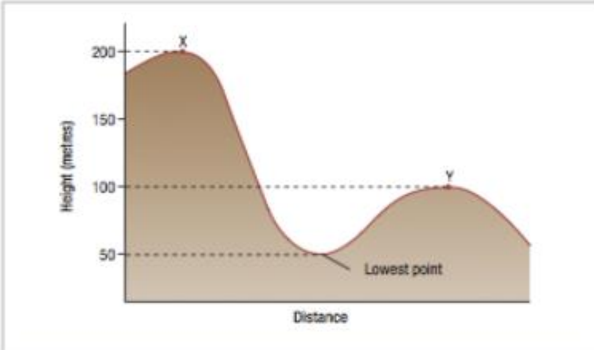


Diagram 1

- **Local Relief**

Local relief is the difference between the highest and lowest points along a transect.



2.3.06 Calculating local relief

Diagram 2

- **Sight lines**

A sight line is the ability to see one location from another. This is often referred to as *intervisibility.* Often the local relief means a higher point between two places stops a person seeing one place from another.

Test your knowledge

1. What is the *local relief* between X and Y on diagram 1?
2. Can a person standing at A see place B on diagram 2?
3. Why would understanding local relief by important for:
   a) A Farmer
   b) A town planner

Why is gradient so important?

Gradient influences many human activities e.g. agriculture, location of infrastructure such as rail lines, and physical events such as landslides and runoff – linked to erosion.

Q: What vocations would this be useful for?

- **Gradient**

Gradient is the ***slope*** of the landform between two given points.

Gradient (GR) = Change in height difference (VR) divided by land distance (HR)

$$GR = \frac{\text{VR (Vertical rise) – use contours}}{\text{HR (Horizontal run) – use map scale to calculate}}$$

E.G. The gradient of a slope that rises 200m between two places 6.4 km apart:

$$GR = \frac{200m \text{ (RISE)}}{6400m \text{ (RUN)}}$$

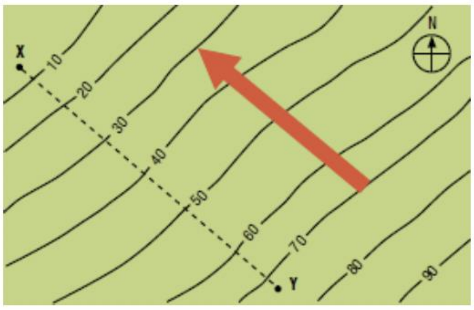
$$GR = \frac{1}{32} \text{ or } 1:32$$

This means that for or every 32 metres travelled you rise 1m

- **Aspect**

Aspect is the *direction* a slope is facing.

Example: What is the aspect of the slope in the diagram?



……

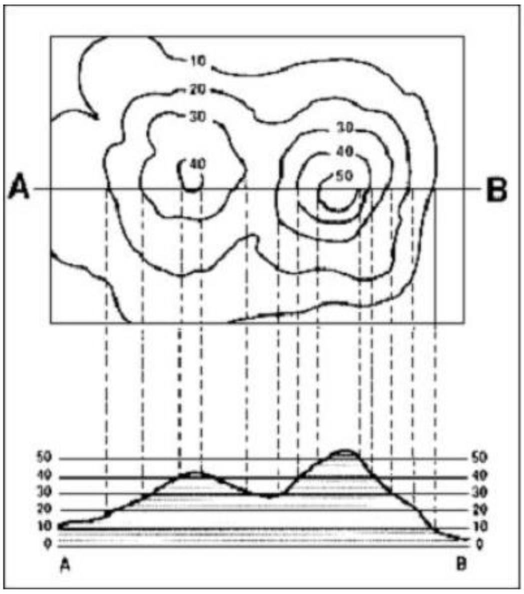
Why is this useful knowledge?

……

……

Cross sections

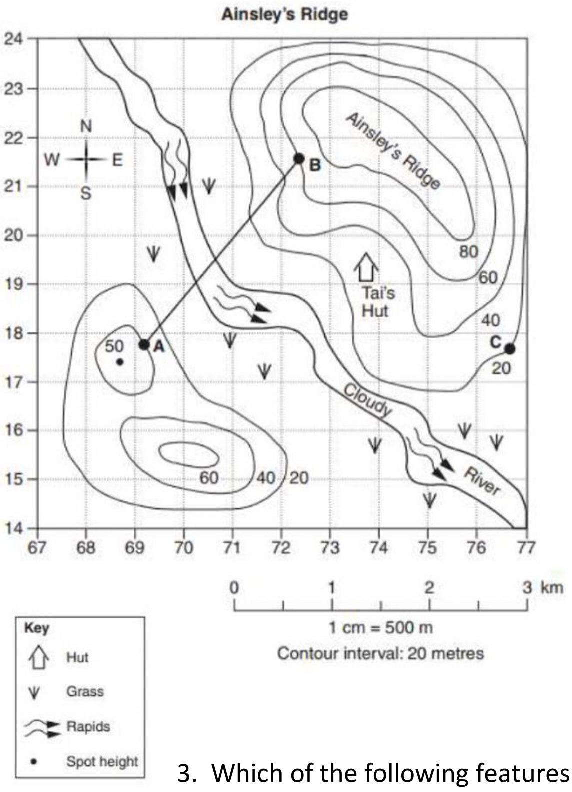
Cross sections are maps represented as graphs. They are made using contour lines and show us what the land would look like if you cut through it from one point to another.



- **Vertical exaggeration**

Vertical exaggeration measures how many times a cross section's vertical axis has been *stretched* compared to the horizontal axis. The horizontal axis is represented by the map scale (ie. horizontal distance across land) and the vertical axis is the height at a given point.

$$\text{Vertical Exaggeration (VR)} = \frac{\text{horizontal scale}}{\text{vertical scale}}$$



Test your skills

1. Can you see point Point B from Point A? Why or why not?

……

……

……

……

2. Can you see GR710143 from the spot height at Point A? Why or why not? *(Hint: draw a line between the two points and determine if there is a higher height ASL than the grid reference blocking vision).*

……

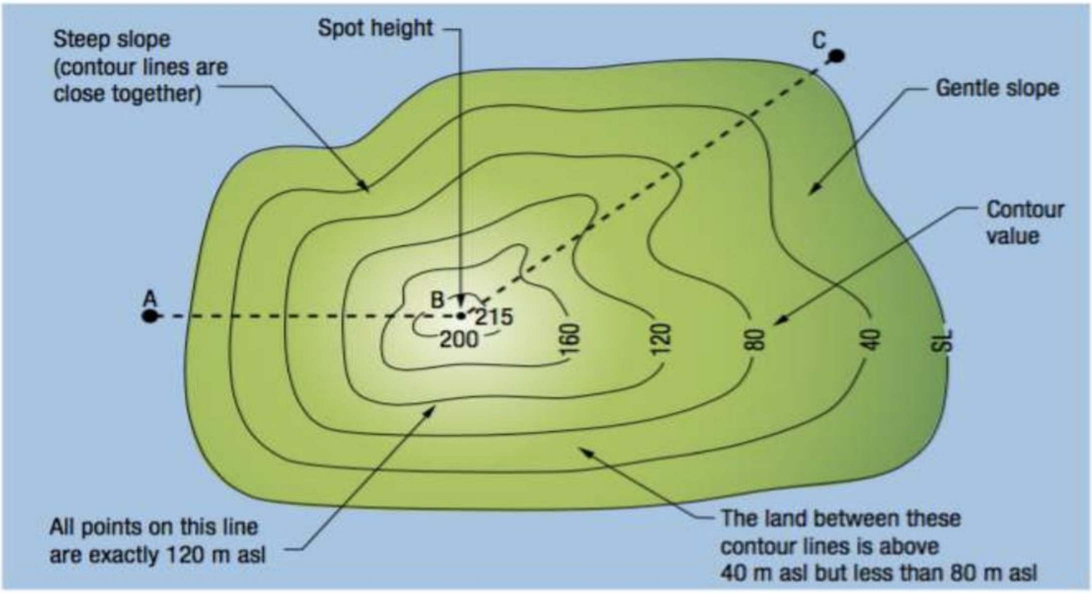
……

……

……

3. Which of the following features is NOT visible from Mt Parsons spot height at GR 089332?
   (A) Wineglass Bay AR 0730
   (B) Fleurieu Point GR 040311
   (C) Coles Bay built-up area AR 0635
   (D) Mt Dove summit GR 081326

Test your skills



Scale: 1:100,000

1. A) Draw a cross section between Point A and Point B

A **B**

B) What is the local relief between A and B?

= Highest point – lowest point
=
=

C) What is the gradient between A and B?

= Rise/Run
=
=

D) What is the vertical exaggeration of the above cross section?

= HS/VS
= 1000/_____
=

2. A) Draw a cross section between Point B and Point C

B **C**

B) What is the local relief between B and C?

= Highest point – lowest point
=
=

C) What is the gradient between B and C?

= Rise/Run
=
=

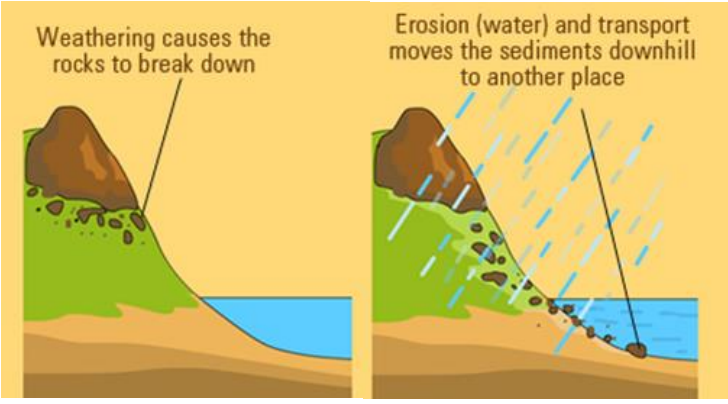
D) What is the vertical exaggeration of the above cross section?

= HS/VS
= 1000/_____
=

Gradational processes

Gradational processes work to smooth out the surface. Exposed rock material is fragmented by weathering, detached by mass movement and agents of erosion and then deposited at lower elevations as debris. Gradational processes act upon the surface of the lithosphere, wearing down high places and filling in low places. Tectonic forces constantly disturb the surface of the land, creating new landscapes upon which gradational processes can work.

Weathering



Weathering is the in situ physical disintegration and chemical decomposition of rocks and minerals at or near the earth's surface by **atmospheric** and **biological agents**. Weathering is an essential prerequisite for many types of erosion as it loosens surface material, making it more readily removed.

- **Physical weathering:** slowly breaks up the rocks of the land surface into smaller particles but does not change their chemical composition.
- **Chemical weathering**: involves the actual decomposition of rocks, primarily by means of exposure to water, oxygen and carbon dioxide. Most of the original minerals formed deep in the earth's crust are changed by chemical weathering into new compounds that are stable in the atmosphere and the temperature and air pressure conditions that exist at the earth's surface.

Physical weathering

- **Unloading:** when rocks which were once deeply buried have the weight and pressure of overlying material removed.
- **Frost action:** when water held in the tiny fissures of rocks freezes and expands, forcing cracks to form.
- **Organic action:** the germination of seeds and the wedging of roots in the cracks of rocks exerts pressure causing cracks to widen. Burrowing animals allow air to penetrate further (e.g. worms and rabbits).

Chemical weathering

- **Oxidation:** when minerals react with oxygen to form oxides. When water reacts with minerals it creates hydroxides. Iron is the most common element in the process.
- **Solution**: when weak acids dissolve minerals in rocks.
- **Hydration**: when rocks expand as their minerals chemically combine with water.
- **Organic acids:** Organic acids are produced when water combines with decaying organic material in humus. The acids attack or weather rocks as they seeps through the soil.

Mass movement

Once weathering has reduced the size of rock particles, it is easier for them to be loosened and removed from the site, known as mass movement. The nature of the moving material varies greatly and includes everything from great slabs of solid rock to loose, unconsolidated rock debris and soil. Sometimes this form of movement will be quite abrupt, as when a landslide releases millions of tonnes of material in a spectacular plunge. At other times it will be imperceptibly slow. Mass movements often leave visible scars on the land surface. Heavy rainfall saturating the land surface may trigger a slump or flow (the sudden downslope movements of earth and rock).

Erosion and deposition

The shaping of the land's surface continues with the processes of erosion, and then the transportation and subsequent deposition of material. The ultimate resting place for eroded and transported material is the lowest place: the ocean floor. Eventually, most loose material will find its way to the sea. It will have been collected and carried there by the agents of erosion: wind, running water and glacial ice. A vast range of erosion, transportation and deposition processes operate on the earth's surface. The most important of these are water, wind and ice. The action of running water (the fluvial process) is normally considered to be the dominant landscape-shaping process, and the action of waves the most dominant process in shaping coastlines.

	WEATHERING		EROSION		
	Mechanical	Chemical	Moving Water	Wind	Glaciers
What it does					
Examples					

1. Explain the role of gradational forces in shaping the earth's surface:
………
………

2. Define what is meant by the term weathering. Why is it such an important process?
………
………

3. Differentiate between *physical* and *chemical weathering*:
………
………
………

Landforms shaped by water: rivers and streams

Fluvial processes

Even the impact of a single ______________ can dislodge particles of earth, feeding them as sediment load into running water or surface ______________ . The running water becomes organised into rivulets and streams, collecting and ______________ with it any loose material it encounters.

Running water is particularly effective in ______________ and semi-arid regions and where human activities have ______________ the protective cover of vegetation that binds the soil together. Where rain falls on ______________ earth, it quickly forms rivulets that erode deep channels, called gullies. Once in the river, the water and its accompanying load erode the rocks and sediments over which the river flows. The processes involved are:

- **Hydraulic action:** This is the power of the flowing water itself. The surging water exerts a dragging action on the riverbed and banks. This can excavate enormous quantities of poorly consolidated (that is, relatively loose) alluvial materials (sand, silt and gravel), especially during ______________ .
- **Abrasion**: This occurs when rock particles that are carried by the swift-flowing current strike channel walls. As they do so they ______________ off chips of rock and earth.
- **Corrosion**: This is due to the chemical ______________ of material from rocks being exposed to the stream by solvents carried in the river.

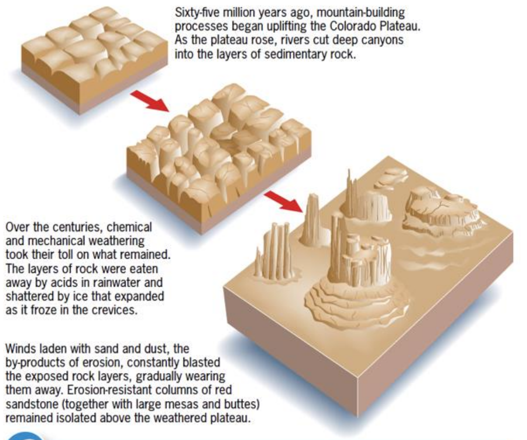


FIGURE 1.4.25

The floor of Monument Valley is hundreds of metres lower than the plateau that once occupied the area.

Landform evolution

River erosion and deposition processes can occur quite ______________ . In contrast, the process of landform evolution takes place slowly. In the mountainous headwaters of river catchments, where gradients are often ______________ , rivers erode downwards, creating narrow V-shaped valleys. Interlocking spurs, river rapids and waterfalls are common landscape features, while floodplains and meanders are largely absent in this section of the river.

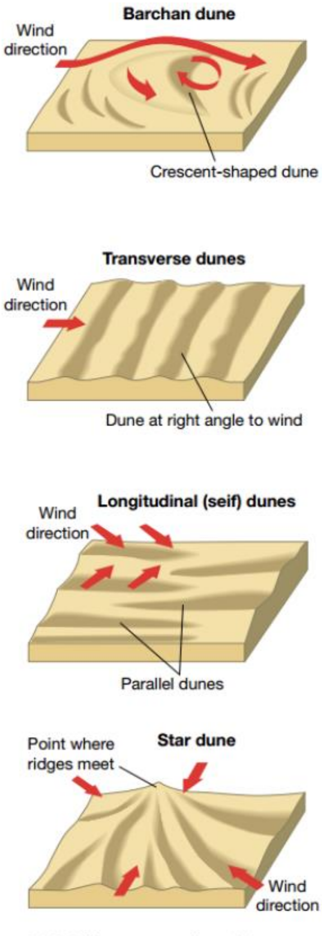
In the central reaches of a river system the mountains have given way to low hills. Here the land continues to undergo substantial downcutting, but the river valleys begin to ______________ . Even further downstream, lateral erosion and valley widening become more prominent and floodplains with meanders start to develop.

Away from the ______________ and hills, lateral erosion dominates. Valleys widen and the reduction in stream velocity results in the deposition of some of the river's load of sediment. These sediments are known as ______________ deposits. They often form extensive lowland or coastal floodplains across which the river will meander.

Word bank:

quickly	*alluvial*	*grind*	*damaged*
broaden	*solution*	*runoff*	*carrying*
floods	*arid*	*mountains*	*steep*
	raindrop	*exposed*	

Landforms shaped by wind



4.3.8 Different types of sand dunes

Winds are particularly effective in shaping landforms in areas where there is little or no vegetation. These include the world's arid and semiarid regions and those areas in which human activity has degraded the land and destroyed the vegetation.

In the zone closest to the ground, the wind picks up weathered rock materials and uses them to 'sand-blast' larger rock structures. This process is known as **abrasion** and it often contributes to the formation of distinctive sculptured rock formations.

On a larger scale the formation of rock-strewn reg surfaces has been, in part, attributed to the removal of finer material by wind. This process is known as deflation. The wind also plays an important role in moving and reshaping dunes (figure 4.3.8)

1. Explain how landforms are shaped by wind. Use an example of a formation above (for examples dunes).

……

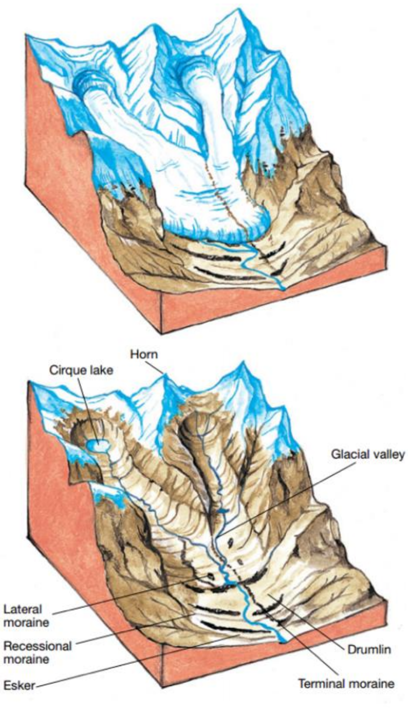
……

……

……

Landforms shaped by ice

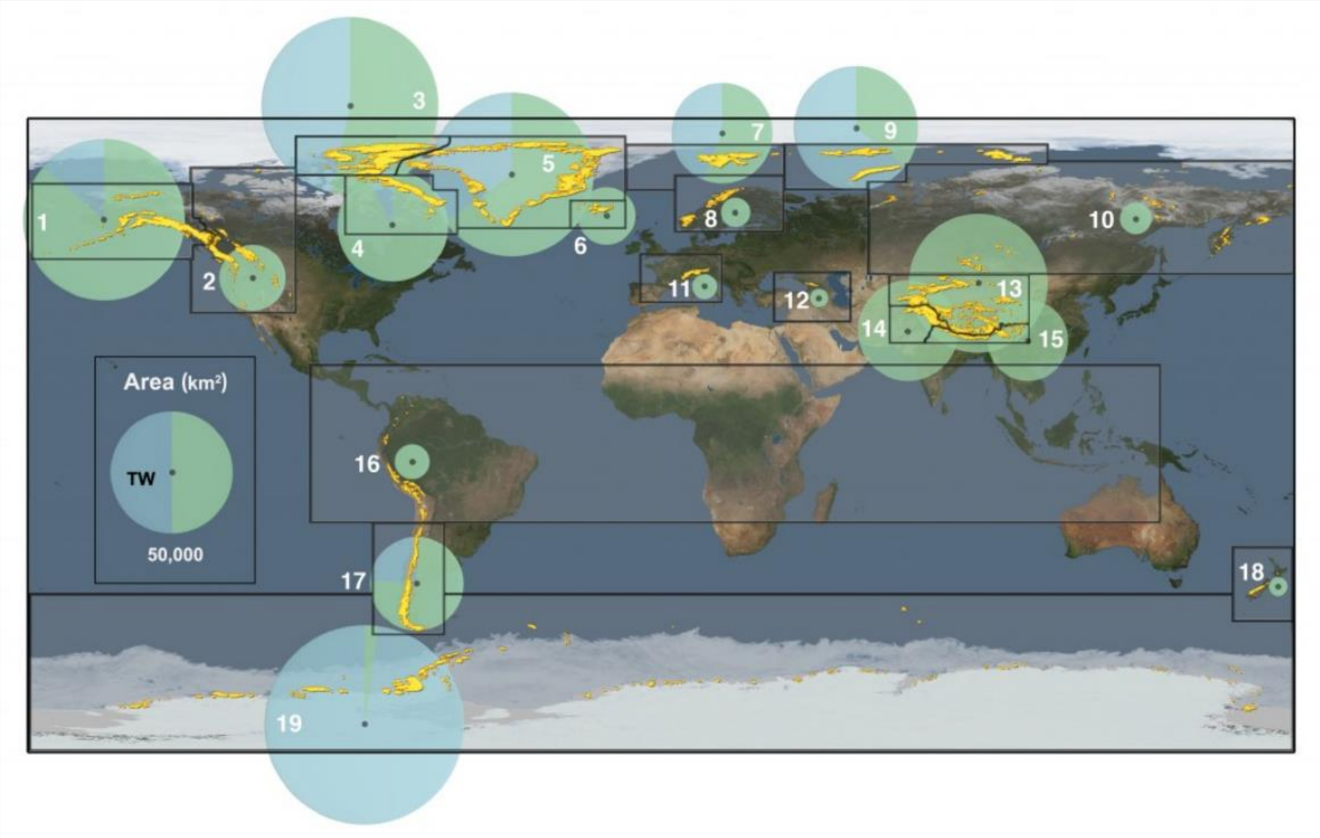
Glaciers are huge masses of ice. They form when snow that has accumulated over many years is compacted to form glacial ice. Gradually, the quantity of snow becomes greater. Due to its increasing weight, the compacted glacial ice is forced to move outwards and downwards under the force of gravity.



4.3.13 The development of glacial landform features

Ice sheets are layers of ice covering relatively flat landscapes. Both ice sheets and glaciers have great erosional and depositional power. The surface of the land is scratched and worn down by the constant grinding action of rock fragments that have been 'plucked' from the ground and embedded in the base of the ice. This process is known as abrasion. The rock-laden glacial ice grinds away the irregular surfaces over which it moves, leaving very distinctive landform features.

Geographical Skill: calculating the rate of increase or decrease between two points estimating the value of proportional circles of different size using a key



— This figure shows the global distribution of glaciers. The diameter of the circle shows the area covered. The area covered by tidewater glaciers is shown in blue. The number refers to the RGI region. From the IPCC AR5 Working Group 1 (Ref. 13).

Tidewater glaciers are valley glaciers that flow all the way down to the ocean. They often calve numerous small icebergs, which can sometimes pose problems for shipping lanes.

Questions:

1. Identify what the circles represent: ……………………………………………………………………………………………………
2. What does the blue area represent: ……………………………………………………………………………………………………
3. Identify the location of the largest glacier: ……………………………………………………………………………………………
4. Identify how many glaciers are larger than 50, 000 km²: ……………………………………………………………………………
5. Identify the locations of the five largest glaciers:
   a. ……………………………………………………………………………………
   b. ……………………………………………………………………………………
   c. ……………………………………………………………………………………
   d. ……………………………………………………………………………………
   e. ……………………………………………………………………………………

Soils

Soils are a complex mix of inorganic minerals usually in the form of clay, sand and silt), air, water and organic matter including bacteria and fungi. Soils provide a foundation for plant and, consequently, animal life on land. The development of soils is the result of the interaction of the lithosphere with the other components of the biophysical environment.

Identifying soils

Soils are developed by physical, chemical and biological processes, including the weathering of rock and the decay of vegetation. For soils to develop, two processes must take place:

1) Water moving down through cracks in the rock strata must cause physical and chemical changes in the original material.
2) The activities of living organisms must bring about further modifications.

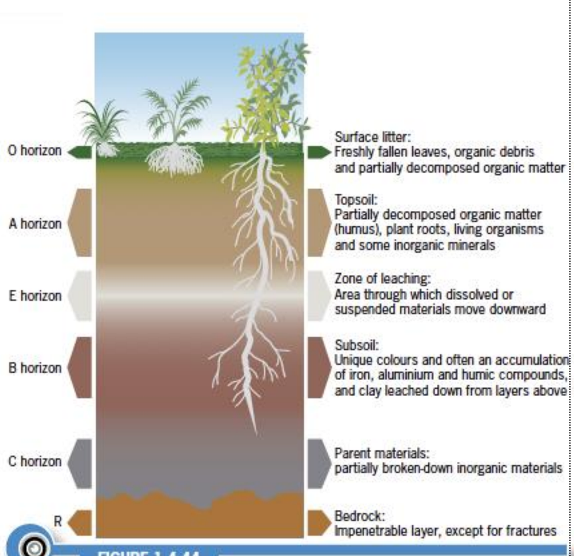


FIGURE 1.4.44

A generalised soil profile.

Each layer has identifiable physical and chemical characteristics (see figure 1.4.44). The presence of these layers constitutes a true soil. It can differ markedly from its original parent material in properties and characteristics. Soils typically comprise several horizons, roughly parallel to the surface, which together form the **soil profile**. Each horizon has a distinct colour, thickness, texture and composition.

Soil characteristics

The four principal characteristics of soil are texture, structure, colour and acidity/alkalinity composition:

- **Texture:** the _______________ of soil particles, e.g. clay, sand, gravel.
- **Structure:** how the particles _______________ together in small masses (aggregates).
- **Colour:** reflects the presence of identifiable substances in the _______________
- **Acidity and Alkalinity:** measured by pH value. A pH of 7 is neutral, 8.5 is _______________, 5.5 is acidic.

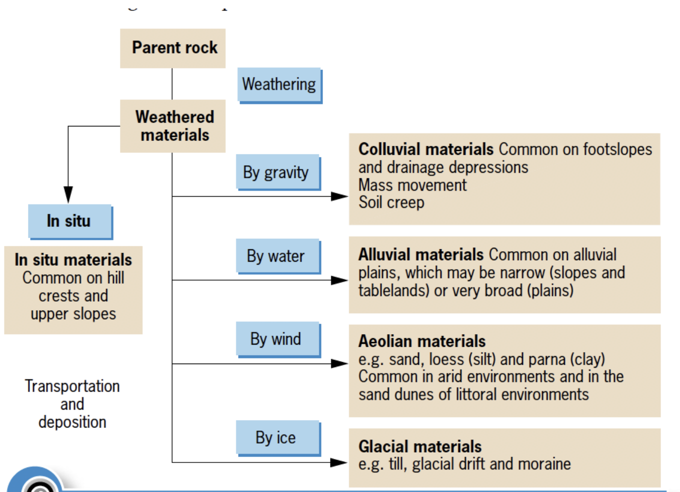


FIGURE 1.4.46

Origin of parent materials.

soil	*alkaline*	*clump*	*size*

Soil formation

Soil formation needs to be discussed in terms of soil-forming processes as well as soil-forming factors. The soil-forming factors control the processes, which in turn lead to the development of the soil.

Soil forming factors

The formation of soil relies on 5 soil forming factors:

- **Parent material:** is the ________________ and starting point of the soil. Soils are either ________________ from weathered ________________ at the site where the soil is located, or from weathered rock eroded in another place and ________________ and deposited in a ________________ site.
- **Climate:** water and ________________ are important factors in soil formation. Precipitation and ________________ influence the process or soil formation
- **Topography:** the ________________ of the land affects soil formation by determining water ________________ and transportation of sediment.
- **Organisms:** biotic ________________ can affect the types of soils occurring in particular places. Vegetation, earthworms and ________________ have a great impact.
- **Time:** soil type is influenced by the amount of ________________ soil processes have been taking place. Soils will change over time.

new	*source*	*bedrock*	*shape*
formed	*temperature*	*transported*	*evaporation*
humans	*availability*	*time*	*activity*

Soil-forming processes

The layer of fine particles produced by weathering does not constitute a real soil until it undergoes additional changes from the interaction of various processes.

- **Movement of water through the soil profile**

Water sinking into the ground takes with it both solid and dissolved matter from the upper part of the soil and deposits it in the lower part. This contributes to the differentiation of soil into horizons, each with its own characteristics.
This process is associated with:

- the leaching of soluble minerals, including calcium, magnesium, sodium, nitrate, chloride, sulfate and carbonate
- the movement and accumulation of organic matter, silicon compounds and iron or aluminium oxides
- clay translocation, which is the movement (eluviation) and deposition (illuviation) of suspended clay particles.

The speed of the above processes is dependent on the ratio of precipitation to evaporation and on soil permeability. For example, highly permeable soils, such as sands, will be more readily leached than impermeable soils.

- **Soil drainage**

Soil drainage, particularly the amount of time a soil is wet or saturated, has very significant effects on the soil. In well-drained soils, which remain wet for only short periods of time, red and reddish-brown colours dominate. Generally, the red colour may be attributed to oxidised iron. Poorly drained soils remain wet for at least several weeks and often all winter. In these soils are found dull yellow and grey colours, which are frequently mottled with patches of red, orange, white and grey.

- **Continual weathering and new mineral formation**

Weathering of primary minerals (those derived from the original rock) is a continual process in soils and leads to the formation of secondary minerals (clays and oxides). The secondary materials may, in turn, also be altered. Some primary minerals, such as quartz, resist weathering and remain in the soil profile for a considerable time.

- **Solution, precipitation and accumulation of soil components**

Many compounds, such as iron and manganese, accumulate in soils. Calcium carbonate can accumulate in soils derived from parent material that is rich in it, such as limestone. It can also accumulate in dry regions where there is little leaching and these soluble constituents are not removed from the profile.

- **Wetting and drying**

Wetting and drying out is important in soils that shrink and expand substantially with changes in moisture content. These are known as expansive soils.

- **Biological activity**

Biological activity includes the accumulation of organic matter and the development of soil structure by plant roots, fungi, animal activity and decomposing organic matter. Numerous other biologically controlled reactions affect nutrient cycling in the soil, particularly that of nitrogen. Human activities can also act as a biological agent. For example, cultivation and excessive grazing can lead to erosion and reductions in organic matter and degradation of soil structure.

Task: Summarise the above information in the table below

Soil forming processes	
Movement of water through the soil profile	**Soil drainage**
Continual weathering and new mineral formation	**Solution, precipitation and accumulation of soil components**
Wetting and drying	**Biological activity**

Human impacts on the Lithosphere: Desertification

Causes of desertification

Desertification is a process where areas close to a desert start to become more desert like, as if the desert was expanding into new territory. It isn't really an area being turned into the desert; however, it means that the soil is becoming more degraded and making it harder to grow crops. Desertification occurs where land use practices leave the soil vulnerable to erosion by wind and water. The practices contributing to desertification include:

- overgrazing—too many livestock on too little land area
- improper soil and water resource management—leads to increased erosion, salinisation and waterlogging of soil
- cultivation of land with unsuitable terrain or soils
- deforestation or removal of natural vegetation without adequate replanting.

Central to the problem is the increased intensity of land use associated with rapid population growth and high population densities. Poverty is a related issue. The poor are often forced by their desperate circumstances to exploit the lands beyond what would normally be regarded as a sustainable level of use. When combined with prolonged periods of below-average rainfall, famines are often the tragic outcome. Land degradation and incidence of famine are two of the major factors contributing to the increasing problem of environmental refugees.

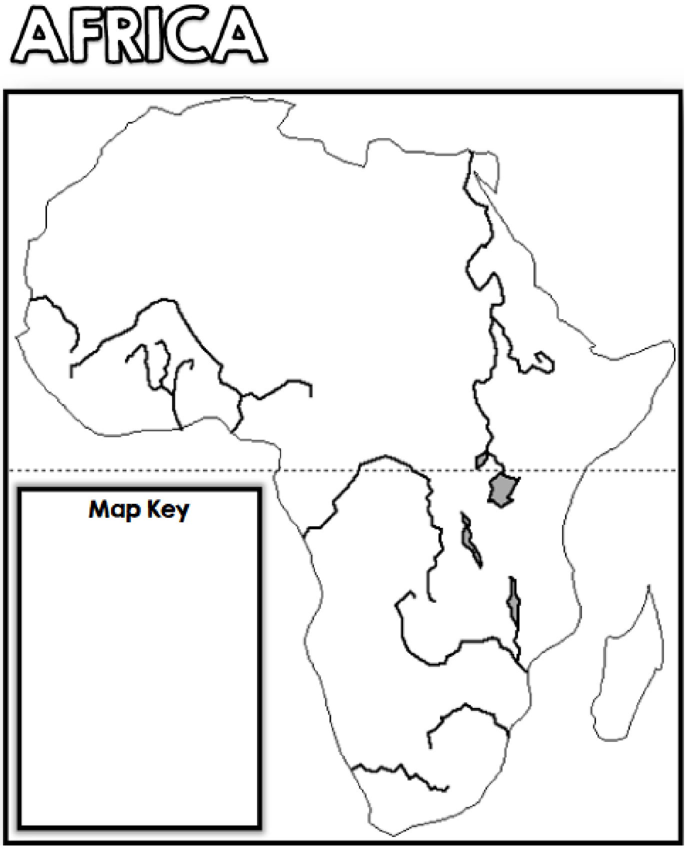
Desertification in Africa

In the African Sahel region, approximately 65 million ha of productive land has been turned into desert in the last 50 years. The increased intensity of land use will inevitably result in overgrazing and overcultivation. The enlarged herds of cattle, goats, sheep and camels will strip the vegetation, exposing the soil to erosion. Fuelwood is the people's main source of energy for cooking and heating. The deforestation associated with the collection of fuelwood makes the situation worse. Africa is particularly vulnerable to this form of land degradation. In a harsh climate, marginally productive land easily becomes sterile. Prolonged droughts, lasting for two to three years, are common over two-thirds of the continent.

Even in 'normal' years, rainfall is very unreliable and in some seasons, does not occur at all. Throughout much of the region rainfall has been below average for the last 15 to 20 years. Some experts argue that this prolonged drought reflects a change in the region's climate, brought about by the large-scale removal of the natural vegetation. In the past, people coped with the poor soils and unreliable rainfall by rotating crops and allowing the most fragile land to lie fallow for up to 20 years. This form of shifting cultivation, together with the land use practices of the nomadic herders, was perfectly sustainable while human and animal numbers did not exceed the 'carrying capacity' of the land.

War and civil unrest have also played a major role in the degradation of the land. Conflicts in Somalia, Ethiopia and Sudan have led to economic collapse and political chaos. In addition to the direct environmental damage caused by the conflict, the allocation of scarce resources to support military activities has detracted from efforts to address the region's environmental problems. Conflict and civil disorder also impact on the people themselves and their willingness and ability to deal with desertification.

In Northern Africa we can see the Sahara Desert which is spreading south, however, countries which are facing the desertification crisis are fighting back by changing farming methods, being careful with how they use plants and trees and building a Green Wall across the continent.



Consolidate your learning:

1. Describe the process of desertification:

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

2. Explain the human impacts that accelerate desertification:

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

3. Explain the environmental factors that have contributed to desertification:

………
………
………
………

4. Predict what will happen to Africa, and other continents, that are affected with by desertification (include the social, economic, political and environmental impacts):

………
………
………
………
………
………
………

The Great Green Wall

ACTIVITY: watch the video on the Great Green Wall and then build a response to the following question by using the bubble scaffold below.

https://www.youtube.com/watch?v=4xls7K_xFBQ

Question: Evaluate the effects of building the Great Green Wall.