4.1 The structure of the Earth

Objectives

- Describe a model for the Earth's structure
- Explain how we know about the Earth's structure

The ground beneath your feet

Imagine you could dig a hole more than 6000 km deep, to the centre of the Earth. What would you find?

Scientists have been curious about the structure of the Earth for many years. They made observations and collected data, and thought carefully about them. They created **scientific models** to explain their observations.

A scientific model is an idea that explains observations. It can be used to make predictions.

Early models of the structure of the Earth

Observations from space give further evidence that the Earth is a sphere.

Flat Earth model

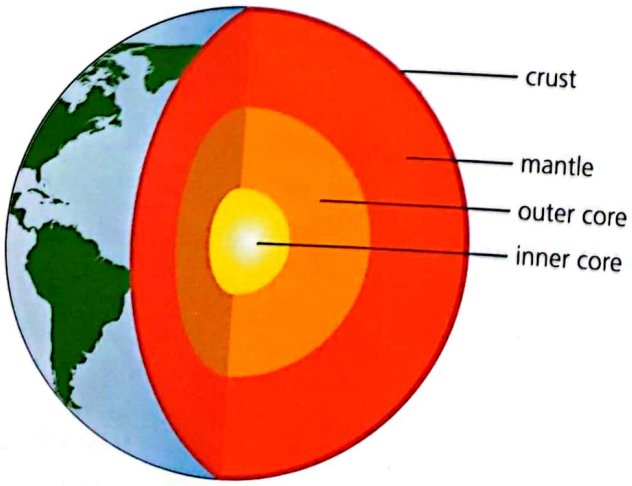
For many years, people thought the Earth was flat. They based this idea on their observations.

Gradually, observations made people think that the flat Earth model might be wrong. Sailors noticed that ships appear to sink as they go over the horizon. Aristotle lived more than 2000 years ago. He saw that the shadow of the Earth on the Moon is round. These observations led to a new model of the Earth, as a sphere.

Ships appear to sink as they go over the horizon.

The hollow Earth model

About 300 years ago Edmond Halley suggested a new model of the Earth. He said the Earth consisted of three hollow shells separated by air. Halley created his model to explain some unusual compass readings.



The modern model for the structure of the Earth.

The modern model of the structure of the Earth

Scientists used many observations and data to create the modern model of the structure of the Earth.

The model states that the Earth is made up of several layers:

- a solid **crust** made of different types of rock
- the **mantle**, which goes down almost halfway to the centre of the Earth. It is solid but can flow very slowly.
- the liquid **outer core**, made up mainly of iron and nickel
- the solid **inner core**, also mainly iron and nickel.

How do we know about the structure of the Earth?

Observations and data from many scientists have contributed to our understanding of the Earth. Scientists studied rocks on the surface and under oceans. They examined rocks brought to the surface by volcanoes.

Shock waves from earthquakes also provided evidence. In the 1930s Inge Lehmann examined shock wave patterns. She couldn't explain them using the model of the time – that the Earth's core was the same all the way through. She created a new model – that the core consists of two parts. Inge Lehmann had discovered the solid inner core.

Inge Lehmann discovered the inner core.

Hotter and hotter

Temperatures increase from crust to core. The core, 6000 km below the surface, is very hot. It may be hotter than the surface of the Sun.

Some of the deepest mines in the world are in South Africa. They are nearly 4 km deep. At these depths the rock temperature is about 60 °C. The air is cooled so that miners can do their work.

Deep South African gold mines are very hot.

Q

1. Name the layers of the Earth, starting from the inside. inner core, outer core, mantle & crust
2. Identify two pieces of evidence that suggest the Earth is spherical.
3. Outline the evidence suggesting that the Earth has a solid inner core.

Lehmann examined shock waves

- The Earth consists of the crust, mantle, outer core, and inner core.
- Temperature increases from the crust towards the core.

4.2 Igneous rock

Objectives

- Describe the properties of igneous rocks
- Give examples of igneous rocks
- Explain how igneous rocks formed
- Link igneous rock properties to their uses

The Earth's crust

Think about the things you've used today. Where did they all come from? The answer is the Earth's crust, the air, and the oceans.

The Earth's crust is made up of different types of rock. We use some types of rock just as they are. We extract metals from other rock types. We process some rock types to make cement and other building materials.

Grouping rocks

The pictures show three types of rock. They have very different properties.

Basalt, an igneous rock.

Limestone, a sedimentary rock.

Marble, a metamorphic rock.

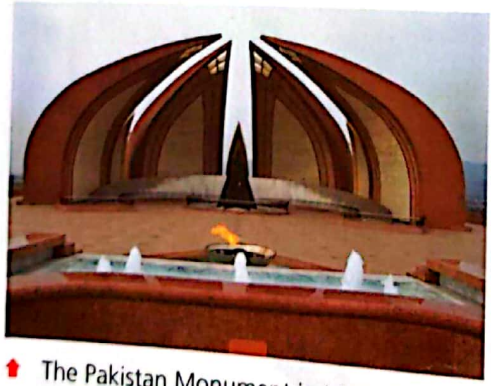
There are many different types of rock. Scientists classify rocks into three groups:

- igneous rocks
- sedimentary rocks
- metamorphic rocks.

Igneous rocks

What do the structures below have in common?

The Giant's Causeway in Northern Ireland was formed from basalt.



The Pakistan Monument in Islamabad, completed in 2007.

This statue of an Egyptian queen, Hatshepsut, is 3500 years old.

Both structures are made from **granite**. Granite is an example of an **igneous rock**. Igneous rocks are made when **magma** (liquid rock) cools and solidifies. Granite consists of interlocking **crystals**, strongly joined together. The crystals are quite big – you can see them easily. Each crystal is made of one substance. Another igneous rock is **basalt**, which makes up much of the seabed.

Properties of igneous rocks

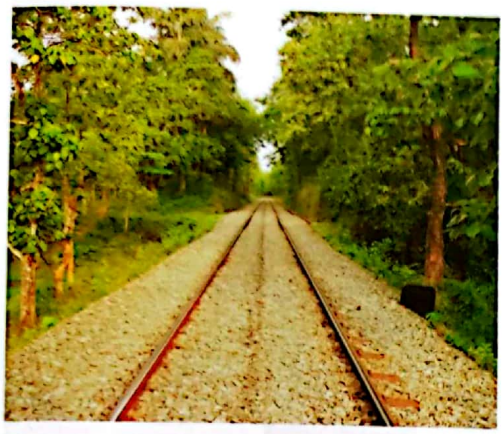
Igneous rocks are hard and durable. The rocks that originally surrounded these granite boulders on Belitung Island have been worn away, but the granite remains.

Most igneous rocks are also **non-porous** – water does not soak into them. This is because there are no gaps between their interlocking crystals.

Granite boulders on Belitung Island, Indonesia.

Using igneous rocks

The properties of igneous rocks explain their uses.



Basalt is hard and durable. It is used as railway ballast.

This sculpture is made from an igneous rock called gabbro. It is hard, durable, and attractive.

Quartz consists of a single mineral, silicon dioxide.

Minerals

Substances that exist naturally as crystals are called **minerals**. Most rocks are a mixture of minerals. Minerals also occur on their own.

Granite is a mixture of minerals. This sample includes quartz (grey crystals), calcium feldspar (white crystals), biotite (black crystals), and potassium feldspar (pink crystals).

Explaining crystal size

Basalt forms when runny liquid rock pours out of volcanoes and cools quickly, often under the sea. As the liquid cools, crystals grow as the particles arrange themselves in patterns. When all the particles are arranged in crystals, there is no liquid rock left. It has all become solid basalt.

Basalt's crystals are tiny. You need a magnifying glass to see them. The crystals are small because the liquid rock cooled and solidified in just a few weeks.

Granite forms when liquid rock cools underground. The cooling takes longer, so its particles have more time to arrange themselves. The crystals grow bigger.

Q

1. Describe the properties of a typical igneous rock.
2. What is a mineral?
3. Explain why you can often see different colours in a lump of granite.
4. Basalt has smaller crystals than granite. Explain why.

!

- There are three types of rock: igneous, sedimentary, and metamorphic.
- Igneous rocks are hard, durable, and non-porous.
- Igneous rocks formed from liquid rocks.
- Rocks that cooled quickly have small crystals.

4.3 Sedimentary rocks

Objectives

- Describe sedimentary rock properties
- Identify and name sedimentary rocks

Sedimentary rock properties

Limestone is a typical sedimentary rock. Sedimentary rocks are less hard than most igneous rocks. This means it is easier to scratch them.

Most sedimentary rocks are **porous**. You can find out if a rock is porous by dropping water onto it. If the water soaks in, the rock is porous. If the water does not soak in, the rock is non-porous.

The structure of a sedimentary rock explains its properties. They are made of **grains**. The grains are held together less strongly than the crystals in igneous rocks. There are small spaces between the grains. Gases (like air) or liquids (like water) fill the spaces.

Identifying sedimentary rocks

You can identify sedimentary rocks by doing these tests:

- Look at the rock through a hand lens or magnifying glass. Sedimentary rocks have separate grains with spaces between them.
- Place a few drops of water on the rock. Sedimentary rocks are porous, so the water will soak in.
- Place the rock in a beaker of water. If you see bubbles, the rock must include air spaces. It is probably a sedimentary rock.
- Try scratching the rock. If you can scratch it with your fingernail or an iron nail it is quite soft. It is likely to be a sedimentary rock.

India Gate, in New Delhi, India, is made of granite and sandstone.

Brick making in Rwanda.

Different sedimentary rocks

Different types of sediment make different types of rock. Each rock type has its own properties and uses.

Sandstone

Sandstone is a hard sedimentary rock. This means it makes a good building material. Its medium-sized grains are made of the mineral quartz. Other minerals cement the grains together.

Claystone and mudstone

Claystone and mudstone have tiny grains. They were squashed together by the weight of the layers above them.

It is easy to mould wet clay into different shapes. Bricks and pottery are moulded from wet clay. They are then fired to make them hard.

Limestone

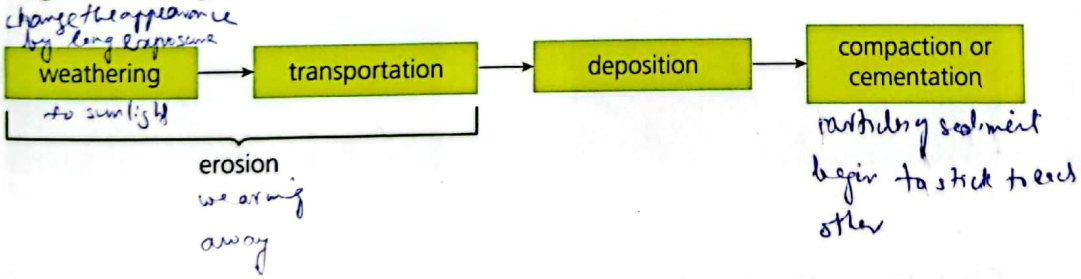
Limestone is a useful building material. It was made from the remains of living things. Billions of dead shellfish piled up on the seabed. Their shells and skeletons broke into small pieces. Over millions of years, the sediments stuck together to form limestone. The process is still happening in the sea around the islands of the Bahamas.

Limestone often contains fossils.

Cement is made from limestone.

Making sedimentary rocks – an introduction

It takes millions of year to make sedimentary rocks. The process happens in stages. The diagram below summarises these stages.



Q

1. Name three sedimentary rocks. Sandstone, claystone, mudstone
2. Explain why claystone is used to make bricks, and why sandstone is used to make buildings. have tiny grains, easy to mould wet clay into different shapes; hard & long lasting
3. Sundara has a rock. Suggest how she could find out if the rock is a sedimentary one.
4. Describe two properties of sedimentary rocks. Explain why sedimentary rocks have one of these properties.

!

- Use a hand lens and water to identify sedimentary rocks.
- Sandstone, claystone, mudstone, and limestone are sedimentary rocks.
- Rock uses are linked to their properties.

4.4 Sedimentary rock formation

Objectives

- Explain how rocks are weathered
- Explain how sediments form rocks

Weathering

Weathering breaks up all types of rock into smaller pieces, called **sediments**. Sediments can be huge boulders or tiny pieces of clay. The sediments may end up in new sedimentary rocks, or they may end up as part of the soil.

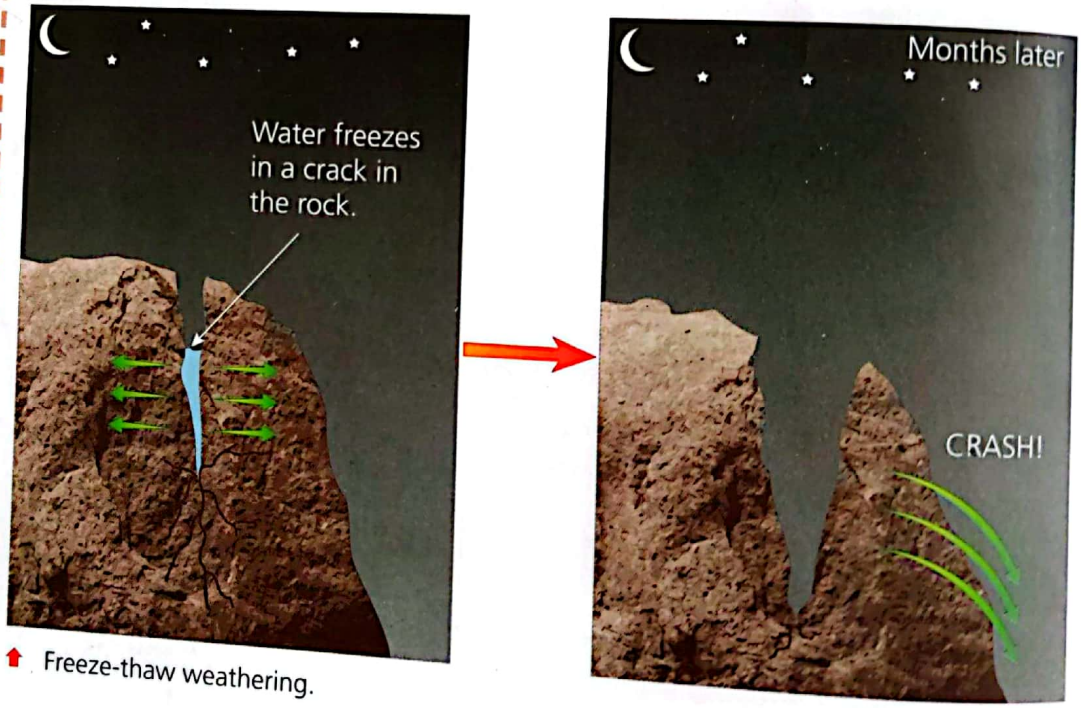
There are three types of weathering: physical, chemical, and biological.

Physical weathering

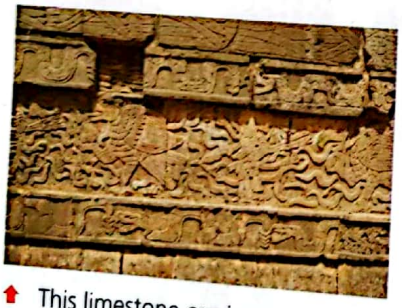
Physical weathering is caused by the effects of changing temperature on rocks. It makes rocks break apart.

One type of physical weathering is freeze-thaw weathering. It happens when water gets into rock cracks:

- On cold nights, water freezes to form ice.
- As the water freezes, it expands.
- The ice pushes against the sides of the crack. The crack gets bigger.
- This happens again and again. The rock breaks.



Freeze-thaw weathering.



This limestone carving was made about 1000 years ago at El Tajin, Mexico. Acid rain is breaking up its surface by chemical weathering.

Chemical weathering

When rainwater falls on some rocks minerals, new substances are formed. This is **chemical weathering**. Chemical weathering happens more in acidic rain.

Biological weathering

Plants and animals break up rocks in many ways. For example:

- Tree roots grow through rock cracks to find water. As the tree grows, its roots gradually break the rock.
- Lichens make chemicals which break down rocks so that the lichens can get the nutrients they need.

Tree roots break up rocks as they grow.

Transportation

Weathering breaks up rock into smaller sediments. These sediments are moved away from their original rock by **transportation**.

Transportation can happen by gravity, or by wind, water, or ice.

Water carries pebbles along the river bed.

The wind carries sand grains from place to place.

Gravity moves sediments in rock falls and landslides.

The processes of weathering and transportation together make up **erosion**. Erosion is different from weathering:

- Weathering is the breakdown of rock into sediments.
- In erosion, a rock is broken into sediments, *and* the sediments are moved away.

New rocks are formed!

Eventually sediments stop moving away from their original rock. They settle in layers. This is **deposition**.

Then the sediments form new rocks. This happens by one of two processes:

- In **compaction** the weight of the layers above squash the sediments together tightly. The sediments are the grains of the new rock.
- In **cementation** new minerals stick the sediments together.

Sediments were laid down in layers to form this sedimentary rock.

Q

1 Describe two ways that a grain of rock could be transported from one place to another. gravity, wind, water / ice.

2 Explain what is meant by *weathering*.

3 **Extension:** Describe three ways in which weathering occurs.

Phy, Chem, Biology

!

- Weathering breaks up all types of rock to make sediments.
- Sediments can be transported by gravity, wind, water, or ice.
- New rocks are formed when sediments settle and are squashed together, or stuck together by new minerals.

4.5 Metamorphic rocks

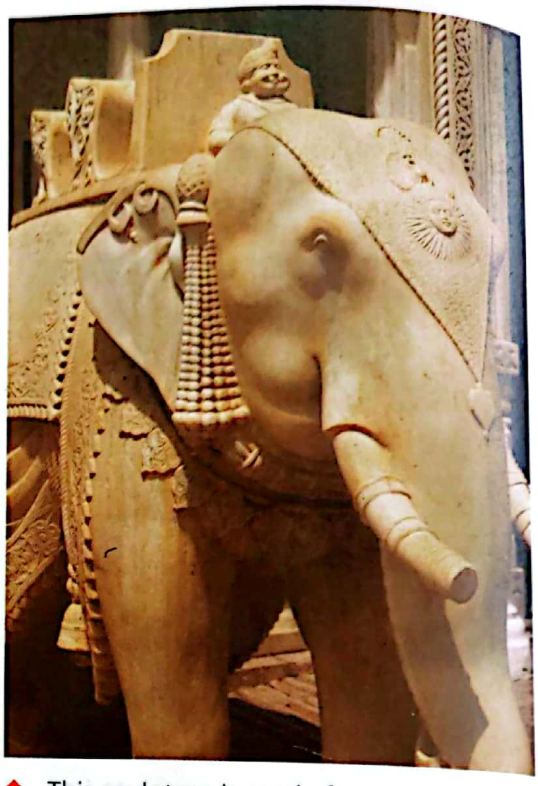
Objectives

- Explain how metamorphic rocks are made
- Identify metamorphic rocks
- Give examples of metamorphic rocks

The same but different

Skilled craftspeople carved these beautiful sculptures from natural rock. The rocks of the two sculptures look and feel very different.

This sculpture is made from limestone.



This sculpture is made from marble.

Both types of rock are mainly one mineral – calcite. The table shows the properties of the two rocks.

Rock	Colour	Texture
Limestone	White, grey, or cream.	Surface often rough. Tiny rounded grains. Gaps between the grains. Fossils often visible.
Marble	Usually white. Often has whirling streaks or spots of brown, red, blue, or yellow.	Surface usually smooth. Interlocking, evenly sized crystals. No gaps. No fossils.

Hot magma makes surrounding rocks change.

Marble from limestone

Conditions are hostile beneath your feet. Just 15 km below the Earth's surface the temperature is 400 °C. The pressure at that depth is 4000 times greater than the surface pressure.

In some places, hot magma comes close to the surface. It heats up the rocks around it. The heat makes rocks change.

When limestone gets hot, its atoms arrange themselves in a new pattern. This makes big crystals which interlock tightly. A new rock has been made – its name is marble.

Both marble and limestone consist mainly of one mineral – calcite. White marble is pure calcite. Coloured marble has tiny amounts of other minerals mixed with the calcite.

Metamorphic rocks

Marble is a **metamorphic rock**. Metamorphic rocks form when heat, or high pressure, or both, change igneous or sedimentary rocks. The rocks remain solid during the process. They do not get hot enough to melt. The changes happen in the Earth's crust.

All igneous and sedimentary rocks can be changed into metamorphic rocks. So there are many different metamorphic rocks.

Recognising metamorphic rocks

Metamorphic rocks are made up of crystals. This means that:

- metamorphic rocks are not porous
- you cannot see separate grains when you look at the rock through a hand lens.

Metamorphic rocks often look squashed or stripy. Some types are made up of thin layers.

More examples of metamorphic rocks

Slate splits into smooth flat sheets. This means it makes good roofing tiles.

Slate is made up of layers.

This fossil formed in mudstone. Its shape changed when high pressures converted the mudstone into slate.

Slate was formed from mudstone. Mudstone is a sedimentary rock. It is a mixture of minerals. High pressures underground squash mudstone. Water is squeezed out. New crystals form and arrange themselves in layers. If the mudstone contains fossils, so will the slate, but they will be squashed out of shape.

Gneiss is another metamorphic rock. It is hard, and often stripy. It is made up of big, interlocking crystals. It was formed at high temperatures and pressures deep within the Earth's crust.

A piece of gneiss.

Q

1. Name three metamorphic rocks.
2. Explain how metamorphic rocks are formed.
3. Explain why metamorphic rocks are not porous.
4. Raj has a piece of rock. Suggest how he could find out whether it is sedimentary or metamorphic.

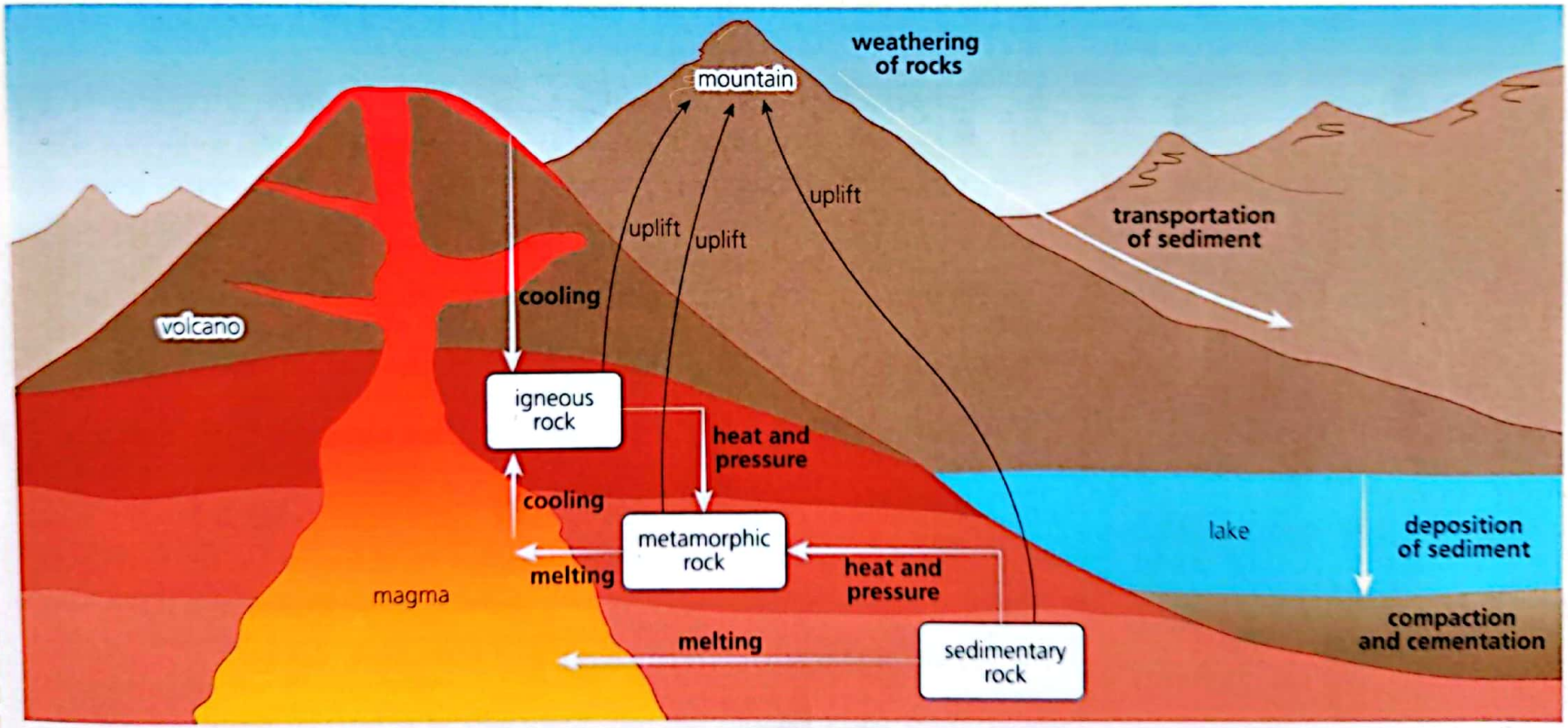
- Metamorphic rocks form when rocks are changed by high temperatures or pressures.
- Metamorphic rocks have interlocking crystals.
- Marble, slate, and gneiss are metamorphic rocks.

The rock cycle

Erosion wears down mountains. The sediments make sedimentary rocks. Under the Earth's surface, high temperatures and pressures may turn sedimentary or igneous rocks into metamorphic rocks.

Some rocks sink deep under the surface. They get hot enough to melt and make magma. The magma is pushed upwards. Some of the magma cools and solidifies underground. Some magma comes out of volcanoes, and solidifies on the surface. Igneous rocks are made.

At any time, huge forces from inside the Earth may push rocks upwards to make mountains. This is called **uplift**. This means that any type of rock – sedimentary, igneous, or metamorphic – may end up on a mountain top.



The rock cycle.

Review 4.13

1 Complete these sentences using words from the list. You may use each word once, more than once, or not at all.

igneous **metamorphic** **sedimentary**

Scientists classify rocks in three groups. Rocks that were formed when magma cooled and solidified are igneous rocks. Rocks formed from fragments of rock are sedimt rocks. Rocks formed by the action of heat and pressure on existing rock are metamp rocks. [3]

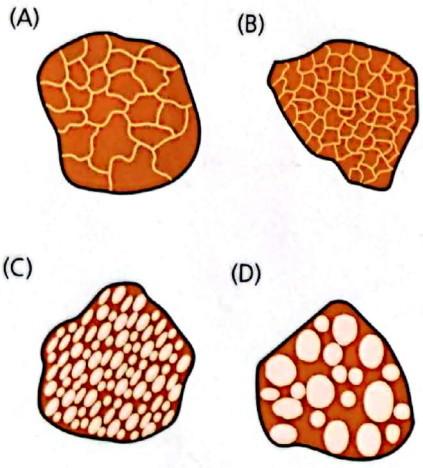
2 Copy and complete the table using the words below.

sandstone **granite** **marble**

Type of rock	Example
igneous	granite
sedimentary	limestone
metamorphic	marble

[3]

3 This question is about the four types of rock shown in the diagrams below.



a Give the letters of two igneous rocks. A, B [1]

b Give the letter of the igneous rock that cooled more slowly. A [1]

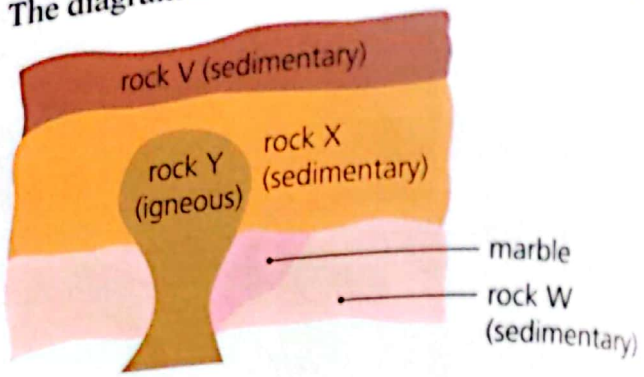
c Give the letters of two porous rocks. C, D [1]

d Give the letters of two rocks that formed when magma cooled and solidified. A, B [1]

e Give the letter of two rocks which could contain fossils. C, D [1]

f Give the letters of two rocks that are made up of crystals. A, B [1]

4 The diagram shows the rocks in the wall of a mine.



a Which rock could contain fossils (V, W, X, or Y)? X [1]

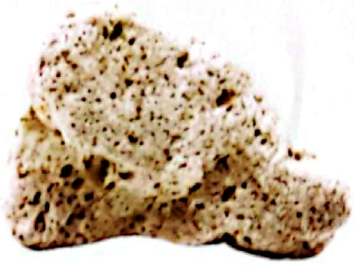
b Which is the youngest sedimentary rock? [1]

c Which is most likely to be limestone? Explain your choice. W [2]

d Suggest how the marble formed. [1]

e Which is most likely to be granite? Explain your choice. Y [2]

5 The photograph shows a piece of pumice.



A student investigated the properties of pumice. He also found out about pumice from secondary sources. He wrote down the notes below.

1 I put it on water and it floated, so it must have a low density.

2 When I pushed the pumice into a beaker of water, bubbles rose to the surface.

3 My text book says pumice is formed from hot lava when it is thrown high into the air by a volcano. The gases that were dissolved in the lava come out of solution, forming the 'bubbles' you can see.

a Give the number of the note which shows that pumice is an igneous rock. [1]

b Use evidence from the notes to describe two ways in which the properties of pumice are not typical of igneous rocks. [2]

c Which note(s) refer to a secondary source? [1]

d **i** Copy the part of the sentence in note 1 which is an observation. [1]

ii Copy the part of the sentence in [illegible] which is an [illegible] [1]

6 Two students investigate some rocks. They write their results in the table below.

Rock	Is it made up of crystals or grains?	Is it porous?	Does the piece of rock contain fossils?
A	grains	yes	no fossils
B	crystals	no	yes, but its shape looks squashed
C	crystals	no	no

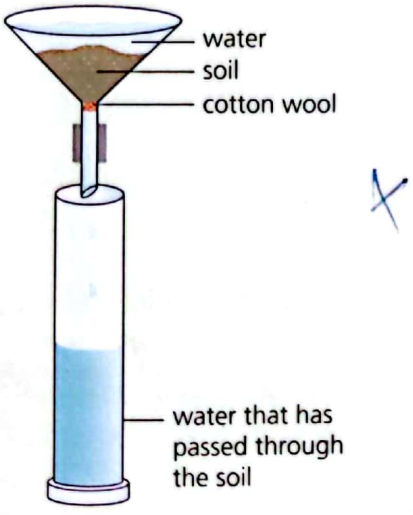
a Name a piece of equipment the student could use to help her decide whether a rock is made up of crystals or grains. [1]

b Which rock is probably a metamorphic rock? [1]

c Which rock might be basalt? [1]

d One of the students, Junaid, says that rock A is a sedimentary rock. The other student, Farooq, says that rock A cannot be a sedimentary rock because it contains no fossils.
Write the name of the student you think is correct. Give a reason for your decision. [2]

7 A student compares the drainage of three soil samples. She uses the apparatus below.



The student writes her results in a table.

Soil sample	Volume of water collected in 1 hour (cm³)
L	15
M	89
N	48

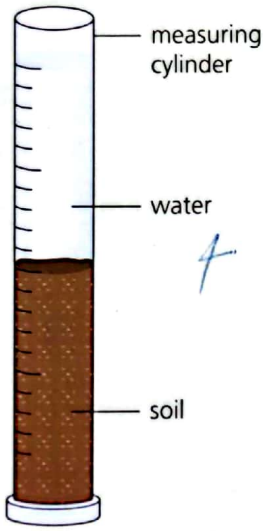
a Give the letter of the soil which drains water most quickly. [1]

b Give the letter of the soil from which nutrients are removed most quickly. [1]

c Give the letter of the soil which remains wet for the longest time after heavy rain. [1]

d Give the letter of the soil which is most likely to be a clay soil. [1]

8 A student wants to compare the amounts of air in soil samples from two fields. She uses the apparatus below.



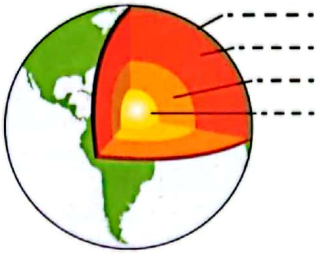
She observes the level of water in the measuring cylinder after shaking the mixture of soil and water. The lower the water level, the greater the volume of air that was in the soil.

a Name the variable that the student changes. [1]

b Name the variable that the student observes. [1]

c Suggest two variables that the student should keep constant. [2]

9 The diagram shows the structure of the Earth.



a Use the words below to label a copy of the diagram.
outer core **crust**
mantle **inner core**

b Copy and complete the table below.

Layer	Solid, liquid, or gas?
crust	
inner core	
mantle	
outer core	

10 The statements below explain how a fossil was formed. They are in the wrong order. Write the letters in the correct order. [4]

a The soft parts of the body slowly break down. Only the bones are left.

b More sand quickly buries the body.

c An animal dies. It falls onto sand at the bottom of a lake.

d Underground water that is rich in minerals seeps into the gaps in the bones. The minerals replace the original minerals of the skeleton.

e The sand above the bones is compressed, and begins to form rock.