INTRODUCTION

☛ Field groups will need measuring tapes, magnetic compasses and clinometers, as well as clipboards, a short ruler and copies of the relevant worksheets for individual pupils. (See **TED12 worksheets**).
Group Leaders will need a plastic bottle of dilute HCl, a small plastic bottle of water; a flexible sheet of foam rubber to demonstrate the shape of folds. A calculator and digital camera will also be useful.

☛ **If the transport is by coach** have the party dropped at the eastern end of the vale at Hapsford Bridge (ST747484), and arrange to be picked up just west of the church in Great Elm. Allow about 4 hours for the visit. From Hapsford Bridge proceed on foot along the road through the lorry park (taking care of any moving traffic), and over the river bridge. Then take the path between two warehouses and the small path to left, alongside river, through the kissing gate and into Vallis Vale. At a wide gravel area, take the short narrow footpath to the north north east, to the exposure through the trees.
Smaller vehicles and minibuses should be parked carefully at the roadside either at Hapsford, or at Fordbury Bottom, ST 749492, from where parties may then make the 25 minute walk eastwards (downstream) along the vale to the broad gravelled area. The exposure is behind the trees along the short path to the northeast, opposite the footbridges to Egford Brook.

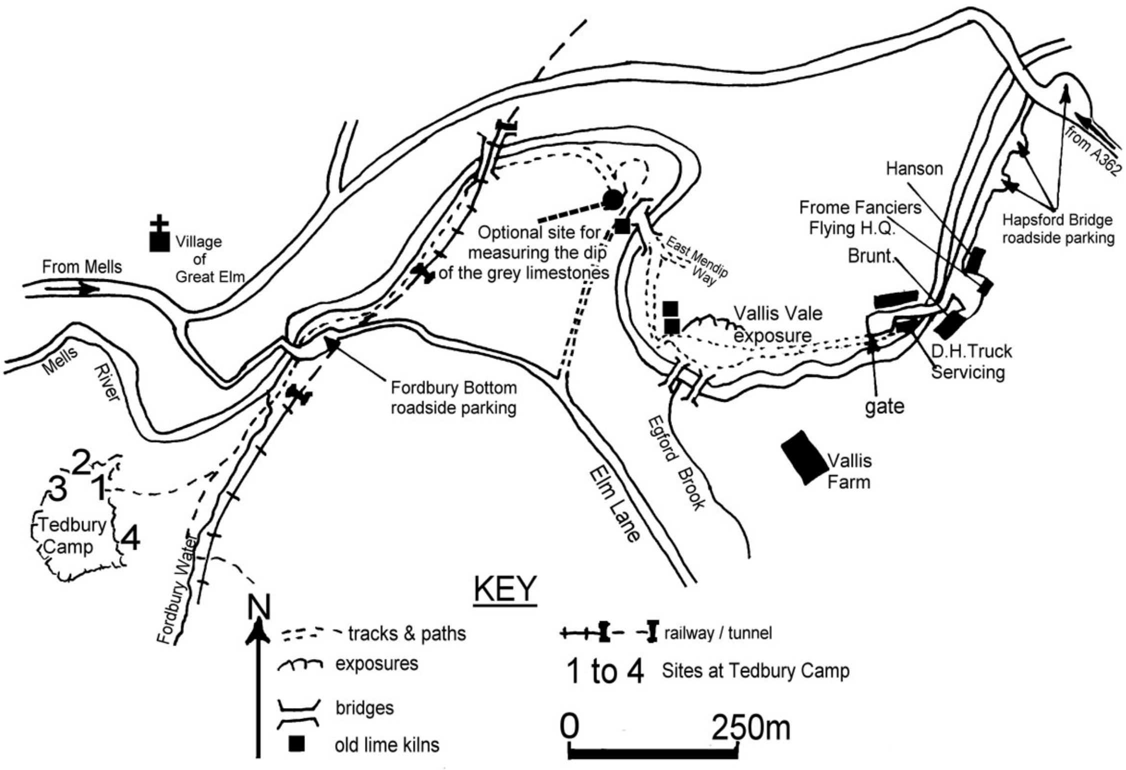


Figure 1. Site map of Vallis Vale and Tedbury Camp
Note: The given name for the exposure referred to here as Vallis Vale is "De la Beche."

☛The field exercises here are divided into ten areas of focus. At the planning stage field leaders should decide which combination of them will meet the needs of any particular group or syllabus.

Field Exercises at Vallis Vale.

NOTE: In order not to anticipate pupil identification of these rocks as limestones, they are referred to here as "older/younger" or "grey/yellow" beds. As an alternative group leaders might want to refer to these two sequences by their geological time period: the lower grey beds are Carboniferous, (deposited about 340 million years) whilst the overlying beds are Jurassic (deposited about 170 million years ago). The geological time gap between the two groups of rocks here is of the order of 170 million years.

☛ Ask the pupils to investigate the **lower** part of the exposure in small groups and collect observational evidence about the grey rocks using worksheet 1 as a guide. Focus on the kind of rock (igneous, sedimentary, or metamorphic) they think it is) and any features they can identify (e.g. crystals, grains, bedding, fossils, joints, weathering etc.)

Collecting specimens is **not** allowed at this protected site. Do not allow climbing on the exposure. Then call the group together to inspect the whole face. It can be best seen from about 15 metres away. (See **Figure 2)**

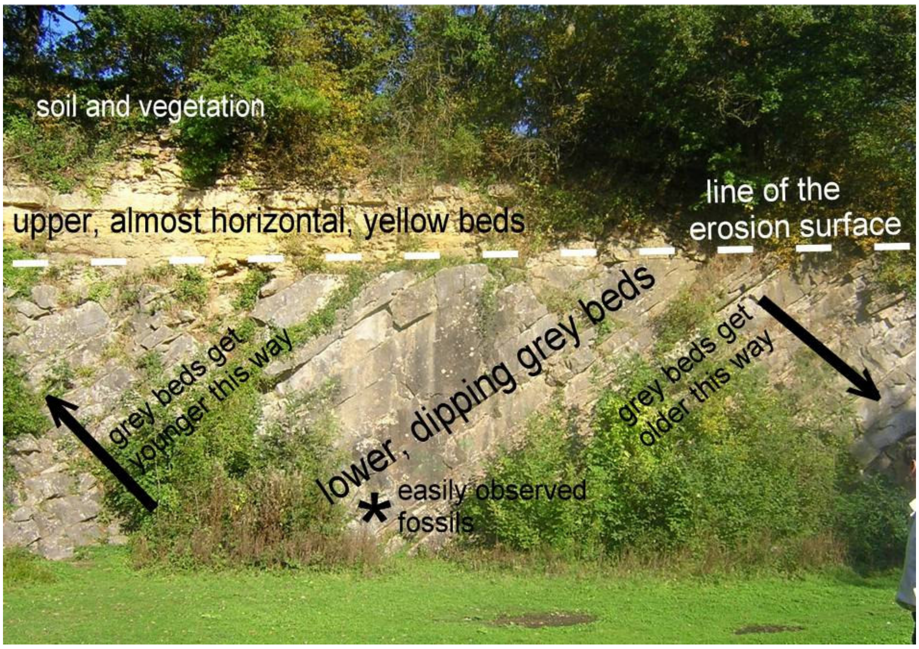


Figure 2. The Vallis Vale exposure

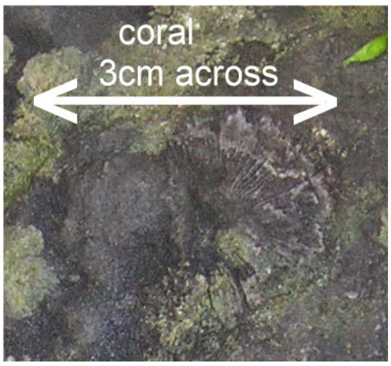


Figure 3. Coral specimen at Vallis Vale

FOCUS ONE: Investigating the two rock cycles.

Suitable questions at this site	Acceptable answers
TASK 1: Concentrate on the lower (grey) part of the exposure. Describe these rocks and the evidence you found when you inspected them closely.	There are many layers which have joints. The layers are tilted down to the left. (dip measurement comes later). They contain fossils (corals and brachiopods, see the asterisked site in **Figures 2 and 3**). They also effervesce with dilute HCl (as applied by the group leader). When water is applied in does not sink in: the rock is non porous. [**NOTE:** There are some harder chert "lumps" which are made of silicon dioxide and will not effervesce]
Are these rocks igneous, metamorphic or sedimentary? Can you name the rock?	Layered rocks with fossils are sedimentary. These contain a large amount of calcite and therefore are limestones.
What elements make up the mineral calcite (calcium carbonate)? What elements make up the mineral chert?	Ca, C and O. Si and O
What are the most common elements in the Earth's crust?	Si, O, Al (Earth has a "glass" lithosphere - with some impurities).
Why doesn't the composition of the rock reflect the composition of the crust?	Sedimentary processes can produce beds showing chemical separations. First by way of sorting by density and size. Hence sandstones are high in Si and O, whilst clays and shales are high in Si, Al and O. Second by chemical (or organic) precipitation from seawater occurs, then elements in solution (e.g. Ca, Na, etc) can become concentrated in the rocks as limestones or evaporites. Third, anaerobic decay of organic matter can produce concentrations of (hydro) carbon, or coal and oil.
What does the fossil evidence tell us about the conditions under which these grey limestones were deposited?	The corals suggest a warm marine environment of normal salinity and well oxygenated. Since the corals are found lying on their side (i.e. not perpendicular to the bedding), they must have been washed around by currents after death.
If the optional dip measuring exercise at the end of this section is to be omitted, then observe the dipping rocks. Ask pupils to estimate (a) the angle of tilt of the beds & (b) the direction they are tilted towards. (The angle of tilt from the horizontal is usually called the **angle of dip.** **The True Dip** is in the direction of steepest slope. All other, smaller angled dips, are "false" dips). Here the apparent dip is close to the true dip	40° to 50° tilt (**angle of steepest dip**) though the estimates will vary widely. Tilted towards the north west. (**direction of steepest dip**).
At this point remind the group that rock cycles can be thought of as having three main stages: **i)** deposition of beds; **ii)** deformation of beds (tilting, folding, faulting, igneous intrusions etc.); and finally **iii)** uplift, weathering and erosion. See worksheet 2.	
Which is the oldest, and which the youngest, of these lower grey beds?	Younger rocks lie on top of older beds. In dipping rocks the younger beds lie in the direction of the dip, i.e. younger to the left and older to the right of the face. **See Figure 1.** (**Principle of Superposition**)

Would these grey beds have been deposited at this angle? **NOTE:** Rock cycle, stage (i)	They would have been laid down roughly horizontally. (**Principle of Original Horizontality**)
If these grey limestones were formed below sea level, and buried below later rocks, but are now at about 100 metres above sea level, what must have happened to them? **NOTE:** Rock cycle stage (ii)	The rocks have been uplifted (Large vertical changes in sea level can be discounted due to the vast amount of water involved in flooding land to this height) and also tilted.
If these beds had been buried deeply and heated, what would have happened to them?	Metamorphism of limestone to marble.
What is the evidence that this didn't happen here?	The rock would have no fossil remains, but be made up of interlocking crystals of calcite.
Now concentrate on the upper part of the exposure (the ones too high to be directly observed). Describe the main features of these rocks.	They are yellow in colour. They are layered and jointed. The layering is approximately horizontal.
Hypothesise as to the kind of rock might this be: igneous, sedimentary or metamorphic?	Layered rocks are usually sedimentary. [This will be checked later, at a safer place]
(The hypothesis will be checked later, but assuming these are sedimentary) Which of these yellow upper beds were deposited first, and which last? **NOTE:** Rock cycle stage (i)	Younger rocks lie on top of older beds. (**Principle of Superposition**). So the oldest lies on the grey beds, and the youngest is just below the soil line.
How have these beds been moved since their deposition? **NOTE:** Rock cycle stage (ii)	Although they have not been tilted much they have been uplifted by earth movements, and are now about 100 metres above sea level.
How can you explain the older beds being uplifted and tilted, but the younger ones only uplifted, **but not** tilted? If a hint is needed point out there are also two episodes of deposition as well as two of uplift and / or tilting.	There were **two** periods of disturbance. First the uplift and tilting of the grey limestones which were eroded before the yellow ones were deposited. Then a second uplift (of both) after the yellow beds were deposited. This means we have **two** Rock Cycles here: one continuing at the present day, and an ancient one, pre-dating the yellow beds.
Point out to the group the "erosion surface" across the exposure separating the two rock formations. (**See figure 2** where it appears as a line) If you could see it in 3D what do you think it would look like?	It would be a 2D surface It appears to be an almost level "line" across the face, and represents a time gap in the depositional evidence. It was formed by erosion of the lower beds, before the upper ones were deposited. [Point out that the current landscape is another erosion surface, which has valley slopes in it).
TASK 2: Ask pupils to draw an annotated field sketch using worksheet 2.	Emphasise that earth history is a long endless sequence of rock cycles, with the one before providing the fragments, and weathering products for the rocks in the cycle following.
TASK3: Using worksheet 2 as a guide ask pupils to summarise the events forming the two rock cycles, and complete the diagram as they do. A completed version of this worksheet for group leaders is to be found in **TED13 teachers' notes**.	i) First deposition of grey limestones in the sea, (about 340 million years ago). ii) Then uplift tilting weathering followed by iii) weathering and erosion (for about 170 million years) to form an erosion surface. END OF FIRST CYCLE. i) Then deposition of the yellow beds (about 170 million years ago) ii) Then uplift and weathering and erosion (i.e. no evidence of deposition after the yellow beds 170 million years ago!). iii) Weathering and erosion by rivers continuing at the present day. i.e. our landscape is another erosion surface! END OF SECOND CYCLE.

FOCUS TWO: Describing start of the next rock cycle.

Suitable questions at this site	Acceptable answers
What kind of processes might have caused this rock face to form here?	The obvious possibility is the river eroding its valley, but the exposure is on the wrong side of the meandering valley (i.e. not the outside of the bend) for it to be the whole explanation, as the cliff would be on the outside of the bend. It is a quarry and is a quarried face now kept cleared by volunteers.
Can you see joints at right angles to these 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, as well as allowing roots to grow into the rock.
What evidence of weathering and erosion of these rocks can you see?	From here not much! They have only been exposed to weathering since about the 1950s. However, there are signs of soil formation near the top of the face, and evidence of biological weathering with tree roots growing into the joints and bedding, and there is a deep valley cut by the river.
TASK 4: Estimate the volume of rock removed by the river to make the vale between Fordbury and Hapsford. Use worksheet 1and a calculator to help you.	Approx. average depth = 25m; Approx. average width = 250 m; Approx. average length = 2500 m Volume = 25 x 250 x 2500 = 1,625,000 cubic metres (approximately 1.6 cubic kilometres)
If humans do not interfere, then what will eventually happen to the fragments (and soluble material) weathered from this exposure and moved by the river?	They will form new sedimentary rocks in the future (i.e. the next Rock Cycle). Sediment in the River Mells might be transported to the River Avon, and then deposited as new sedimentary rocks forming in the Severn Estuary and the eastern Atlantic.
What kind of fossils representing present-day times might be found in these new rocks by geologists millions of years in the future?	Accept most answers that recognise the need for resistant parts: e.g. ipods, boats, cars, cans, shellfish, dolphins, washed – in trees, drowned birds, (and maybe even human skeletons) etc. but not jelly fish etc.

FOCUS THREE: Investigating a lost mountain range.

☛ Remind pupils that they have been describing events where large volumes of crustal rocks (lithospshere) have been uplifted by many hundreds of metres and tilted by many degrees from the horizontal on at least two occasions. This requires vast amounts of energy and the next section investigates the first episode of this larger scale phenomenon.

The observations for this section are acquired during the walk from Vallis Vale to Tedbury Camp.

Group leaders may wish to omit this section and continue with “setting the scene” for Tedbury Camp.

Suitable questions at this site	Acceptable answers
Draw attention to the map on worksheet 3. The dip arrows are drawn for these **same** limestones, but at other locations in the area. What do the dip arrows tell us about the tilting of these beds?	In one part of the map they dip northwest, whilst in another part they dip SE. i.e. there is an up-fold, or anticline, where the beds dip away from each other.
(Move the group up close to the face). Using a clinometer and compass, measure the dip amount and direction of a suitable bedding plane, & plot on worksheet 3 at point “**a**”. (**TED12 worksheet**).	Dip measurements, depending on exactly where they are taken, should be fairly close to 40° (**angle of dip**) towards the north west, or 340° magnetic. **TIP:** Use a clipboard to get a plane surface for measurement. First use the clinometer to find the “horizontal” across the bedding plane (dip= 0°), then measure the **true dip** amount and direction at **right angles** to this horizontal.

After they have plotted this dip on their map, ask them to predict the direction of dip at the two remaining sites "**b**" and "**c**"). These predictions will be checked at these two sites later.	Accept all suitable speculation, then wait and see. Begin the walk upstream towards Fordbury Bottom and Tedbury Camp. NOTE: Point "**b**" is below a footbridge, alongside the path just after the bridge across the Mells River. (See **Figure 1**) Point "**c**" is where the Fordbury path enters the quarry at Tedbury Camp.
When point "**c**" (Tedbury Camp) is reached, remind the group of their preparatory work on folding. Ask them to predict which direction they would expect to find an anticlinal (up-folded) axis in these rocks. (Refer to preparation work on fold shapes, or demonstrate the geometry using flexible card or foam rubber sheets).	Dip measurements in folded rocks point away from anticlines (and towards synclines). The anticline would be expected to be to the SE of these three sites, and probably running at right angles to the dip.
Using the map on worksheet 3, where would the anticlinal axis be predicted to run? Draw it on the map	This is a very imprecise way of defining a fold axis, but from the dip information on the map it would be roughly between the opposing dip arrows and at right angles to them. This will give a roughly NE-SW direction. [In fact the Beacon Hill anticline runs more ENE-WSW.]
What kind of rock deformation is shown by folding?	Plastic deformation. [Brittle fracture would have produced faulting.]
What forces could have done this?	Plate tectonic forces, when plates collide, are the only known forces strong enough to compress large volumes of crust.
From the map showing folds across Ireland and southern England, what can you say about this plate collision? (See worksheet 3)	It affected much more than the rocks in Vallis Vale. The folds run roughly east-west, so compression would be expected to be south-north. (The flexible sheet of card or rubber may be needed as a prompt about direction of forces)
What kind of plate margin would this have been?	A destructive plate margin: a closing ocean with an oceanic trench.
What kind of rocks form in the centre of fold mountains?	Metamorphic and igneous rocks (as found in Cornwall). (See worksheet 3)
Remind pupils that Earth Science is studied at many scales, from the microscopic up to the size of continents and planets. Ask them if they can name any present day fold mountains of the same size as these, caused by a more recent plate collision.	Any modern fold mountain range: Alps, Rockies, Andes, Himalayas, etc.

FOCUS FOUR: Setting the scene.

☛Before leaving this site, it is important to set the scene for the work at the Tedbury Camp exposure. This requires pupils to understand two ideas.
First, that these rocks, and the erosion surface, once extended out of the quarry face above your heads, and also extend to the left, right, and inwards under the fields beyond. (This is the **Principle of Lateral Continuity**, which tells us that these beds may be found elsewhere (e.g. Tedbury Camp).
Secondly, that the processes that are happening today are the same ones that happened in the past. (This is the **Principle of Uniformitarianism**). Then tell them the next site is one where they can actually stand on that erosion surface and inspect the evidence for themselves.

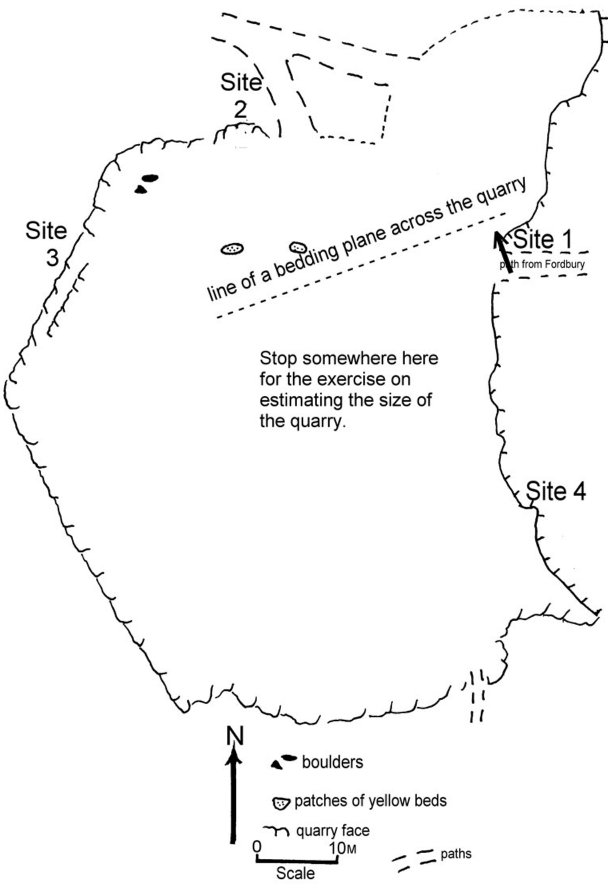
Ask the group what they would look for in order to recognise these beds if they saw them somewhere else? [ANSWER: Horizontal "yellow" (limestone) beds on top of dipping grey limestones, separated by an "erosion surface"].

☛ Either return to the minibus the way you came and drive via Great Elm to Fordbury Bottom, or if the party is to be picked up by coach in Great Elm later, continue westwards (upstream) to Fordbury Bottom, and on to Tedbury Camp on foot. (See **Figure 1**)
After crossing the road at Fordbury Bottom, the path is through the gate across the road. It passes alongside a railway and crosses the stream on a footbridge to the right and then follows the stream bank to the left. Where the path forks in the woodland take the right hand path. It is steeply uphill to the quarry platform. (See **Figure 1**) The route up to the camp is narrow and fairly steep in places: when wet it is slippery. Warn the group to be careful of their footing, and to stay out of the stream and off the railway.

Field Exercises at Tedbury Camp.

☛ If the optional exercise on dip measurements has been taken, then site 1 is point "**c**", the final dip reading. Complete the worksheet 3 exercise before continuing.

☛ Allow the group to stand on the broad flat area of the quarry close to Site 1 at the eastern lip of the site. (See **Figure 4**) A first impression of the flat surface is that it is a man-made surface. It is in fact natural, being only cleared of the overlying yellow beds for quarrying operations, however, it may look dissimilar to the Vallis Vale exposure just visited.
Large parties may be split between the Tedbury sites, each of which can accommodate 15 to 20 pupils.



Site 1 is just on the right as you reach the quarry. (See **Figure 4**)
In this position draw the attention of the group to the nature of the rock in the edge of the quarry (as opposed to the flatter surface). It is clearly bedded and dipping to the right, however, measurement will show that the dip is in the same direction as at Vallis Vale, (where the beds dip to the left): i.e. to the north west (about 50° to 342°).

Once the bedding is established then the large expanse of flat surface can be seen to be cutting across the bedding. (See **Figure 5**) This is the same geological relationship as at Vallis Vale, except, here, the erosion surface separating the two rock successions can be closely inspected in three dimensions. This site is not a protected site, but damage to the exposure by collecting should be kept to a minimum.

The first task is to link the geology at this spot with the Vallis Vale exposure visited earlier.

Figure 5. The eastern edge of Tedbury Camp.

FOCUS FIVE: Confirming lateral continuity of the beds.

Suitable questions at Site 1	Acceptable answers
If the "Investigation of the Lost Fold Mountain Range" exercise has been started, then make the final dip measurement here and complete worksheet 3. If not go to the next question.	See TED 13 Teacher's Notes
Using your answers on **Worksheet 1** what features can you see in these grey rocks which allow you to identify them as the same as those at Vallis Vale? **NOTE:** Don't allow the relative dip to confuse things. These beds appear to dip "right" instead of "left" because they are being viewed from a different viewpoint from Vallis Vale.	Grey limestone beds, dipping (here to the right, but still at 40° at 340° or to the NW); well jointed; containing fossils; reacts with dilute HCl. and are non porous. (Use the water test)
Use a compass to measure the direction of dip and demonstrate that the "difference" in dip direction from Vallis Vale is not real, but due to a change in the direction of observation. Ask which part of the Vallis Vale exposure these beds represent?	These are the grey beds seen at the base of Vallis Vale. Careful observation of the quarry edge will reveal shelly bands deposited parallel to the bedding demonstrating the presence of sea currents. Point out that the fossils they contain indicate they were deposited in the Carboniferous period about 340 million years ago.
Ask if they can see the "erosion surface" from Vallis Vale. (Give reassurance that it is not man made, although it has been cleared of overlying beds)	It is the large almost flat surface cutting across the top of the beds. (There are patches of yellow beds still remaining where the yellow beds weren't entirely cleared away)
Using the **Principle of Cross Cutting Relationships,** work out which came first, the limestone beds or the erosion surface	The erosion surface cuts the bedding, and so is later than the bedding.
Ask if they can see the yellow beds last seen at the top of the Vallis Vale exposure? **TASK 5:** Mark an arrow on their map of the quarry (Worksheet 3) to show the direction of dip of the grey beds. Label Site 1 on the map. Also draw one or two grey bedding planes trending across the quarry floor. (See **Figure 4**)	They are on top of the grey beds - at the rear and edges of the quarry where they have not been cleared away. (NOTE: **Principle of Lateral Continuity** states that sedimentary layers extend in three dimensions and might therefore be found elsewhere.) Having established that the surface is the lateral continuation of the one seen at Vallis Vale, move to Site 2 to inspect the yellow beds in some detail.

☛ Walk the group along the top surface towards the western edge of the quarry. Ask them to choose a grey bed and walk along it noticing changes in the surface. This should produce chance "finds" e.g. the two patches of yellow beds and associated fossils, and cause for discussing issues dealt with in later sections. Whilst not easy to plan, this opportunity can produce interest and excitement. For the interpretation of many features see the following sections.

Bring the group to site 2 on the northern edge of the quarry. Remind the group that they hypothesised that these beds would be sedimentary rocks when they saw them at Vallis Vale. At site 2 give the group chance to examine the yellow beds which were inaccessible at Vallis Vale. Ask them to work in small groups using the second part of the table on Worksheet 1 to help them look at the exposure (and the fragments lying around).

FOCUS SIX: Identifying the Yellow Beds

Suitable questions at Site 2	Acceptable answers
Describe the rock and the different grains and fragments in it, and now they are held together.	It is made of ooliths (small spherical bodies of calcium carbonate formed by wave action in warm shallow water), and fossil fragments, bonded together by mineral cement (calcite)).
What other observations can you made about this rock? Here the group confirms their hypothesis made at Vallis Vale that these beds are sedimentary.	It is bedded; the beds are almost horizontal; they are jointed; it contains fossil fragments. These beds sit directly on top of the dipping grey beds. Testing with dilute HCl indicates a sedimentary rock, a limestone. The water test indicates it is porous. **NOTE:** The fossils indicate the rocks were deposited in the Jurassic period (about 170 million years ago).
It is a very different limestone from the one you are standing on. How many differences can you find between the two? **TASK 6:** On worksheet 1 complete the second part of the table identifying the differences between the two limestones. **NOTE:** Remind the group that rocks are mixtures of minerals and vary in composition depending on exactly how they were formed.	The limestone is yellow in colour, more porous (test it with water), coarser grained (the rounded 1mm grains are called ooliths, and were formed by wave action in warm shallow water. (See **Figure 6**). Also these beds are nearly horizontal and contain different fossils, from the grey ones. Many of the fossils have been weathered out by acidic water leaving spaces in the rock. See **Figure 6.**
Are the fossils whole, or broken? What does this tell you about the conditions in which the rock was deposited?	Often broken. It suggests they were washed around by strong currents before being buried.

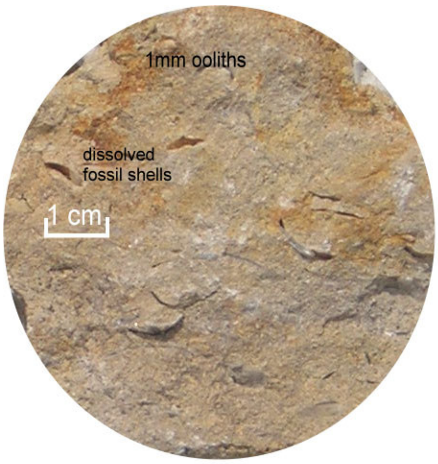


Figure 6. The yellow limestone.

FOCUS SEVEN: Finding the missing beds

Suitable questions at Site 2 (or 3)	Acceptable answers
What evidence can you see for the weathering of these yellow rocks at site 2?	The joints in the limestone are open, there is soil formed on the top (signs of chemical weathering) and there is vegetation growing into the soil and rock (signs of biological weathering). There are also fragments of the rock lying around (a result of human physical weathering!). **NOTE:** Remind the group that erosion marks the end of one rock cycle and the start of another.
Ask the group what has happened to the beds that used to lie on top of the highest bed at site 2	They have been eroded away.
Ask the group how they could prove that at one time there were more beds lying on top of site "B". (If they need a hint, suggest they look around the quarry face to the west). [Walk the group the few metres to site "3" tracing by eye any single bed continuously from one site to the other. Point out that the Geological record of evidence is made up by fitting together lots of small pieces in the right order.]	By using the **Principle Of Lateral Continuity**: trace the top thick bed of limestone around the northwest corner of the quarry to Site "3" where some of these upper beds are still present.
TASK 7: Explain that Earth Scientists find out what used to be on top by "correlating" or matching rocks between exposures. They are to do this by measuring the bed thicknesses at sites 2 and 3 using worksheet 4??	There is almost an extra 2 metres of beds at site "3". These include the top of the thick limestone at site "2" and more thinly bedded limestones, which indicates more frequent pauses in deposition. (See **Figures 7a and 7b**) In the past there were many hundreds of metres of rock above this site.

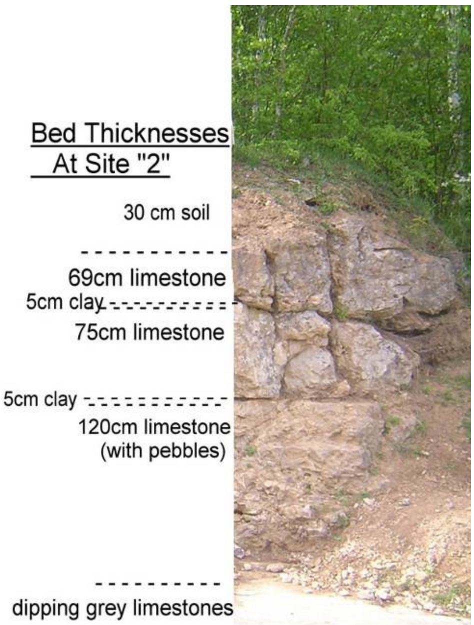


Figure 7a. Measured succession at Site "2"

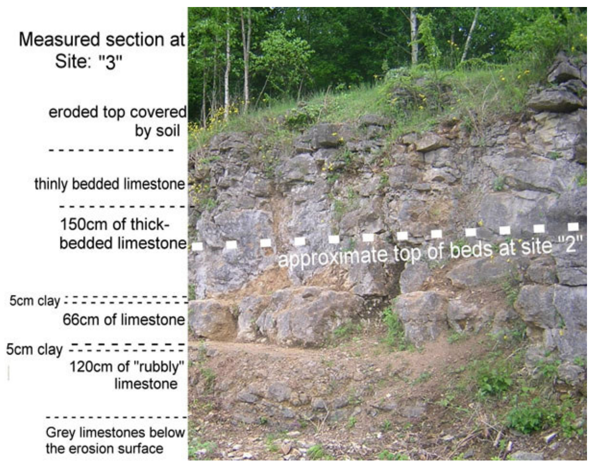


Figure 7b. Measured succession at Site "3"

☛ Continue to Site 4 on the south eastern edge of the quarry. There is a 1m step down to a grassy area from where the features of the surface can easily be viewed. Care should be taken getting the party down the step.
By this point in the visit many observations of the erosion surface are likely to have already been made. Essentially the edges of the grey limestones were subjected to a long period of erosion, until they formed an almost flat rocky surface. By 170 million years ago (in the Jurassic period), the rocky surface was being swept clear by marine waters which allowed no deposition to occur. However, the rocky surface was clearly colonised by marine organisms, adapted to live in such an environment. These included oyster type shells, cemented to the rock surface, and boring organisms which cut into the rock. These animals included bivalves, but also marine worms (not earth worms!). When the yellow beds began to be deposited the first sediments fell into the bores and filled them up with a contrasting sediment from the grey limestone. (See document **TED4 briefing** for further details).
At site 4 is an opportunity to understand something of the events of this ancient period of erosion. Have the group facing west, and locate a suitable site as in **Figure 8.**

At this site we begin by investigating events at the close of 170 million years of "gap" in the record.

Figure 8. The bored limestone surface at Site 4.

Notice that the bedding is dipping to the right, whilst the thickness of bored limestone is almost horizontal, following the top of the erosion surface. i.e. both cut across the limestone bedding and are therefore younger than the tilting of the beds.
This is an important observation since it establishes that the animals that bored the limestone are also younger than the GREY limestone: i.e. they are Jurassic, (Mesozoic) not Carboniferous (Palaeozoic) fossils.
(See **TED4 Briefing** for more details)

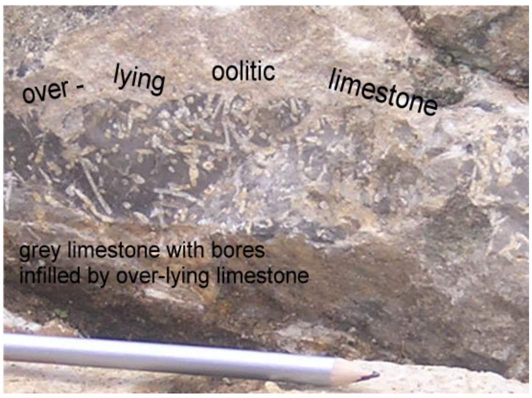


Figure 9. Infilled bores at Site 4.

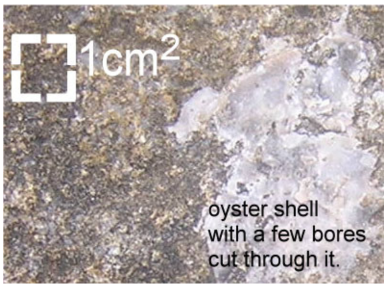
The grey limestone below the erosion surface is penetrated by small animal borings, which have become filled by yellow sediment as the overlying rock was deposited
These cross-cutting borings suggest a long period of **repeated** colonisation by boring marine animals, and "oyster" type bivalves, cemented onto the surface, before the yellow rocks were deposited.

It is important to stress that these animals are not the same age as the grey limestone. They bored into it after deposition, they are **not** silised inside it, and so are nger. (See **TED4 briefing** for more details).

FOCUS EIGHT: Investigating an ancient ecology.

Suitable questions at Site 4	Acceptable answers
Begin by asking the group to summarise the observations they have made whilst walking across the erosion surface.	It is quite possible that cemented oyster shells have been found. It is also possible that the "dimples" have also been seen. These are the tops of bores, about 1mm across, filled with softer yellow sediment, that have been slightly eroded out to leave a small depression. (See **Figure 10**). At this time also admire any other fossils that have been found. Point out they have been concealed from the gaze of scientists for about 170 million years.
Then ask the group to imagine (hypothesise) what it might have been like if they had been standing on that erosion surface just before the first of the younger sequence of marine limestones was being deposited. If prompting is needed, ask: What they would have been standing on? What they would have been standing in? What might they have been able to see? Then ask which parts of their speculation might actually become fossilised as evidence to be seen in present day rocks?	**NOTE**: The purpose here is to help prepare the group to visualise a dynamic environment, and its ecology from the evidence they will shortly "see" for themselves. ANSWER: solid rock surface, made up of dipping grey limestone, before the first yellow bed was deposited. ANSWER: several metres of seawater. ANSWER: Accept speculative answers that might include reference to different kinds of (now extinct) marine animals, (they will have seen fossil corals and brachiopods), sediment being transported, waves, currents etc. ANSWER: essentially the sediment itself, and the shelly parts of the animals, with the soft tissue decaying, or being eaten, after death. (and also the bores they left in the hard grey limestone).
Draw the group's attention to the edge of the quarry (see **Figure 8**). Ask if the group can locate the bedding and the erosion surface.	The erosion surface is the almost horizontal surface, and the bedding dips at about 50^{o} to the right.
Ask how to work out which is younger, the bedding or the erosion surface	The erosion surface cuts across the bedding, so it is younger. (**Principle of Cross Cutting Relationships**).
Ask the group to speculate on the origin of the shapes filled with yellow sediment in the grey limestone.	The groups should appreciate the shapes were voids, later filled in. Suggestions of any forces capable of causing long thin tubes in limestone should be recognised. In fact they are bores of different sizes by a variety of marine organisms. (Mainly worms *Trypanites*, but stress they were marine, **not** earth worms).
TASK 8: On worksheet 4 make a sketch of the edge of the erosion surface showing the burrows. Measure the depth of the deepest one you can see, and mark it on your sketch (See **TED8 worksheets)**	
What does the presence of these fossils boring into and cemented onto the erosion surface tell you about the conditions of the time?	They are fossils of animals adapted to rough marine waters. The lack of sediment indicates no deposition occurred for a while, whilst these animals colonised the rock surface.
Point out the dimpled nature of the erosion surface and the yellow "lines" in the grey limestone and ask what they might be.	There are three kinds of burrow, the most common made by rock boring worms (e.g. *Trypanites*) but also bivalves (e.g. *Pholadomya*). (Elsewhere on the top surface are "oyster" (*Liostrea*) attachments). That is they were marine organisms.
Did these marine animals bore into the grey limestone before or after the limestones were tilted?	After, because the burrowing is downwards from the erosion surface, not downwards from the bedding planes.

Using **The Principle of Cross Cutting Relationships** can you work out **when** the rock was bored by these animals? (Hint: why are the burrows coloured yellow?)	They clearly bored down from the erosion surface, which itself cuts the dipping edges of the grey limestones, therefore they are later than these beds. They are also filled with the yellow sediment lying on top, so they come before the overlying beds. These animals were biologically weathering the eroded top of the grey limestones "just before" the yellow rock was deposited. (See **Figure 9**)
When these animals were boring this surface was it above Sea Level, below Sea Level or at Sea Level?	It would be below Sea Level – or these marine organisms would not survive.
How do you explain its present position over 100 metres above Sea Level now?	Uplift by Plate Tectonic forces. The same uplift which moved the yellow beds. This second period of uplift is associated with the formation of the Alps, and the folding of the rocks in the Weald of Kent and Sussex about 24 million years ago..
TASK 9: Allow the group to complete the tasks on worksheet 5. This will involved small groups investigating the edge and top surface of the grey limestones.	At the conclusion of this exercise summarise the results: there were several periods of colonisation by both marine worms and bivalves; there were many thousands of worm bores per square metres, suggesting an environment with food, oxygen, and seawater of normal salinity; these animals were adapted to living in strong currents; there was very little sediment deposited, suggesting the currents swept it away.



The grey limestone shows around 10 - 15 marine worm bores per cm^2. (NOTE: This does not mean they were all living here at the same time).

The grey patch is the remains of the cemented shell of an oyster which colonised after the first worms.

The oyster shell also shows a few bores by worms which colonised the surface later.

Figure 10. Multiple colonisation of the erosion surface.

FOCUS NINE: Considering the evidence for biological evolution.

Suitable questions at Site 4	Acceptable answers
Point out that very few of the species of fossils found fossilised in the grey limestone have been found in the younger rocks, and very few of the species found fossilised in the yellow rocks have been found in the older grey rocks. What scientific theory might explain this observation?	The answer is the extinction of the earlier (Palaeozoic) species and the evolution of later (Mesozoic) ones. [NOTE: Logically however, there are other possibilities that cannot be eliminated in the short time you have. These are that: these different species were living at the same time, just in a different marine environment, somewhere else; similar collections of species might actually be in both rocks, but just haven't been found yet.] Darwin's theory of evolution.
Point out that this is the basis of the **Principle of Rocks Identified by their Included Fossils,** so Palaeozoic age fossils in a bed mean Palaeozoic age rocks. Ask pupils if they can recall any other evolutionary changes in the 170 million years **since** the deposition of the yellow rocks.	The most likely ones are: Continuing dinosaur evolution and final extinction (except for birds); Extinction of large marine reptiles (NOTE: Ichthyosaurs etc. are **not** dinosaurs). Extinction of ammonites and belemnites; Human evolution.
TASK 10: Complete the summary column of events for this site on worksheet 6.	

☛Walk the group about halfway from the south east corner of the quarry and stop in the middle. Allow the group to appreciate the size of the site.

FOCUS 10: Uses of the limestone:

Suitable questions for halfway across the quarry.	Acceptable answers
Ask the group to estimate the size of the cleared space. (Point out they can use the map and scale to help) Suggest the average thickness of rock removed is about 2metres, and ask approximately what volume of rock has been removed	Its about 50m x 70m = 3500 square metres. (This is a low estimate, ignoring the corners) 3500 x 2 = 7,000 cubic metres
To estimate an approximate value of the quarried rock use a notional £2 per cubic metre Help pupils to explore the cost-benefit aspects of this situation. The need for the raw material, jobs, contributions to the economy of the area against traffic, dust, noise, and visual impact. Draw pupils' attention to the efforts made to reduce these impacts: screening from the road, use of rail transport, damping down dusty areas, etc.]	7,000 x £2 = £14,000 (i.e. not a huge amount really).
What might the grey limestone have been used for?	This was a road stone aggregate quarry making use of the physically resistant, non porous limestone, in road making.
Why did the quarry company only want the grey limestone for road stone and not the yellow one?	It is more physically resistant than the yellow one, and more therefore suitable for road stone aggregate. Being non porous it is also chemically resistant, despite being composed of calcium carbonate.

What are the advantages of large quarries such as this one (and Whatley Quarry, 1km away, over the hill)?	Jobs for people, more thriving rural economy (Workers spend money in towns and villages, construction material for roads, concrete products, coastal defences, etc.
What are the disadvantages for an area like this for large quarrying operations?	Help pupils to see answers in terms of landscape (unnatural, possibly ugly, slopes); natural history (disruption to wildlife); disruption to local communities (dust, heavy road traffic etc)
What can be done to offset the effects of these disadvantages?	Screen the site with earth banks and trees; minimise the effects on wildlife and reinstate the natural area afterwards; use rail to transport the limestone aggregate; wash down areas producing dust. etc.
Ask pupils to speculate on what might be done with a site like this after quarrying had finished.	There are lots of possibilities. Not all feasible. Restored and landscaped to agricultural land; Left as a quarry, but landscaped; Leisure use (mountain biking, dog walking, adventure playground etc); educational or research use; as a tip for domestic waste (but be careful of contaminating the water table). There are also reasons for protecting the exposures for geo-diversity purposes. Also supporting wildlife – quarrying has always had a bad press from wildlife enthusiasts so industry is keen to increase biodiversity in restoration schemes.
TASK 11: Summarise these ideas on the table on worksheet 7.	

NOTE: Transport costs reduce the quarry profits and increases the cost of the aggregate to the customer. Each lorry carries 20 tonnes and it costs about 20p per mile to move the rock. The cost of a lorry load of aggregate doubles every 30 miles it travels. Using bigger lorries is more economic, but increases the traffic problems: that is why rail is used when possible.
The policy is to extend quarries (in areas where people are familiar with them) rather than open new ones, keeping the impact to a smaller area. Hence the number of large quarries in the Mendips.

It is possible, by **prior** arrangement with the field centre, to conclude this visit with a guided tour around Whatley Quarry (one of Europe's largest).
Contact: Whatley Quarry, Whatley, Nr Frome, Somerset. BA11 3LF.
EMAIL: gill.odolphie@hanson.biz
TELEPHONE: 01373 475931.

Alternatively there is a public footpath around the perimeter of Whatley Quarry, which allows anyone to have a good view of the quarry at any time. Return to Fordbury Bottom (or your coach at Great Elm) and drive to the quarry entrance at GR 733479, either via Frome, or the village of Mells

To access the footpath, park adjacent to the right hand side verge at the quarry entrance. Walk 10 yards north on the road side and then over the stile on your left. Walk along the path that follows the eastern side of the quarry. Then over a stile and follow the hedge as it bends to the left. Walk past the first copse and then walk to the top of the hill (environmental screenbank for the quarry) on the left. This gives an excellent view of Whatley Quarry.