Rocks

8

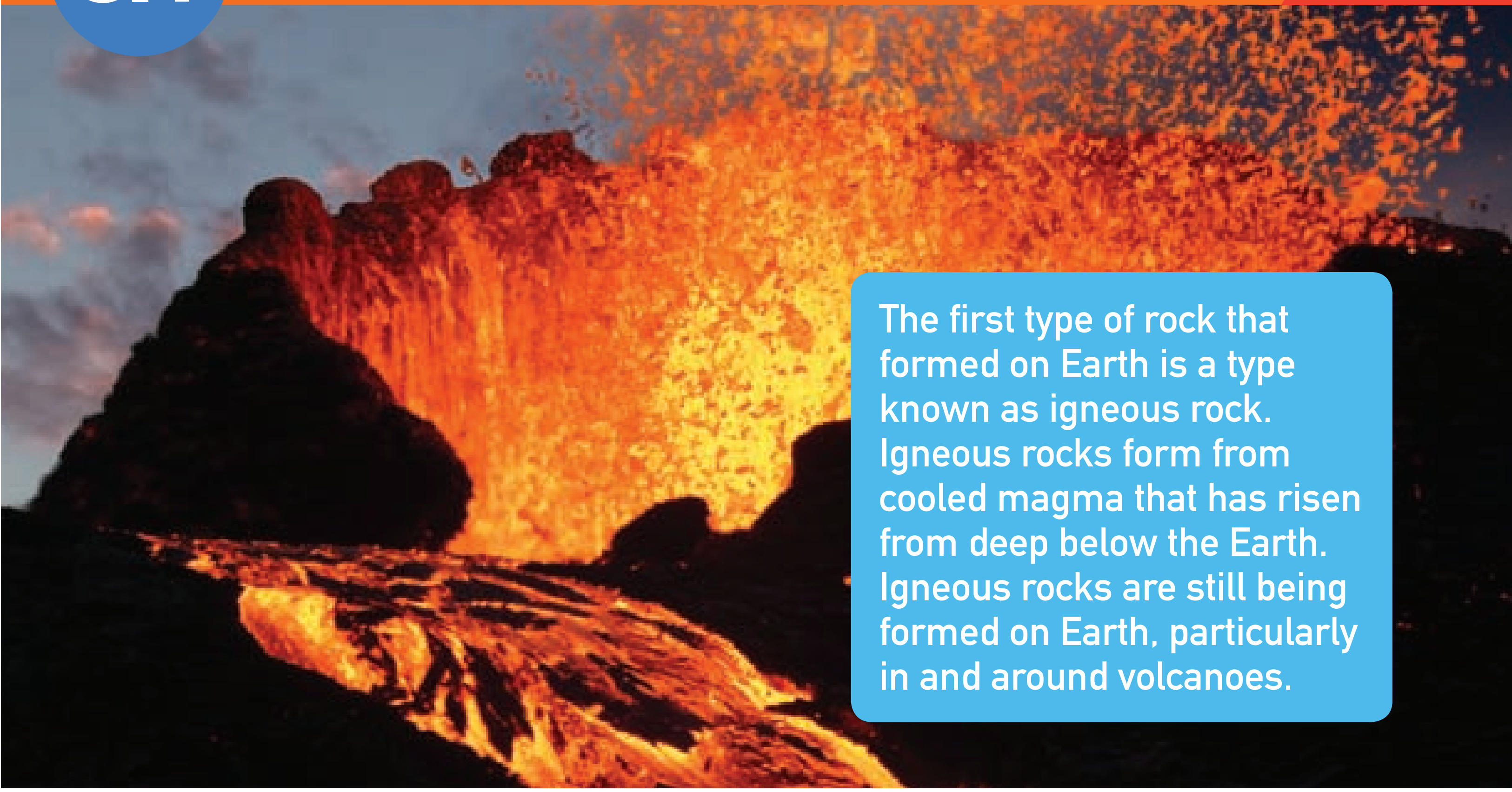
HAVE YOU EVER WONDERED…

- how rocks are made?
- what comes out of volcanoes?
- what is in a rock?
- why some rocks are strange shapes?

After completing this chapter students should be able to:

- outline the stages in the formation of igneous, metamorphic and sedimentary rocks, including indications of timescales involved
- identify a range of common rock types by their observable properties
- recall that rocks are a collection of different minerals
- outline the role of forces and energy in the formation of different types of rocks.

8.1 Igneous rocks



The first type of rock that formed on Earth is a type known as igneous rock. Igneous rocks form from cooled magma that has risen from deep below the Earth. Igneous rocks are still being formed on Earth, particularly in and around volcanoes.

Structure of the Earth

Geology is the study of rocks. Although geologists cannot actually see what is inside the Earth, their research shows that it consists of layers. This structure is shown in Figure 8.1.1.

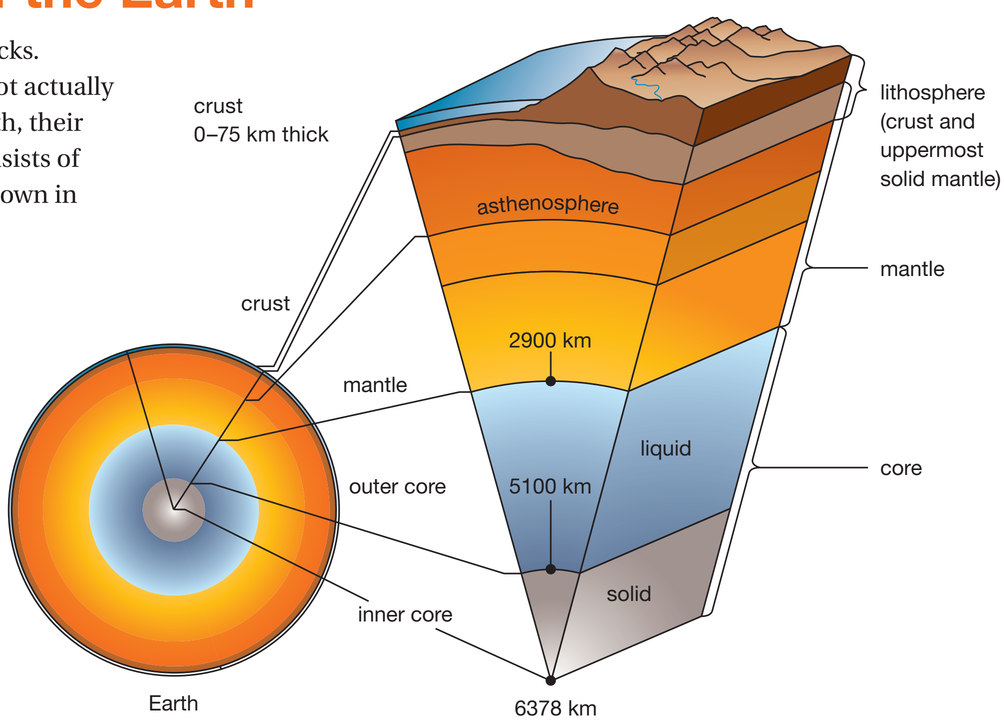


Figure 8.1.1 Every earthquake and earth tremor and every volcano provides geologists with a little more information about the structure of the Earth. They have concluded that the Earth is composed of layers.

The first rocks

The first rocks of the crust and upper **mantle** formed long ago when material called magma cooled and solidified. **Magma** is very hot molten (melted) rock.

Scientists think that magma forms within the lower mantle. Dissolved gases make magma less dense than the surrounding rock and pushes it upwards through any fault or crack in the crust above. On the way, magma melts more rock from the upper mantle and crust. If the magma reaches the surface, it is known as **lava**. Lava has a temperature of about 1200°C when it erupts at the surface of the earth. These eruptions form volcanoes, one type of which is shown in Figure 8.1.2. Below the surface, the magma is even hotter.

Igneous rocks

Magma rising into the crust begins to cool because it loses heat to the cooler rocks around it. If magma reaches the surface to become lava, then it cools very rapidly, especially if the eruption happens under the ocean. Magma that does not reach the surface cools much more slowly. Rock is formed when the magma or lava cools so much that it solidifies. Some rocks form at the surface or under the ocean, and some form below ground.

Rocks formed from cooling magma are known as **igneous rocks**. Igneous rocks were the first types of rocks to form and were the start of the Earth's crust. Rocks formed by magma reaching the surface are classified as **extrusive igneous rocks** as shown in Figure 8.1.3. Those rocks formed from magma cooling below the ground surface are classified as **intrusive igneous rocks**.

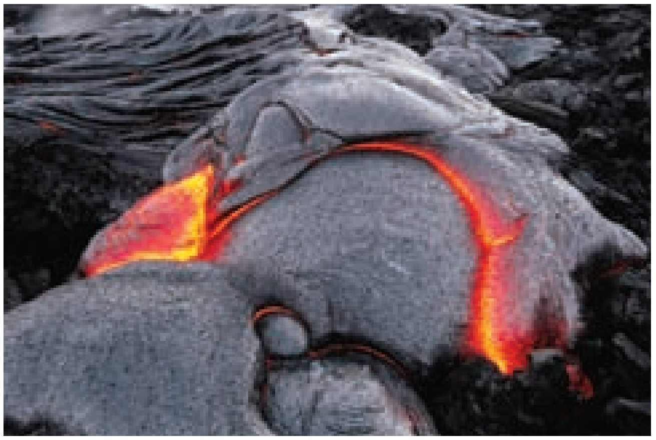


Figure 8.1.3 Lava cools to form extrusive igneous rocks.

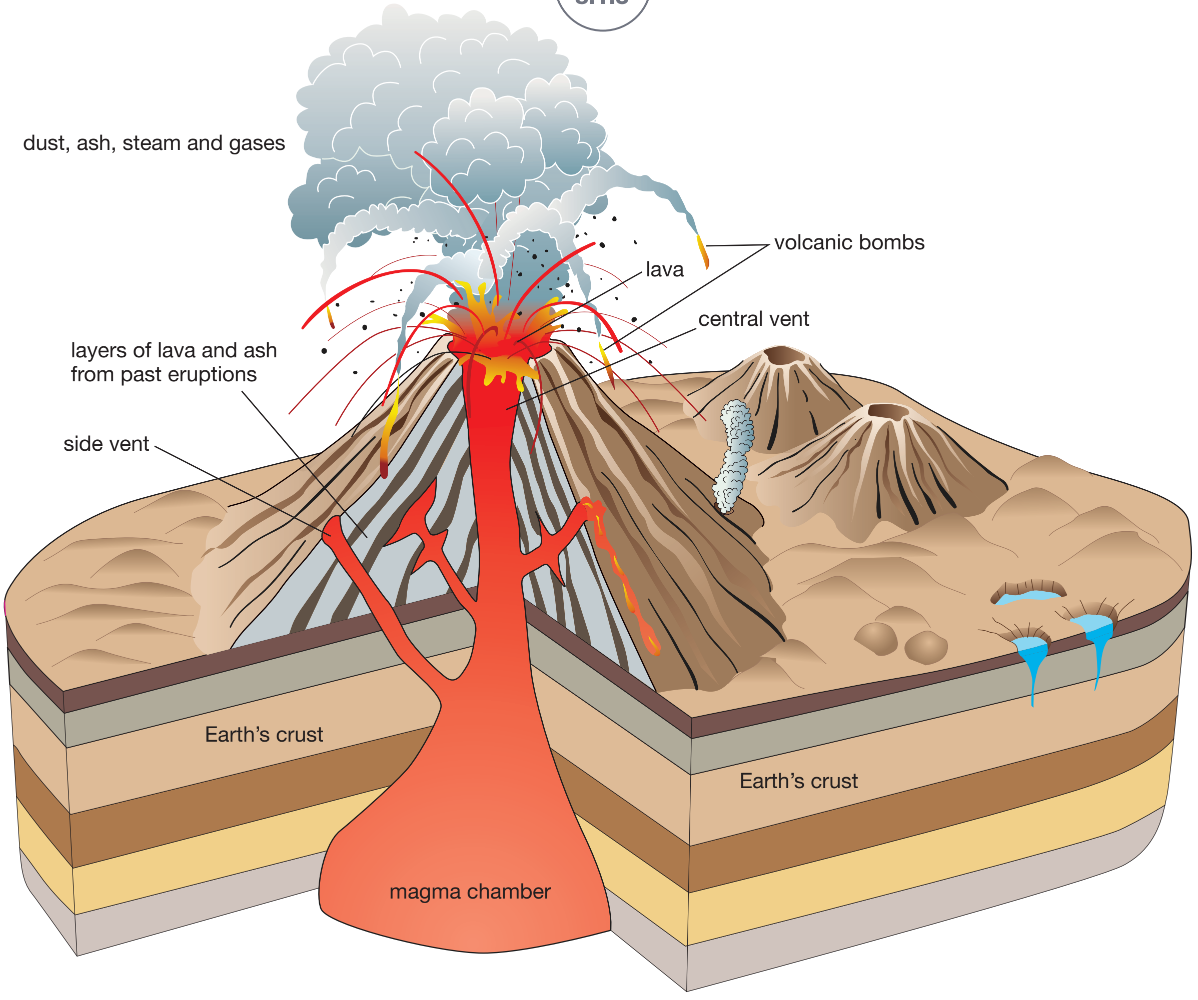


Figure 8.1.2 Structure of a volcano

Crystals

When magma is solidifying, particles in the liquid may clump together to form structures called crystals. **Crystals** are solids that have a variety of special shapes. You can see some in Figure 8.1.4.

Figure 8.1.4 Crystals form in igneous rock. The slower the cooling on formation, the larger the crystals formed.

When magma cools quickly, it forms rock with very small crystals or no crystals at all. This is because rapid cooling does not give crystals enough time to grow.

Slow-cooling magma produces larger crystals because the crystals keep growing for longer. While the magma remains liquid, the particles can move around and keep adding to a nearby growing crystal. Rock formed by slow cooling usually has crystals large enough to see without using a magnifying glass.

Minerals

Rocks are made up of chemical substances called **minerals**. Minerals are particular combinations and arrangements of atoms that can be identified by their physical properties. Two physical properties of minerals are the size and shape of the crystals that form them.

Characteristics of igneous rocks

Not all rocks are igneous. The other rock types are sedimentary and metamorphic. The following general characteristics will help you identify which rocks are igneous. Igneous rocks are:

- hard, because the minerals they contain are hard
- strong, because the mineral crystals that make them up are strong
- made of interlocking crystals that have grown into each other and lock together.

INQUIRY science 4 fun

Comparing crystals

No

Are all crystals the same?

Collect this …

- super-saturated solutions of magnesium sulfate, sodium chloride, aluminium potassium sulfate and copper sulfate
- 4 test-tubes in a test-tube rack
- 4 eye-droppers or Pasteur pipettes
- petri dish
- stereomicroscope or monocular microscope (40×)
- 4 glass slides
- methylated spirits from your teacher
- access to marking pen

Do this …

1. Label each test-tube and glass slide with the name of one of the solutions using the marking pen.
2. Put a drop of each solution on its labelled slide and observe it under the microscope. Look first at the edge of the drop of solution.
3. If the crystals are slow to form, ask your teacher to add a drop of methylated spirits. Try it both with and without methylated spirits.

Record this …

Describe what happened.

Explain why you think this happened.

1 p287

Interlocking crystals are crystals that have grown into each other. Sometimes this is very difficult to see unless you use a microscope. You can see what interlocking crystals look like in Figure 8.1.5.

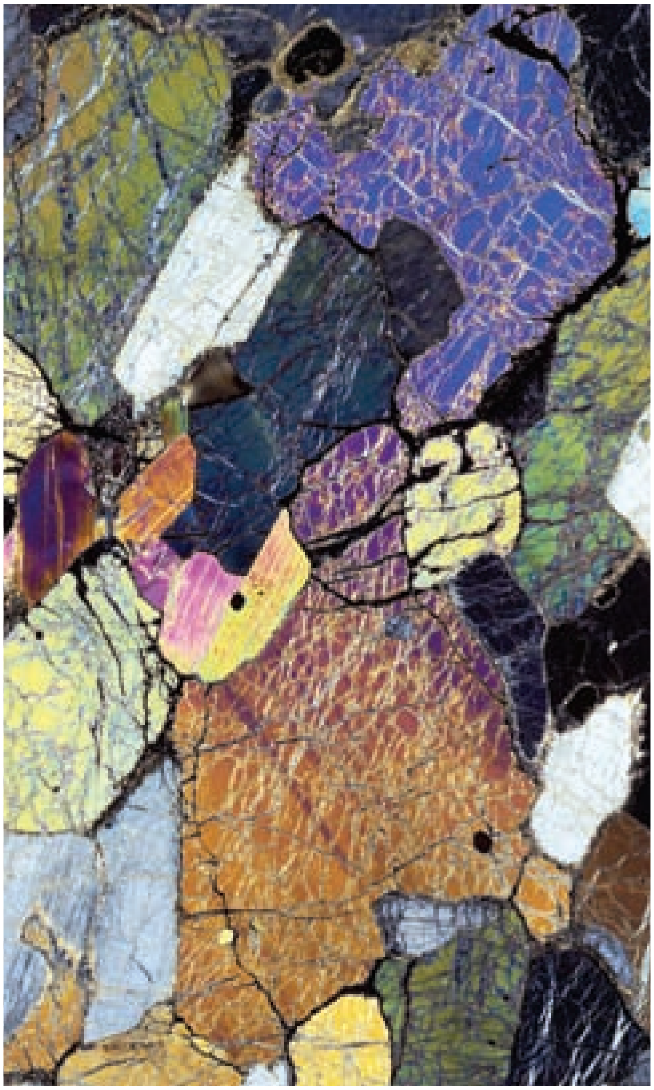


Figure 8.1.5 A jigsaw-like pattern of interlocking crystals indicates that the rock is an igneous rock. These are interlocking crystals of the igneous rock peridotite.

A sea of lava

SciFile

The Deccan Traps in India is an area about half the size of India, consisting of layers of basalt more than 2 km thick. It was formed by massive volcanic eruptions about 66 million years ago that lasted about 30 000 years.

Classifying igneous rocks

Many igneous rocks were formed millions of years ago. Since they formed, many underground intrusive rocks have been exposed at the surface, and many above-ground extrusive rocks have been buried. Therefore the current position of an igneous rock is not enough to classify it as intrusive or extrusive. To do this, geologists need to look at the texture and colour of the rock.

Texture describes whether the rock is smooth or has obvious grains, lumps, air bubbles or interlocking crystals in it.

Colour is linked to the minerals the rock contains. Dark-coloured rocks usually have a high content of heavy minerals such as olivine, a green mineral. Olivine contains heavier elements such as iron. Light-coloured rocks contain high levels of silica-like minerals. These have lighter elements, such as silicon, oxygen and aluminium. Typical minerals are quartz and the feldspars. Figure 8.1.6 shows examples of igneous rocks.

Figure 8.1.6 Colour is a characteristic that can be used to classify igneous rocks.

Extrusive igneous rocks

Extrusive igneous rocks have very small crystals in them. The rapid cooling of these rocks makes the minerals solidify very fast, so large crystals don't have a chance to grow. The crystals may be hard to see with eyes alone, but usually can be seen very clearly with a microscope. The rock may have to be sliced into thin sections to be able to see the crystals. Figure 8.1.7 shows a view through a microscope of the crystals in an extrusive igneous rock.

Figure 8.1.7 A microscopic view of an extrusive igneous rock

Basalt is an example of an extrusive rock with small, visible crystals, while obsidian is an example of an extrusive rock with no crystals. Obsidian is like glass, and is often called volcanic glass. It cools too fast for any crystals to form. You can see the glassy texture of obsidian in Figure 8.1.8.

Figure 8.1.8 Obsidian is an extrusive igneous rock that is characterised by its lack of crystals.

Many extrusive rocks contain a large number of spaces in them. These are caused by gas bubbles, trapped when the magma cooled very quickly. This gives them a rough bubbly texture. An example is pumice, a light grey igneous rock. It is so light that it floats in water. It has obvious holes and is not very hard.

Scoria is another type of rock that explodes out of volcanoes, and it also has many holes. Scoria has no obvious crystals, is a dark colour, and is much more dense than pumice. It sinks if placed in water. You can see samples of pumice and scoria in Figure 8.1.9.

Figure 8.1.9 Pumice and scoria are extrusive igneous rocks exploded out as volcanic bombs. These rocks are full of holes caused by gas bubbles.

Intrusive igneous rocks

Intrusive igneous rocks contain large crystals, which can usually be seen without a microscope. These crystals are the result of slowly cooling magma. The crystals also interlock with each other. Two examples of intrusive igneous rocks are granite and dolerite. It is easy to see the crystals in the granite shown in Figure 8.1.6 on page 281. It is composed of three main minerals: quartz, feldspar and biotite. Figure 8.1.10 shows these three minerals as clumps of pure crystals.

Figure 8.1.10 The three main minerals in granite are quartz, feldspar and biotite.

The sparking rock

When quartz is squeezed, it gives out a burst of electricity, which can form a spark to light your gas barbecue. This property of quartz is called piezo electricity, and the igniters are called piezo igniters.

SciFile

2 p288

8.1

Uses of igneous rocks

Most igneous rocks are very hard and strong. They are very good for buildings and other stone structures that need to be strong and last a long time. Some common uses for igneous rocks are listed in Table 8.1.1. Two uses are shown in Figure 8.1.11.

Table 8.1.1 Uses of igneous rocks

Igneous rock	Use
Basalt	Buildings (for example Melbourne bluestone), concrete (as crushed rock), floor tiles
Dolerite	Road surfaces (where it is called 'blue metal'), concrete (as crushed rock)
Granite	Buildings, monuments, road surfaces, kitchen benchtops
Scoria	Landscaping, filters and concrete (all as crushed rock), barbecue rocks
Pumice	Cleaning dead skin off feet, emery boards for shaping nails, some soaps that feel rough on your skin
Obsidian	Scalpel blade for surgery in hospitals, ornaments and jewellery. Ancient people used it for cutting, spear and arrow points, and pots and vases

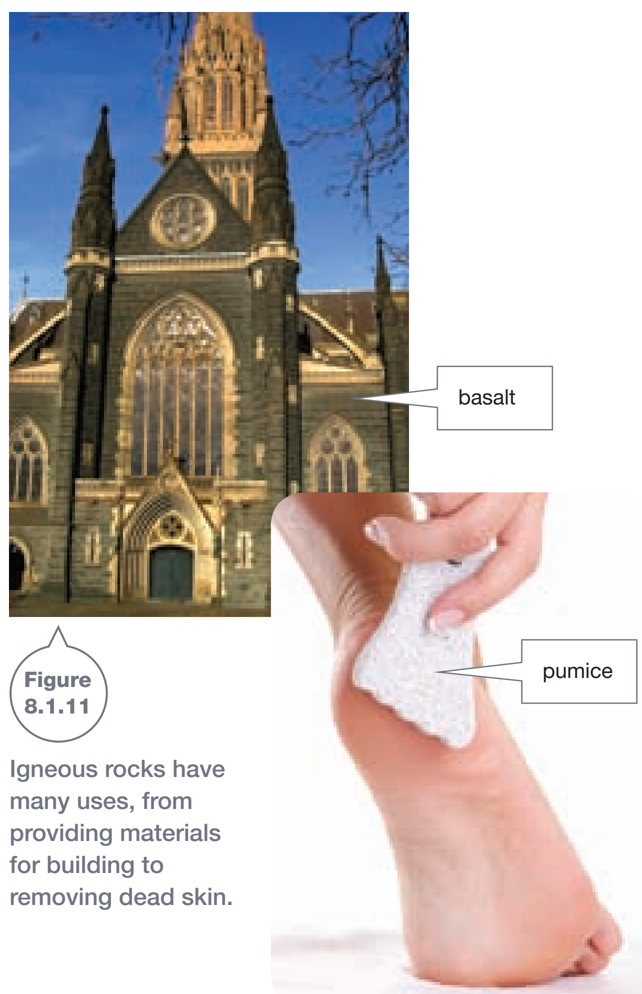


Figure 8.1.11 Igneous rocks have many uses, from providing materials for building to removing dead skin.

SCIENCE AS A

HUMAN ENDEAVOUR

Use and influence of science

All four engines have failed!

Figure 8.1.12 Volcanic dust first caused BA009 to glow in an effect called St Elmo's fire. It then caused all four engines to stop.

'Ladies and gentlemen, this is your captain speaking. We have a small problem. All four engines have stopped. We are doing our best to get them going again. I trust you are not in too much distress.' These are the words of Captain Eric Moody, British Airways Flight 009, 24 June 1982.

This announcement marked one of the first encounters with volcanic ash by a commercial airliner. On the night of 24 June 1982, a British Airways Boeing 747 was flying from Kuala Lumpur (Malaysia) to Perth. It flew through an ash cloud from Indonesia's Mount Galunggung volcano.

All four engines failed and the plane began a slow steady fall from the sky. For the next 14 minutes the crew tried to re-start the engines. They succeeded at last, but only after the plane had fallen 7000 metres to only 4000 metres above the Indian Ocean. The aircraft then made an emergency landing at Jakarta, Indonesia.

Later examination showed that the aircraft engines had stalled because of the volcanic ash. The engines only re-started once the aircraft had descended out of the volcanic ash cloud and into clear air.

Volcanic ash clouds consist of fine particles of rock, mainly silica. These rock particles are like tiny glass beads. There are also corrosive gases in the ash clouds that react to form droplets of sulfuric acid and other substances. When this ash melted in the hot section of the engine, it formed a glassy coating. This caused loss of thrust and engine failure. The ash particles also wore away engine parts, the body and the windscreen, and clogged fuel and cooling systems.

All countries responded to the incident. Their solution was to gather meteorological observations from various sources on the ground and the air in many countries along the flight routes. They then identify the ash clouds and forecast their height, movement and dispersion (spread). The information is then sent to guide aircraft clear of any threat.

8.2

SciFile

Chaos in the air!

In April 2010, Mt Eyjafjallajökull in Iceland began a series of eruptions that threw huge clouds of volcanic ash into the air. Winds then pushed the ash across Great Britain and Europe. As the winds shifted direction, so did the ash cloud, covering different countries as it did so. As a safety precaution, all aircraft in those countries were grounded (not allowed to fly). The disruption lasted a month.

8.1 Unit review

Remembering

1 **Name** the outer layer of the Earth.

2 **Name** the hot molten rock that:
- a pours out of volcanoes
- b has not reached the surface.

3 **Name** two igneous rocks that are:
- a extrusive
- b intrusive.

4 **List** the three minerals in granite.

5 **List** the main characteristics of igneous rocks.

Understanding

6 **Define** the following terms.
- a geology
- b igneous rock
- c extrusive igneous rock
- d lithosphere

7 **Explain** how and why crystal size is affected by how fast rocks cool.

8 Pumice can be formed by lava cooling in water. **Explain** why igneous rocks such as this do not have any visible crystals.

9 **Explain** why dark-coloured igneous rocks tend to be heavier than light-coloured ones.

Applying

10 A geologist removed some rock from the edge of an old lava flow. No crystals could be seen when the rock was studied under a microscope. The rock was a dark colour and it was hard, but very brittle. It was easily broken into pieces by hitting it, and broke into very sharp, thin strips, which were very lustrous (shiny). **Apply** your knowledge of rock types and formation to:
- a **identify** the type of igneous rock it is
- b **explain** why no crystals could be found even though the rock was obviously igneous.

Analysing

11 **Compare** interlocking crystals with the pieces of a jigsaw puzzle.

12 **Contrast** the mineral composition of dark- and light-coloured igneous rocks.

13 a **Contrast** the uses of granite and scoria.
- b **Explain** why each rock suits that use.

14 **Compare** the ways in which intrusive and extrusive igneous rocks form by listing their similarities and differences.

15 **Contrast** the appearance of igneous rocks that are extrusive and those that are intrusive.

16 Copy the following table into your workbook.

	Small crystals	Large crystals	Holes	'Glassy'
Light colour				
Dark colour				

- a **Identify** where each of the following rocks should be placed in the table: basalt, granite, pumice, obsidian, scoria.
- b Rhyolite is an extrusive igneous rock that is chemically very like granite but has very small crystals. **Analyse** the data and decide where you would place rhyolite in the table.
- c Gabbro is an intrusive igneous rock that is chemically like basalt. **Analyse** this information and decide where you would place gabbro in the table.

Evaluating

17 **Evaluate** the following two statements. Are they correct, incorrect or a bit of both? **Justify** your answers.
- a All magma is lava.
- b All lava was once magma.

18 Dolerite is an igneous rock formed below the Earth's surface. It is similar to basalt in its chemical composition, containing relatively little silica.
- a **Assess** whether dolerite is likely to have smaller or larger crystals than basalt.
- b **Justify** your decision.

19 Porphyry is an igneous rock that has a mixture of crystal sizes. It has large crystals set in a rock consisting of mainly fine grains, often too small to see. You can see an example in Figure 8.1.13. It has been suggested by geologists that porphyry forms in two stages. **Use** your knowledge of crystallisation and cooling rates to **propose** an explanation for how this type of rock most likely forms.

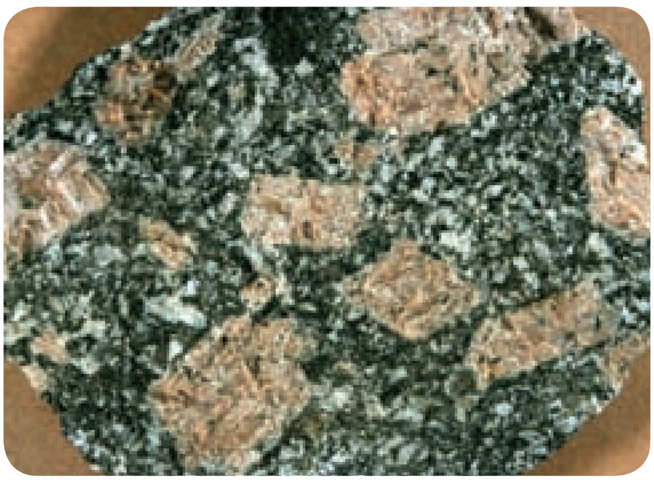


Figure 8.1.13 Porphyry

20 In the Science4Fun activity on page 280, it was suggested that you look at the edge of the solution for crystals and not in its centre. **Propose** a reason why.

21 Refer to page 284 and **propose** reasons why the following happened.
- a i Before the engines failed, the pilots of BA009 observed a glow known as St Elmo's fire around their aircraft.
  - ii The windscreen of BA009 was so badly scratched that the pilots needed to look out of their side windows to land the aircraft.
- b i All aircraft were grounded in parts of Europe after the eruption of Mt Eyjafjallajökull.
  - ii Although the disruption lasted a month, different countries were affected at different times.
  - iii All aircraft in Iceland were still flying while Mt Eyjafjallajökull was erupting.

Creating

22 a **Construct** a diagram of an erupting volcano on the edge of the sea, showing at least three different places where extrusive and intrusive igneous rocks may form.
- b In your diagram, **construct** magnified views showing what the different rocks may look like. Add short notes next to each magnified view explaining what these views show.

Inquiring

1 Search around your home and find two rocks or objects made from rocks you suspect are igneous. Write a brief description of each rock and list the features that you used to decide it was igneous. After checking with your parents, bring the rock to school if possible and ask if you can observe it with a hand lens or stereomicroscope. Classify the rock as best you can into the categories shown in the table in Question 16, and identify an igneous rock that is most like yours.

2 Research the importance and uses of quartz. Explain how the use of the mineral is due to its properties.

3 The Earth has a magnetic field around it, which can be detected by a compass. Research how ancient people could use the iron mineral called magnetite to navigate at sea.

4 Research the use of obsidian in scalpel blades and explain why it is used rather than steel.

8.1 Practical activities

1 Cooling and crystal size

Purpose

To investigate how cooling rate affects the size of crystals.

Materials

- rubber gloves
- oven mitt or towel
- 3 × 50 mL test-tubes and test-tube rack
- 4 × 250 mL beakers
- ice
- cotton wool
- hotplate or Bunsen burner, tripod, bench mat, gauze mat
- stirring rod
- filter funnel
- a sample of about 25 g of potash alum

SAFETY

Wash your skin with soap and water immediately if you come into contact with potassium aluminium sulfate solution.

Call your teacher immediately if it contacts your face or eyes.

Be careful at all times with boiling water.

Procedure

1 Put about 100 mL of water into a 250 mL beaker and heat it until it is boiling. Turn the hotplate or Bunsen burner off once the water boils.

2 While waiting for your water to boil, make an ice bath by half-filling another of the beakers with ice water.

3 Insulate another beaker with enough cotton wool to allow a test-tube to sit upright in the middle.

4 Wearing rubber gloves, carefully lift the beaker of hot water off the gauze mat and tripod and place it on the benchtop. Dissolve all the potash alum in the hot water. It all should dissolve if you stir it well with the stirring rod.

5 Place the three test-tubes in a test-tube rack. Put a filter funnel in one of the test-tubes. Hold the beaker of hot solution with an oven mit or towel so it will not burn you. Carefully pour about 25 mL of the saturated solution into the filter funnel. The test-tube should be about half full. Repeat this process for the other two test-tubes. Place a plug of cotton wool in the mouth of each test-tube.

6 Place one test-tube in the cotton wool, one in the ice water, and one in an empty beaker as shown in Figure 8.1.14.

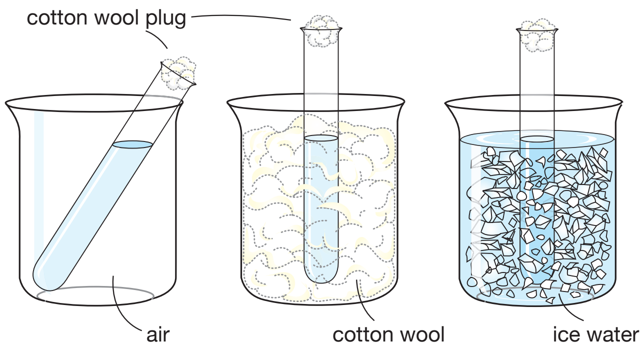


Figure 8.1.14

7 Leave the beakers in a safe place such as a cupboard for at least a day.

Results

Observe the contents of the test-tubes in the next lesson. Record your observations.

Discussion

1 **State** which test-tube had the biggest crystals and which had the smallest crystals.

2 **State** which test-tube cooled the fastest and which cooled the slowest.

3 **Use** the results of this experiment to **explain** the difference between crystal sizes in extrusive and intrusive igneous rocks.

8.1 Practical activities

2 Comparing igneous rocks

Purpose

To compare the characteristics of different igneous rocks.

Materials

- various igneous rock samples: pumice or scoria, basalt, obsidian, granite, dolerite, gabbro, porphyry
- access to stereomicroscope, hand lens or magnifying glass
- margarine lid or white tile
- blunt probe or mounted needle
- smashed up granite rock grains
- graph paper

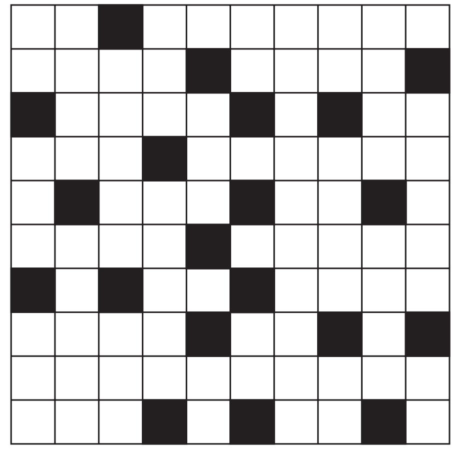


Figure 8.1.15

Procedure

1 Use your microscope or hand lens to study the smashed-up granite rock sample. Describe the three main different minerals that are present. Use colour, crystal shape and hardness in your description.

2 Place each of the intact rock samples on a margarine lid or white tile, and record your observations in a table like the one below. Record the:
   - a main colour of the rock
   - b colour and size of its crystals (if visible). For size of crystals, try to estimate the length in millimetres. Do this for each of the different types of crystal that you can see.
   - c percentage of dark minerals. Do this by comparing your rock with a piece of graph paper on which you have coloured some squares black. Use a piece of graph paper 10 squares by 10 squares. If you colour in 20 of the squares, this will show you what 20% looks like, as in Figure 8.1.15. Create another piece for 30%, and so on. Compare these pieces of graph paper with the rock to estimate the percentage of the rock that is dark.

3 Use the crystal size as a guide to classify the rock as intrusive or extrusive. For other features, add anything else you notice about the rock, such as its weight, texture and lustre.

Results

Copy the table below into your notes. Draw as many rows in as you have rock samples.

Discussion

1 **Specify** which rocks were mainly dark coloured.

2 **Specify** which rocks had clearly visible crystals.

3 **Compare** the crystal size and the rock colours for your different samples. Was there any relationship between these? For example, did all dark rocks have large crystal sizes?

4 **Account** for the low density of any of these rocks.

Rock name	Main colour of rock	Colour and size of crystals	Percentage of dark minerals	Extrusive or intrusive	Other features
Granite					
Basalt					