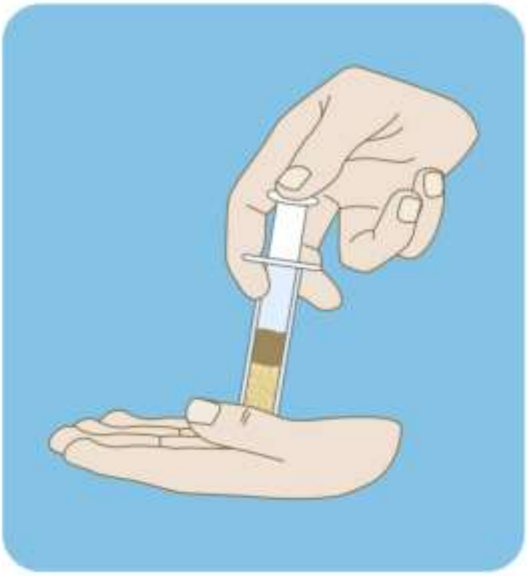
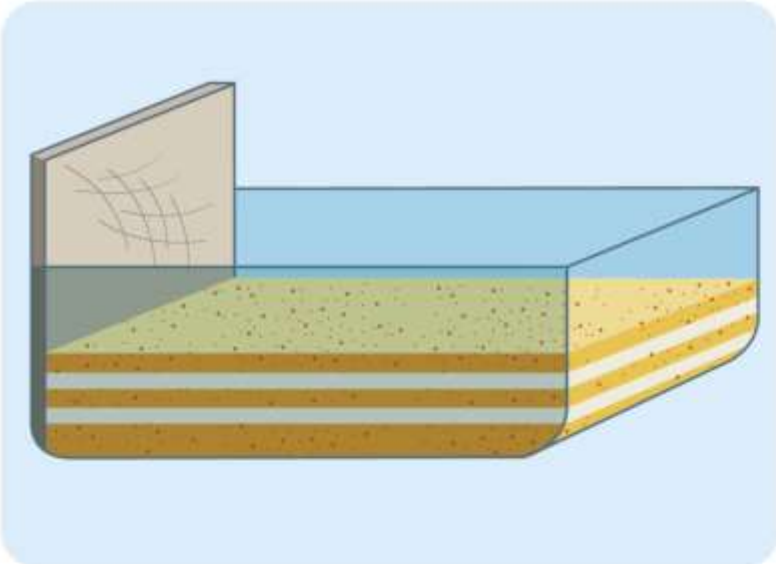
Teaching the Dynamic Earth

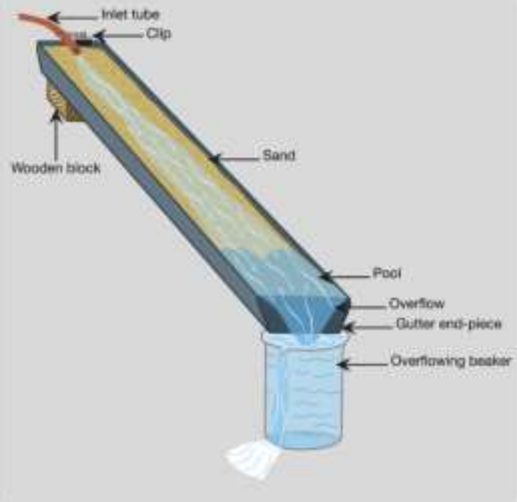
The dynamic rock cycle: hands-on activities on the processes involved in the rock cycle

ESEU KS3 science/geography workshop material

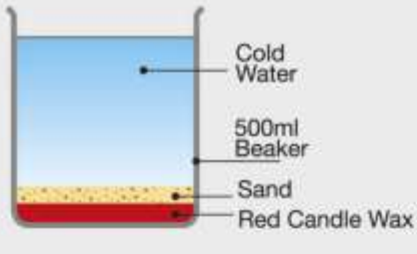
Earth science for KS3







Magma processes simulated by candle wax



EARTH SCIENCE EDUCATION UNIT

With the support of:

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ESEU Secondary Workshops

The dynamic rock cycle
Earth science for KS3 science/geography

Contents

Summary

Try a series of 'hands-on' activities experimenting on and simulating the processes involved in the rock cycle. Use the integrating model of the rock cycle as a means of encountering common rocks and Earth-processes in a practical, investigative way.

Earth Science Education Unit workshops

These workshops have been devised for teachers and trainee teachers. They are intended to provide participants with a range of activities that can be used in the classroom, whilst helping them to develop the skills for using the activities in an engaging and motivating way that will enthuse and educate their pupils, whilst developing their critical thinking skills. The workshops should also develop the background Earth science knowledge and understanding of the teachers involved.

The workshop format may be transposed directly into a classroom, but often this is not appropriate. Similarly, individual activities, and the worksheets on which these are based, may be transferable directly into a classroom situation, but will often require modification for the classes and situations in which they are used, during which suitable risk assessments are undertaken.

Workshop outcomes

The workshop and its activities provide the following outcomes:

- identification and terminology of rock cycle products, including soils, sediments and rocks;
- knowledge and understanding about rock cycle processes and timescales, including weathering, erosion/transportation, deposition, compaction/cementation, metamorphism, melting, crystallisation, extrusion and deformation;
- methods of teaching the abstract concept of the rock cycle, using a range of teaching approaches;
- introduction to a range of Earth science laboratory activities, from simple modelling to more complex investigations;
- approaches to activities designed to develop the thinking and investigational skills of pupils;
- links between laboratory models and planetary processes, some of which are locally active and therefore relevant to pupils;
- an integrated overview of the geological Earth science commonly taught to 11 – 14 year olds, based on the National Curriculum.

Curriculum references

<table>
<tr><th>England</th><th>Scotland</th><th>Wales</th><th>Northern Ireland</th></tr>
<tr>
<td>Science: Lower KS2
Years 3 and 4
Working scientifically
• asking relevant questions and using different types of scientific enquiries to answer them
• setting up simple practical enquiries
• making systematic and careful observations
• using results to draw simple conclusions,
• using straightforward scientific evidence to answer questions or to support their findings

Year 3
Rocks
• compare and group together different kinds of rocks on the basis of their appearance and simple physical properties
Linked with work in geography, pupils should explore different kinds of rocks, including those in the local environment
Pupils might work scientifically by: observing rocks, including those used in buildings and gravestones, and exploring how and why they might have changed over time; using a hand lens or microscope to help them to identify and classify rocks according to whether they have grains or crystals, and whether they have fossils in them

Science: Upper KS2
Working scientifically
• recording data and results of increasing complexity using scientific diagrams and labels, classification keys, tables, scatter graphs, bar and line graph

KS3
Working scientifically:
• ask questions and develop a line of enquiry based on observations of the real world, alongside prior knowledge and experience.
• make predictions using scientific knowledge and understanding
• select, plan and carry out the most appropriate types of scientific enquiries to test predictions, including identifying independent, dependent and control variables, where appropriate.
• use appropriate techniques, apparatus, and materials during fieldwork and laboratory work, paying attention to health and safety.
• make and record observations and measurements using a range of methods for different investigations; and evaluate the reliability of methods and suggest possible improvements.
• apply sampling techniques

KS3 Chemistry:
• the rock cycle and the formation of igneous, sedimentary and metamorphic rocks.

Human and physical geography
KS3
understand, through the use of detailed place-based exemplars at a variety of scales, the key processes in: physical geography relating to:
• geological timescales and plate tectonics; rocks, weathering and soils</td>
<td>Sciences
Early
Biological systems
I can identify my senses and use them to explore the world around me.
SCN 0-12a

Properties and uses of substances
First
Through exploring properties and sources of materials, I can choose appropriate materials to solve practical challenges.
SCN 1-15a

Second
Earth's materials
Having explored the substances that make up Earth's surface, I can compare some of their characteristics and uses.
SCN 2-17a
Third
Through evaluation of a range of data, I can describe the formation, characteristics and uses of soils, minerals and basic types of rocks.
SCN 3-17a

Social studies
People, place and environment
First
I can describe and recreate the characteristics of my local environment by exploring the features of the landscape.
SOC 1-07a
Second
I can describe the major characteristic features of Scotland's landscape and explain how these were formed.
SOC 2-07a
Third
Having investigated processes which form and shape landscapes, I can explain their impact on selected landscapes in Scotland, Europe and beyond.
SOC 3-07a</td>
<td>Science
KS2
The sustainable Earth
• a comparison of the features and properties of some natural and made materials
• how some materials are formed or produced

Science
KS3
Enquiry
• Pupils should be given opportunities to carry out different types of enquiry, e.g. pattern-seeking, exploring, classifying and identifying,

Geography
KS3
Pupils should be give opportunities to:
• observe, measure, extract and record data through carrying out practical investigations and fieldwork

Literacy and Numeracy Framework
Oracy- developing and presenting information and ideas
Year 3
OS1,OS2,OS3
OL1.OL3
OC1,OC2
Year 4
OL2,OC1.OC2

Numeracy - developing numerical reasoning
KS2.1,KS2.5, KS2.7, KS2.19</td>
<td>The world around us
Foundation stage
Strand 3: Place
KS1
Features of the immediate world and comparisons between places;
• about materials in the natural and built environment (G); (H);
• about the properties of everyday materials and their uses (S&T);
• the similarities and differences between buildings features and landscape in their locality and the wider world (G)

KS2
Ways in which people, plants and animals depend on the features and materials in places and how they adapt to their environment;
• about the origins of materials (S&T)</td>
</tr>
</table>

Starter activity
- rock cycle products and processes

Preparation:

Before the group arrives:

- Lay out the A4 cards of the rock cycle products on benches/tables around the room in a 'cycle' in the correct sequence (it may be useful to Blu tac™ these to the bench/table top so they are not moved).
- Check that you have the A4 rock cycle process cards in the right order.
- Check you have the rock 'flash cards' in the right order.
- Lay out the eight rock cycle activities around the room, with the Activity number cards, preferably in a circle that corresponds to the rock cycle.
- Put the glass slides for Activity 6 in the freezer or the freezing compartment of a fridge.
- Collate sets of the A4 Rock Cycle Diagram cards, sets of rocks, bags of soil, bags of sand, and photos, to give to each group of participants (around three in a group).
- Put up the copy of the OS Ordnance Survey Geological Map of the United Kingdom by the British Geological Survey (if available).
- Set up the computer/projector with the ESEU 'Dynamic Rock Cycle' PowerPoint.

Activity:

Participants are asked to place a series of rock cycle products in the correct places on a diagram of the rock cycle, then to consider how all these are linked by rock cycle processes. They can use the 'Rock reference sheet' provided, if necessary. The rock cycle is described as a narrative on page 10.

- Ask participants to place the rock cycle products (sediments, photographs and rocks) in the correct places on the Rock Cycle Diagram.
- Check that they have put these in the correct places, by putting your set of the photos, bags and rocks in the correct places on the rock cycle A4 cards you have laid out around the room. At the 'Sedimentary sequence' card, demonstrate how sedimentary sequences build up by adding dessertspoon-fulls of different coloured sand to the water in the cylinder. Preferably do not mention the names of the rocks (noting that the names of rocks are not required in the KS3 curriculum); instead use terms like: cemented pebbles; cemented sand; compressed mud; cemented calcium carbonate; low grade metamorphic rock; medium grade metamorphic rock; high grade metamorphic rock; metamorphosed calcium carbonate; metamorphosed sand; coarse-grained, pale-coloured igneous rock; coarse grained, dark-coloured igneous rock; fine grained, dark coloured igneous rock (sometimes with preserved gas holes).
- Use the 'Flash cards' to name the rocks (saying that even though pupils, and their teachers, don't need to know the names of the rocks, knowing the names is useful – they are listed at the back of this booklet).
- Place the A4 cards of the rock cycle processes in the correct places between the A4 rock cycle products cards, around the room.
- You might like to walk around your laid out rock cycle, first around the whole cycle, then around the sedimentary part of the cycle (missing out the metamorphic and igneous bits), and then the sedimentary/metamorphic part (missing out the igneous bits) to show how the cycle can be 'short circuited'.
- Explain that, for most of these processes, there is an associated activity set out around the room.
- Ask each group of participants to try out each activity, giving them around 15 minutes to do so. Note for them that each activity is fully described in this booklet, and that in the feedback session, that will follow, they will be asked to:
  - Name the topic they did
  - Explain what they did, and demonstrate it briefly
  - Suggest how this relates to the real world
  - Say if they would use it; if so, how it would it best be used with a class, e.g. group practical work; teacher demonstration; part of the circus, etc?
  - Suggest any safety implications

Questions:	***Answers:***
Why has so much emphasis been placed on the rock cycle as an integrator of all the processes and products?	*Because it is an abstract concept, that many pupils are likely to find difficult to understand, and will need concrete support for their understanding.*
How can the influence of the rocks cycle on learning be maintained?	*After the lesson, stick up the A4 cards of the rock cycle products and processes around the room, so that any time the pupils enter the room, they are coming into the rock cycle.*

Pupil learning outcomes:
Pupils will be able to place examples of rock cycle products (rocks, sediments, photographs) in the correct positions on a rock cycle diagram and describe how these are formed by rock cycle processes.

Resources:
Enough for one per group of around three people, with an extra large set to be used by the session leader:

- A4 diagram of 'The Rock Cycle'
- 'The Rock Reference Sheet'
- Sedimentary rocks, e.g.
  - Conglomerate (cemented pebbles)
  - Sandstone (cemented sand)
  - mudstone (compressed mud)
  - limestone (made of calcium carbonate)
- Metamorphic rocks, e.g.
  - slate (low grade, from mudstone)
  - schist (medium grade, from mudstone)
  - gneiss (high grade, from mudstone)
  - marble (low to high grade, from limestone)
  - metaquartzite (low to high grade, from sandstone)
- Igneous rocks, e.g.
  - lava (e.g. fine grained, dark coloured basalt)
  - granite (coarse grained, pale coloured, rich in Si, poor in Fe, Mg)
  - gabbro (coarse grained, dark coloured, rich in Fe, Mg, poor in Si)
- Photograph of 'Rocks at the Earth's surface'
- Photograph of 'Sedimentary sequence'
- Small sealed plastic bag containing dry soil
- Small sealed plastic bag containing loose sand ('mobile sediment')

One of each of the following, for demonstration:

- Laminated cards of rock cycle products:
  - Rocks at the Earth's surface
  - Rotten rocks/soil
  - Mobile sediments
  - Sedimentary sequences
  - Sedimentary rocks
  - Metamorphic rocks
  - Magma
  - Intrusive igneous rocks
  - Extrusive igneous rocks
- Laminated cards of rock cycle processes:
  - Weathering (tens to hundreds of years) ▪ Erosion and Transportation (seconds to tens of years)
  - Deposition (seconds to tens of years)
  - Compaction and cementation (hundreds to millions of years)
  - Metamorphism (millions of years – during mountain building)
  - Melting (tens to millions of years)
  - Rising (days [extrusion] to millions of years [intrusion])
  - Crystallisation (seconds to weeks [extrusion]; thousands to millions of years [intrusion])
  - Extrusion (seconds to weeks)
  - Uplift (hundreds to millions of years)
  - Deformation: folding, faulting and uplift (seconds [faulting] to millions of years [folding, faulting, metamorphism during mountain building])
- 'Flash cards' of rock names:
  ▪ conglomerate ▪ sandstone ▪ mudstone ▪ shale ▪ clay ▪ limestone ▪ slate ▪ schist ▪ gneiss ▪ marble ▪ metaquartzite ▪ lava ▪ granite ▪ gabbro
- Activity number cards
- A transparent 200 ml measuring cylinder nearly full of water
- Containers of two different coloured sands, e.g. red, white (to be kept close to the measuring cylinder nearly full of water)
- Dessert spoon
- Blue Tac™ (optional)
- OS Ordnance Survey Geological Map of the United Kingdom by the British Geological Survey (if available)

Ideas for following up the activity:
This activity should lead the pupils into the other activities in the workshop.

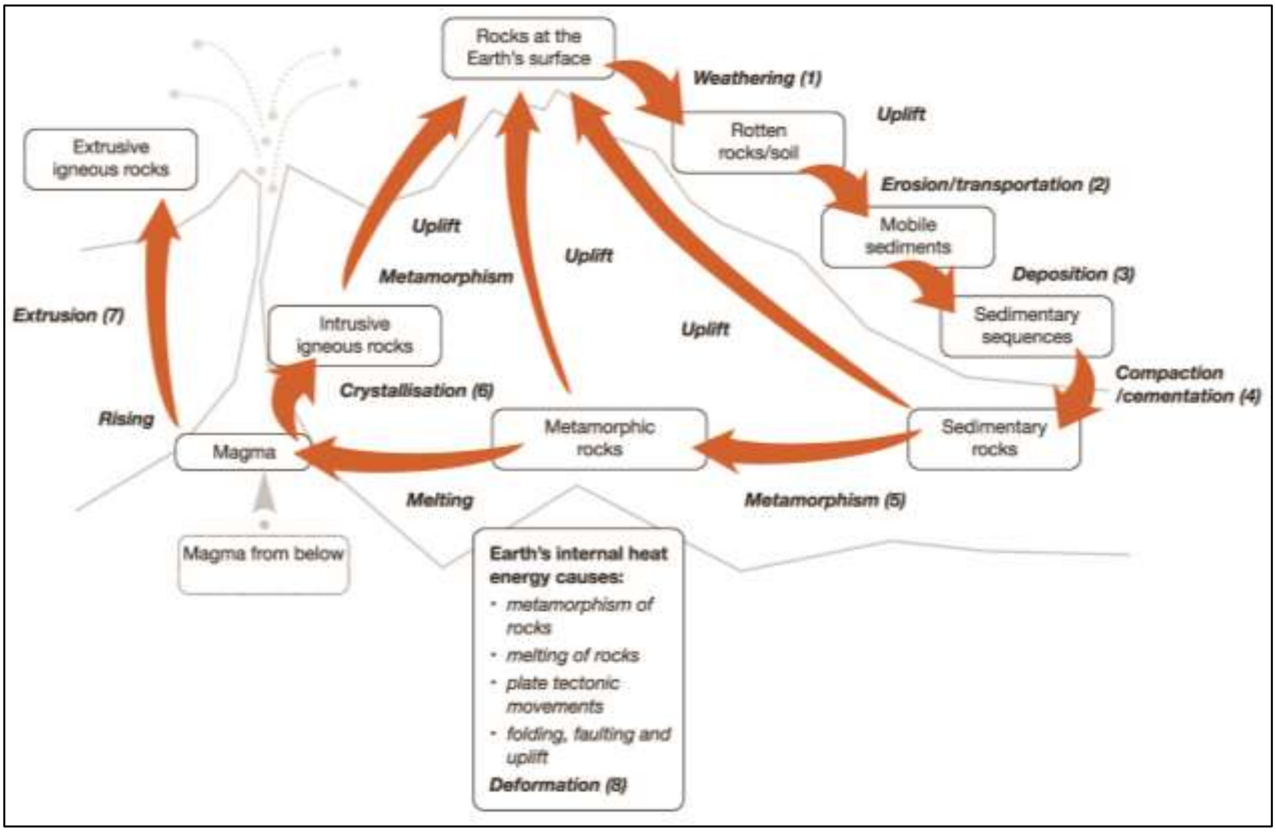
'Sedimentary sequence'
© Peter Kennett

'Rocks at the Earth's surface' © Peter Kennett

Extension ideas for more able or faster pupils:

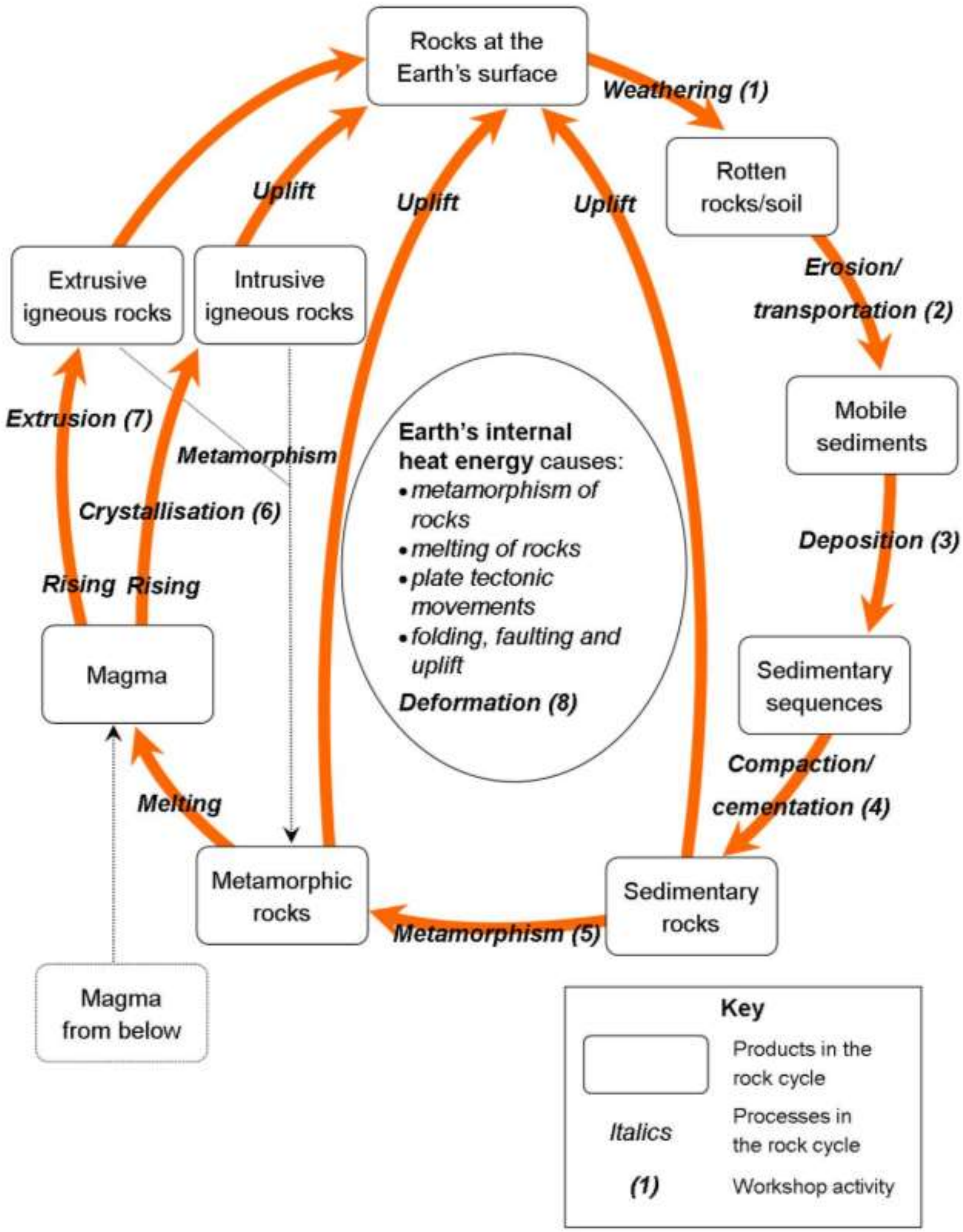
The activity is an interest raising exercise, designed to be done by the whole group through exploration, discussion and presentation.

The 'Diagrammatic version of the rock cycle' picture below is an alternative version to ESEU's rock cycle diagram (next page) and, given as a PowerPoint slide (available on the CD ROM). This shows how the diagrammatic version of the cycle can be related to more 'real world' situations.



'Diagrammatic version of the rock cycle'
redrawn from an original by BP International Limited, with permission.

THE ROCK CYCLE



The Rock Cycle – as narrative

Imagine sitting on a beach in front of a cliff of sandstone and wondering how the sandstone formed. The sand grains of the beach are the same as the sand grains in the sandstone. The sand is made by the water on the beach grinding rocks down into small fragments. Where land is sinking, in river, beach or sea areas, sand and mud can be laid down layer by layer for a long time, perhaps hundreds or thousands of years. The layers are usually flat, horizontal and widespread with younger layers laid on top of older ones. Eventually great thicknesses build up compressing the layers beneath. By this time the layers at the bottom will have been compressed by the layers above and crystals will have grown between the grains from the waters that flowed through, cementing them together into a sedimentary rock. **Sedimentary rocks** form fairly steadily and continuously in this way.

We can find out how ancient sediments were deposited by looking for the clues they contain and by studying how sediments are deposited today. Modern sands may have ripple marks or plant and animal fragments typical of the windy deserts, rivers, beaches or sea beds where they were laid down. Lime sands are deposited in tropical seas and most contain shelly fragments. Where salty waters dry out, evaporite minerals are precipitated. Organic materials are deposited in tropical swamps. Lavas and volcanic ash layers are found near active volcanoes. All these can be preserved in ancient rock sequences.

Many sedimentary rocks are no longer flat-lying. Sometimes tilted and eroded rocks have flat-lying sedimentary rocks on top showing that the older rocks must have been tilted and eroded before more sediments were laid down on top and eventually became rocks. If the two sets of rocks contain fossils, the fossils are often different because of the great time gap, perhaps millions of years, between the laying down of the older sediment and the younger sediments. The tilting of rocks is part of large-scale folding that can sometimes be seen in small scale too, in cliffs and road cuttings. The power of the compressive forces that caused the folding can be judged from how much the original horizontal layers have been crumpled up and how much the fossils they contain have been compressed or stretched. Where the rocks couldn't bend, they often broke and slid to form faults. Such folded and faulted rocks are associated with ancient or modern mountain zones. Faults are caused by compression, by 'pull apart' tensional forces, or when rocks slide past one another. Many rocks also contain other cracks and fractures.

Crystalline rocks are often found where sedimentary rocks are folded and faulted. There are two major types. **Igneous rocks** formed from molten rock that, being less dense, rose up into and cut through the surrounding rock. Igneous rocks usually have randomly orientated crystals; the slower the cooling, the larger the crystals. They may have finer grained, chilled margins and the rocks they cut may have baked (metamorphosed) margins. If the molten rock reached the surface it caused volcanic activity. **Metamorphic rocks** formed when the heat and pressure became so great that the existing rocks recrystallised (without melting) to produce new rocks with the same chemistry but different structure. At low levels of metamorphism some original features, such as layering and fossils, are preserved as new metamorphic features (like the cleavage in slates) develop, but at high levels the rock is completely transformed, often with strong metamorphic layering or banding. Folding, faulting, metamorphism, intrusion and volcanic activity happen during mountain-building events. Some igneous and metamorphic rocks can be dated using the radioactive minerals they contain.

These rock-forming processes are linked in a dynamic cycle that relates to other key Earth cycles. The water cycle produces the precipitation that plays a key role in weathering and results in the downhill flow of water and ice causing transportation and deposition. The rock cycle and water cycles together contribute to the recycling of the elements and compounds that form the Earth. For example, carbon is cycled through the biosphere, soil, oceans, limestone and fossil fuels. The main energy source for the biosphere and the water cycle is solar radiation whilst the internal part of the rock cycle is driven by the Earth's energy resulting from radioactive decay. A key part of the rock cycle is the plate tectonic cycle.

Source of activity:
Based on the Earth Science Education Unit's KS3 'Dynamic Rock Cycle' workshop.

Rock reference sheet

Hand specimen	Close up
	
Conglomerate - pebble-sized grains cemented/ compressed together – a coarse-grained sedimentary rock.	

Hand specimen	Close up
	
Sandstone – sand-sized grains cemented/compressed together, often with layers (bedding) – a medium-grained sedimentary rock.	

	
Mudstone – mud-sized grains compressed together, often with fine layers (lamination) – a fine-grained sedimentary rock.	

	
Limestone – lime grains cemented/compressed together; lime (calcium carbonate) reacts with dilute acid.	

	
Coal – plant material compressed together – a black sedimentary rock.	

	
Basalt – dark-coloured, fine-grained (too small to be seen) interlocking crystals (dark-coloured crystals are usually rich in iron/magnesium) – a fine-grained, dark-coloured, iron/magnesium-rich igneous rock, often with gas holes.	

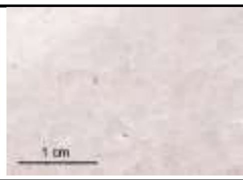
	
Granite – pale-coloured, coarse-grained (clearly visible) interlocking crystals (pale-coloured crystals are usually rich in silicon) – a coarse-grained, pale-coloured, silicon-rich igneous rock	

	
Peridotite – very dark-coloured, coarse-grained (clearly visible) interlocking crystals (dark-coloured crystals are usually rich in iron/magnesium) – a coarse-grained, very dark-coloured, very iron/magnesium-rich igneous rock	

	
Slate – mud-sized (too small to be seen) interlocking crystals parallel with each other; can break into sheets (cleavage) – a fine-grained, low-grade metamorphic rock	

	
Schist – clearly visible interlocking crystals parallel with each other – a medium-grade metamorphic rock	

	
Gneiss – clearly visible interlocking crystals in bands – a high-grade metamorphic rock	

	
Marble – clearly visible interlocking crystals – formed when limestone is metamorphosed; the calcium carbonate crystals react with dilute acid	

Activity 1: Different types of weathering - breaking up or breaking down material at the Earth's surface

(tens to hundreds of years)

Activity:
Investigate three different types of weathering described in the individual activities 1A, 1B and 1C below (the three types covered by the KS3 National Science Curriculum). Be ready to tell the rest of the group about the activities and the results.

Note for pupils:
Weathering loosens solid material and removes dissolved material. If solid material is removed – this is erosion.

Learning objective:
Pupils will: be able to investigate weathering; understand that weathering loosens solid material and removes dissolved material; understand that weathering is distinct from erosion - in which solid material is removed.

Pupil practical or teacher demonstration:
Pupil practicals.

Time needed to complete the activity:
See each activity.

Preparation and set-up time:
See each activity.

Ideas for following up the activities:
Exhibit examples of biological weathering (display/collect your own), e.g.:

- an oyster shell that has been bored (!) by marine organisms (and will not survive much longer in one piece)
- a rock covered by mosses and lichens; this represents the first stages of biochemical weathering of rocks on the Earth's surface. (The growth of tree roots along bedding planes and joints also exert powerful physical forces, which break up rocks)

Source of activities:
Based on the Earth Science Education Unit's KS3 'Dynamic Rock Cycle' workshop.

1A: Weathering - A physical example (heating and cooling)

Activity:

- Carry out a risk assessment (see pages 64 and 65 at the end of this document). Some teachers are happy for pupils to carry out this activity and others are not, and use it as a demonstration instead. Eye protection should be worn by all those within range.
- Heat the corner of a granite chip (15-20mm) strongly in the Bunsen flame and then dunk it into a beaker of cold water (do not drop it to the bottom of the beaker or the glass may crack).
- Repeat the process until grains fall off and it crumbles.

Questions:	***Answers:***
How many cycles were needed?	*Usually 3 or 4.*
How does this represent the 'real world'?	*In deserts, heating during the day, cooling at night).*
Where on Earth might activity like this take place?	*In deserts.*
In what ways is it unrealistic?	*Deserts get nothing like as hot as this.*
Why might you expect a rock containing several minerals to break down by heating and cooling more quickly than one made of only one mineral?	*It is the differential expansion of the different minerals that causes weakening and break-up – there is much less effect in monomineralic rocks.*

Learning objective:
To demonstrate how cycles of heating and cooling can cause a granite chip to break up.

Time needed to complete the activity:
10 minutes

Preparation and set-up time:
5 minutes

Resource list:

- Granite chips (15-20mm)
- Bunsen burner
- Heat proof mat
- Eye protection
- Tongs
- Matches
- 500ml beaker of water

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1B: Weathering - A physical example (freezing and thawing)

Activity:
This activity will have been set up beforehand, as follows:
- Use two shallow plastic containers.
- Get two chips (15-20mm e.g. basalt, granite, limestone, slate, porous sandstone) of several different types of rocks and put one of each rock into each container. Cover each set of rocks with water and put one into a deep freeze.
- When frozen, remove the container from the deep freeze and allow the ice to melt.
- Put it back in the deep freeze and freeze it again, then repeat several times.
- Answer these questions by comparing the two containers (remembering that the rocks in both containers will have been covered by water; one container will have been frozen and thawed several times and the other left at room temperature).

Questions:	***Answers:***
How do the results in the two containers compare?	*The rocks in the frozen/thawed container have broken down more than those in the other*
How do the different rocks compare?	*Some rocks break down faster than others.*
Which types of rock broke down most quickly?	*The permeable ones.*
Can you explain why?	*Water penetrated the pore spaces and, expanded and contracted.*
How does this represent the 'real world'?	*The same occurs naturally [on freezing/thawing]*
Where on Earth might activity like this take place?	*Tops of mountains or areas near ice sheets.*
In what ways is it unrealistic?	*It is pretty realistic.*
Why was a plastic container used and not a glass one?	*Glass could shatter as the water freezes and expands.*

Learning objective:
To demonstrate how water becomes acid as carbon dioxide is added and then to show how this acid reacts with limestone.

Time needed to complete the activity:
Several days, unless a demonstration only is shown.

Preparation and set-up time:
5 minutes

Resource list:
Either:
- Pre-prepared display of different rocks, previously soaked and placed in and out of a freezer

Or:
- 2 small chips (5-7mm) of several different types of rock (some porous, some non-porous e.g. sandstone, limestone
- 2 shallow plastic containers

1C: Weathering - A chemical example

Activity:

- Carry out a risk assessment (see pages 64 and 65 at the end of this document).
- Add some Universal indicator to a small amount (e.g. 2cm depth) of tap water in a drinking glass or small beaker. Record the indicator colour.
- Make some "carbonic acid" by blowing exhaled air through a straw into the tap water. Record the colour of the indicator now.
- Add a spatula full of ground-up limestone to the beaker and stir well.
- Observe the tube at intervals and look for any change in the colour of the indicator.

Questions:	***Answers:***
What has happened?	*Indicator originally neutral-green became acid –yellow, orange or pink.*
Can you explain why?	*Limestone reacted and made it neutral [green again].*
How does this represent the 'real world'?	*Blowing into the water produces 'naturally' acid 'rain'. The 'acid rain' reacts with limestone and a neutralisation reaction occurs.*
Where on Earth might activity like this take place?	*Wherever naturally acid rain falls on limestone.*
In what ways is it unrealistic?	*Limestone usually has larger particles than ground-up limestone.*
Why might some rocks be attacked at a faster rate in industrial areas?	*Industrial pollution adds more acid to rainwater (in addition to more carbon dioxide giving carbonic acid, there can be sulfur dioxide giving sulfuric acid and nitric oxides giving nitric acid).*

Learning objective
To demonstrate how water becomes acid as carbon dioxide is added and then to show how this acid reacts with limestone.

Time needed to complete the activity:
10 minutes

Preparation and set-up time:
15 minutes

Resource list:

- Drinking glass or small beaker, 100ml or 250ml
- Universal indicator
- Drinking straws
- Spatula
- Ground-up limestone (e.g. crushed chalk)
- Tap water

© Pete Johnson

Activity 2: Erosion and transportation - rock resistance

(seconds to tens of years)

Activity:
Investigate rock resistance to find out how rocks erode at different rates and use this to explain the formation of uplands and coastal headlands by the more resistant rock types.

There are many different ways in which rocks are eroded in the natural world. It is not always possible to imitate these different ways in the laboratory. We do not have nearly so much time available either! However, we can try.

Note: These activities are done 'dry', to speed up the process and reduce mess. Use three or four different types of rock such as crumbly sandstone, limestone, granite, slate. Some specimens may be destroyed by the activity. The noisy container shaking need take only 10 seconds. The debris produced by each rock is easier to compare if each type of rock is shaken in a separate container. The provision of a balance allows quantitative comparisons to be made. By using rocks from the local area you can gain insight into the development of the landscape in your home region.

Carry out a risk assessment (see pages 64 and 65 at the end of this document).

Before your group does these investigations, think how you can improve them from these outlines to get the most useful information. How can you set up some sort of control, so that you can compare the results with the original rock samples?

Investigation A: Test how much each rock is affected by being bashed against rocks of the same type and other rocks. Use a plastic container. Warn pupils not to inhale the dust when the lid of the container is removed.

Investigation B: Test how much each rock can resist being worn away, using a file and/or emery paper.

Questions:	***Answers:***
Which rocks did you find were the most resistant?	*Those with interlocking crystals, igneous and metamorphic.*
Where on Earth might these processes be occurring naturally?	*In fast-flowing rivers or on wave-pounded beaches.*
How could these simulations of natural processes be made more realistic?	*Add water.*
Which rocks are most likely to form hills or headlands in coastal areas?	*The toughest ones.*

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Pupil learning outcomes:
Through these activities, pupils come to realise that some rocks resist erosion more than others. The more resistant rocks will then form upland areas and coastal headlands, whereas the more easily eroded rocks form valleys and bays.

The eroded materials are transported away by gravity, water, wind or ice and will eventually become deposited in an accumulation of sediment which may become a sedimentary rock.

Pupil practical or teacher demonstration:
Pupil practical.

Time needed to complete the activity:
30 minutes.

Preparation and set-up time:
15 minutes.

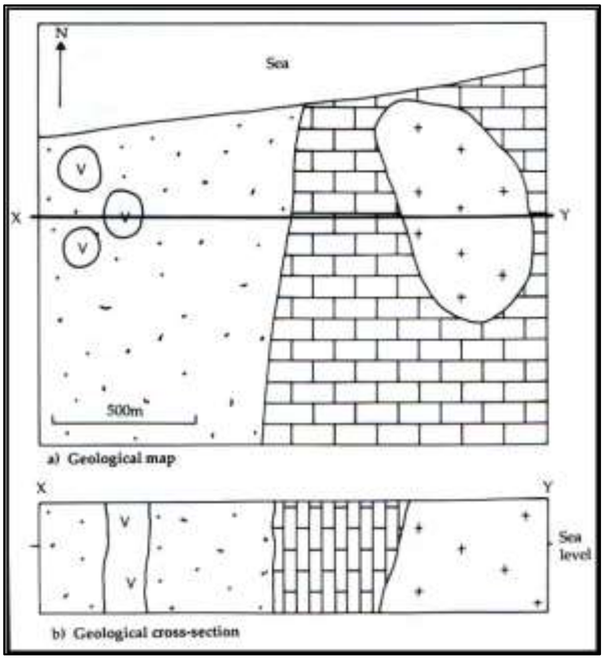
Resources:

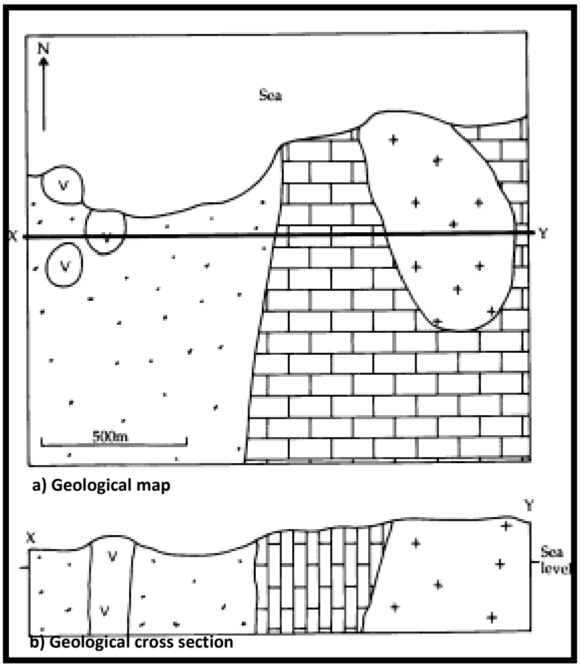
- Expendable rock specimens, 4 x 25g (approx) pieces of each rock are needed, such as:
  - crumbly sandstone (sedimentary)
  - limestone (sedimentary)
  - granite (igneous)
  - slate (metamorphic).

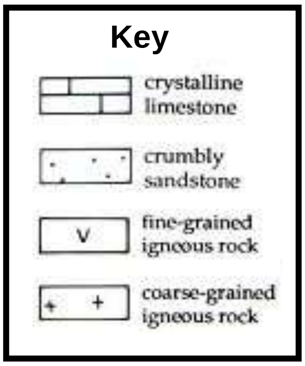
  An alternative is to use locally available rocks of variable resistance.
- Two plastic containers with wide necks and tops
- Mechanic's file
- Emery paper
- Eye protection
- Electronic balance
- Tray

Ideas for following up the activity:
Relate the results to geological maps and cross sections of a mythical area seen with a straight coastline and a flat land surface before erosion, and with headlands/bays, hills/valleys after erosion (e.g. 10,000 years later).

Repeat the activity using rocks from the local area. Relate the resistance of each rock type to the local relief (hills and valleys: headlands and bays).







Learning objective:
To investigate the relative rates of erosion of rocks by attrition and by chemical action.

Source:
This activity is based on ESTA's "Moulding Earth's Surface – Landshaping" in "The Science of the Earth 11-14" series.

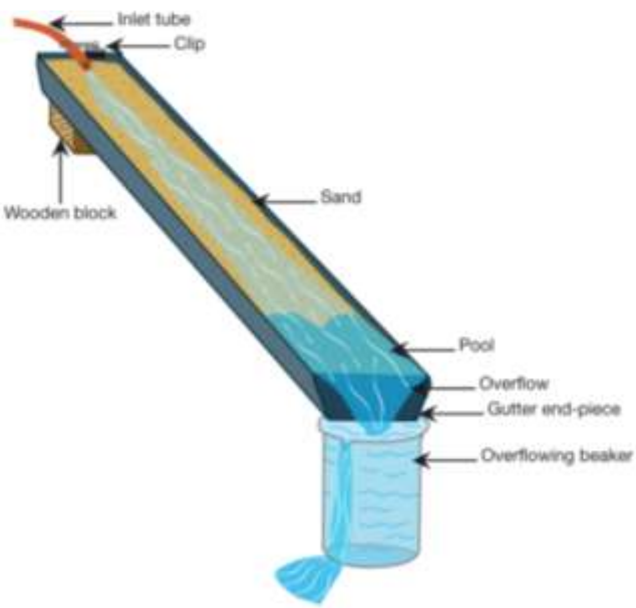
Activity 3: Deposition - the movement of sand in flowing water

(seconds to thousands of years)

Activity:
Investigate the processes by which sediment grains are eroded, transported and deposited by flowing water, in the lab. See 'Further notes' about moving water on the next page for more guidance on these processes.

Set up the apparatus as shown below and turn on the tap gently. It is very important to experiment with this apparatus in advance of your lesson.

Ask pupils to be ready to tell the rest of the group about the investigation and their results.



Observations and Questions:	***Answers:***
If you are the first to use the apparatus, notice what happens to the water as it fills up the gutter.	*The water becomes absorbed in the sand until it is saturated – it then flows over the surface.*
Once it is running uniformly, look carefully for places where *erosion* is taking place. How is the sand being moved at these spots?	*From the plunge pool at the top and on the channel beds and margins.*
Study where the sand is being moved along the bed. This is known as "*transportation*" of the sediment. Exactly *how* is it being moved?	*By rolling, sliding and bouncing along the channel floors.*
Find places where *deposition* is taking place.	*On the insides of braided channels and in the microdelta in the pool at the end.*
Are the newly formed layers of sediment horizontal or inclined?	*Inclined at around* 20^{O}.
How do they build out into the pool at the end of the gutter?	*As a series of sloping layers.*
Try changing the flow rate and discuss any differences you spot.	*Everything moves and develops at a faster rate.*
Try adding a few pieces of gravel and study the flow around them.	*Often upstream scour and downstream deposition shadows can be seen.*
When you have finished, try to match the gutter work to modern sedimentary environments and rock specimens. Would your investigations enable you to say which way former currents flowed?	*The downward sloping layers in the microdelta in the pool slope in the direction of flow. Cross bedding in ancient sandstones is the preservation of these layers and slopes [downward] in the ancient palaeocurrent direction.*

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Pupil learning outcomes:

- Moving water can pick up and move bits of rock/dead organic material (sediment).
- Real sedimentary processes are being investigated in the lab – sediment grains are visibly eroded, transported and deposited in different ways.
- Small scale braided channels form and a micro-delta builds into a pool.
- The study of the gutter experiment can be extended by considering it as a simulation of a river/sea situation, where a 'river' and 'delta' are formed.

Resources:

- 1m length of guttering (square section guttering is preferred) with two end pieces
- Washed sand to fill the gutter to within 2cm of the top
- Rubber tubing to connect to a lab tap
- Clip (to fix the tubing to the gutter)
- Container such as a large beaker to put in the sink to catch any sediment washed over the end of the gutter – preventing it from blocking the sink
- Small pieces of gravel (approx 50g)

Extension ideas for more able or faster pupils:

The gutter provides scope for several investigations into the ways in which sediment is moved in water.

Further notes:

Moving water: what exactly are we observing?

Moving water can move more than just the things that float in it, or are dissolved in it. It also has a dragging effect which can pick up and move solids that wouldn't float in standing water. Therefore, it can shift sediment (bits of rock or dead things). The faster the water is flowing, the more energy it has. It can then move more material and larger pieces. When it flows more slowly or stops flowing, this material sinks to the bottom again. It is said to be deposited.

What is so important about this?

There are lots of reasons why these processes are important. The material that rivers move is responsible for the erosion they do, which creates high and low areas by cutting down through the Earth's surface. Huge amounts of topsoil vital to agriculture can be washed off the land, and gullies can be cut through fields, both making it harder to grow food. The material is spread out and dropped when rivers flood beyond their banks, creating the flat floodplains upon which many of our cities and farms are to be found. The material is also spread out and dropped when rivers reach the sea and slow down, creating the fertile deltas upon which millions of people live. The material is dropped when rivers slow down in dams, building up behind the wall and reducing the amount of water that can be stored in the dam. It can build up in harbours and estuaries making them too shallow or treacherous to navigate. It can be dropped in river beds when the river is flowing very slowly, making the river shallower and increasing the risk of flooding. And much of this material – mostly sand and gravel – can be dug up and used as a very important building resource.

Source of activity:

This activity is based on ESTA's "Second-hand Rocks" in "The Science of the Earth 11-14" series.

Activity 4: Compaction and cementation - sediments into rocks

(hundreds to millions of years)

Activity:

Carry out a risk assessment (see pages 64 and 65 at the end of this document).

All sediment was once loose. To become rock, the grains need to be squeezed together (compacted) and/or glued together (cemented). The amount of the compaction and the strength of the cementation affect the properties of sedimentary rocks.

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Try this exercise to see how sand can become sandstone. **HINT - don't overdo the water!** Use a plastic cup for all mixing, before inserting the mixture into the syringe.

1. Put some damp sand in a syringe which has had the nozzle cut off
2. Put the open end of the syringe on the palm of your hand and press the plunger in hard.
3. Carefully push the sand pellet out of the syringe onto a piece of paper, label it and leave it on one side.
4. Mix three parts of damp sand with one part clay.
5. Repeat steps 1, 2 and 3 using the sand/clay mix instead of the sand.
6. Repeat the same three steps but this time use a mix of five parts of damp sand and one part of plaster of Paris powder.
7. Leave your "rocks" to dry.
8. Which of the pellets is most like a rock?
9. Plan an investigation which will give you evidence to show which is most rock-like.
10. Carry out your investigation.

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Questions:

- Do your results support your conclusion?
- How could you improve your investigation if you could do it again?
- Do you think that sandstone can be formed from sand by pressure alone?
- Be ready to tell the rest of the group about the investigations and your results.

The compaction of sand and mud can be modelled with coins and matchsticks, respectively, which can be 'compressed' between two pieces of wood.

Pupil learning outcomes:

- The extent of compaction depends upon the type of sediment.
- Little compaction takes place when sand is converted to sandstone.
- In muds and clays, water may initially comprise 80% by volume of the sediment; a great deal of compaction takes place when this is squeezed out.
- Sands become sandstones when natural cement crystallises in the pore spaces. The natural cement is formed from new minerals that crystallise from circulating waters.

Resources:

- 2 plastic syringes (20cm^3), with the nozzle cut off at the end of the barrel
- Tray
- Eye protection
- Disposable cups
- Plastic spoons
- Water dropper
- 250g of dry sand
- 10g of powdered clay
- 10g of plaster of Paris powder
- Water
- Apparatus for testing strength of the pellets, e.g. file, variety of masses, heavy ball-bearings

Notes:
Do not let pupils pour plaster of Paris down the sink.
There is no significant hazard with the use of small quantities of plaster of Paris.

Source of activity:
This activity is based on ESTA's "Second-hand Rocks" in the "Science of the Earth 11-14" series.

Activity 5: Metamorphism - detecting the distortion

(millions of years – during mountain building)

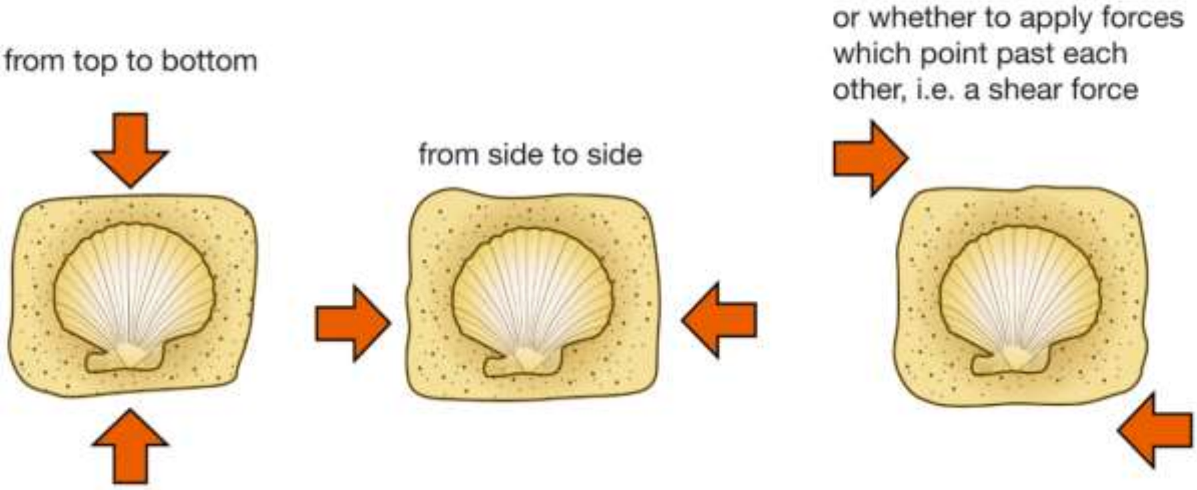
Activity:
These activities simulate the effects of pressure in forming metamorphic rocks.

Metamorphic rocks are formed by the action of heat and increased force on the original rocks. These activities concentrate on the effects of force acting on an original sedimentary rock. If the force is intense enough and acts for a long time, the rock recrystallises (without melting). Some of the new minerals are platy in shape and become aligned at right angles to the main force. This produces new planes along which the rock will split, in preference to the original bedding planes. The new alignment planes, called cleavage planes, are made use of when slate is split for roofing materials. More intense metamorphism will destroy the fossils and form coarser-grained metamorphic rocks.

5A – Squashed 'fossils'
Carry out a risk assessment (see pages 64 and 65 at the end of this document).
Work in small groups to make a squashed 'fossil', but do not show other groups what you are doing.

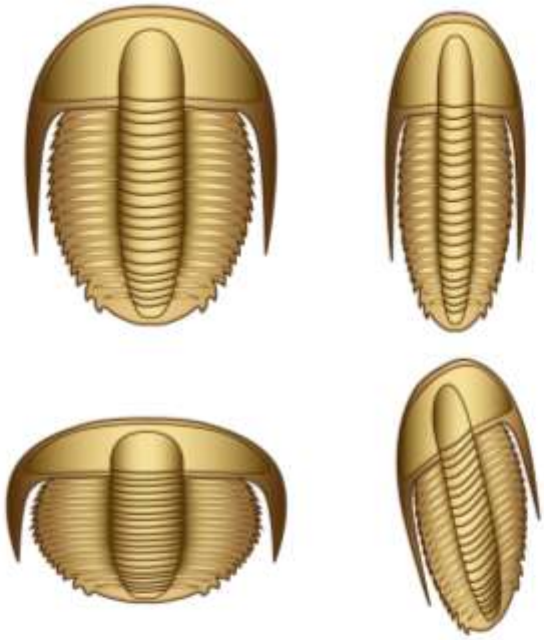
- Soften the modelling clay.
- Make a mould by pressing the outside of a shell carefully into the clay. Remember to make a rim to contain the plaster.
- Carefully remove the shell, to leave the imprint in the clay.
- Squeeze the mould so as to change the shape of the shell imprint as shown in the picture below. First choose whether to squeeze it from top to bottom, from side to side, or whether to apply forces as shown in the third picture, i.e. shear forces. Whichever you choose do not distort the shape too much. Remember how you squeezed the mould, it will be important later.
  Mix up some plaster in a disposable cup by placing less than 1cm of water in the cup and stirring in enough plaster to make a runny cream.
- Pour the plaster into the distorted mould and leave it to set for a few minutes.
- Leave any remaining plaster to set in the cup. Wash the stirring rod or plastic spoon.
- When your plaster fossils have set, scratch your initials on the base and then carefully take your fossil cast out of the mould.
- Pass your fossil to another group. See if they can work out the directions of the forces which you used to distort the fossil.
- Do the same for theirs. Did you get it right?
- How could the **same** distortion have been produced by forces acting in **different** directions?

Decide whether to apply forces:



'Distortion'
© originally from The Earth Science Teachers' Association, Metamorphism - 'Under Pressure' from ESTA, *Science of the Earth 11 - 14, Hidden Changes in the Earth,* redrawn by ESEU

Study each of the drawings below. They show several trilobites found in slates. The top left is an undistorted trilobite; the trilobites in the other pictures have been distorted by forces in the Earth.



© Chris King, redrawn by ESEU

Questions:	***Answers:***
These fossils have been distorted by moderate forces which have changed the rock from a mudstone to a slate. What would happen to the fossils if the forces had been much greater?	*They would have been destroyed.*
By about how much has each trilobite been squeezed? By about how much have the surrounding rocks been squeezed? By about how much has the region in which the rocks are found been squeezed? How might this scale of deformation have been caused?	*If the trilobite has been compressed by a quarter, so have the surrounding rock and the region.* *The only 'vice' big enough and powerful enough to cause distortion on this scale is the 'vice' of two colliding continents, moved by plate tectonic forces.*

N.B. Fossils may be found in low grade metamorphic rocks, as well as in sedimentary rocks.

5B – Squashed 'spaghetti rock'

Take about twenty short pieces of spaghetti, used matchsticks, or something similar, to represent the flaky minerals in a rock like a mudstone. Drop them onto a table so that they scatter randomly. Then use two school rulers, bringing them slowly together, 'compressing' the pieces of spaghetti between them; the pieces tend to line up parallel to the rulers. This shows the way in which the flaky minerals become aligned as they recrystallise under intense sideways pressure in the Earth, to produce a slate. Use another ruler to 'split' the aligned pieces down the middle, like the way in which a slate may be evenly cleaved.

© Peter Kennett

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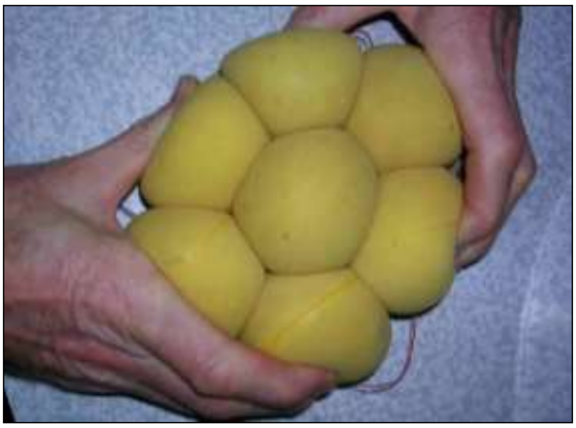
5C Squashed spheres

Take seven soft spherical objects, such as marshmallows or foam tennis balls, and place them on a table so that they are touching each other. This is like the grains of sand in a sandstone, or the grains of calcite in a limestone. Now squeeze the balls together, until there is no space between them.

They will form roughly hexagonal shapes, representing the texture of a quartzite rock [from sandstone] or a marble [from limestone], where the original minerals have recrystallised under greatly increased pressure in the Earth.

© Peter Kennett



© Peter Kennett

Pupil learning outcomes:

- Many metamorphic rocks, such as slate, are formed deep below ground, under great pressure, mostly lateral pressure.
- They sometimes contain fossils which have been badly squashed.
- The result of the squashing gives clues about the directions of the forces which squeezed the rocks.

Pupil practical or teacher demonstration:
Pupil practical.

Time needed to complete the activity:
30 minutes.

Preparation and set-up time:
15 minutes.

Resources:

5A

- About 20 short (eg 4 cm long) pieces of spaghetti or used matchsticks
- 2 x 30 cm rulers (or similar strips of wood)

5B

- 7 x marshmallows or soft foam balls

5C

- Plasticine™, modelling clay or similar
- Several cockleshells or similar shells
- 50g of plaster of Paris powder
- Disposable cups
- Plastic teaspoons or stirring rod
- Water

Note: Do not let pupils pour plaster of Paris down the sink.

Ideas for leading into the activity:
Metamorphic rocks are formed by the action of heat and increased force on the original rocks. This activity concentrates on the effects of force acting on an original sedimentary rock. If the force is intense enough and acts for a long time, the rock recrystallises (without melting) and any fossils become distorted. Some of the new minerals that form are platy in shape and become aligned at right angles to the main force. This produces new planes along which the rock will split, in preference to the original bedding planes. The new alignment planes, called cleavage planes, are made use of when slate is split for roofing materials. More intense metamorphism will destroy the fossils and form coarser-grained metamorphic rocks.

Source of activity:
These activities are based on ESTA's "Hidden Changes in the Earth" in "The Science of the Earth 11-14" series.

Activity 6: Crystallisation
- fast or slow cooling, large or small crystals

(Extrusive – seconds to weeks; Intrusive - thousands to millions of years)

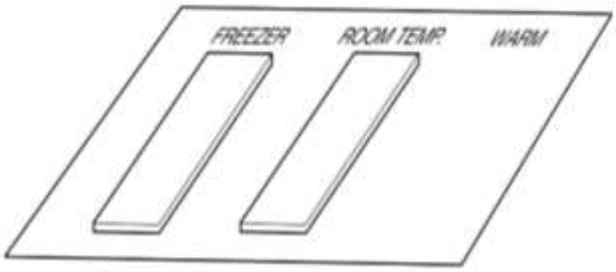
Activity:

Carry out a risk assessment (see pages 64 and 65 at the end of this document).

We can find out why the crystals in igneous rocks have different sizes through simulating the growth of crystals from magma by growing crystals from a melt in the laboratory. You are using Salol, which melts at 42°C.

Begin melting some Salol in a boiling tube in a water bath (don't overheat it or it will supercool and will not crystallise easily!)

Take a piece of dark-coloured paper and label it as shown below. Put a microscope slide on the 'room temperature' part of the paper.



Ask for a pair of microscope slides chilled in a freezer and put one on the dark-coloured paper (make sure you have started heating the Salol before asking for the cold slides or they will warm up). Take a stirring rod with some melted Salol from a water bath and quickly put a few drops on the slide from the freezer and on the one at room temperature. Place slides of the same temperature on top. Watch what happens.

Answer the following questions:

	Answers:
On which slide did crystals form first?	*Coolest*
On which slide did crystals grow fastest?	*Coolest*
On which slide did the largest crystals form?	*Warmest*

If you had warm slides, would you expect the crystals:

	Answers:
to form straight away or after some time?	*After sometime*
to grow quickly or slowly?	*Slowly*
to be large crystals or small crystals?	*Large*

Write down your predictions.

Test your ideas by warming two slides in a beaker of warm water, or on a warm hot plate. Put one on the paper; add liquid Salol as soon as you can; put the second slide on top and watch carefully.

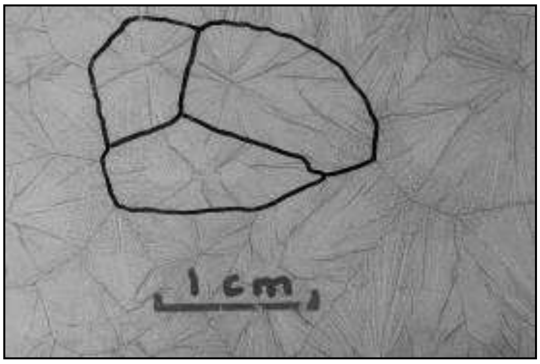
Were you right?

Now apply your ideas. Some igneous rocks are made of large crystals:

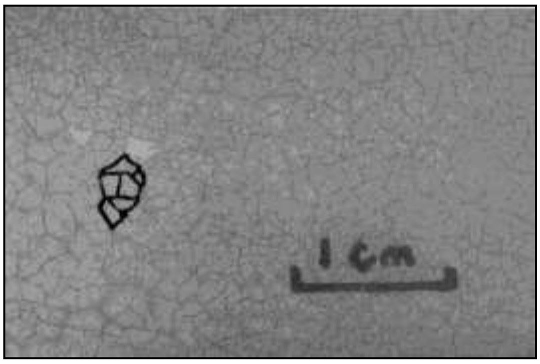
	Answers:
Did they cool slowly or quickly?	*Slowly*
At what rate did fine-grained igneous rocks cool?	*Quickly*

Some igneous rocks melt and crystallise deep within the crust, whereas others come to the surface in volcanoes. Which of the resulting igneous rocks will have the smallest crystals? *(Surface ones)*

Be ready to tell the rest of the group about the activity and your results.



'Salol cooled slowly on a warm slide'
© Peter Kennett



'Salol cooled quickly on a cold slide'
© Peter Kennett

Pupil learning outcomes:

- Many kilometres below the surface of the Earth the temperature is high enough to cause partial melting. The magma produced rises upwards because it is less dense than the overlying rocks.
- Crystallisation may take place within intrusions at different levels of the crust or at the surface, if extrusion takes place.
- Intrusions may subsequently be exposed at the surface by weathering and erosion processes.
- Igneous rocks form from melts which may exceed 1000^{O}C. This activity models the behaviour of a cooling magma, but at a much lower temperature (around 40 ˚C).
- There is a link between cooling rates and the sizes of crystals produced.
- The largest crystals of Salol are formed from the slowest cooling melt.
- Pupils will discover a link between cooling rates and the sizes of crystals that are produced.
- Coarse-grained rocks, like granite, are formed by slow cooling at depth, whereas volcanic rocks formed by cooling much more quickly at the Earth's surface, like basalt, are fine-grained.
- Igneous rocks are classified according to their mineral content as well as their crystal size.

Pupil practical or teacher demonstration:
Pupil practical.

Time needed to complete the activity:
40 minutes.

Preparation and set-up time:
15 minutes.

Resources:

- Salol (phenyl–2–hydroxybenzoate), approximately 5g
- Boiling tube
- 250ml beaker
- 6 microscope slides (plus some spares)
- Stirring rod
- Eye protection
- Hand lens
- Hot water (e.g. from a kettle)
- Access to a freezer
- Sheet of dark-coloured A4 card or paper
- Samples of igneous rocks of various grain sizes (e.g. granite, gabbro, basalt)

Ideas for following up the activity:
The Salol crystals provide an insight into the size of crystals as a function of cooling, but they misrepresent real rock textures. Igneous rocks typically contain several minerals which crystallise at different times and rates and so have different sizes. Pupils could examine specimens of igneous rock, preferably with polished surfaces, to observe the size, shape and relationships between crystals.

Experimental modelling of the crystallisation of two chemicals may be demonstrated by dissolving equal quantities of copper sulphate and potassium nitrate in warm dilute sulphuric acid. The solution is cooled and poured into a watch glass to crystallize.

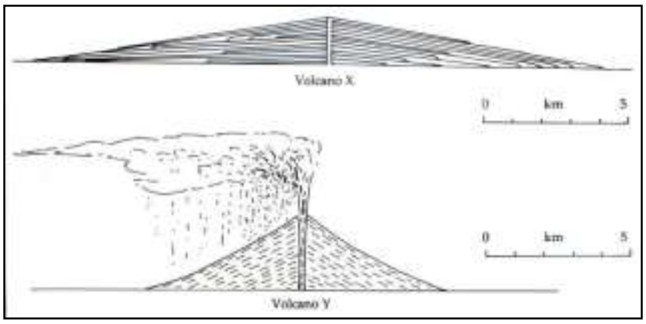
Source of activity:
This activity is based on the Earth Science Teachers' Association's (1991) 'Magma - Introducing Igneous Processes' in 'The Science of the Earth 11-14' series, published by Geo Supplies, Sheffield.

Activity 7: Extrusion
- Igneous rocks 'in the laboratory'
(seconds to weeks)

Activity:
Carry out a risk assessment (see pages 64 and 65 at the end of this document).

Treacle is a liquid, like lava, and the runniness of both of these liquids can be changed in similar ways. So we can carry out laboratory experiments on treacle and then use these to understand how lava flows along.

- Plan a treacle investigation using the sheets at the end of this activity.
- Carry out your investigation by following your plan. Be sure to clean up afterwards.
- Do not forget to record your results and to plot them on a graph.
- Write down what your investigation showed.
- Were your first ideas right or wrong?
- Could your investigation have been better? How?
- How could your investigation be used to explain the shapes of the volcanoes in the diagrams below?
- Be ready to tell the rest of the group about your investigation and your results.



© Earth Science Teachers' Association (ESTA)

Pupil learning outcomes:
- The viscosity of a liquid can be changed in a variety of ways.
- The laboratory behaviour of treacle is used to model the characteristics of lava.
- Evidence of the gas content is preserved as 'bubbles' in some lavas like pumice; others preserve larger crystals in finer-grained background material.
- The eruptive behaviour of molten rock gives rise to a variety of volcano types and extrusive igneous rocks.

Pupil practical or teacher demonstration:
Pupil practical.

Time needed to complete the activity:
40 minutes.

Preparation and set-up time:
15 minutes.

Resources:
- Treacle or syrup

Items requested by pupils may include:
- Bunsen burner, tripod and gauze (or hot water bath)
- Heat proof mat
- 4 x Spatulas or teaspoons
- 2 x Glass stirring rods
- 2 x Sets of tongs
- 6 x Boiling tubes with bungs
- 2 x Boiling tube racks
- Stopclock or watch
- Thermometer
- Washed sand (small amount – e.g. half a cupful)
- Stand with clamp and boss
- Eye protection
- Petri dishes or tiles with 'props' to allow tilting
- Ruler
- Hot soapy water
- Test tube brushes and cloths

Note: The least messy way of doing this investigation is if pupils retain the treacle in the boiling tube throughout, by inserting a bung before tipping the tube.

Further Notes:

Eruption controlled by the viscosity of magma

Pupils will discover that the viscosity of a liquid can be changed in a variety of ways. The laboratory behaviour of treacle is used to model the characteristics of lava. The violence of volcanic eruptions and the resulting products are shown to be related to the viscosity of the lava. The viscosity of lava and treacle is modified by changes in: temperature; gas content; water content; concentration of solids, e.g. crystals in lava, sand in treacle

Evidence of the gas content is preserved as 'bubbles' in some lavas like pumice; others preserve larger crystals in finer grained background material. Lava viscosity also depends upon the chemical composition of the melt, but this cannot be simulated easily using treacle.

The eruptive behaviour of molten rock gives rise to a variety of volcano types and extrusive igneous rocks. Differences in the nature of the original magma and subsequent changes as it rises towards the surface, influence the type of lava erupted. Lava viscosity has a controlling influence on the character of eruptions and the types of volcanoes produced. Low viscosity lavas flow freely from volcanoes to form flat sheets of lava which can cover large areas.

As the lava degasses, fire fountains can be produced and you can go and watch or film these as the eruptions are fairly safe. These volcanoes have shallow slopes of 10° or less. High viscosity magmas may just be squeezed out of a vent, but often they solidify in the mouth of a volcano. Then the force steadily increases until a catastrophic eruption blasts large blocks of lava and huge volumes of ash into the sky. These fall back to Earth producing steep-sided cones with slopes of around 30°. Stay well away from this type of eruption.

SCIENTIFIC ACCURACY

- *Whilst the treacle model of magma correctly shows that the temperature of the magma, the amount of crystals it contains and its water/gas content (as well as its composition), all play key roles in how explosive eruptions are…*
- *…water content has the opposite effect of that shown by the treacle model.*
- *For complex reasons, the more water a volcanic magma contains, the more explosive it becomes.*

Source of activity:

This activity is based on the Earth Science Teachers' Association's (1991) 'Magma' in 'The Science of the Earth 11-14' series, published by Geo Supplies, Sheffield.

LAVA IN THE LABORATORY: PLAN A TREACLE INVESTIGATION

Changing the 'runniness' of treacle

I think I can change the runniness of the treacle by:

(a) making it more runny (two or more ways)

....

....

(b) making it less runny (at least one way)

....

....

My 'runniness' investigation

In my investigation, I am going to make the treacle more/less runny by:

....

....

I plan to change the 'runniness' in steps by:

....

....

I plan to find out how runny the treacle is at each step by:

....

....

I will need the following apparatus and materials (use only the apparatus and materials available in the laboratory):

....

....

LAVA IN THE LABORATORY: PLAN A TREACLE INVESTIGATION

When the apparatus to test the runniness of the treacle is set up, it will look like this:

I will plot the results of my investigation in a table like this:

I will use the results from the table to plot a graph like this:

I think my results will show that:

....

....

....

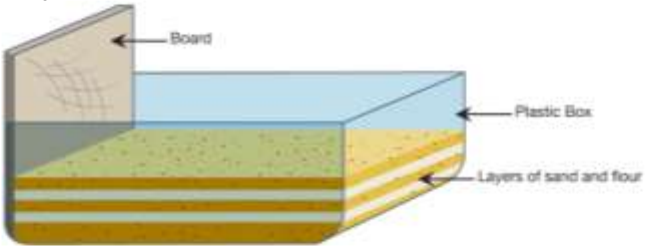
Source:
This activity is based on ESTA's "Magma" in "The Science of the Earth 11-14" series.

Activity 8: Deformation
- make your own folds and faults

(seconds [faulting] to millions of years [folding, faulting, metamorphism during mountain building])

Activity:
This activity shows how folded and faulted rocks can provide evidence of the size and direction of the forces which produced the deformation.

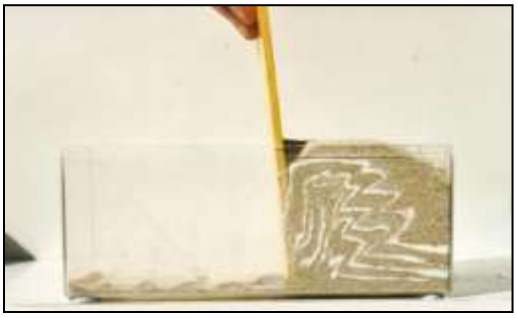
When forces are applied to solid materials they may bend or break. When sands or sandstones bend, folds are produced; when they break, faults are formed.



© ESEU

Find out what types of folds and faults are produced by compression by following these instructions.

- Place the board vertically inside one end of the box.
- Build up several thin layers of flour and sand. Do not fill it more than half-full. (Only thin layers of flour are needed, sprinkled along the front of the box alone, in order to save flour and to allow the materials to be reused several times.)
- Very carefully, push the vertical board across the box, so that it begins to compress the layers.
- When you notice the layers beginning to bend, stop pushing the board.
- Hold the board upright and draw a scaled diagram of the result.
- Continue pushing the layers with the board until the sand is about to overflow the box.
- Hold the board upright and draw a scaled diagram of the result.
- Then add arrows to your diagram to show the directions of the forces which were acting whilst you compressed the layers with the board.
- Are the layers still horizontal, or are they folded?
- Did one set of layers slide over the rest? If you have been careful, you will have produced a fault in which layers of rock are pushed up and over other layers. These types of faults are often nearly horizontal.
- How could you use the same apparatus to find out what happens when sands and sandstones are stretched (put under tension)?
- Be ready to tell the rest of the group about the activity and your results.



© Chris King, ESEU

Pupil learning outcomes:

- Rocks experience enormous pushing and pulling forces because continents move around, jostling each other.
- These forces can bend (fold) rocks or snap them along a fault, or both.

Further Notes:

Rock deformation

Rocks frequently become fractured during their history, but school laboratory investigations on real rocks are difficult to carry out with any finesse. The activity described uses layers of fine sand and flour which behave like layers of rock.

Pupils should appreciate that faulted rocks at the Earth's surface contain clues about the ancient pressures which deformed them.

The near-horizontal faults produced by compressional pressures are called thrust faults (more steeply inclined faults are produced by tensional stresses and these can be formed in the same transparent box as in Activity 8, by putting the vertical board in the centre of the box, filling one side with sand and flour as before and moving the board gently away).

Large scale pressures acting within the lithosphere are caused by plate tectonic movements. Where plates are converging, the compressional stresses produce near horizontal thrust faulting. Where plates diverge, the tensional stresses produce steeper faults, called normal faults.

Pupil practical or teacher demonstration:
Pupil practical.

Time needed to complete the activity:
10 minutes.

Preparation and set-up time:
10 minutes.

Resources:
Per pupil / pair / small group:

- Empty clear plastic box (e.g. Ferrero-Rocher chocolate box - not the 'tray' variety)
- About 500g of dry sand
- About 25g of flour
- Spatula or dessert spoon
- Eraser or similar flat object (for tamping down the sand/flour)
- Piece of board or plastic to snugly fit into the box
- Tray for tipping out sand

Ideas for leading into the activity:
Show the photograph of some rocks which have been folded or faulted. Explore how everyday things get folded or broken.

Demonstrate with the bars of toffee if available how forces can bend or snap things. Try to show that you are effectively using pushing forces from the sides – a kind of squeezing.

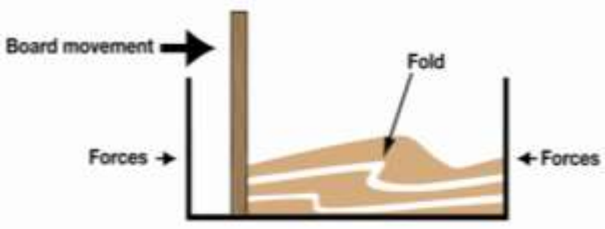
Ask pupils to apply forces to either side of a piece of paper to show folding. We are focusing on the idea of pushing forces being applied towards each other (i.e. compression).

Ask if they can fold a lump of rock by pushing from the sides. Why can't they do it?
Not strong enough; the rock is too brittle.

Explain that, several kilometres deep in the crust, the rock is hot - but not hot enough to melt. Like the warm toffee, rock in this state becomes more "bendy" and can be folded before it breaks. Folded rocks like the ones in the pictures tell us that, at some time in the past, they have been a few kilometres below the surface and have been slowly squeezed by sideways pressures.

Explain that we are going to simulate folds and faults using sand and flour as our 'rocks' because we only have tiny forces available to us in the classroom.

Concluding discussion:
Display again the picture of the folded rock. Does it look like what is in the squeeze boxes? Some diagrams of what might be expected are shown below.



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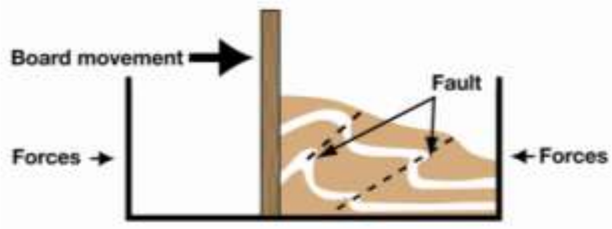
This is a sideways view of a squeeze-box after the sliding board has been moved a short distance to the right.



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This is a sideways view of a squeeze-box after the sliding board has been moved a longer distance to the right.

Further notes:

How can rocks be folded?

Continents are moved slowly across the surface of the globe by plate tectonic forces. When continents meet each other, enormous forces are produced, even though they are moving very slowly. These forces can be "pushing" or "pulling" forces. They can slowly fold solid rock if it is warm enough. To be warm enough, it must be deep in the crust - several kilometres down, but not far enough to be melted. It is a bit like toffee. If you try to bend it, it will snap if it is cold or bend (fold) if it is warmer. This is a useful demonstration or experiment in its own right, with lots of potential for fair testing and recording results using different variables.

What happens when rocks don't fold?

If the pressure is applied too quickly, or is too great, or the rock isn't warm enough, then the rock will not fold but will break like any other brittle solid. The line of the break is called a fault. The pressure is still on the two sides of the fault so the bits of rock usually start sliding slowly past each other. The initial movement – the break – causes shockwaves in the surrounding rocks and creates an earthquake.

What's the difference between deformed rocks and metamorphic rocks?

Where heat and pressure cause the rock itself to change, it changes to a metamorphic rock. Where the rock stays the same but its bulk is bent (folded) or snapped (faulted) then this is deformation. Often they occur together.

'Folded rocks' Isle of Arran, Strathclyde and Ayrshire Area © Lorne Gill/SNH

Folded layer in a Shetland boulder © Peter Craig

'Recumbent fold', Crackington © Peter Kennett

A normal fault in Precambrian rocks near Manila, Utah © Bruce Molnia, image courtesy Earth Science World Image Bank (www.earthscienceworld.org/images)

Aerial view of the San Andreas Fault © U.S. Geological Survey/photo by Scott Haefner

Aerial view of rock strata offset by fault line, **Southern Nevada** © Marli Bryant Miller, marlimillerphoto.com

The science of simulation, again

Once again, we are talking about time scales and spatial scales and forces that can't be brought into the classroom or the laboratory. So our scientific way of investigating how these forces affect rock is simulation. The simulation in this activity is designed to investigate pushing (compressional) forces. It is useful for pupils to understand why science sometimes needs to use a simulation. There is no choice. It is real science, not just a way of demonstrating for teaching purposes.

The imaginative leaps, again

In this activity the teacher is again faced with the challenge of helping pupils over imaginative leaps. The activity needs to be thought of as taking millions of years. It needs to be considered in the context of solid rock, not sand and flour. And it needs to be thought of as often happening over areas of hundreds or thousands of kilometres. The geological map and pictures of deformed rock will help. But both the picture and the map are abstract things. They are also snapshots in time – you don't 'see' forces in either. There is a challenge to help pupils to understand what the simulation is showing before its usefulness as a teaching aid can be realised.

The results

The near-horizontal faults produced by compressional pressures are called thrust faults, meanwhile the whole deformational effect is of a series of chevron folds.

Angular fold within thinly-bedded sedimentary rocks, Arkansas Novaculite
© Earth Sciences Department,
University of Arkansas at Little Rock

Using the box to simulate the effects of tensional forces

More steeply inclined faults are produced by tensional stresses and these can be formed in the same transparent box, by putting the vertical board in the centre of the box, filling one side with sand and flour as before and moving the board gently away.

© Peter Kennett, ESEU

A steeply-inclined normal fault
– formed by tensional forces pulling apart the rock mass, allowing the rocks on the right to slide downwards. Orgreave opencast site, South Yorkshire.
© Peter Kennett, ESEU

Source of activity:

This activity is based on the Earth Science Teachers' Association's (1991) 'Earth's Surface Features' in 'The Science of the Earth 11-14' series, published by Geo Supplies, Sheffield.

Plenary activities: Rock cycle simulations in wax

Plenary activity I: The rock cycle in wax

Activity:
Carry out a risk assessment (see pages 64 and 65 at the end of this document).

When you have taught about the rock cycle, revisit and revise it with your pupils using a candle, as follows. After each demonstration, ask: What rock cycle process does this represent?

	Answers:
Grate fragments off the candle using a cheese grater (or scrape them off with a sharp metal object).	*Erosion*
Allow the pieces to fall down onto a piece of paper.	*Transportation (by gravity)*
The pieces build up on the piece of paper.	*Deposition*
Press down on the pile of candle wax fragments with the palm of your hand, saying that this would happen to the sediments at the bottom as more sediments pile up on top	*Compaction*
Holding your hands vertical, move them together to compress the candle wax fragments into a ridge of wax.	*Metamorphism*
Warm the base of the candle with a match and point out the liquid wax.	*Melting*
Let the liquid wax fall onto paper and solidify	*'Crystallisation'*
Ask which rock cycle processes this simple model can't demonstrate.	*Weathering, cementation, rising, extrusion, uplift.*

Red candles © loyna

Cheese grater © Emj

A box of matches
© Oxfordian Kissuth

Pupil learning Outcomes
Pupils can:
- describe the major rock cycle processes;
- explain how they are linked together through the rock cycle;
- link simple practical demonstrations to an abstract model.

Pupil practical or teacher demonstration
Teacher demonstration.

Time needed to complete activity
10 minutes.

Preparation and set up time
None.

Resource List
- Candle
- Cheese grater or knife or other metal object to scrape off wax fragments (about two dessertspoons full)
- Piece of paper
- Matches

Extension ideas for more able or faster pupils:
Ask pupils how some of the rock cycle processes that cannot be demonstrated using a candle, could be demonstrated in other ways. Some can be shown by the 'Wax volcano' demonstration, Plenary Activity II overleaf.

Ask pupils what energy sources drive the rock cycle processes – most of the external processes are driven by solar energy, largely through the water cycle, whereas most internal processes are driven by the Earth's energy (largely from radioactive decay) through plate tectonic processes.

Further notes:
- **weathering** is the break-up or break down of rocks in place (*in situ*) in which no solid material is moved away, by chemical, physical or biological activity - it cannot be demonstrated using the candle;
- **erosion** is the removal of material by the action of gravity, water, wind or ice – the candle demonstrates removal of wax fragments by physical activity (abrasion) and their falling away through gravity;
- **transportation** is the movement of fragments by gravity, water, wind or ice until they are deposited – the candle demonstration shows transportation downwards by gravity;
- **deposition** is the laying down of material – shown here by the build-up of wax fragments on the paper beneath;
- **compaction** is the compression of sediments by the weight of the deposited material above; compression alone can cause muds to become mudstones – it is shown here using the palm of the hand;
- **metamorphism** is the change of sedimentary rocks (or igneous rocks) into metamorphic rocks by heat and increased pressure during mountain building episodes – it usually involves lateral compression, demonstrated here by making a ridge of wax in which the wax fragments are aligned at right angles to the pressure (as in metamorphism) and the 'rock' becomes less porous and 'harder' (Note: small scale metamorphism mainly by heat occurs near hot igneous bodies – this type of metamorphism cannot be shown by the candle);
- **melting** of a rock to magma (through either partial or total melting) happens when rocks become hot enough – shown here by heating the wax with a match;
- **rising** of hot magma occurs because it is less dense than the surrounding rock – not shown by the candle;
- **crystallisation** occurs when a magma cools and solidifies – shown by the wax solidifying here, although candle wax doesn't strictly crystallise, it just solidifies;
- **extrusion** occurs when magma reaches the surface, either as lava flows or explosively as bombs and ash (not shown by the candle demonstration);
- **uplift** is the pushing upward of great masses of rock, usually during mountain-building episodes; as the overlying rock is eroded away, deeper and deeper layers are exposed (not shown by the candle demonstration).

Source of activity:
The activity is published on the Earthlearningidea website as 'The Rock Cycle in Wax' (http://www.earthlearningidea.com/) and devised by Chris King.

Plenary activity II: A wax volcano in the lab

Activity:
Volcanoes are exciting – hence all the volcano footage on TV. They can be used to fire pupils' imaginations, and safe analogues of the behaviour of molten rocks can be demonstrated in the school laboratory. This is a teacher-led demonstration for the whole class. It also demonstrates how 'rocks' may form below 'ground', as well as on the surface.

Carry out a risk assessment (see pages 64 and 65 at the end of this document).

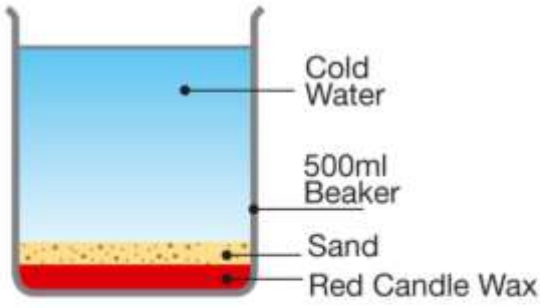
Set up the apparatus as included in the 'Resource list', this should be done in advance because of the time taken to melt and set the wax.

Pupils watch attentively from behind the safety screen, whilst the teacher applies a strong Bunsen flame to the base of the beaker, on the tripod and gauze. They must not lose concentration, because the "eruption" often happens without much warning, other than an ominous crackling sound as the wax melts! The Bunsen is removed whilst there is still some wax left on the bottom of the beaker.

Points to bring out:
(depending on the level of the pupils)**:**

- The sand and the water represent the crust of the Earth.
- The wax layer represents a layer in the Earth, deep in the crust or below the crust (lower crust or mantle).
- The mantle/lower crust is solid. It is being heated at a point source.
- When the wax melts, it rises, because of its lower density. It represents molten rock, known as **magma**.
- Some of the wax rises rapidly to the surface, imitating a volcanic eruption. It is very runny and spreads out evenly over the surface of the water (usually). This represents the way in which some **lavas** may cover huge areas, arising from fissure eruptions, which are quantitatively more important than the better known individual volcanoes.
- Some of the wax can be seen rising through 'tubes' of wax, which insulate it from the surrounding cold water and enable it to reach the surface. This happens in nature too.
- Some of the wax sets very quickly in the cold water, forming grotesque shapes. These represent **intrusive igneous** rocks. Once the wax has all set, the 'lava layer' may be removed and the water poured off, in order to study the shapes of the 'intrusions'. This is equivalent to the removal of layers of rocks by weathering and erosion.
- Reference can be made to the geological map of the UK. Widespread sheets of lava form the Antrim Plateau in Northern Ireland: masses of intrusive igneous rocks are shown as big red blobs in Devon and Cornwall, the Southern Uplands of Scotland etc.
- Pupils can be challenged to say which aspects of the model are <u>not consistent</u> with the natural world. The most important one is that the surface eruption sets very slowly, whilst the 'intrusions' set very quickly. In reality, the reverse would be true, because of the higher ambient temperatures at depth and the insulating properties of several kilometres of rock. Lavas may become solid within days, months or years, whereas a deep-seated intrusion of several tens of cubic kilometres may take millions of years to cool to the ambient temperature. Of course, the wax merely sets: it does not form crystals.

Magma processes simulated by candle wax



© originally from The Earth Science Teachers' Association, 'Magma – from buried batholith to violent volcano', Investigating the Science of the Earth (SoE3)*, Geological Changes – Rock Formation and Deformation*, redrawn by ESEU

Pupil learning outcomes:
Pupils can:
- appreciate how magma can be formed from solid rock by melting;
- explain how magma rises because it has a lower density than the surrounding material;
- interpret the model in terms of intrusion, eruption and the products of these;
- contrast the model with reality.

Pupil practical or teacher demonstration:
Teacher demonstration.

Time needed to complete the activity:
The demonstration itself takes about ten minutes, with discussion to follow.

Preparation and set up time:
Beforehand the wax needs to be melted so that it spreads across the bottom of the beaker to about 0.5 cm depth. When this has solidified, it should be covered by about 1 cm depth of pre-washed sand. Then the beaker should be filled with water to about three-quarters full. This all takes about ten minutes to prepare.

Resources (and safety notes):
- 1 x 500ml glass beaker
- Red candle wax, about 1cm deep, previously melted and poured into the base of the beaker
- Washed sand, in a layer about 1cm deep on top of the wax layer
- Very cold water to top up the beaker (from a fridge) - about three-quarters full
- Bunsen burner, heat proof mat, tripod and gauze
- Gas supply (or bottled gas burner etc.)
- Eye protection
- Safety screen

Note: The activity is safer than it sounds - the only potential hazard is a cracked beaker, with some localised spillage of hot wax: the water remains cold throughout. Water, sand and candle wax are all non-toxic.

Extension ideas for more able or faster pupils:
- At KS4, the model can be related to plate tectonic theory.
- In reality, complete melting of rocks below ground is seldom achieved. Rocks partially melt, and the minerals of lowest melting points are the ones which rise (they are also the least dense minerals). This can be shown by preparing a mixture of chopped wax and gravel in a container and stirring it to keep it mixed as it sets. When heated, in front of pupils, the wax melts, and rises, whilst the gravel does not.
- When pupils study the properties of seismic waves in the Earth, they will appreciate that the mantle is generally solid, with only about 5% of liquid in some parts of the upper zone of the mantle, in between the crystals of the rocks. Localised heating, and/or reduction in pressure, lead to partial melting, but the magma chambers which form are only tens of kilometres across, not mantle-wide.
- Studies of the chemistry of igneous rocks show that partial melting of rocks produces three main types of magma, depending upon the nature of the tectonic plate boundary.

Further notes:
Pupils will have seen TV coverage of volcanic eruptions, and may even have spent holidays in volcanic regions. They will also know that temperatures generally rise with depth in the Earth. (This is because of radioactive decay of minerals within the Earth, and the fact that the tens of kilometres of overlying rock provide a very good insulator).

The demonstration can follow the showing of selected video clips of volcanic eruptions. Note that, many pupils (and writers of school textbooks!) believe that there is a universal layer of molten rock lying below the Earth's crust. They often erroneously equate this imaginary layer with the mantle, which is, in fact almost entirely solid. Pupils also find it difficult to visualise that some molten rock can set below the Earth's surface, to form intrusive igneous rocks.

Level:
Either KS3 (11-14 year olds), as a simple demonstration of igneous activity, or can be extended to KS4 (14-16 year olds), with discussion of the structure of the Earth and the physical properties of its layers. It can also be related to plate tectonics.

Source of activity:
The original idea for the wax volcano model came from Mike Tuke and is described in his '*Earth Science Activities and Demonstrations*' published by John Murray (1991).


'A Wax Volcano in the Lab' © Peter Kennett


Example of Volcanic eruption from Mount Etna, Sicily, Italy © Fabricius

Names of common rocks

Sedimentary

Sedimentary rock – made of deposited sediment

- conglomerate (pebble-sized grains cemented/compressed together – a coarse-grained sedimentary rock)
- sandstone (sand-sized grains cemented/compressed together, often with layers (bedding) – a medium-grained sedimentary rock)
- mudstone (mud-sized grains compressed together, often with fine layers (lamination) – a fine-grained sedimentary rock)
- shale (mud-sized grains compressed together with fine layers (lamination) that cause the rock to break apart easily - a fine-grained sedimentary rock)
- clay (mud-sized grains, compressed but the rock remains soft as it still contains water - a fine-grained sedimentary rock)
- limestone (lime grains cemented/compressed together; lime (calcium carbonate) reacts with dilute acid)
- coal (plant material compressed together – a black sedimentary rock)
- flaggy sandstone with bits of fossil fish (sand-sized grains cemented/compressed together, often with layers (bedding) – a medium-grained sedimentary rock containing fragments of fish fossils)

Metamorphic

Regional metamorphic rock – rock formed from other rock by heat and increased pressure during mountain-building episodes

- slate (mud-sized (too small to be seen) interlocking crystals parallel with each other; can break into sheets (cleavage) – a fine-grained, low-grade metamorphic rock)
- schist (clearly visible interlocking crystals parallel with each other – a medium-grade metamorphic rock)
- gneiss (clearly visible interlocking crystals in bands – a high-grade metamorphic rock)
- marble (clearly visible interlocking crystals – formed when limestone is metamorphosed; the calcium carbonate crystals react with dilute acid)
- metaquartzite (clearly visible interlocking crystals – formed when quartz-rich sandstone is metamorphosed)

Thermal metamorphic rock – rock formed from other rock through baking by a nearby molten igneous rock (magma)

- hornfels (fine-grained interlocking crystals - formed when mudstone (shale or clay) is metamorphosed by heating)
- marble (clearly visible interlocking crystals – formed when limestone is metamorphosed; the calcium carbonate crystals react with dilute acid)
- metaquartzite (clearly visible interlocking crystals – formed when quartz-rich sandstone is metamorphosed)

Igneous
Extrusive igneous rock – from magma extruded from the Earth's surface (flowing out or being blasted out)

- basalt lava with gas holes (e.g. dark-coloured, fine-grained (too small to be seen) interlocking crystals (dark-coloured crystals are usually rich in iron/magnesium) – a fine-grained, dark-coloured, iron/magnesium-rich igneous rock, often with gas holes)

Intrusive igneous rock – from magma intruded into the Earth's crust that cools slowly

- granite (pale-coloured, coarse-grained (clearly visible) interlocking crystals (pale-coloured crystals are usually rich in silicon) – a coarse-grained, pale-coloured, silicon-rich igneous rock)
- gabbro (dark-coloured, coarse-grained (clearly visible) interlocking crystals (dark-coloured crystals are usually rick in iron/magnesium) – a coarse-grained, dark-coloured, iron/magnesium-rich igneous rock
- peridotite (very dark-coloured, coarse-grained (clearly visible) interlocking crystals (dark-coloured crystals are usually rich in iron/magnesium) – a coarse-grained, very dark-coloured, very iron/magnesium-rich igneous rock)

gabbro (intrusive igneous rock)	**limestone** (sedimentary rock)
granite (intrusive igneous rock)	**mudstone** (sedimentary rock)
slate (metamorphic rock)	**conglomerate** (sedimentary rock)
sandstone (sedimentary rock)	**schist** (metamorphic rock)
marble (metamorphic rock)	**gneiss** (metamorphic rock)
shale (sedimentary rock)	**metaquartzite** (metamorphic rock)
basalt (extrusive igneous rock)	**clay** (sedimentary rock)

Activity 1 Weathering

Activity 2 Erosion and transportation

Activity 3 Deposition

Activity 4 Compaction & cementation

Activity 5
Metamorphism

Activity 6
Crystallisation

Activity 7 Extrusive igneous rocks

Activity 8 Deformation

Weathering

(1)

Tens to hundreds of years

Erosion/ transportation

(2)

Seconds to tens of years

Deposition
(3)
Seconds to thousands of years

Compaction/ cementation
(4)
Hundreds to millions of years

Metamorphism (5)

Millions of years – during mountain-building episodes

Melting

Tens to millions of years

Rising ***Days (extrusion) to millions of years (intrusion)***
Crystallisation (6) ***(under Earth's surface) Thousands to millions of years***

Extrusion (7)

Seconds to weeks

Uplift

Hundreds to millions of years

Deformation: folding, faulting and uplift (8)

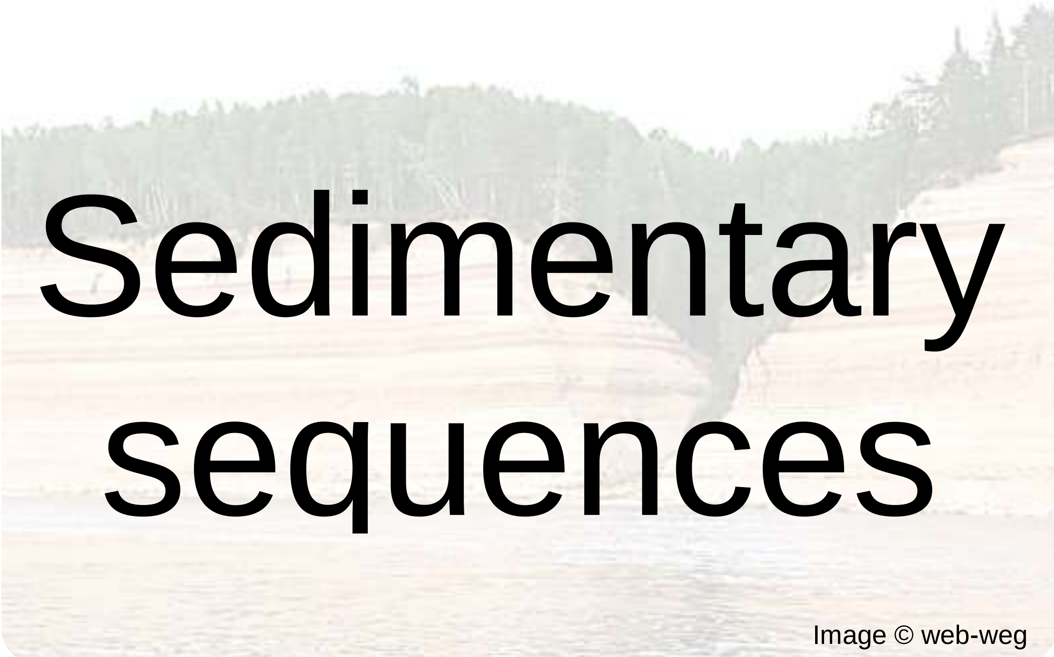
Seconds (faulting at active Earth zones) Seconds to millions of years (faulting, folding metamorphism during mountain-building episodes)

Image © Sten Porse

Image © Wamito

Sedimentary rocks

Image © Benkid77



Sedimentary sequences

Image © web-weg

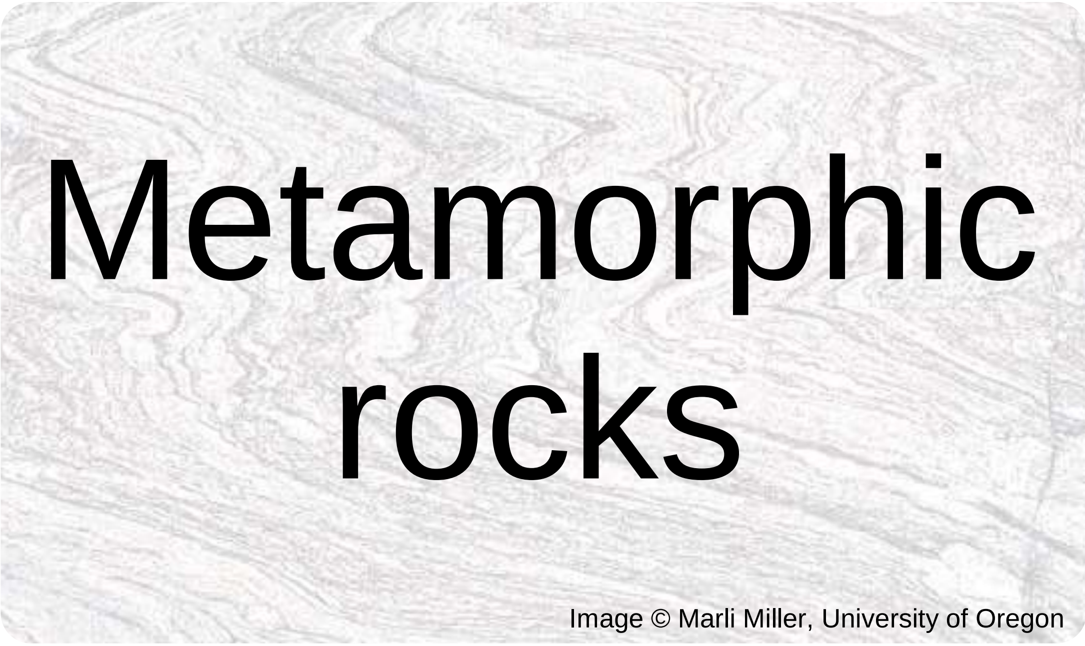
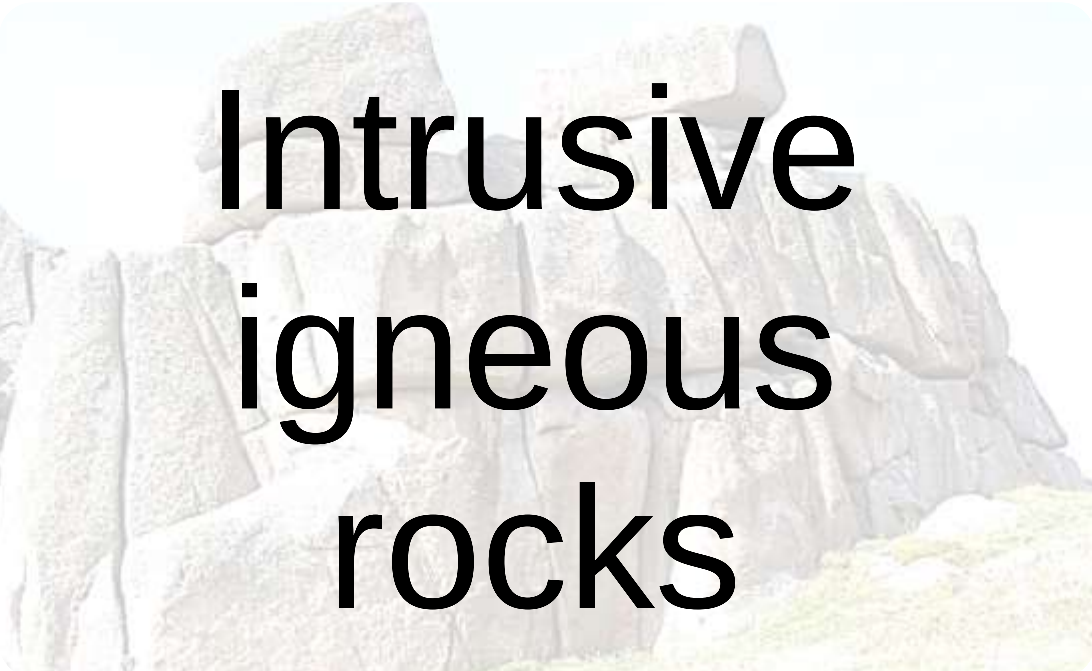


Image © Marli Miller, University of Oregon

Image © Author unknown

Extrusive igneous rocks

Image © Alcinoe Calahorrano



Intrusive igneous rocks

Image © Jim Champion

Rocks at the Earth's surface

Image © Uwe Gille

Rock Cycle feedback

- Name the topic you did
- Explain what you did: briefly demonstrate
- How does this relate to the real world?
- Would you use it? If so, how is it best used with a class; group practical work; teacher demonstration; part of the circus, etc?
- Any safety implications?

Resource list

Starter activity – Rock cycle products and processes Resource list:	Supplied By Facilitator	Supplied By Institution
One for every group of three pupils/participants, with an extra large set to be used by the session leader:		
A4 diagram of 'The Rock Cycle'	✓	
The 'Rock Reference Sheet'	✓	
Sedimentary rocks, e.g. conglomerate, sandstone, mudstone, shale, clay, limestone	✓	
Metamorphic rocks e.g. slate, schist, gneiss, marble, metaquartzite	✓	
Igneous rocks e.g. lava, granite, gabbro	✓	
Photograph of 'Rocks at the Earth's surface'	✓	
Photograph of 'Sedimentary sequence'	✓	
Small sealed plastic bag containing dry soil	✓	
Small sealed plastic bag containing loose sand ('mobile sediment')	✓	
One of each of the following, for demonstration:		
Laminated cards of Rock cycle products:		
Rocks at the Earth's surface, Rotten rocks/soil, Mobile sediments, Sedimentary sequences, Sedimentary rocks, Metamorphic rocks, Magma, Intrusive igneous rocks, Extrusive igneous rocks	✓	
Laminated cards of rock cycle processes:		
Weathering, Erosion and Transportation, Deposition, Compaction and cementation, Metamorphism, Melting, Rising, Crystallisation, Extrusion, Uplift, Deformation	✓	
'Flash cards' of rock names:		
conglomerate, sandstone, mudstone, shale, clay, limestone; slate; schist; gneiss; marble; metaquartzite; lava; granite; gabbro	✓	
Activity number cards	✓	
200 ml transparent measuring cylinder nearly full of water		✓
Containers of two different coloured sands (eg .red sand and white sand)	✓	
Dessert spoon	✓	
Blue Tac™ (optional)		✓
OS Ordnance Survey Geological Map of the United Kingdom by the British Geological Survey (if available)	✓	

Activity 1: Weathering – breaking up or breaking down material at the Earth's surface Resource list:	Supplied By Facilitator	Supplied By Institution
Granite chips (15-20mm)	✓	
Bunsen burner		✓
Heat proof mat		✓
Eye protection		✓
Tongs		✓
Matches		✓
500ml beaker		✓

Either:		
Pre-prepared display of different rocks, previously soaked and placed in and out of a freezer	✓	

Or:		
2 small chips (5-7mm) of several different types of rock (some porous, some non porous e.g. sandstone, limestone)	✓	
2 shallow plastic containers	✓	
Drinking glass or small beaker, 100ml or 250ml		
Universal indicator		✓
Drinking straws		✓
Spatula		
Ground limestone (e.g. crushed chalk)	✓	
Tap water		✓

Activity 2: Erosion and transportation – rock resistance	**Supplied By**	
Resource list:	**Facilitator**	**Institution**
Expendable rock specimens e.g. 4 X 25g (approx) crumbly sandstone (sedimentary) 4 X 25g (approx) limestone (sedimentary) 4 X 25g (approx) granite (igneous) 4 X 25g (approx) slate (metamorphic)	✓	
Optional: expendable specimens of rocks of variable resistance, as appropriate to the local area.		✓
Two plastic containers with wide necks and tops	✓	
Mechanic's file	✓	
Emery paper	✓	
Eye protection		✓
Electronic balance, e.g. to 200g, accuracy to 0.1g or better		✓
Tray		✓

Activity 3: Deposition – the movement of sand in flowing water	**Supplied By**	
Resource list:	**Facilitator**	**Institution**
1m length of plastic gutter (square section is preferred) with end stops	✓	
Washed sand (to fill the gutter to within 2cm of the top)	✓	
Rubber tubing to connect to a lab tap	✓	
Clip (to fix the tubing to the gutter)	✓	
Container such as a large beaker to put in the sink to catch any sediment washed over the end of the gutter – preventing it from blocking the sink		✓
Small pieces of gravel (approx 50g)	✓	

Activity 4: Compaction and cementation - sediments into rocks	**Supplied By**	
Resource list:	**Facilitator**	**Institution**
2 x Plastic syringes (20cm^3) – with nozzles cut off at the end of the barrel	✓	
Tray		✓
Eye protection		✓
Disposable cups		✓
Plastic spoons		✓
Water dropper		✓
250g dry sand	✓	
10g powdered clay	✓	
10g plaster of Paris powder	✓	
Water		✓
Apparatus for testing the strength of pellets, e.g. file, variety of masses, heavy ball-bearings.		✓

Activity 5: Metamorphism – detecting the distortion	**Supplied By**	
Resource list:	**Facilitator**	**Institution**
About 20 short (eg 4 cm long) pieces of spaghetti or used matchsticks	✓	
2 x 30 cm rulers (or similar strips of wood)		✓
7 x Marshmallows or soft foam balls	✓	
Plasticine™, modelling clay or similar	✓	
Cockle shells or similar shells	✓	
50g plaster of Paris	✓	
Disposable cups		✓
Plastic teaspoons or stirring rods		✓
Water		✓

Activity 6: Crystallisation – fast or slow cooling, large or small crystals	**Supplied By**	
Resource list:	**Facilitator**	**Institution**
Salol (phenyl – 2 – hyroxybenzoate), approximately 5g	✓	
Boiling tube		✓
250cm^3 beaker		✓
6 microscope slides (plus some spares)		✓
Stirring rod		✓
Eye protection		✓
Hand lenses (one per member)		✓
Hot water (from a kettle or heated on a Bunsen)		✓
Access to a freezer		✓
Sheet of dark coloured A4 card or paper		✓
Samples of igneous rocks of various grain sizes e.g. granite, microgranite, gabbro, rhyolite, basalt	✓	

Activity 7: Extrusion - igneous rocks 'in the laboratory'	**Supplied By**	
Resource list:	**Facilitator**	**Institution**
7A: Lava in the laboratory		
Treacle or syrup	✓	
Bunsen burner, tripod and gauze (or hot water bath)		✓
Heat proof mat		✓
4 x Spatulas or teaspoons		✓
2 x Glass stirring rods		✓
2 x Sets of tongs		✓
6 x Boiling tubes with bungs		✓
2 x Boiling tube racks		✓
Stopclock or watch		✓
Thermometer		✓
Washed sand (small amount, e.g. half a cupful)	✓	
Stand with clamp and boss		✓
Eye protection		✓
Petri dishes or tiles with props to allow tilting		✓
Ruler		✓
Hot soapy water		✓
Test tube brushes and cloths		✓

Activity 8: Deformation – make your own folds and faults **Resource list:**	**Supplied By**	
	Facilitator	**Institution**
Empty clear plastic box (e.g. Ferrero-Rocher chocolate box - not the 'tray' variety)	✓	
About 500g of dry fine sand	✓	
About 25g of flour	✓	
Spatula or dessert spoon		✓
Eraser or similar flat object (for tamping down the sand/flour)		✓
A piece of board to fit snugly into the box	✓	
Tray for tipping out sand		✓

Plenary activity I: The rock cycle in wax **Resource list:**	**Supplied By**	
	Facilitator	**Institution**
Candle		✓
Cheese grater or knife or other metal object to scrape off wax fragments (about two dessertspoons full)		✓
Piece of paper		✓
Matches		✓

Plenary activity II: A wax volcano in the lab **Resource list:**	**Supplied By**	
	Facilitator	**Institution**
1 x 500ml glass beaker		✓
Red candle wax, about 1cm deep, previously melted and poured into the base of the beaker		✓
Washed sand, in a layer about 1cm deep on top of the wax layer		✓
Very cold water to top up the beaker (from a fridge) - about three-quarters full		✓
Bunsen burner, heat proof mat, tripod and gauze		✓
Gas supply		✓
Eye protection		✓
Safety screen		✓

Note: Where 'washed sand' is required, it can be prepared in a large sink by running a hose/tube for 10 minutes into a bucket half-full of sand, and allowing the clay particles to overflow with the water and wash away. Fine sand can be sieved out from poorly sorted sand by running it dry through a kitchen sieve.

Teaching points of ESEU workshop activities

Activity	Pattern (construction)	Challenge (cognitive conflict)	Explanation of thinking (metacognition)	Relevance (bridging)	Practical teaching points
1. Weathering • Heating • Freezing/thawing • Chemical	• The more you heat and cool it, the weaker it becomes • Permeable rocks break down by freeze thaw • Breath -> acid, limestone -> neutral or even slightly alkaline	• Many minerals vs monomineralic rocks • Vesicular basalt doesn't break down fast	• Reasoning on conflict. Real world? Where on Earth …? • Reasoning on conflict. Real world? Where on Earth …? • Real world? Where on Earth …?	• Takes place in deserts (high diurnal range), rarely in UK • Takes place in areas that freeze and thaw, ie not permanently frozen areas • Going on outside the door • UK rocks mostly attacked by chemical and biological weathering, physical limited	• Significant danger makes this into a teacher demo in some schools • Needs preparation beforehand by several cycles of freeze/thaw
2. Erosion and transportation (rocks with shaker, file, acid, etc)	Toughest rocks are crystalline rocks. Weakest rocks are poorly cemented sedimentary rocks	Limestone crystalline? Tough rock reacts with acid (limestone) so doesn't fit pattern – why?	Is the test fair? What environment does it simulate?	Hard rocks make hills and headlands, soft rocks make bays and valleys. All the ups and downs and coastline ins and outs of the UK (and world) explained. When you are going uphill – what does this mean?	Pupils should shake all at the same time. Adding water adds an unnecessary complication
3. Deposition (gutter)	Process (erosion, transport, deposition) depends on flow rate	How will grain size and/or grain density affect processes?	Three variables (at least) need to be taken into account.	Processes happen in puddles, ponds, seas and the oceans They result in grains sorted by size and density. Cross bedding gives flow direction, eg. Triassic river in the Stoke area flowing north	Difficult for many to see at once – so this may be a circus activity. Be wary of pupils spraying the lab with the rubber tubing
4. Compression and cementation (syringes)	The tougher the gluing material, the tougher the 'rock'	Which tests will produce the most effective results? Different tests produce different rankings – why?	Explanation of different rankings	Sandstone cannot be made from sand by compression – some form of glue is necessary. The tougher the 'glue' (cement) the tougher the rock – ref. to Activity 2.	Best results if left overnight. Do least destructive tests first.

Teaching points of ESEU Workshop activities continued...

5. Metamorphism (squashed fossils)	Pressure directions can be deduced from type of deformation	Can the same effect be produced by tension as by compression?	What can be deduced from the direction and scale of deformation?	If fossils in N. Wales are compressed N-S by a quarter, then N Wales was compressed N-S by a quarter – what could have done this? (plate containing Scotland colliding with plate containing England)	Deal with point in some textbooks that metamorphic rocks don't contain fossils. Wash out all containers.
6. Crystallisation (Salol)	Smaller crystals = faster cooling – prediction from this	When it doesn't work and why	Explanation of observations, ie. why does fast cooling cause smaller crystals?	Coarse igneous rocks cooled slowly (great thicknesses of insulation above) – many thousands of years. Crystals as big as classrooms have been found. Fine grained rocks crystallise quickly over days at the surface (lavas)	Don't overheat the Salol – 50^{o} is fine – otherwise supercooling more likely. Putting slides on top makes crystallisation easier to see – even on OHP. Two phase practical used to give two chances of getting it right.
7. Extrusion (treacle)	Viscosity effects of temperature, sand and water content	Slope should not be a variable	How can the changes be explained using the particle model?	Hot, crystal-free, water rich lavas produce flat volcanoes. Cool, crystal-rich, water-poor lava produce steep volcanoes. In steep volcanoes – lava usually crystallises in vent and causes great explosion (eg. describe Krakatoa). Pupils should be nowhere near when this happens.	Keep treacle in test tube (of same temperature) during temperature investigation. Get different groups to investigate different things.
8. Folding/faulting (Ferrero Rocher box)	Compression and tension produce different styles of faults			Similar things found in N. Wales with E-W axes. Explanation? Scotland hitting England and squeezing Wales. Gives some idea of the pressures involved.	Dry sand needed

Risk assessments

Potentially Hazardous Activity	Who/What may be Harmed?	Hazard Rating (A)	Likelihood (B)	Risk (AxB)	Further Action Required?
Weathering (heating, freezing and chemical)	Demonstration of heating granite chip to red heat in Bunsen flame holding granite chip with tongs, before quenching. If done as a demonstration in class, there is a hazard of fire and burns from the gas burner and of burns from the granite chip and hot tongs.	2	1	2	Wear eye protection and keep observers at least 2 m away, follow general advice on the use of gas burners: CLEAPSS Laboratory Handbook, section 9.10.2.
	Pupil activity of heating granite chip to red heat in Bunsen flame holding granite chip with tongs, before quenching. If done as a demonstration in class, there is a hazard of fire and burns from the gas burner and of burns from the granite chip and hot tongs.	2	2	4	All in group should wear eye protection and keep observers at least 2 m away, follow general advice on the use of gas burners: CLEAPSS Laboratory Handbook, section 9.10.2.
	Use of Universal indicator in water, into which a pupil blows. Universal indicator is a flammable fire hazard.	1	1	1	Keep Universal indicator away from naked flames. Wear eye protection during use. If eye contact, immediately flush the eye with water. If skin contact, wash off with soap and water. If swallowed, trivial amounts cause little problem but seek medical advice. Pupils should not share straws – risk of infection.
Erosion and transportation	Shaking rock specimens in plastic container – when lid is removed there is a potential dust inhalation problem.	1	1	1	Instruct participants to open the top well away from the nose and not inhale dust.
Deposition	Has no recognised hazard associated with it.	N/A	N/A	N/A	N/A
Compaction and cementation of sediments	Use dilute (0.5M) HCl in dropper bottle.	2	2	4	Refer to CLEAPSS Hazcard No. 47
Metamorphism	Plaster of Paris sets with an exothermic reaction and has been known to cause burns when used in large quantities. The amounts being used here are very small and there are therefore no recognised hazards in this context.	1	1	1	No

Risk assessments continued...

Potentially Hazardous Activity	Who/What may be Harmed?	Hazard Rating (A)	Likelihood (B)	Risk (AxB)	Further Action Required?
Crystallisation (Salol)	Heating of Salol in water bath. There is a hazard of fire and burns from the gas burner. There is a potential hazard of the beaker being knocked off the tripod. Salol may be irritating to the eyes, respiratory system and skin. *(Salol has a number of synonyms including Phenyl salicylate and Phenyl-2-hydroxybenzoate)* Salol is flammable.	2	1	2	All in group should wear eye protection and keep observers at least 2 m away, follow general advice on the use of gas burners: CLEAPSS Laboratory Handbook, section 9.10.2. See CLEAPSS Hazcard No.52 for Salol. Ensure heating is done well away from the edges of the bench on a heat-proof mat. Wear eye protection. If Salol comes into contact with the eyes immediately flush the eye with water and seek medical advice. If skin contact, wash off with soap and water. If swallowed, seek medical advice.
Extrusion (treacle)	Heating of treacle in water bath. Ensure that the treacle is heated in the water bath and not directly, using a Bunsen burner. There is a hazard of fire and burns from the gas burner. There is a potential hazard of the beaker being knocked off the tripod.	2	1	2	All in group should wear eye protection and keep observers at least 2 m away, follow general advice on the use of gas burners: CLEAPSS Laboratory Handbook, section 9.10.2. Ensure heating is done well away from the edges of the bench on a heat-proof mat.
Extrusion (wax volcano)	The water remains cold throughout so poses no risk. A thin layer of wax is melted in a beaker – it could crack the beaker and exude onto the bench, but this is unlikely. The wax is melted using a Bunsen burner. There is a hazard of fire and burns from the gas burner.	2	1	2	The presenter should wear eye protection, a safety screen should be used for all spectators watching close to the activity - keep observers at least 2 m away, follow general advice on the use of gas burners: CLEAPSS Laboratory Handbook, section 9.10.2.
Deformation	Has no recognised hazard associated with it.	N/A	N/A	N/A	N/A

Hazard Rating (A):
1= Insignificant effect
2= Minor Injury
3= Major Injury
4= Severe Injury
5= Death

Likelihood of occurrence (B):
1= Little or no likelihood
2= Unlikely
3= Occasional
4= Probable
5= Inevitable

Risk Priority (AxB):
12-25= High risk – take immediate action
6-11= Medium risk – take action as soon as possible
Less than 6= Low risk – plan future actions where required