Key Stage 3

Evolution Detectives

Student worksheet

This worksheet is about mudstone – a rock made from grains of clay minerals compacted together – and mud, these same grains mixed with water.

This lesson is inspired by research at Oxford University into Australian mudstone fifteen times older than the dinosaurs. Traces of oxygen, nutrients, and early life in the mudstone has helped to entirely reshape our picture of evolution and how the Earth formed.

Rocks on Earth

There are three kinds of rock on Earth: igneous, metamorphic and sedimentary rocks.

Igneous rocks form from magma in the Earth's mantle cooling into interlocking crystals, e.g. granite and basalt.

Metamorphic rocks form when heat and/or pressure changes the structure of existing rocks, e.g. mudstone can become slate at lower temperatures and schist at higher temperatures.

Sedimentary rocks form near the Earth's surface from layers of deposited sediments, including plants and animal remains, e.g., sandstone, mudstone, limestone.

Weathering, erosion, transportation, deposition, and **lithification** – the compaction and/or cementation of new rocks – can change, destroy and form new sedimentary rocks, whilst heat and pressure form new igneous and metamorphic rocks over millions of years. Because of high temperatures and pressures, fossils don't occur in igneous rocks, and rarely in metamorphic rocks, except slate, which is formed at relatively lower temperatures and pressures.

Our atmosphere is currently 78% nitrogen, 21% oxygen, 0.04% carbon dioxide, plus other gases, but this is its **dry composition**. There is usually lots of water vapour in the air too, but its amount varies day to day, season to season, and place to place. Scientists are very interested in the amount of gases in the atmosphere, because they can change the living things that evolve and the kinds of rocks that form. Remember, many sedimentary rocks contain animal and plant remains. We can learn about the atmosphere of Earth in the past and atmospheres on other planets by studying rocks, and so learn about life. When there is more carbon dioxide in the atmosphere, we also find more carbonate rocks (limestones). Living things can act as a **carbon sink** to store up carbon, and then become new rocks such as limestone and coal after they die.

Your task: Follow the River

Mudstone can form when grains of clay minerals are deposited in slow-moving rivers, oceans, lakes.

1. Using the river diagram, label sites along the river basin where **weathering, erosion, transportation** and **deposition** take place.

Do any of these occur more than once?

2. Swap with a neighbour and use the answer sheet to mark their answers. Discuss your choices.

https://www.oxfordsparks.ox.ac.uk/content/ancient-mysteries-marvellous-mud

What makes Acid Rain?

Burning fossil fuels releases gases including **carbon dioxide**, **nitrogen oxides**, **sulphur dioxide** and **water vapour**.

Rain is naturally a little bit acidic. When we say "acid rain", we mean rain that is more acidic than usual because of **carbon dioxide**, **nitrogen oxides** and **sulphur dioxide** dissolving in moisture in the air to make **carbonic, nitric** and **sulphuric acids** that later fall to Earth in raindrops. Although the acid is very **dilute**, there is lots of it, and it gradually corrodes materials such as limestone rock ($CaCO_3$).

$$CaCO_3 + 2H^+ \rightarrow H_2CO_3 \rightarrow CO_2 + H_2O$$

Your task: Acid Rain

Explore the chemical reaction between a weak acid and chalk powder (limestone).

1. Put a little chalk powder in a pot.
2. Pour a small amount of acid on top.
3. Record your observations in the table. Repeat the test.

Why is it important to repeat the experiment?

What variables do you need to keep the same?

Test	Observations
1	
2	

Your task: Make Your Own Mud

Make your own mud by mixing some dried powdered clay particles with water.

1. Place a little of your powdered samples in a pot and cover with water.
2. Add a little pH indicator and record the pH in the table.
3. Stir, and record any changes.
4. Add a little iron salt, wait 5 minutes, record the pH and see if there are any changes.

This iron-containing mud simulates the kind of environment in which some kinds of microbes respire minerals. To understand more, read **What is Biomineralisation?**

What is the pH of tap water before adding the powders?

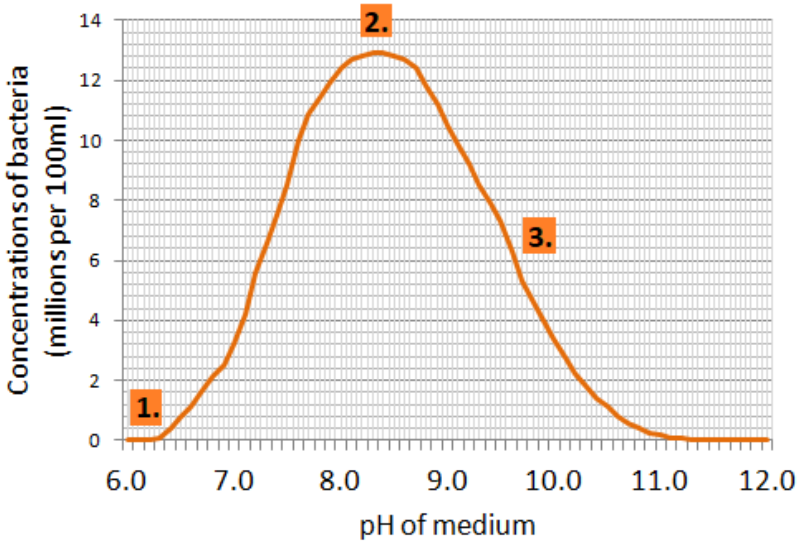
Mud	pH	Any changes?
1		
2		

What is Biomineralisation?

Some rocks, muds, and clays form shapes because they were built by living things **respiring** them. Microbes use respiration to gain energy, like we do, but **microbial respiration** is different from animal respiration: microbes gain energy by exchanging electrons with iron (or other metals). This changes the chemistry of iron-containing minerals. Some microbes digest rock, or produce it as a waste product when they make energy. One mineral, for example, hydroxyapatite, $Ca_5(PO_4)_3(OH)$, only forms long fibres when it is made biologically. Finding **fibrous** hydroxyapatite crystals in mudstone may be sign, or 'fingerprint', of early life.

pH affects not only chemical reactions, but also biological action: different microbes operate at different pHs.

The chart shows what happens to bacteria that survives best at pH 8.5. Can you describe what is happening at 1, 2 and 3?



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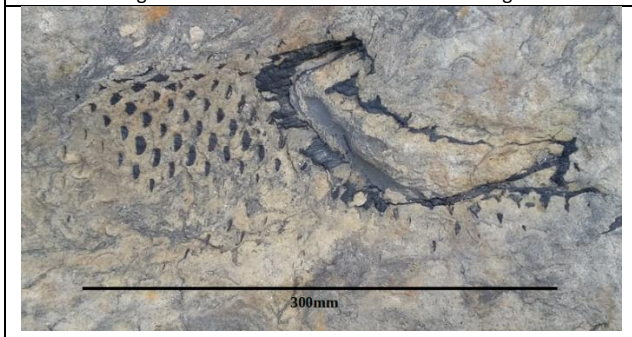
Some basic life forms can survive in extreme pH conditions. For example, in the strong acid of your stomach! Scientists can tell from the structure and texture of rocks which ones were created by living things. This is a bit like if you were climbing a mountain and saw a stone cottage – you would know right away that the cottage had been built by people, and wasn't just how the rocks had fallen naturally.

Your task: Evolution Detectives

The table shows some rocks and their ages. Remember, not all rock of a particular kind is the same age!

1. Examine the rocks in the following table, and decide if they provide any evidence for life using your own knowledge, the pictures, and what you have learnt this lesson.
2. Create a timeline for the evolution of life using those rocks which show evidence for life

Evolution Detectives

Rock	Age	Evidence for life?
 Hydroxyapatite in mudstone Acknowledgement: Professor Gregory C. Finn brocku.ca	810 million years	
 Limestone Acknowledgement: Elizabeth Devon	340 million years	
 Schist Acknowledgement: Elizabeth Devon	1.7 billion years	
 Basalt Acknowledgement: Elizabeth Devon	35,000 years	
 Slate Acknowledgement: Peter Kennett of the Earthlearningidea Team	275 million years	
 Sandstone Acknowledgement: Elizabeth Devon	150 million years	

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Your task: Eras of the Earth

Match up the Eras of the Earth with their dates and the events that took place during this time.

Neoproterozoic	66 million years ago-now	• Nuna supercontinent forms • Great Oxygenation event occurs – increasing the Earth's oxygen • Eukaryotic life evolves
Mesoarchean	252-66 million years ago	• Believed to be the era in which the first life evolved • High pressure no-oxygen atmosphere • Earth's crust develops
Mesoproterozoic	541-252 million years ago	• Cambrian explosion – the evolution of fish, amphibians and land animals • Coal beds are formed • Supercontinent Pangaea forms
Eoarchean	1000-541 million years ago	• Pangaea breaks up • Dinosaur populations boom, then big dinosaurs become extinct • Temperatures are high and sea levels low
Paeleoarchean	1600-1000 million years ago	• Photosynthesis evolves • Supercontinent Kenorland forms and breaks up • Earth begins to cool
Neoarchean	2500-1600 million years ago	• Supercontinent Vaalbara starts to break up • Earliest reefs form • Atmospheric carbon dioxide reaches pre-industrial levels
Cenozoic	2800-2500 million years ago	• Supercontinent Rodinia forms • Sexual reproduction evolves • Nuna supercontinent breaks up
Mesozoic	3200-2800 million years ago	• Earliest fossils of multicellular life • Rodinia breaks up • In a "snowball Earth" ice sheets reach the equator
Paeleoproterozoic	3600-3200 million years ago	• Himalayas form • Large mammals evolve • South America attaches to North America

Paeleozoic	4000-3600 million years ago	• Supercontinent Vaalbara forms • A large asteroid collides with Africa • Earliest fossilised bacteria