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Many ideas involved in this Earth-Science On-Site excursion will revise ideas from Key Stage 3 work. See document **BB6 KS3 Prep**.

At Key Stage 4, in addition to the knowledge and understanding of geological processes gained in Key Stage 3 Physics, the pupils' knowledge of the response of materials to deforming forces, needs to be revised and slightly extended. See parts 1 and 2 below.

INTRODUCTORY WORK.
In addition to the Key stage 3 concepts the following themes should form the basis of the preparatory lesson in school within a week prior to the field visit. The three themes are focused on understanding faulting, folding and igneous intrusion.

Part 1: 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, demonstrating brittle failure.

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.

Part 2: That folds are formed gradually, under compressive stresses. *Time about 20 minutes*
The beds on the Boulmer foreshore are simply tilted to the SE, but the beds at Cullernose Point have been folded. The north–south trends of the folds indicate an east-west compressive force, perhaps created in association with the stresses which also caused nearby faulting.

Part 3. 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 1**)

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.

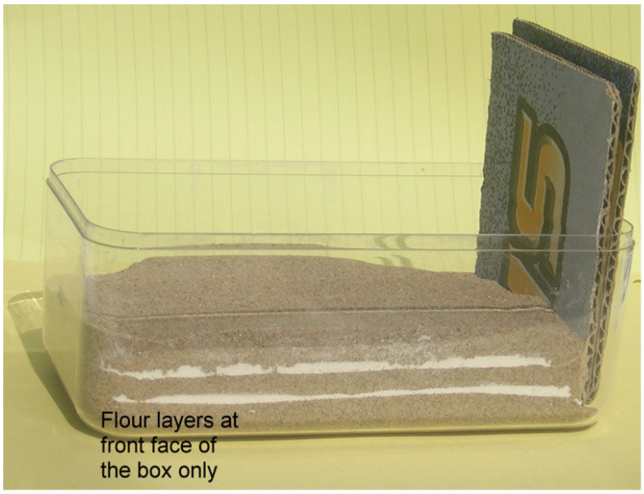

Figure 1. Making folds in sand

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 2.** Photographs or sketches of the intermediate stages are also instructive.

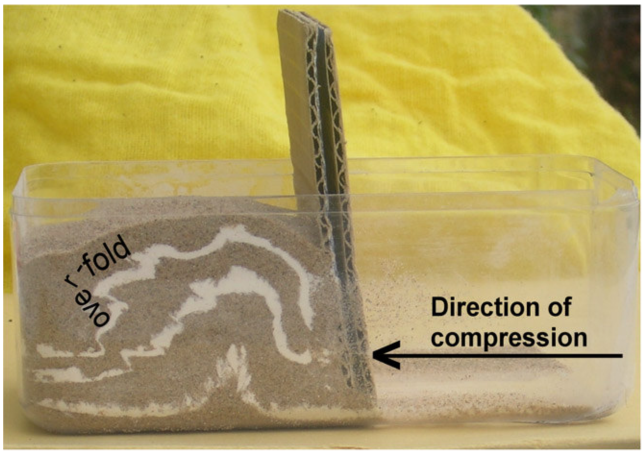

Figure 2. Folds in layers of sand and flour.

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 4. Igneous Processes.
There are no exposures of igneous rocks in the Barr Beacon area, however, pebbles of basalt will be found on the scree in Pinfold Quarry. In order to understand how these pebbles were formed and came to be found here some understanding of igneous rocks is necessary.

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, or on the surface as basalt).

2. Basic magma derives from the **partial melting of an otherwise solid upper mantle.** Igneous rocks, therefore, are characterised by **interlocking crystals.**

4. Hot magma moves upwards through cold "country rock" by virtue of being **less dense**. 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.

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 than basalt.

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 this area the age given for the dolerite intrusions is 295 million years and forms one of many links between the two time scales.

The fundamental geological principle is **The Principle of Uniformitarianism:** which states that the biological, physical and chemical processes we see today, operated in much the same way in the past, i.e. "The present is the key to the past". In establishing the **relative time scale** the following 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. **Principle 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. **Principle 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. **Principle 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. **Principle 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.