Introduction

☛ Field groups will need measuring tapes, compasses and clinometers, hand lenses and grain-size comparator cards, as well as clipboards, a short ruler and copies of the relevant field sheets for individual pupils. (See **DRY13 worksheets**).
In addition Group Leaders will need a plastic bottle of dilute HCl, a small plastic bottle of water; a flexible sheet of foam rubber, or paper, to demonstrate the shape of folds.

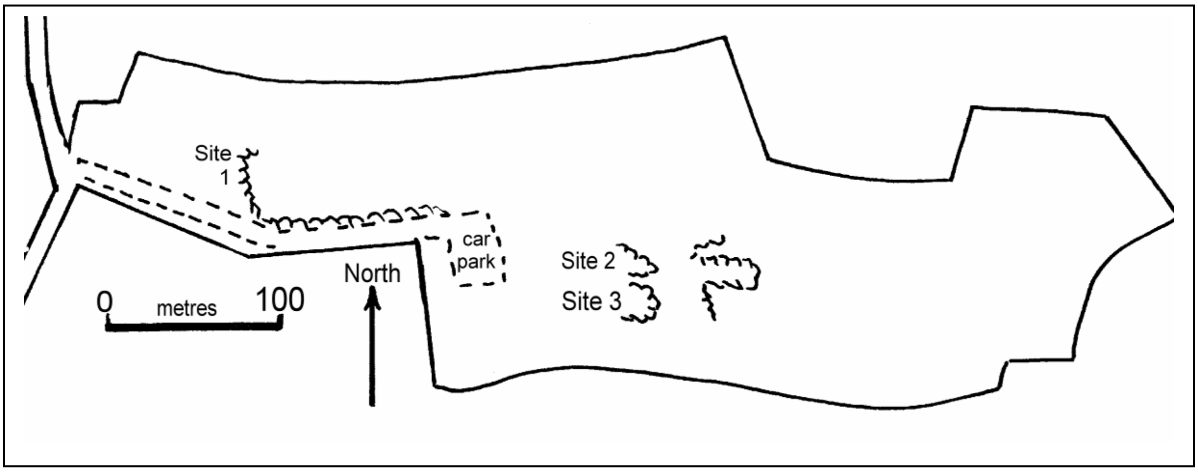

Figure 1 Site Map Of Dryhill Nature Reserve

Additional information about these sites is given in document DRY9 Field Notes.

At Site 1
Bring the party to Site 1, at the north end of the prominent crag near the entrance to the Nature Reserve. Remind pupils of the purpose of the field excursion: to investigate the Rock Cycle. Then at **Site 1**, focus the attention on what can be seen in the exposure in terms of major features: bedding planes, joints, and weathering.

Suitable questions at this site	**Possible acceptable answers**
Can you see layers in these rocks? Are they horizontal?	Yes there are many layers. They are not horizontal, that are dipping down to the right (South).
Estimate as best you can the angle at which they are dipping. [Draw a dip arrow on your map (Pupil Worksheet 5) at point "a" to show the dip to the south]	Anything from 30 to 40 degrees to the south.
Can you see joints at right angles to the bedding planes?	Yes there are many
How might these joints affect the rate of weathering of this rock?	It divides the rock into blocks to allow physical weathering and also increases the surface area to acidic rain and chemical weathering.
Can you see what has happened to the material weathered from this rock face? How did it get there?	It has formed a small scree slope at the foot of the slope. It fell under the effects of gravity
What kind of rock might this be: igneous, sedimentary or metamorphic?	Layered rocks are usually sedimentary.
What kind of processes might have caused this rock face to form here?	There are no natural processes (like rivers, or glaciers) to explain it. It is part of a quarry. It is man made.

Using **Pupil Worksheet 1**, make a labelled sketch of the outcrop labelling the main features you have seen. On the map (Pupil Worksheet 1), ask pupils to draw an arrow, at point "a" to show these beds dipping in the direction they have observed. (An arrow showing the dip at **Site 3** has already been drawn as an example.)

Before leaving **Site 1**, draw pupil's attention to **Site 2** on the map, and ask them to predict what rocks they might find there, and whether they will be horizontal or dipping. [Speculation might include more sedimentary rocks, dipping to the south, as here at site 1.]

At Site 2

☛ Walk the group eastwards along the roadside, past the car park and on towards **Site 2**, concealed in the trees to the right (a compass heading of 105 degrees North from the car park) (see **Figure 1**). **Site 2** is on the left (north); **site 3** on the right (south). Sites 2 and 3 can accommodate parties up to 15. Larger parties can be split between the two sites and alternate these exercises. In both sites the ground underfoot is uneven, and can be overgrown.

At **Site 2** emphasise the importance of preliminary observation, and the interpretation of natural processes. The correct use of terms, particularly "weathering" (rock break-down in situ) and "erosion" (movement of weathered material) should be emphasised. To avoid identifying the rock names prematurely, the old quarryman's names may be used. The more resistant limestone is "Rag" and the less resistant sandstone is "Hassock".

First comment on the accuracy of the predictions made for this site by the group whilst at **Site 1**. Although the rocks are very similar, there are important differences in dip direction and bed thicknesses.

Suitable questions at this site	Possible acceptable answers
How many different rock types seem to be visible at this site	Two.
Can you tell if one rock type is more resistant to weathering and erosion than the other? If so how?	Yes, one is more resistant. One is standing proud "sticking out" or the other is forming a series of depressions or groves.
Describe how the less resistant Hassock rock is being broken down (weathered).	It is crumbling away to a sandy (use a hand lens and grain-size comparator card to establish medium sand) material. This might be caused by frost (physical weathering) action, but this is unlikely because there are no "lumps" of this rock as would be produced by physical weathering). It is more likely to be by chemical weathering, caused by acidic rainwater of the mineral holding the grains together. It is also brownish in colour, indicating chemical weathering of iron minerals (in this case Glauconite).
How is this material being moved (eroded)?).	It is being moved down the slope. This might be by gravity alone, but also by rain wash (and children sliding down the exposure!).
Describe how the more resistant Rag rock is being broken down (weathered).	There is much less evidence for this process, other than some discolouration of the surface of this rock (chemical weathering). There is clear evidence of biological weathering by the growth of tree roots into the rock. The lumps of this rock lying around the quarry floor indicate physical weathering, but are likely to be the result of past quarrying activities by humans, rather than frost action.
How is this material being moved (eroded)?	Chemical weathering often involves removal of material in solution. The lumps will have moved downslope by gravity
Which of these two rocks would make the better building stone, and why?	The Rag was widely used for building stone from the Roman times, but also as a road aggregate during the last century. It can be found in walls at Rochester Castle, the White Tower in London and The Westgate at Canterbury. This is because it is physically strong enough to take the weight of overlying stones in a wall, and chemically resistant enough to last a long time. This contrasts with the poorly cemented Hassock

Direct pupils' to investigate the rock type. What name would Earth Scientists use for each?

Suitable questions at this site	Acceptable answers
What are the three main groups of rock types?	Sedimentary, igneous, metamorphic.
What evidence can you see that suggests these may be sedimentary rocks? [Allow pupils to investigate, without climbing the face]	They break down into grains by having the cement weathered away. They are in layers. (there are also some fossils, but they will not have found them yet)
Are these rocks permeable i.e. lets water through them? (Porosity is the percentage of void space within the rock. Porous rocks are often permeable)	Placing a drop of water of each rock type demonstrates that the sandstone outcrop is very permeable, whilst the limestone is much less so (find a limestone piece with a depression in it where the water will pool for several minutes).
Can you name the two rock types. What tests can we use?	The hassock is a sandstone, which reacts with dilute HCl because the cementing material is calcite. The Rag is a limestone (with a lot of sand in it) and reacts with dilute HCl also.
Can you find any fossils?	There are traces of a single bivalve shell (at point "b" on the worksheet) which is not collectable and should not be damaged by the attempt. It has been separated from the other shell by currents after the animal died.

Remind the pupils that layers of sedimentary rock are evidence of weathering erosion, transport and deposition in a previous rock cycle, in this case about 115 million years ago. The order and thickness of these beds provide evidence for these processes, but to collect measurements in sequence, start with the oldest (the bottom one) and work upwards. Here we arbitrarily pick one bed as a starting point. (See Pupil worksheet 2). When the exercise has been completed, ask the following questions.

Suitable questions at this site	Possible Acceptable answers
What do you notice about the sequence of layers or beds?	They are repetitions of two rock types, of approximately equal proportions (the limestone beds are slightly thicker than the sandstones).
What grain sizes have you recorded? What does that tell you about current strength ?	Medium sand size grains. Currents of moderate strength.
Where must these sand grains have come from to finish up in these rocks?	From the weathering of other rocks in an earlier rock cycle. Either older sandstones, or possibly from igneous rocks containing quartz crystals. They were brought to the sea probably by rivers (wind and ice are other, less likely, theoretical possibilities).
What other evidence have you found that tells us about the way these rocks were formed?	There is at least one bivalve in the sequence. This could indicate freshwater, but is in fact a marine species. It also tells us that the water was oxygenated, of normal salinity and that there was food (bivalves are filter feeders).
Where did the calcite come from to make the bivalve shell?	Bivalves take calcite from solution in the seawater, but the calcium carbonate got into the seawater in the first place by chemical weathering of older rocks.
If you could have stood on this spot when these beds were being deposited what kind of a place would you have seen?	A sea area with some currents bringing in sand. Also shellfish, so water depth would not be too deep to allow bottom living shellfish to survive. (One estimate suggests a depth of 20 metres)
Why do you think the rock types keep alternating?	There must have been an alternating set of circumstances affecting the area.
Ask for hypotheses (guesses made by scientists) as to what those alternating circumstances might have been.	Try to keep the hypotheses focused on the processes of the Rock Cycle: weathering, erosion, transport and deposition: e.g. alternating supply of material; alternating current strengths. (In fact the main difference seems to be the amount of broken echinoid shells now re-precipitated as calcite cement, and the current ideas are: 1) Seasonal storm conditions washing in broken echinoid skeletons from deeper water. 2) Seasonal increase in numbers of echinoids due to breeding cycles. 3) Periodic changes in the conditions suitable for echinoids, e.g. warmth, food, etc. 4) Periodic stronger currents bringing in sand which buries the echinoids and kills them).

Remind pupils that sedimentary rocks are deposited horizontally (the Principle of Original Horizontality) and that their dips today are evidence of physical pressures in the rocks since they were deposited. Take the dip measurement (or make an estimate) of a suitable bedding plane. Point “b” is suitable. (It should be about 15 degrees east of north, and between 30 and 55 degrees from the horizontal, depending on the exact point of measurement. This reading can be plotted on the map (**Pupil Worksheet 1**) of the site, at point “b”.

Before leaving for **Site 3**, ask the group to predict what rocks they might find at **Site 3**. [Speculation might include: sedimentary rocks, older than those here due to the dip at **Site 2** since they lie opposite to the direction of dip].

At Site 3.

☛ Walk the group to the next quarry, just 20 metres further south, and approach the face at the eastern end.

Here the intention is to draw in the bigger picture, but first focus the group's attention on observation skills. Ask them to describe the beds in the exposure, and apply the ideas from the first site.

Suitable questions at this site	Possible acceptable answers
Do the rock types seem to be similar to those in the previous quarry?	Yes.
What signs of weathering and erosion can you see?	Some rain washed material may be present at the foot of the slope. Tree roots can be seen growing into the rocks at the southern end of the face.
Can you see any soil layers being formed form these weathering processes?	Yes, at the top of the slope. It is a thin soil, mainly because the surface on which it is forming is a quarried surface and has only been exposed to soil forming processes since the 1960s.
Are these beds dipping like the beds in the previous quarry?	They are dipping, but these beds dip towards each other (The fold is called a syncline)

Ask pupils to plot the dip for the beds at point "c" on their map **(Pupil Worksheet 1**)

Suitable questions at this site	Acceptable answers
Which of these beds is the youngest, and which the oldest?	The Principle of Superposition says the oldest rocks are below, with the youngest rocks on top. So here the youngest rock is at the top, and in the centre of the syncline.
What sort of pressures could cause folds like these? [Suitable sheets of paper, or foam rubber can be used to demonstrate the relationship between folds and compressional forces].	Compressional forces, at right angles to the fold direction (i.e. compression from north – south)
Which came first, the deposition, or the folding?	The beds must have been deposited first, then were folded later. Principle of Cross Cutting relationships
What else has disturbed these rocks since they were deposited, apart from being tilted?	They have been uplifted from just below sea level to about 90 metres above sea level (i.e. probably more than 100 metres in total). [They have also been faulted, but this is very hard to see here, and probably will not be noticed]
What kind of forces can compress and uplift large parts of the Earth's crust?	Plate Tectonic forces. These are associated with the tectonic events that raised the Alps, and created the Wealden anticline, of which these rocks are a part.
What kind of a plate margin must there have been where the Alps are now?	A destructive plate margin, closing an Ocean (The Tethys Ocean, see Fig 1, in document DRY 4)
If humans did not interfere, what might eventually happen to the weathered sand from this quarry?	It might eventually reach the River Darent and be transported north to the River Thames near Dartford, and then east to the North Sea, to start another rock cycle. [NOTE: The North Sea is **not** oceanic floor, nor a destructive plate margin.]

Using Pupil Worksheet 3, ask the group to **identify, and explain** as many changes to the face as they can since the photograph was taken in April 1970.
(The differences are mainly: several prominent blocks are missing from the face – probably due to weathering and slipping, although there is little evidence for this at the foot of the slope; vegetation growth on the skyline; removal of the willow sapling from the right of the 1970 picture, and other vegetation clearance at the base of the face.)

Using **Pupil Worksheet 4,** ask the pupils to produce an annotated sketch of the main features of the face.