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In-school learning in preparation for field visit to Boulmer Foreshore.

List of the concepts needed
Sound knowledge and understanding of geological processes should form the basis of the preparatory lesson(s) at KS3 in school within the 1 to 2 weeks prior to the field visit.

KS3 geological processes **Time: 80 minutes**
In broad terms the KS3 'geological processes' is the study of the 'Rock Cycle'.

Learning objectives for KS3

1. be able to describe and explain ways in which rocks are weathered.
2. be able to observe and describe the key features of a rock specimen, including colour, texture and mineral content.
3. be able to classify specimens of common rock types, using observed features, as igneous, sedimentary or metamorphic, and name such common rock types.
4. be able to describe and explain how sedimentary rocks may be formed by processes including the erosion, transport and deposition of rock fragments.
5. be able to make reasonable suggestions as to how a common sedimentary rock type they have described was formed, and how long the process took.

A. Weathering (10 minutes)
As the basis of a brief question and answer session, use photographs of rocks that have suffered weathering. Suggested images:

- boulder(s) showing onion-skin weathering.
- boulder(s) split in half – e.g. Devil's Marbles.
- jagged, broken rocks on mountain ridges, preferably with patches of snow still visible.

An internet search yields many possible images for classroom use. Examples:
http://www.geos.ed.ac.uk/undergraduate/field/holyrood/spheroids.html
http://academic.brooklyn.cuny.edu/geology/leveson/core/topics/weathering/picturegallery/display/newjerseygarret_mt_1.html
http://www.au.au.com/cameras/images/devils-marbles.jpg
http://www.thewalkzone.co.uk/Lake_District/walk_36/180203h.jpg

Some internet images provide useful background discussion about the weathering mechanisms involved. Tasks in small groups: show the pupils the photographs and give them one minute to come up with suggested causes of the weathering depicted in each image. There is probably no single 'correct' answer in any of these situations because weathering is rarely one process operating on its own. Weathering is usually caused by a combination of physical and chemical weathering processes. It is the pupils' suggestions and subsequent discussion generated that are important. If pupils do not suggest chemical weathering, the teacher may need to pump-prime the discussion by asking them whether chemical changes might be possible in any of these examples.

B. The rock cycle (35 minutes)
This session is based on the rock cycle. A simplified pictorial version of the rock cycle should be used in the session and this diagram can be downloaded from:

http://www.washington.edu/uwired/outreach/teched/projects/web/rockteam/WebSite/rockcycle.htm.htm

Activity 1: provide a set of six common rock types (sandstone, shale, conglomerate, granite, dolerite/basalt with crystals just visible, slate or schist or gneiss). Tasks in small groups:

- agree key features of each specimen (colour, texture, etc), and how the grains are held together (which allow them to identify whether they are sedimentary, or igneous or metamorphic).
- provide a set of name labels; groups have to decide quickly which label belongs to each specimen, and be able to justify (for able groups, provide more name labels than specimens!).
- plenary agreement on correct labelling and why the name label is appropriate.

Activity 2: teacher shows quick demonstrations of:
(1) sedimentation jar filled with water then 3 charges of different sediment (the last one being muddy to show slow fall of sediment).

(2) a volcano in a laboratory. This demonstration of a volcano uses wax and sand. Details are available from:

http://www.earthscienceeducation.com/workshops/worksheetindex1.htm

3) effects of pressure on rocks. This simulation of the distortion of fossils by metamorphism uses modelling clay and cockleshells. Details are available at:
http://www.earthscienceeducation.com/workshops/rockcycle/metamorphism.htm

Task for small groups using the rock cycle diagram:

- decide what part of the rock cycle each demonstration is modelling.
- decide at which point in the rock cycle each specimen would have been formed.
- agree on the rough timescale needed for each rock type to have been formed, including the difference, for sedimentary rocks, between time for deposition and time for a deposit of loose sediment to be turned into a hard rock, and also how that may happen.

Activity 3: How did sediment become hard rock? This can be modelled for sandstone, as shown on the JESEI website at:

http://www.chemsoc.org/networks/learnnet/jesei/sedimen/index.htm

C. Sedimentary processes (35 minutes);

Introduction:
The following ideas are used in the field:

a) rock fragments are abraded (have pieces broken off) during transport;
b) erosion and deposition happens according to the size (weight)of the fragment in a flowing current;
c) larger (heavier) fragments are usually moved by rolling along the bottom, which causes them to become rounded;
d) that rounding / angularity refers to the sharpness of the edges of pebbles and can be described on a progressive scale. (Here the scale is of 1 to 6);
e) that well rounded pebbles are characteristic of significant amounts of transport by water. (Sand grains do not become well rounded during water transport);
f) that sediments become deposited together roughly according to grain size (mass) as a current slows down: larger fragments (sand and gravel) first and finer ones (muds) settling out in very quiet water.

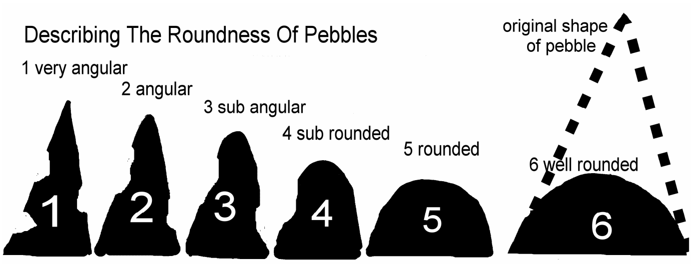


Figure 1. Rounded and angular edges.

Activity 4: the following diagram could be used in conjunction with appropriately selected specimen pebbles to practice the description of rounding.

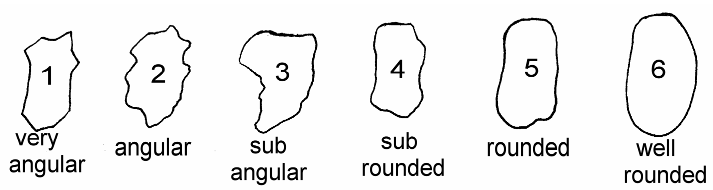


Figure 2. Rounded and angular pebbles.

Activity 5: pupils place cubes of sugar in a closed container and shake for 30 seconds and then observe changes to the shape and size of the cubes. Repeat activity at 30 second intervals, weighing & measuring the cubes at each stage. Tasks in small groups:

- decide what is the cause of the changes they have observed.
- decide what part of the rock cycle is modelled in the experiment.
- agree what will affect the degree of rounding and size reduction of rock fragments in the rock cycle.

Activity 6: provide three piles of sediment (one of gravel, one of soil and one of sand) and watering cans for pupils to use to pour water over the sediments to see how far the water spreads the sediment. Tasks for pupils work in small groups:

- agree what needs to be done to ensure the test will be a fair test.
- pour 2 litres of water slowly over each pile of sediment.
- observe what happens and measure how far the water spreads each pile.
- agree which type of material was spread further.
- predict what would happen if they poured 4 litres of water over each pile of sediment.

Activity 7: teacher shows demonstrations of river erosion, transport and deposition using a child's slide extension or a very long tray covered with a sand and gravel (pea-sized) mixture.
Tasks for pupils in small groups:

- decide how the different types of sediment are moved along the river bed in this model.
- agree where erosion takes place and what evidence shows that erosion has occurred here.
- agree where deposition occurs and why deposition occurred at this place.
- decide what different results they could expect to see if (a) the slope of the tray is increased and (b) a greater volume of water is poured into the tray.

Activity 8: teacher shows a demonstration of the formation of ripple marks using a fish tank (approximately 100cms long, 50cms deep and 50cms wide) and two wooden cylinders 3cm diameter and slightly longer than the width of the tank.
Put clean, well sorted sand of fine to medium grain size into the tank, sufficient to line the floor of the tank to a depth of several cm. Place the tank on the wooden rollers, and fill the tank with water to a depth of 15-20cm. Gently and rhythmically rock the tank back-and-forth in an oscillatory motion until ripples form on the sediment surface. (This does not take long, but there is the potential for disaster if the tank is rocked too vigorously!).

Details of **Activities 5 and 6** (and of related practical activities) are available at:
http://www.kented.org.uk/ngfl/subjects/geography/rivers/Teacher%20Plans/whatiserosionanddeposition.htm

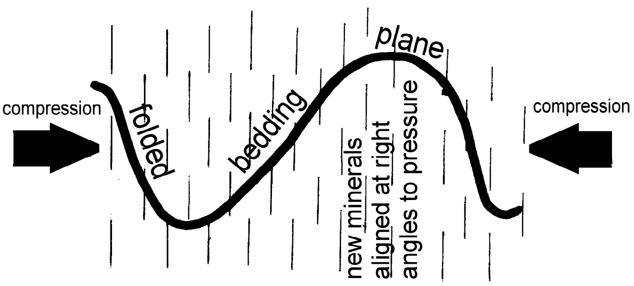
D. Igneous Processes.
The central feature of this ESO-S visit is observation of igneous (dolerite) intrusions. The large dyke at Boulmer, and the sills at Snableazes and Cullernose Point require some preliminary understanding of the geometry and origins of such features and their relationship to the bedding of the country rock they intrude.

Activities:
1. Although videos and three-dimensional models are useful for establishing the main ideas and definitions, the ESEU workshop demonstration "**A volcano in the laboratory**" and the "**Lava in the laboratory"** pupil activity are extremely useful for demonstrating the processes involved, using red wax as a proxy for intrusive magma, and syrup as a proxy for extrusive lava.
Details are available at: http://www.earthscienceeducation.com/workshops/rockcycle/volcano.htm

2. Pupils should examine and describe crystalline igneous rocks and relate the crystal size to rate of cooling, and the overall colour to acid or basic magmas. E.g. Granite, and rhyolite (both acid rocks), and basalt and dolerite (both basic rocks).

A summary of the central ideas and definitions is given below.
1. **Magma** is liquid rock underground. (In this case it is iron and magnesium rich, or basic, magma which crystallised underground as the dark coloured rock, dolerite).
2. Basic magma derives from the **partial melting of an otherwise solid upper mantle.**
3. Igneous rocks are characterised by **interlocking crystals** and joints which form as the solid rock continues to cool and contract. In sheet-shaped intrusions these joints are perpendicular to the cooling surfaces. As a crude rule of thumb: vertical joints in sills and horizontal joints in dykes. In ideal circumstances the stresses form **hexagonal columns**.
4. Hot magma moves upwards through cold "country rock" by virtue of being **less dense** than those rocks. It follows lines of previous fractures such as faults and joints causing an extension of the crust equivalent to the width of the intrusion. Intrusions which cut across bedding in this way are called dykes. (At Boulmer the dyke is around 30 metres across.)
5. **Lava** is the molten rock erupted on the surface, and cools quickly to form Basalt. **Basalt** is the fine grained extrusive equivalent of **dolerite**, which crystallises more slowly underground and therefore has slightly bigger interlocking crystals.
6. Where the hydraulic pressure is insufficient to drive the intrusion further upwards through the country rock, the magma may spread out sideways, often along bedding surfaces, to form a **sill**. Here the ground's surface is displaced upwards by the thickness of the intrusion. (At Snableazes and Cullernose Point this is around 20 metres.)
7. Both sills and lavas can be parallel to the bedding, but the heat from sills, being intrusions, **metamorphose** the country rock both beneath **and** above. Lavas extruded on the surface cannot do this. Sometimes sills "step across" bedding planes and continue at a higher, or lower, level. This is called a **transgressive sill**.
8. Dykes and sills effectively "cut across" or metamorphose, the country rock and so are younger than them, (even if, as a sill, they occur above them in the quarry.) **Principle of Cross Cutting Relationships**.

E. Regional Metamorphism (caused by pressure and heat) *(10 minutes)*
Activity 9: This demonstration mimics new minerals forming at right angles to pressure in clay rocks, which causes it to split, or cleave, into flat pieces, as the sedimentary shale (or mudstone) becomes metamorphosed into slate.



In rocks containing clay minerals the effect of severe folding can cause a cleavage (a new direction of splitting) to form. This occurs when new minerals that grow, do so at right angles to the direction of pressure. This means that such cleavage tends to run parallel to the axes of folds and cause the beds (now called metamorphic slates) to cleave across the bedding planes.

Figure 3. Cleavage and Folding.

This can be simply modelled by using several randomly scattered pencils (or spaghetti pieces etc.) and confining them between two converging surfaces. For a whole group this is best done on an overhead projector screen. In practice these new minerals are flat, or platy, in shape, not elongate like pencils. (This effect can be modelled in the air with sheets of paper, illustrating the cleavage between the flat sheets, but this can be more tricky). This demonstration should be accompanied by specimens of slate showing cleavage.

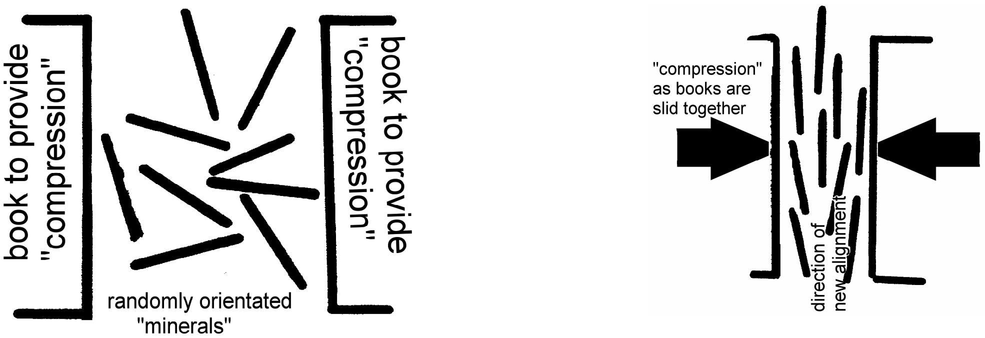


Figure 4 (a and b). Demonstration of cleavage formation.

E. Contact Metamorphism (caused by heat)
Intruded hot molten magma loses heat to the surrounding rocks as it cools and crystallises. This baking of rocks is known as contact metamorphism. When clay-rich rocks are baked they re-crystallise and harden. Limestone recrystallises to form marble during metamorphism. Inspection of the properties of clay, limestone and marble before and after firing in a pottery kiln is instructive. At Snableazes close inspection of baked shales is possible.
An addition feature where igneous rocks cool more rapidly against the cold rocks they intrude is that grain sizes become finer towards the contact where cooling was faster. Investigations using salol on glass slides to demonstrate crystal formation and also the formation of igneous intrusive complex are part of the Earth Science Teachers Association workshop series. For more information see
http://www.earthscienceeducation.com/workshops/rockcylce/metamorphism.htm

FOLLOW-UP WORK.

The suggested follow up work is a summary of the evidence for the two rock cycles seen during the visit. A completed version allowing teachers to assess pupil responses can be found in **BOU9 Group Leaders' Notes**.

As an alternative, the more graphical, last worksheet (**worksheet 9**) could be used instead. A completed copy of the follow-up work can be found in **BOU9 Group Leader's Notes.**

Alternatively, the final exercise on local building stone could be used.

BUILDING STONES SURVEY:
Using the ideas from the preparation exercises pupils conduct a survey of the use of different building materials in the area of the school, using the worksheets at the end of this document.
After the ***On-Site*** visit, as a homework exercise, pupils are asked to describe in detail two uses of stone as part of a survey of building stone in the local area.

The term "building" may need to be very loose. Suitable sites could include a local church, gravestones (helpfully dated), school buildings, local walls, high street shop fronts, kerbstones, cobblestones, local monuments, bridges, and the pupil's own home. In particularly unhelpful areas concrete, cement and bricks could be designated as "man-made" stone for the purpose of this exercise.
Teachers (or pupils) should identify two sites to work on (perhaps taken from the preparatory homework exercise above). Remind pupils about situations where permission is required, and appropriate behaviour is expected. Also, draw attention to thoughts about safety, if kerbstones, or a cobbled road is chosen.

Pupils should record:

- the location or address of the building / construction.
- a sketch of the relevant part of the site, labelling the rock being surveyed, and the use to which it has been put.
- A description of at least two different rocks (perhaps on two buildings) and the use to which they have been put. For each describe the rock, identify it as igneous, metamorphic, or sedimentary, and give the reason it has been used for this purpose.
- Finally record the evidence for the effects of weathering on the chosen rock, identifying the kind of weathering responsible, giving the reasons for their conclusion.

Suitable copies of homework record sheet for the follow-up exercise are to be found on the following pages.

EARTH SCIENCE HOMEWORK **Pupil Name ………………………….**

The Two Rock Cycles at Boulmer.

1. SUMMARISING THE ROCK CYCLES:

FIRST CYCLE: deposition. What can you say about the deposition of the older beds on the foreshore HINTS: Evidence for deposition; fossils, grain size etc.
FIRST CYCLE: uplift and tilting. What can you say about the changes to the beds cause by plate tectonics? HINTS: tilting, faulting, intrusions etc.
SECOND CYCLE: weathering and erosion. What evidence of present day weathering and erosion have you seen on the foreshore?
SECOND CYCLE: sediment transport. What evidence have you seen for the different ways sediments are being transported on the foreshore today?
SECOND CYCLE: deposition. What kinds of modern deposits have you seen and what rock types might they form in future? HINT: Don’t forget plant and animal evidence – and which parts might survive as fossils.

EARTH SCIENCE HOMEWORK **Pupil Name ....**

2. BUILDING STONE SURVEY

ADDRESS OF BUILDING (OR DESCRIPTION OF THE SITE).	DRAW IN THIS SPACE A LABELLED SKETCH OF THE STONE USED AT THIS SITE.
DESCRIPTION OF FIRST ROCK TYPE. IS IT METAMORPHIC IGNEOUS, OR SEDIMENTARY? (circle the answer) WHY DO YOU THINK THIS ROCK HAS BEEN USED IN THIS PARTICULAR WAY? [think about its strength, chemical and physical resistance, attractiveness for decoration etc.] DESCRIBE ANY EVIDENCE OF PHYSICAL OR CHEMICAL WEATHERING [explain how it has occurred & label it on your sketch]	