Mary Anning – fossil hunter

Mary Anning had the thrill of discovering a fossil of a complete ichthyosaurus when she was only 11 years old.

Mary has been described as the greatest fossil collector ever.

She did manage to scrape a meagre living for her family with the support of a small grant from the government.

Mary was made an honorary member of the Geological Society of London before she died (a great honour indeed for a woman in Victorian times!).

The actual fossil is now in the Natural History Museum in London

The story of Alfred Wegener

The idea that continents are moving around on the surface of the Earth is difficult to believe.

It was in 1915 when Alfred Wegener first suggested his theory of continental drift. Few of his fellow scientists took his ideas seriously. It took about 50 years for them to come around to his way of thinking. Unfortunately, Alfred had died many years before that happened.

One day, Alfred was studying a scientific paper on fossils. He noticed how similar the fossils found in Africa and South America were. This made him curious. Looking at an atlas of the world, people had already spotted that the coastlines of Africa and South America looked like two pieces in a jigsaw. But Alfred went further and suggested that at one time, millions of years ago, they had been joined together. He suggested they had slowly drifted apart.
He could offer scientific evidence to support his idea. He noticed matches between the types of rock found in Africa and South America. There were also matching rocks across other continents. This led him to think that millions of years ago all the continents had been joined together. He called this ‘super-continent’ Pangaea.

However, scientists already had a theory that could explain the similar fossils on different continents. They believed that in the past bridges of land linked the continents to each other. But, they argued, the bridges must have sunk below the oceans by now. And Alfred couldn't explain how the continents had moved. So his ideas were never accepted in his lifetime.

Over 20 years after his death, scientists discovered direct evidence of Alfred’s drifting continents. Exploring the ocean floor, they found new rock forming on either side of massive cracks that run between continents. Then the old ‘land bridge’ theory was dropped. A new theory, called plate tectonics, which could explain Alfred’s ideas, became accepted by the scientific community.

In this chapter you will find out about the different types of rocks and soils. You will also discover what scientists know about the internal structure of the Earth, and how fossils and the fossil record can be used to estimate the age of the Earth.

**Key points**

- We can characterise rocks by properties such as their texture (arrangement of grains) and porosity (ability to absorb water).
- **Sedimentary rocks** are formed when layers of sediment are buried under more recent deposits. Under the pressure, and with the help of mineral ‘cements’ between the particles of sediment, rocks are formed.
- **Metamorphic rocks** are formed when existing rock experiences high pressure and/or temperature (without melting). Bands of minerals are often visible if the metamorphic rock is formed under pressure.
- **Igneous rocks** are formed when molten rock solidifies. Slow cooling, inside the Earth’s crust, produces rock with large crystals. Faster cooling, at or near the Earth’s surface, produces rock with small crystals.
- The Earth consists of a thin crust on top of a largely solid layer of rock called the mantle. Below that we get the Earth’s core, made up of nickel and iron.
- Fossils and rocks give us evidence for the events that took place on Earth during the period of ancient history, before humans existed on our planet.
There are many different rocks formed by different mixtures of minerals.

Look at the photo of granite rock below:

Granite is a rock made from a mixture of minerals. How many different minerals can you see?

**Practical activity** Comparing rocks

Record your descriptions of the different rocks provided. Use a hand lens to aid your observations.
- Sort your rocks into groups on the basis of your observations.
- Compare your groupings with others in your class.

**Texture and porosity of rocks**

The **texture** of a rock describes the way its grains fit together. There are two main types of texture in rocks:

- **Crystalline** texture. The mineral grains are crystals in the rock. The grains all interlock. There are no gaps between the crystals. Granite is an example.

- **Fragmental** texture. The minerals form randomly shaped fragments or grains that do not fit together neatly. Another mineral often ‘cements’ the grains to each other. Sandstone is an example.

Rocks that have spaces between their grains can soak up water better than rocks with interlocking crystals. The water fills the gaps between grains in rocks such as sandstone. We say these rocks are **porous**.
The grains in sandstone are non-interlocking

**Practical activity** A closer look at granite and sandstone

**Texture**
Use a hand lens to look at the structure of granite and sandstone.
- What do you notice about the way the individual ‘grains’ interlock? Which rock has grains that do not interlock?

**Porosity**
- Predict which of the two rocks will be better at soaking up water (which rock is more porous). Explain your reasoning.

Weigh a sample of each rock when dry.
- Record the masses in a table like the one below:

<table>
<thead>
<tr>
<th>Rock</th>
<th>Mass when dry / g</th>
<th>Mass when wet / g</th>
<th>Increase in mass / g</th>
<th>Percentage increase in mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>granite</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>sandstone</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Now submerge each rock in water.
- What do you notice?

Remove the rocks from the water and let excess water drip off. Then weigh the rocks again.
- Record your results in your table and fill in the rest of the table.
- What is your conclusion? Was your prediction correct?

**Summary questions**

1. Copy and complete:
   Most rocks are _____ of minerals. There are two main types of rock _____: crystalline and _____.
   When the grains in a rock do not _____ the rock is _____, meaning it can _____ up water.

2. Try to think up a model you could use to help explain the porosity of rocks to a younger student. It should demonstrate the interlocking and non-interlocking minerals.
8.2 Types of rock

Learning outcomes
After this topic you should be able to:
- explain how sedimentary, metamorphic and igneous rock are formed
- list the characteristics of each rock type.

Sedimentary rock
Pieces of weathered rock eventually settle in another place as sediment. Over time, layers of sediment build up. The separate bits of rock become a layer or bed of rock.

You can imagine the pressure building up as layer upon layer of sediment is deposited. This squeezes water out from the gaps between the grains of sediment. Under this pressure, the edges of the grains can join together. This is called compaction.

Another process also helps the sediments to form rock. Water that passes between the gaps in grains can evaporate. This leaves behind any solids that were in solution. The solid that comes out of solution acts like a glue or cement. It sticks the grains of sediment together. This is called cementation.

Rocks formed like this are called sedimentary rock.

Sedimentary rocks:
- are porous (absorb water)
- usually have grains that do not interlock
- can contain fossils.

Metamorphic rock
Rocks under pressure
Sometimes sedimentary rocks are subjected to very high temperatures and/or pressures. When this happens, chemical reactions take place in the solid rock. New minerals will form crystals. The new rock formed is called a metamorphic rock.

Slate is a metamorphic rock, formed under high pressure. It was made from mudstone or shale, which are both examples of sedimentary rock. In mudstone the clay minerals are mainly jumbled up. The new minerals in slate are all lined up in one direction:
Heating up rocks

Beneath the Earth's surface, rocks can get very hot. They can be subjected to extreme heat near molten rock, called magma.

The magma rises towards the surface in areas where we find volcanoes. The Earth movements that build mountains also generate great heat. During metamorphism, the rocks may get very hot but do not melt. Marble is formed by the action of heat on limestone or chalk.

The general characteristics of metamorphic rocks are:
- they are made of crystals that are often too small to see with the naked eye
- their crystals are usually interlocking, so the rocks are non-porous
- they often have bands of minerals running through them
- they do not usually contain fossils (any fossils that are found will be distorted).

Igneous rock

Forming crystals

Granite is an example of an igneous rock. It is hard and shiny. We saw above how molten rock, called magma, can rise towards the Earth's surface. Sometimes it actually escapes from the surface during volcanic eruptions. The molten mixture of materials that breaks through the surface is called lava.

As magma or lava cools down, the interlocking crystals that make up igneous rock are formed. Large crystals form when magma cools down slowly deep underground, as in granite. Small crystals form when molten rock cools quickly, as when basalt forms on the seabed.

Igneous rocks generally:
- are hard and non-porous
- are made up of interlocking crystals
- contain no fossils as these are destroyed in molten rock.

Summary questions

1 Copy and complete the following sentences:
   Sedimentary rock is formed by the processes of ______ and ______. The ______ increases as ______ of sediment and rock build up above. This causes the edges of ______ to fuse ______, and water is squeezed out. ______ left behind act as a ______ between the grains, so forming rock.

2 Copy and complete the following sentences:
   New rocks that have been formed by the action of ______ and/or heat (without ______ the rock) are called ______ rocks. You can often see ______ of minerals running through the rock.

3 Explain the formation of igneous rocks, including why some have small crystals and some have large crystals.
The characteristics of each type of soil are determined by:
- the size of the rock fragments it contains
- the chemical composition of the rock fragments
- the amount of organic materials mixed in it. This organic material is called **humus** and originates from living organisms.

**Sedimentation test:** stir two large spatulas of soil in a measuring cylinder of water then leave it to stand overnight. The densest bits in the soil settle out first and sink to the bottom. The low density humus floats on top.

Some people classify soils into six main types:
- clay, sandy, silt, peat, chalky, loam

Others simplify this to just three categories of soil:
- clay
- sandy
- loam

A **clay** soil contains very tiny pieces of weathered rock. This means that there are few gaps between particles for water to drain through. Therefore clay soil can become waterlogged in heavy rain. It contains little air, especially when wet, because there is not much space between its small particles. You can recognise clay soil as it is lumpy and sticky when wet but turns rock-hard and can crack when dried out.

Compare this with a **sandy soil**, which feels gritty to the touch, and drains water quickly because of its larger grains of rock. This also means that there are more gaps between soil particles for air. (This is needed by organisms that live in the soil, e.g. the roots of plants.) The sandy soil does have a disadvantage in that heavy rain can wash away the soluble nutrients from the soil. We say that the nutrients are leached from the soil.

A **loam** soil has a more equal mixture of small and large grains of rock. This means it can retain water without getting waterlogged. It also contains more humus than clay or sandy soil.
Practical activity: Investigating soil

Water content
We can test the water content of a soil by warming it gently in an oven.
- Weigh the soil sample before and after warming to work out the mass of water lost.
Spread the soil out to dry on a dish in the warm oven. This will evaporate the water.
- Calculate the percentage of water in each sample of soil tested.

Humus content
Take a sample of soil that has been warmed to evaporate the water (as in the previous test) and weigh it.
Spread the dried soil sample on a tin lid. Heat it strongly on the tin lid. It is best to do this in a fume cupboard to limit the smells in the laboratory. Heating strongly burns off the humus from the soil.
- Calculate the percentage of humus in each sample of dry soil tested.

⚠️ Make sure you wear eye protection.

Key terms
- clay
- humus
- loam
- sandy soil

Permeability test: This measures the rate at which water will drain through a soil sample so that soils can be compared.

Summary questions
1. What else, besides deposited rock fragments, do we find in soil?
2. Draw a table to compare the grain sizes, ease of drainage and amount of air in clay, sandy and loam soils.
3. What differences would you see between a sandy soil and a loam soil in a sedimentation test?
4. Describe a method to carry out the permeability test shown above to compare the three types of soil.
The crust

Have you ever wondered what is inside our planet? To get inside, first of all you would have to go through the Earth's relatively thin crust. It can be as thin as 5 km under the oceans, increasing to about 70 km under the continents. Compare these distances to the 13,000 kilometres of the Earth's diameter. This thin crust is the least dense of the Earth's layers.

The mantle

Under the crust is the Earth's mantle. This layer goes down almost halfway to the centre of the Earth. The mantle is almost entirely solid. However, there is a small amount of molten material between the crust and the uppermost part of the mantle.

The Earth's crust and upper mantle is made up from huge slabs of rock, called tectonic plates. These move very slowly and cause earthquakes and volcanic activity where the giant plates rub against each other.

The Earth's core

Beneath the mantle is the outer core. This is a dense liquid, made of molten iron and nickel. Both of these metals are magnetic.
Finally, at the centre of the Earth, there is the inner core. This is the densest part of the Earth. Unlike the outer core it is solid because of the very high pressure. It is also made of iron and nickel.

The outer and inner cores make up just over half of the Earth’s diameter.

**Practical activity**  
Reseaching planet Earth

**a Old models of the Earth**

People have had different theories about the structure of the Earth over the ages.

Find some of these old ideas about our planet using secondary sources, such as books, the internet or videos.

**b Finding out what is inside the Earth**

The Earth is about 13,000 kilometres in diameter but the deepest hole ever drilled is only about 13 kilometres deep. So how do scientists know what is deep within our planet?

Using secondary sources, find out the ways in which scientists obtain their information.

Present your results from a and/or b on a poster to share with the rest of your class.

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**Expert tips**

Only about 10% of the Earth’s mantle is a thick (viscous) liquid, found around the edges of mainly solid rock. But this is enough to cause movement of the Earth’s huge tectonic plates.

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**Key terms**

- crust
- inner core
- mantle
- outer core

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**Summary questions**

1. Draw a labelled diagram of the Earth shown in cross-section (as though the Earth had been sliced in half).
2. Where do we find the thinnest parts of the Earth’s crust?
3. Why does the Earth behave like a giant magnet?
4. Some people compare the structure of the Earth to an egg with cracks in its shell. Evaluate this model, explaining its good points and its faults.
In this topic we will look at some of the evidence scientists use to make deductions about the history of our planet from its rocks and fossils.

Fossils are the remains (or imprints) of animals and plants that lived thousands or even millions of years ago. The dead plant or animal was preserved in sediments that eventually turned into rock (see page 144). The hard parts of their bodies were replaced by minerals. Look at the ages of some organisms that have lived on Earth:

Fossils found in rock give us clues about the history of the Earth. For example, the fossils of tropical fern leaves found in coal deposits suggest that coal formed in areas with hot, swampy conditions. Because of its coal deposits, many scientists believe that Britain was once near the Equator, and that it has gradually moved thousands of miles northwards as a result of continental drift (see page 140).

Where we find the same fossil species in rocks from different parts of the world, we can deduce that the rocks are about the same age. Such deductions are more reliable when the fossils used are of animals or plants that existed for a relatively short period of time.
We can also get some idea of the relative age of rocks by studying the changes in the fossils present. Throughout time, species of plants and animals have become extinct or have evolved into new forms. We can use evidence from their fossils to deduce which rocks are older. The simpler and less developed an organism, the longer ago it must have lived. More sophisticated organisms evolved from these original simple forms.

Fossils of species that only existed on Earth for a relatively short time period are more useful for dating rocks than those species that existed for a long time.

Fossils show signs of evolving over time

The age of the Earth

People have always been interested in finding out the age of the Earth. But can fossil evidence help us to answer the question ‘How old is the Earth?’ Scientists are doubtful. It is unlikely that there was any life when the Earth was first formed. It is thought that the early Earth was a ball of molten rock. When it did cool down enough to form a crust around the outside, the molten rock constantly burst through. This created a volcanic atmosphere, unsuitable for life.

So scientists use the oldest rocks they can find to estimate the age of the Earth. These igneous rocks contain some radioactive substances. Some of these substances take millions of years to break down into different substances. Scientists know how quickly they decay into other substances. By analysing the amount of these other substances that are present in a rock, scientists can estimate its age. Their best estimates at present place the Earth at about 4.6 billion years old (that is 4 600 000 000 years old).

This is much older than the oldest fossils ever found.

**Expert tips**

The vast timescales involved in geological history are hard for anyone to imagine. But if the history of the Earth was represented by a 24-hour clock, then humans only arrived on Earth at about one second to midnight!

**Key terms**

- fossil

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**Summary questions**

1. What is a fossil?
2. Look at the fossils in the illustration above.
   a) Which of the three fossils is the oldest?
   b) Which can give the most precise age of the rock it is found in?
3. a) What is the problem with trying to age the Earth from fossil evidence?
   b) What do scientists use instead of fossils to estimate the age of the Earth?
1 Identify the rocks below as igneous, metamorphic or sedimentary.

Rock X: It is made from plate-like crystals all lined up in the same direction. The rock fragment has parallel flat sides where it has been split. [1]

Rock Y: There are particles of sand visible held together by an orange-brown mineral. Bits of sand crumble off the surface of the rock quite easily. [1]

Rock Z: There are three different types of interlocking crystal arranged randomly in this hard rock. [1]

2 a Explain the process whereby limestone can be changed into marble. [2]

b Explain the process whereby slate can be formed from mudstone. [2]

3 a i Name an igneous rock made up of large crystals. [1]

ii Under what conditions is this type of rock formed? [1]

b i Name an igneous rock with very small crystals. [1]

ii Under what conditions is this type of rock formed? [1]

c Explain the difference we find in the size of crystals in igneous rocks using the particle theory where necessary. [2]

4 A scientist says that the oldest fossils found are 600 million years old so the age of the Earth is 600 million years.

Do you think the scientist is correct? Explain your answer. [2]

5 An agricultural scientist wanted to find out which of his trial fields would drain most quickly. He took soil from each of his four fields, labelled them A to D, and carried out the test shown below:

He found that it took soil A 45 seconds to drain a set volume of water, soil B took 32 seconds, soil C took 17 seconds and soil D took 78 seconds.

a Put the scientist’s results into a suitable table. [2]

b Show his results on a suitable graph. [4]

c Which property of the soils was the scientist testing? Choose i, ii, iii or iv.

i How acidic the soil is

ii How well the soil drains

iii Its density

iv Its texture [1]

d Which soil would be best suited to a crop that needs well-drained soil to grow well? [1]

e Which soil is most likely to be a clay soil? Explain why. [2]

f Which soil is most likely to be a sandy soil? Explain why. [2]
6 Sami and Des were investigating how rocks can be worn down. They made six cubes from plaster of Paris. They weighed the cubes then put them in a tin can with a lid. They shook them for 30 seconds then weighed the six largest blocks again, making sure no bits were lost from the can. They replaced the blocks in the can and repeated this several times.

Here is a graph of their results:

![Graph showing loss in mass over time.]

7 The structure of the Earth is shown below:

![Diagram of Earth's structure with labels A to E.]

a Name the parts of the Earth labelled A to E. [5]

b Which layer of the Earth:
   i contains fossils? [1]
   ii is made up of solid iron and nickel? [1]
   iii is found beneath the Earth’s giant tectonic plates? [1]
   iv varies in thickness between 5 km and 70 km? [1]

c i Which of the following is the best estimate of the age of the Earth?
   - 4.6 thousand years old [1]
   - 4.6 million years old [1]
   - 4.6 billion years old [1]

   ii Scientists can estimate the age of the Earth. State what they observe and measure to work this out. [2]

d i What do we call the rock formed from fragments of rock that settle in layers? [1]

   ii If these rocks are put under high pressure and baked at high temperatures, what type of rock forms? [1]