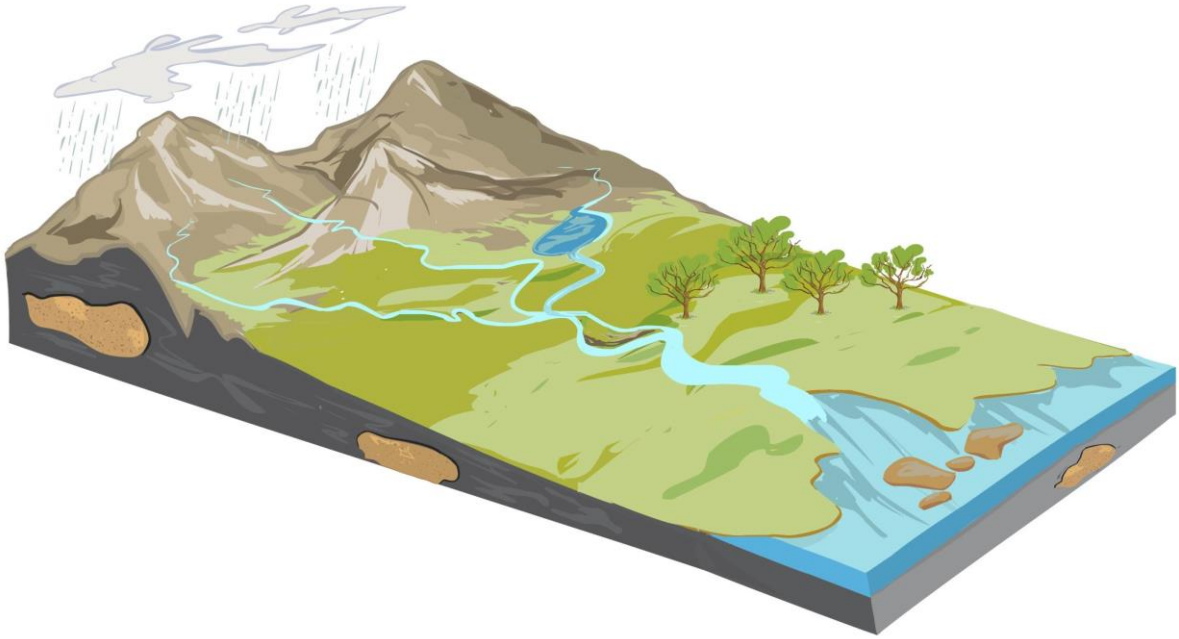
Key Stage 3 – Evolution Detectives

Notes for teachers

At a glance

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 entirely reshape our picture of evolution and how the Earth developed.

In this lesson, students will be making and studying the properties of their own mud using pH experiments. They will be thinking about how pH affects microbes, and the ways that mudstones form, erode and break down. They will look at water, earth and air as they explore the science of evolution and wonder about how to identify traces of early life on Mars.



Learning Outcomes

- Understand more about pH and its impact on chemical and biological reactions.
- Understand the impact of acid rain on the formation of rocks and the rock cycle.
- Develop good laboratory and scientific skills.
- Develop links between fields such as biology, chemistry, physics and geology, and understand how research is interlinked.

Each student will need

- A copy of the student worksheet
- Some powdered chalk
- A sample of weak acid (suggestions: 2 mol dm^{-3} HCl)

- Some rock components (suggestions: sand, powdered clay, powdered zeolite)
- An iron (II) salt (suggestions: iron (II) sulfate, iron (II) chloride)
- A pH indicator (suggestions: universal indicator)

You may also wish to print or write out the **Follow the River** answer sheet included in appendix 2.

Possible Lesson Activities

1. **Starter activity**
   - Write the below key words up on the board and introduce the class to their meanings.

   Key words: biogeochemistry, biomineralisation
   - Play the animation, 'Ancient Mysteries in Marvellous Mud' (see weblinks).
   - Challenge the class to research and match the eras on the **era matching sheet** to what was happening on Earth at that time, and place the eras in the correct chronological order (answers in appendix 1). They will need to use the internet to do research.

2. **Main activity: Acid Rain**
   - Ask the class to read through **Rocks on Earth** on the provided worksheet.
   - Ask the class to discuss or map out what they already know about acid rain and chemical weathering.

   Physical weathering describes the wearing down of rocks by processes such as freezing, heating and wetting. Chemical weathering describes the wearing down of rocks by chemical reactions like dissolution and reacting with small amounts of acid slowly over time, e.g., carbonation of limestones.

   pH affects mudstone formation as well as erosion. Ask the class to discuss how and share ideas.

   The solubility of particles may be different at different pHs. A high or low pH may cause some particles to dissolve and travel further than others

   Microbes may affect the deposition or erosion of minerals. Each kind of microbe will have an optimum pH, the pH where they are most active, and will be destroyed at much higher or lower pHs.
   - Provide the students with a sample of powdered chalk and a sample of acid. Ask the students to pour some acid onto their powdered chalk and record their observations.
   - Ask the class to complete **Follow the River** on the provided worksheet. The answer sheet is provided in appendix 2).

3. **Main activity: Make Your Own Mud**
   - Ask the class to read through **What makes Acid Rain?** on the provided worksheet.
   - Ask the class to discuss acid rain with each other. You may wish to talk about the materials they are using to make mud.

   Zeolites are a naturally occurring volcanic minerals, and the key ingredients of cat litter. Cat litter is often made from silica or bentonite clay – a clay form of aluminium silicate (where zeolites are crystallised minerals of aluminium silicates). Aluminium silicates are negatively-charged open frameworks that house positive metal ions (often sodium and calcium) and water molecules inside them. They are highly water absorbent (which is why they work well for cat litter) and the name "zeolite" means "boiling rock" because heating them releases around 10% of the mass as water.

- Ask the class to make their own mud, following the instructions provided. Each student will need two samples of powdered clay or sediment, some water, and pH indicator (see appendix 3).
- Encourage the students to record and discuss their results, and compare these to the results of the previous experiment.

4. Main activity: Biomineralisation

- Ask the class to read through **What is Biomineralisation?** on the provided worksheet.
- *Extension:* ask the class to draw curves on the pH-bacteria graph for bacteria that survive best at pH 4 and pH 11. Ask the class to research pH in different parts of the human body, and in the foods we eat and drink.
- Challenge the students to look at the pictures of rocks and sift back through the information to work out whether they provide any evidence for the evolution of life. For those that do, encourage them to write a timeline of evidence for the evolution of life.

5. Plenary

- Ask the students to plan a mission to Mars. What mineral structures should scientists be looking for, and **how can they gather samples without contaminating the planet**? This activity could complete the lesson, or form a homework for review in a future lesson. Encourage them to think about atmosphere as well as rocks, and evidence in rocks for previous atmospheres.

Web links

Oxford Sparks animation 'Ancient Mysteries in Marvellous Mud':
https://www.oxfordsparks.ox.ac.uk/content/ancient-mysteries-marvellous-mud

Iron-respiring bacteria:
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC123774/ (open source)
https://pubs.acs.org/doi/abs/10.1021/es990021x (not open source)

Appendix 1. Answers to era-matching

Cenozoic 66 million years ago-now

- Himalyas form
- Large mammals evolve
- South America attaches to North America

Mesozoic 252-66 million years ago

- Pangaea breaks up
- Dinosaur populations boom, then big dinosaurs become extinct
- Temperatures are high and sea levels low

Paeleozoic 541-252 million years ago

- Cambrian explosion – the evolution of fish, amphibians and land animals
- Coal beds are formed
- Supercontinent Pangaea forms

Neoproterozoic 1000-541 million years ago

- Earliest fossils of multicellular life
- Rodinia breaks up
- In a “snowball Earth” ice sheets reach the equator

Mesoproterozoic 1600-1000 million years ago

- Supercontinent Rodinia forms
- Sexual reproduction evolves
- Nuna supercontinent breaks up

Paeleoproterozoic 2500-1600 million years ago

- Nuna supercontinent forms
- Great Oxygenation event occurs – increasing the Earth’s oxygen
- Eukaryotic life evolves

Neoarchean 2800-2500 million years ago

- Photosynthesis evolves
- Supercontinent Kenorland forms and breaks up
- Earth begins to cool

Mesoarchean 3200-2800 million years ago

- Supercontintent Vaalbara starts to break up
- Earliest reefs form
- Atmospheric carbon dioxide reaches pre-industrial levels

Paeleoarchean 3600-3200 million years ago

- Supercontintent Vaalbara forms
- A large asteroid collides with Africa
- Earliest fossilised bacteria

Eoarchean 4000-3600 million years ago

- Believed to be the era in which the first life evolved
- High pressure no-oxygen atmosphere
- Earth’s crust develops

Appendix 2. Answers to follow the river

Weathering – everywhere
Erosion – attrition of rocks in river and abrasion of the valley by the water
Erosion – outer meanders of the river
Transportation – along river
Deposition – estuary
Deposition – inner meanders of the river

Appendix 3. Examples of pH tests

Example: using cabbage water indicator, powdered zeolite (a volcanic mineral) and sodium silicate, then iron (II) sulfate

Indicator with water:

Zeolite and warm water:

Sodium silicate and warm water:

After adding iron (II) sulfate (the zeolite can also be filtered and will have turned green. Over time, it turns brown as the iron oxidises). If you add indicator to the sodium silicate and wait, it gradually turns from green to yellow/brown:

(sodium silicate)