Funded by Defra's Aggregates Levy Sustainability Fund, administered by English Nature.

Many ideas involved in this Earth-Science On-Site excursion will revise ideas from Key Stage 3 work. In addition to the knowledge and understanding of geological processes gained in KS3 Physics, the pupils' knowledge of the response of materials to deforming forces, needs to be revised and slightly extended. See parts 2 to 5 below.

INTRODUCTORY WORK.
The following themes should form the basis of the preparatory lesson in school within a week prior to the field visit.

Part 1: Rounding and angularity. *Time about 10 minutes*
This section of revision from key stage 3 is especially significant as a preparation for the Mosedale On-Site field visit. Three of the sites are "drift" deposits (un-cemented glacial and post glacial deposits at the surface) and the following, additional ideas are used in the field:

a) rock fragments their edges abraded (have pieces broken off) during transport;
b) erosion and deposition in a flowing current is influenced by the size (weight) of the fragment;
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.

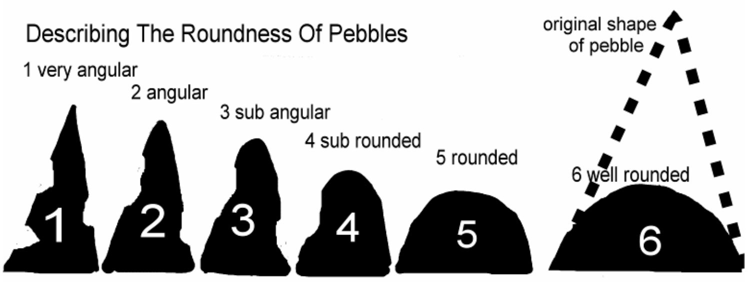

Figure 1. Rounded and Angular Edges.

In addition to the activities from Keystage 3 on the rounding of materials, the following diagram could be used in conjunction with appropriately selected specimen pebbles to practice the description of rounding.

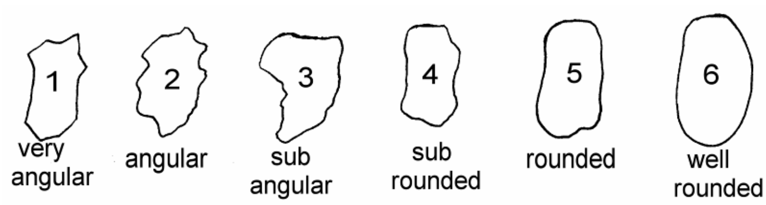

Figure 2. Rounded and angular pebbles.

Part 2: The Response of materials to bending forces. *Time: about 15 minutes*
In KS3, pupils are likely to have investigated the behaviour of springs and rubber bands when they are stretched. Under lower stresses, both show a linear relationship (known as **Hooke's law**) between force (load) and extension. This is called elastic deformation. However as the stress increases, the behaviour of the two materials begins to differ; neither obeys Hooke's law any more, but the spring becomes permanently deformed, while the elastic band becomes much more difficult to stretch further, and eventually snaps.

However, it is unlikely that pupils will have investigated behaviour of materials under **bending** forces. For the purpose of this preparatory lesson, a few quick qualitative demonstrations should be enough to achieve the following **learning objectives**:

- know that under low bending forces, a strip of material will exhibit **elastic deformation;**
- know that under higher bending forces, a strip of material will exhibit **plastic deformation,** becoming permanently bent;
- know that under very high bending forces, a strip of material may snap, suffering **brittle fracture;**
- know that some materials deform in these ways more readily than others.

For quick demonstrations the teacher will need to 'sacrifice' e.g. a few (old) wooden rulers (or wooden skewers), a few (old) plastic rulers (or similar plastic strips which do eventually show brittle fracture) and a few metal (steel) rulers (or similar metal strips which can be bent by hand). If a variety of metals in strip form such as copper, zinc, aluminium, are available for comparative purposes, so much the better. A steel wire coat hanger could be used to show brittle fracture after 'working' in the plastic stage.

Finally leave the class with the (unanswered) question: Is it possible to bend rocks in this way?

Part 3: That folds are formed gradually, under compressive stresses. *Time about 20 minutes*
This activity is taken from the Earth Science Education Unit (ESEU) workshop "The Dynamic Rock Cycle". Contact the Earth Science Teachers Association website at www.earthscienceeducation.com for free materials relating to the teaching ideas of The Dynamic Rock Cycle. Contact eseu@keele.ac.uk for details of their facilitator scheme for free In-Service Training for science departments, funded by the UK Offshore Operators Association (UKOOA).

Part 4. Make your own folds.
Learning Objectives.
1) Folds are caused by compression of rocks;
2) Folds are three dimensional, and form with their axes at right angles to the major stress;
3) Folds are evidence of ancient stress pattern in the Earth's crust.

Equipment: a box with transparent sides (a chocolate box, or component drawer), a spatula or desert spoon, a tray (to catch spilt sand), a cardboard paddle to fit snugly across the box, 500g of dry fine sand, 25g of flour, a photograph of folded rocks, digital camera (optional).

Teachers may want to do this as a demonstration, or, with multiple kits available teachers may want pupils to complete the exercise in small groups and discuss it afterwards to draw out the learning points.

Procedure: Place the cardboard paddle vertically at one end of the transparent box. Then build up several layers of sand and flour, but DO NOT fill the box more than half full. (It is useful to place the flour layer ONLY against the front face of the box, thus using less flour, and making the sand re-useable a second and third time.) (See **Figure 3.**)

Very carefully, push the vertical paddle across the box, so that it begins to compress the layers. When you notice the layers beginning to bend, stop pushing. Hold the paddle upright and take a digital photograph, or draw a scaled diagram of the result.

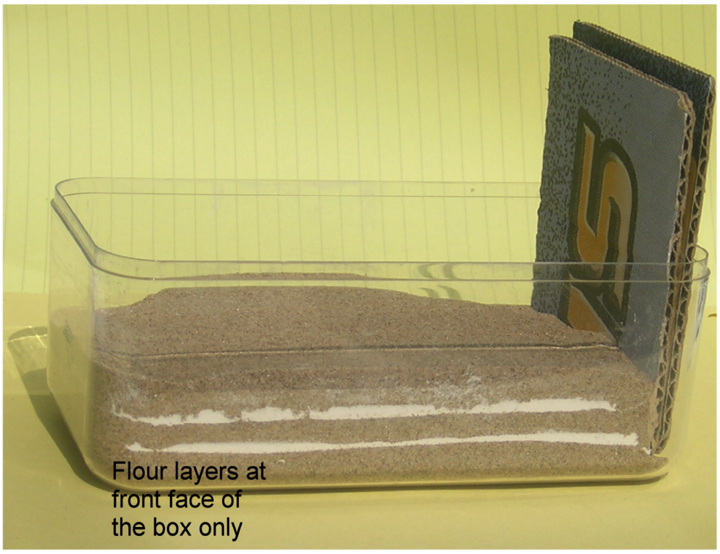

Figure 3. Making folds in sand.

Continue pushing the layers with the paddle until the sand is about to overflow the box. Hold the board upright and again photograph or draw a scaled diagram of the result. It should have features looking something like **Figure 4.** Photographs or sketches of the intermediate stages are also instructive.

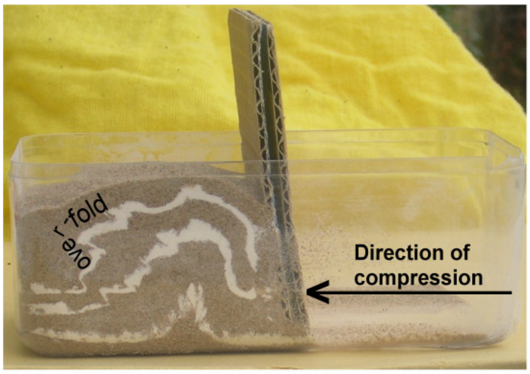

Figure 4. Folds in layers of sand and flour.

The Discussion: Describe the folded nature of the layers, bringing out the following points;

- The layers have been compressed into about 40% of their original length.
- In order to do this they have deformed, or "folded" into upfolds and downfolds.
- That this bending or "folding" happened over a period of time.
- That the view is only of the end (or profile) of the fold, which actually runs all the way across the box, and formed at right angles to the main direction of compression.
- Real folds in real rocks are therefore evidence of ancient compression directions in the Earth's crust.

Then add arrows to your diagram (or printed digital photograph) to show the directions of the forces which were acting whilst you compressed the layers with the paddle.

Part 5. Understanding Folds And Cleavage.

Teachers may want to leave "folding" as upfolds and downfolds, but the discussion of the exposure at School House Quarry will probably be easier with the following vocabulary introduced during the preparation for the visit.

1) There are two kinds of simple folds, **anticlines** and **synclines.**
2) The tightly curved part of a fold is called the "**axis**". The relatively straight parts of the folds are called "**limbs**".
3) The limbs of a syncline dip **towards** the axis: The limbs of an anticline dip **away** from the axis.
4) The axis forms at right angles to the compression that produces the folding.
5) In rocks containing clay minerals a new cleavage also forms at right angles to the compression. (See **Part 6** below.)

Point out that the axis of a fold is an imaginary line running along the top of a fold (See the "creases" in **Figure 5**).

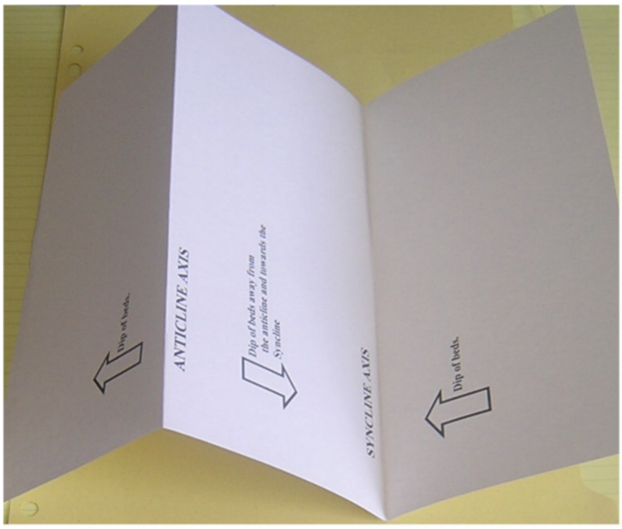

Figure 5. Fold shapes in paper.

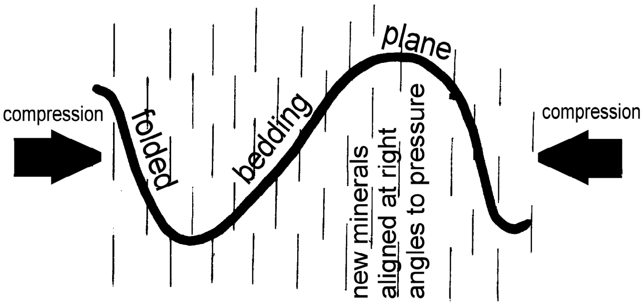

Figure 6. Folds and cleavage.

In rocks containing clay minerals (like the ones at School House Quarry) 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 rocks (now called metamorphic slates) to cleave across the bedding planes.

This can be simply modelled by using several randomly scattered pencils (or broken spaghetti pieces etc.) and confining them between two converging surfaces. (See **Figure 7(a) and 7(b**)). This demonstration may best be performed on an overhead projector screen. This demonstration should be accompanied by specimens of slate showing cleavage.
NOTE. In practice these new minerals "grow" rather than rotate, as in the demonstration. Also they are thin and platy in shape, not elongate like pencils. This idea can also be modelled in the air with several sheets of paper trapped between two hands. This mimics the "cleavage" between the sheets, but can be more tricky to manage).

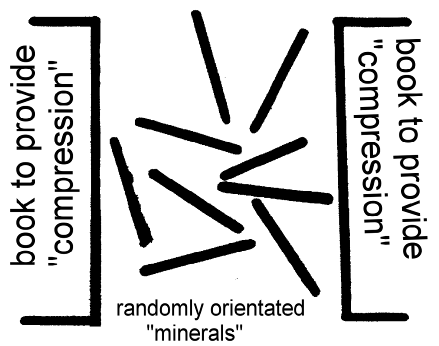

Figure 7(a). Cleavage demonstration.

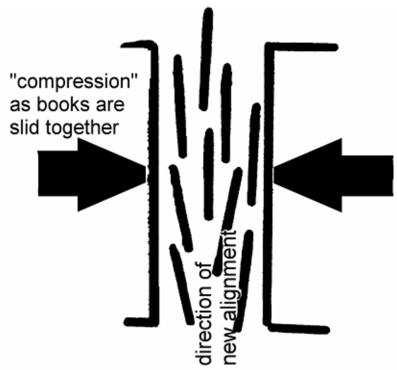

Figure 7(b). Cleavage demonstration.

TEACHERS' NOTE:

It is only possible to get an **absolute age** in millions of years, for a geological event if it is possible to use radiometric dating techniques. The most usual form of dating for geological events is to establish a **relative age**: i.e. which order the events in a sequence occurred. Thus geologists use two concepts of time, an **absolute time scale**, and a **relative time scale**. Research is constantly attempting to improve accuracy of the absolute timescale, and the match between the two.

In establishing the **relative time scale** six laws and principles are used:

1. **Law of Original Horizontality:** all sedimentary rocks were originally laid down in a more or less horizontal attitude.
2. **Principle of Lateral Continuity**: In principle, a sedimentary rock is laid down in a layer (or bed) that extends sideways (originally horizontally) and a bed may therefore be found in other places.
3. **Law of Superposition**: in any sequence of strata that has not been overturned the topmost layer is always the youngest and the lowermost layer the oldest.
4. **Law of Faunal and Floral Succession**: Fossil organisms have succeeded one another in a definite recognisable order over geological time. It follows that the same combinations of fossils in rocks have a similar (relative, not absolute) age, as do the rocks that contain them. This means that the relative age of sedimentary rocks may be identified by the fossils they contain.
5. **Law of Cross- Cutting Relationships:** any structure (fold, fault, weathering surface, igneous rock intrusion, etc.) which cuts across or otherwise deforms strata must be younger than the rocks and structures it cuts across or deforms.
6. **Law of Included Fragments:** particles are older than rock masses in which they are included. So the pebbles in a conglomerate are from rocks older than the conglomerate itself.