INTRODUCTION
At any one site it is helpful to think of interpreting the evidence preserved in the rocks as a recurring pattern of events, often referred to as the rock cycle: These events are:
a) **Transport and deposition** of fragments, forming sedimentary rocks;
b) **Deformation** (including folding, faulting, intrusion by igneous rocks or metamorphism); and
c) **Uplift, weathering and erosion**, leading to deposition of sedimentary rocks at the beginning of the next cycle.

The evidence for the events in The Rock Cycle can be "read" from the rocks in any exposure. However, some parts of the story are always missing, because geological evidence has many "gaps" in it caused by a combination of never having been deposited and preserved in the first place, loss by erosion, and the fact that much is still buried and unknown. This means it is important to remember that the "story" at any one site is but fragments of a single Earth Science story that has an "invisible "prologue" and "epilogue" each millions of years long, but for which we cannot see the evidence at any one site, because it is not available to us.

This is the story at Vallis Vale / Tedbury Camp, and the evidence for two Rock Cycles, with the evidence for any intervening ones being eroded away.

The First Rock Cycle.

a) Transport and Deposition:
The oldest rocks seen on this excursion are the fine grained grey Carboniferous limestones deposited about 340 million years ago. These rocks are made up of fine grained calcium carbonate and the skeletons of marine animals, like brachiopods, corals and algae. The **calcium** component of calcite ($CaCO_3$) arrived in the sea water as a result of chemical weathering of rocks on land, being transported as ions in solution by rivers.

The **carbonate** component arrived partly by the same process in the form of hydrogen carbonate ions and partly by direct solution of carbon dioxide in the sea. Marine animals, like corals and brachiopods, used the material in solution to make their shells. The presence of these fossilised animals indicate that the sea was warm, and of normal salinity and well oxygenated, suggesting that the area was close to the Equator at this time. After the animals died, their shells became buried in the fine grained calcite "mud" (i.e. calcite, not clay mud) to form the limestone. The sea here must have been deep enough so that waves did not re-erode the fine grained calcite. In addition some beds have chert (SiO_2) nodules, formed at the same time as the limestones, or shortly afterwards.

b) Deformation: Folding and Faulting:
Around 290 million years ago these beds were affected by plate tectonic forces which raised up east-west trending fold mountain ranges across southern Ireland and southern England (including what is now Somerset) and northern Europe.

These structures suggest compression in a direction aligned approximately north-south, roughly at right angles to the line, or axes, of the folds which form a sweeping arc across southern Ireland and the south western peninsula. The Beacon Hill anticline in the Mendips indicates a change in the trend of these folds to ENE-WSW under the younger rocks to the east. (See **Figure 1**)

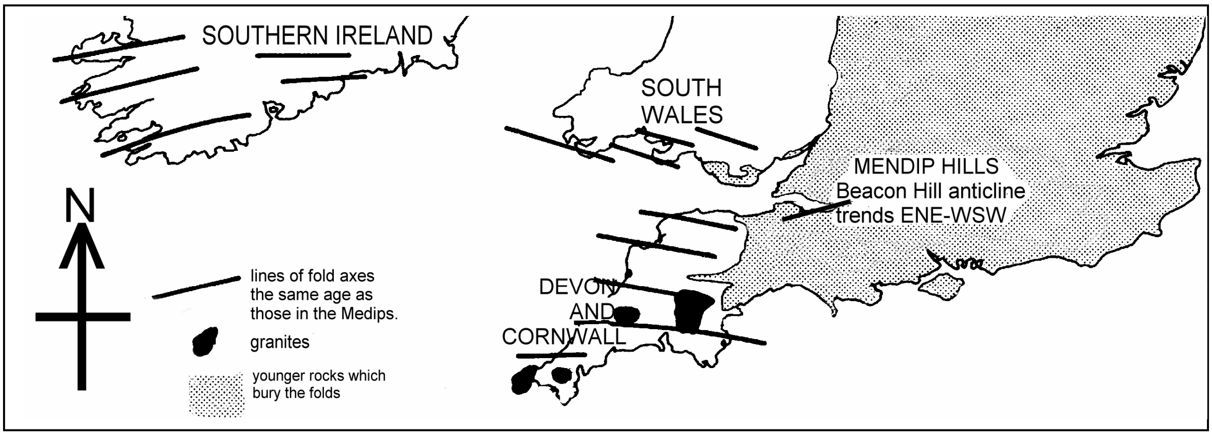

Figure 1. Map showing folded Carboniferous (and older) rocks.

Plate tectonics theory (and evidence from many other sites) suggests this folding event was caused by the closing of an east-west trending destructive plate margin to the south, across what is now the south west British Isles and Northern Europe. At this time the Cornish granites were also intruded and low grade regional metamorphism of the rocks of the SW peninsula occurred. The granites are only are the tops of a single large curving batholith. In our area there are no granites or metamorphic rocks, only folding and some faulting, The main fold here is the east northeast - west southwest trending Beacon Hill anticline, mostly buried below younger rocks. Only the beds forming the steeply dipping northern part of this fold can be seen on this excursion, below the younger rocks.

c) Uplift, Weathering and Erosion (and mass extinction):

During a long period of geological time the folded Carboniferous rocks in this area were subjected to weathering, erosion, and then further deposition and re-erosion. By around 175 million years ago the area had been eroded to an almost level rock platform. This rock surface was then flooded by the sea and bored (biological weathering) by marine organisms like worms (*Trypanites*) and bivalves (*Pholadomya*). The worm borings are 2 to 5mm across whilst the bivalve borings are 1cm to 2cm across. Oysters (*Liostrea*) also colonised the rock surface and their shells are found still cemented into life position.

Mass extinction.

A mass extinction is defined as a period in time when the loss (extinction) of fossil species from the record, equals or exceed 75%. [NOTE: the number of lost **genera** may total less than 75%]. There are five recognised mass extinctions in the fossil record since the beginning of the Palaeozoic. This does not include the sixth mass extinction that some scientists think is currently being caused by human activity, and which could prompt useful discussion with groups. (See **Figure 2**).

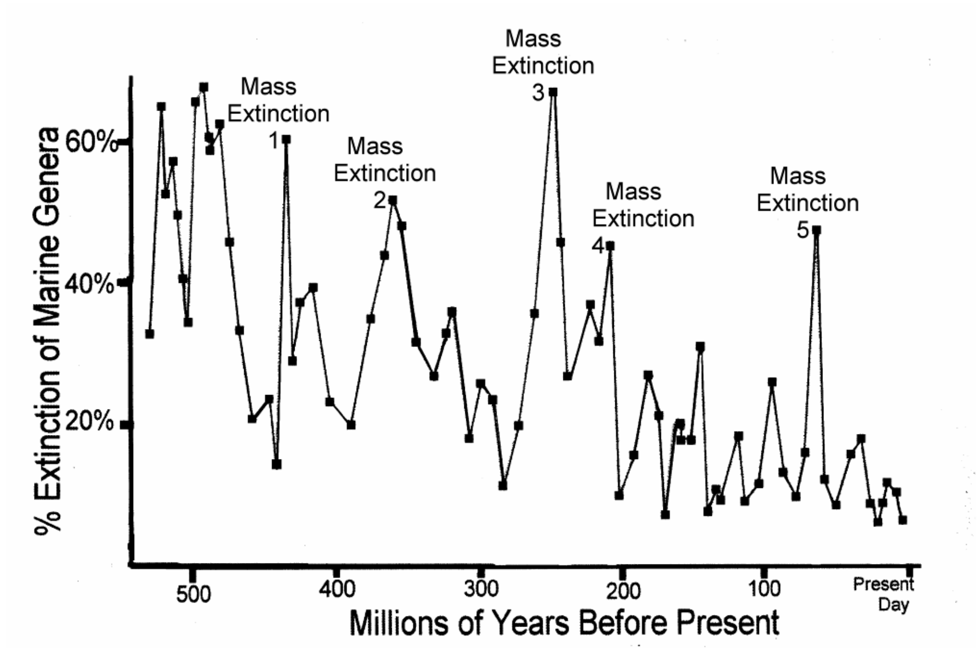

Figure 2. The sequence of mass extinctions.

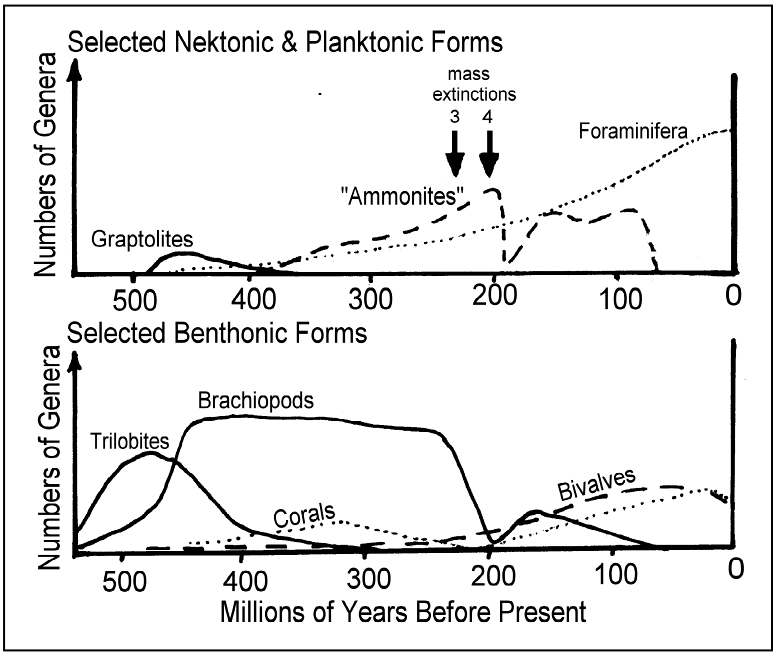

Figure 3. Some faunal changes through geological time.

During these periods of mass extinction the evidence is for a significant and relatively rapid change in life on Earth, with the loss of many previously existing species and the appearance of many new ones. This is interpreted as evidence for biological evolution. The third and fourth of these mass extinctions occurred during the 170 million year "gap" in the depositional record at Tedbury.

As a result, the fossils found before and after this period form very different collections of species. (See **Figure 3** for examples.

Some genera and groups are gone forever, and new ones are present. For example: trilobites and graptolites, common in the early Palaeozoic, are gone; corals almost became extinct, but new species of modern corals replace them; brachiopod species have been dramatically reduced in numbers, as have amphibians; "ammonite" species reduce in number, but recover quickly during the Jurassic period; bivalve species (for example oysters) begin to increase, as do echinoids.

An important feature of this evidence is that species with very similar habitats show very different responses during these periods of mass extinction. Interestingly the numbers of foraminifera, which are marine planktonic (floating) organisms (as were the graptolites, which became extinct) continue their steady increase of numbers through all five periods of mass extinctions.

Theories about the possible explanations for mass extinctions has included: planetary collision with an asteroid; reduction of marine shallow water habitats due to continental collision; sudden increases in volcanic activity changing the opacity of the atmosphere and reducing sunlight (and photosynthesis); increased predation or competition from other newly evolved species.

As a result of mass extinctions 3 and 4 there is a significant biological division between the fossils in the older grey Carboniferous limestone, assigned to the "Palaeozoic" (old life), and those in the yellow Jurassic limestones, assigned to the Mesozoic (middle life), and this allows us to broadly identify the age of the rocks by the fossils they contain (**Principle of Rocks Identified by their Contained Fossils)**. Consequently, it is important to recognise that the Mesozoic fossils boring into the Palaeozoic grey limestones are **younger** than those beds, and dug their way into these rocks millions of years after they were deposited. The more usual situation is where both the fossils and the beds containing them are of the same age, in this case, either Palaeozoic Era or Mesozoic Era.

Several cycles of colonisation of the erosion surface by larval forms of these organisms can be deduced since the later bores and larger "crypts" (a crypt is illustrated at "4" in **Figure 4**) cut across earlier ones. The complex nature of the colonisation of this submerged rock platform is indicated by the fact that *Liostrea* overlie bored limestone, and also have been bored themselves by later worms, after the death of the oyster. By using the **Principle of Cross Cutting Relationships**, eight phases of colonisation by marine organisms before the deposition of the yellow limestone, can be inferred. (See **Figure 4**)

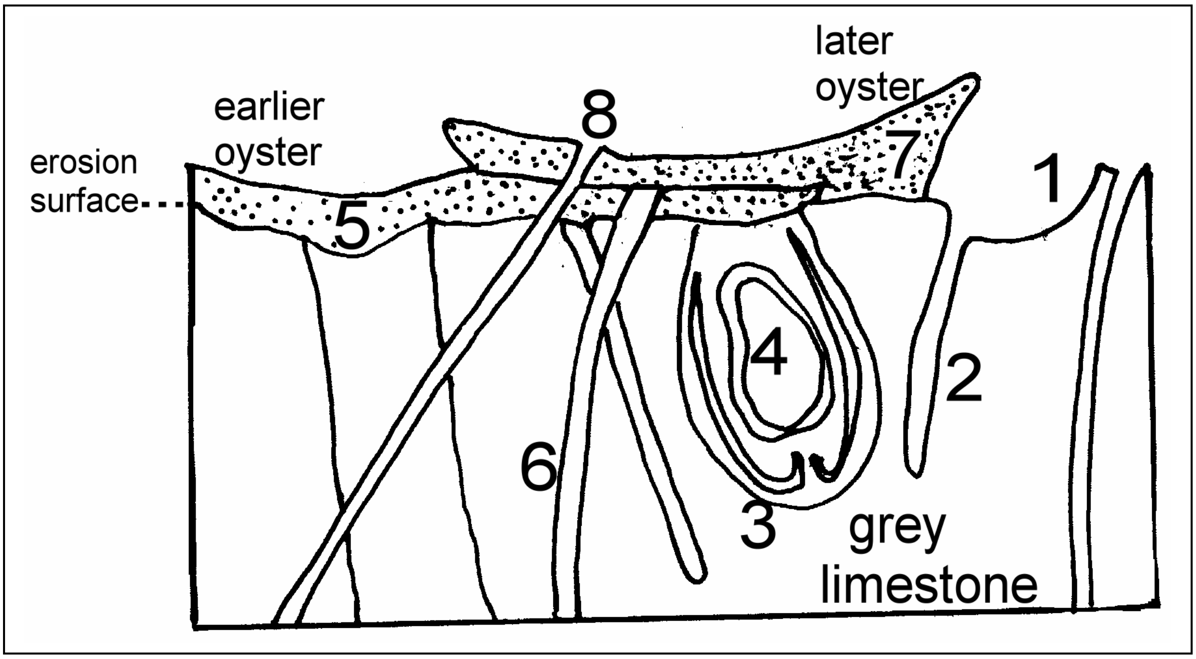

Figure 4. Diagram showing the colonisation sequence of the erosion surface.

The presence of these fossils, which are adapted to survive in strong currents, along with the initial absence of sediment, indicates a prolonged period where the rock surface was swept by strong waves and currents and was being repeatedly colonised by animals adapted to life in a turbulent marine environment, before the deposition of the overlying younger beds began.

Evidence that this colonisation of the rock surface occurred before the deposition of the overlying yellow Jurassic limestone is that the bores are now filled with yellow sediment which fell into them during the first episode of deposition of the overlying Jurassic limestones. This yellow sediment, being softer than the grey limestone has now been weathered out to leave a dimple at the surface at the site of each bore.

The Second Rock Cycle.

d) Transport and Deposition:

Here, the geological record has a large gap of about 170 million years where erosion meant that no rocks survive after the grey limestones at Vallis Vale and Tedbury. The next piece of evidence we have in the geological record, after the bored and encrusted erosion surface, are the yellow sedimentary rocks that were deposited on top of it.

These are Jurassic limestones containing shelly fragments of marine bivalves, belemnites and ammonites, many species of which had not evolved when the grey limestones were deposited. This allows rocks to be dated by the Mesozoic fossils they contain, since only animals living in the sediment can be fossilised within it. A simple ecology of the time can be pieced together from the fossils likely to be found during a visit to the site; bottom living (benthonic) filter feeders, such as bivalves, and marine worms, along with grazing animals like gastropods, living on algae and plankton. Predators like ammonites and belemnites lived in the waters above. Evidence from further afield also suggests large marine reptiles (which are **not** dinosaurs) such as plesiosaurs and ichthyosaurs were the top predators in these Jurassic seas.

These Jurassic benthonic animals with shells, took the calcite they needed from the seawater, which contained dissolved calcium carbonate weathered from the land surface and transported to the sea by rivers. After they had died their shells became buried with the sediment to form limestones. The evidence that these beds were deposited in a shallow marine area, are the included ooliths, which are formed today by wave action in warm shallow water where calcite is being precipitated. **The Principle of Uniformitarianism**, allows us to conclude that these ancient ooliths formed in a very similar way. No doubt there were many thousands of metres of later rocks deposited on top, but we have no evidence of them in this area.

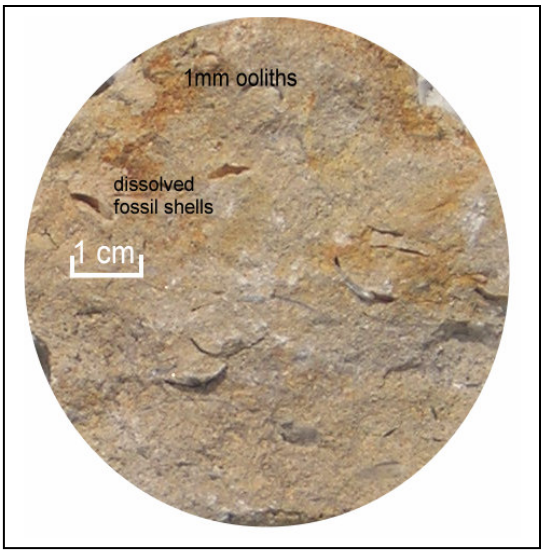

Figure 5 The Jurassic Limestone

e) Deformation: Folding and Faulting:

Much later these beds were uplifted with very little evidence of folding or faulting in these two particular sites, although there is faulting of this age in the area, and many miles to the east younger rocks were folded into the Wealden anticline at this time. Further south the effects of this period of folding were more severe, raising the Alpine -Himalayan ranges of fold mountains across southern Europe. Such events are now interpreted as a result of the closing of a destructive plate margin. In the case of the Himalayas, this is the closing which brought about the collision of India with Asia.

f) Uplift, Weathering and Erosion:

There is no evidence of rocks younger than the yellow Jurassic limestones at this site. Those that were deposited have been lost by ancient periods of weathering and erosion. After uplift or the crust, these rocks today are about 100 metres above sea level and are undergoing modern day processes of weathering, soil formation and erosion. Modern streams, like the Mells stream, have cut through the overlying Jurassic limestones in places to reveal the folded Carboniferous beds beneath. (See **Figure 6**)

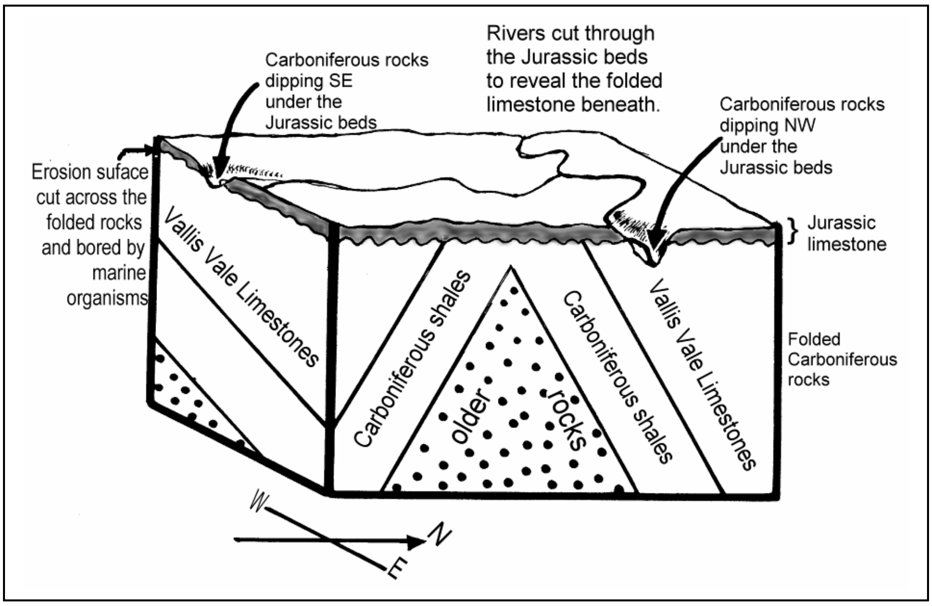

Figure 6. A simplified block diagram of the Vallis / Tedbury area.

Quarrying (which might be regarded as a form of biological weathering), has so recently exposed the quarry faces that obvious evidence of physical and chemical weathering has not had time to develop, although some surface discolouration, colonisation by lichens and penetrating tree roots can be seen. In time, if human action does not intervene, the weathered material from this area will find its way into the Mells River and be transported to the River Avon, and eventually become part of the modern day sediments in the Severn Estuary.

EARTH SCIENCE PRINCIPLES
In this area it is possible to demonstrate the following Earth Science principles.

1) **The Principle of Uniformitarianism:** The biological, physical and chemical processes we see today, operated in much the same way in the past. “The present is the key to the past”

2) **The Principle of Original Horizontality**: Bedding planes represent the original horizontal at the time of deposition of sedimentary rocks. Their current angle shows the accumulated amount of distortion caused by earth movements since deposition. An exception to this principle is the underwater scree slopes at this locality which were deposited at a steep angle.

3) **The Principle of Lateral Continuity of Beds**: This states that sedimentary layers extend in three dimensions and might therefore be found elsewhere.

4) **The Principle of Superposition**: In a bedded sequence of strata, the oldest layers were deposited first, and are found below the younger layers, which were deposited later.

5) **The Principle of Rocks Identified by the Fossils they Contain**: This states that, because animal species have evolved and changed over time, that any sedimentary rock containing fossils, must have been formed at the time those animals existed on earth. (Unless those fossils are in pebbles worn from older rocks and cemented into much younger ones. It does happen – but not on this visit).

6) **The Principle of Cross-Cutting Relationships:** Structures, like faults and joints, which cut through rocks must be later, and therefore, younger than the structures they cross cut. They must also be older than the ones that cut across them.