Exploring the Lost World... of *The Pales*

Geology is not just accessible to boffins and eccentrics... when we look in the right way, anyone can discover and understand worlds that are long, long gone. By using our curiosity and understanding of how the world works, we can explore landscapes and life of a past so ancient that its only remaining traces are in the rocks...

This activity will lead you through the evidence we can see in the Pales Meeting House Quarry: a Site of Special Scientific Interest (SSSI). This protected status means that you **must not** hammer or deface the outcrops in any way, but there is normally plenty of loose rock that you can examine lying around the quarry. You can also look closely at the faces themselves, but **beware of loose rocks** and always check for danger above you before approaching. A hard hat is highly recommended!

The Spotters' Guide

The main part of this activity is aimed at getting you to look carefully at the evidence in the rocks, and think about what it means. This might be very unfamiliar to you... but don't worry! Most of geology is very intuitive, and it relies only on having lived in the world of today, and taken notice of how it works...

Ultimately, we will work up to estimating what length of time is represented by the rocks of this quarry. But to do that, we need to understand what the rocks are made of, how they formed, and where. You may not get everything worked out, but see how many of these features you can find!

1. Layering

Stand back from the quarry face, and look for layers. Sedimentary rocks are laid down in layers, one on top of another. The oldest layers are at the bottom, and younger ones at the top. The type of sediment (e.g. sand or mud) changes as the environment changed when the layers were formed.

If you can see the layering in this rock, whichever bit of the quarry you are looking at, **sketch it in the box on the right**. It won't be flat, because the rocks have been uplifted and bent by ancient continental collisions. The angle of the layers is also different in different parts of the quarry, because the rocks have been folded. That doesn't matter: just draw the bit in front of you!

2. Lamination

In part 1, we checked that these rocks were laid down in layers. This is good, because these rocks tell us directly about the environment in which they formed. Every environment leaves its marks on the rocks that form in them...

This time, find a bit of rock that shows a fresh vertical surface (you might need to break it), and look for much finer layering within the beds. You should be able to find alternating darker and lighter bands.

Draw what you see (left) at the scale given!

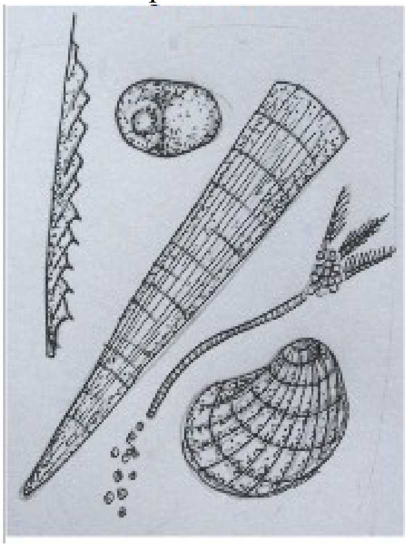
So... what could have caused these different-coloured, very fine layers?

3. Fossils (answers on next page!)

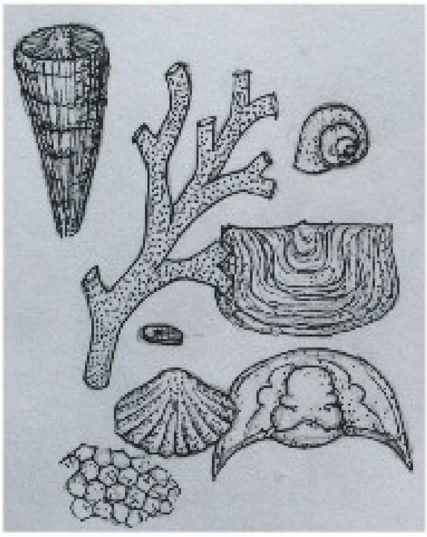
To work out more about the environment the rocks were formed in, we could do with some fossils. The Pales quarry has many of them; look around in the loose blocks, and you should find something with a bit of effort. Of course, different fossils represent animals and plants living in different places, at different times, so this can tell us a lot about how to interpret the rocks...

The first stage is to see what you can find, and then compare with the three sets of drawings below. Which set of fossils (and environment) best represents what you see at The Pales?

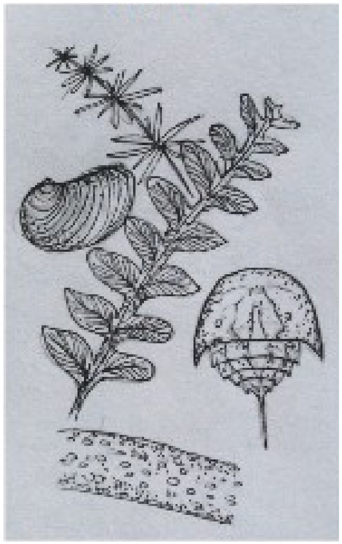
1
Open Sea



2
Shallow Sea

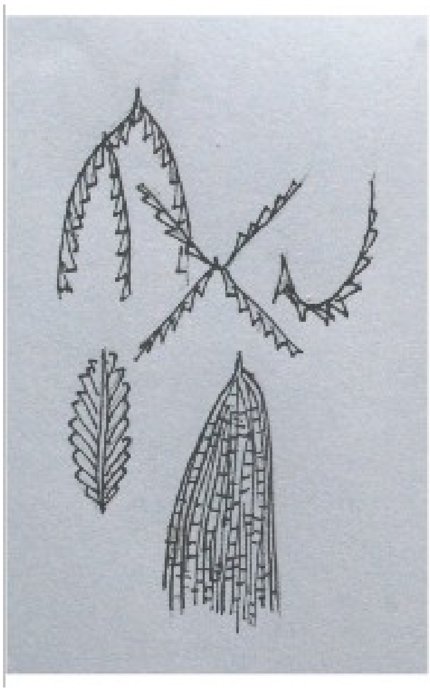


3
on land

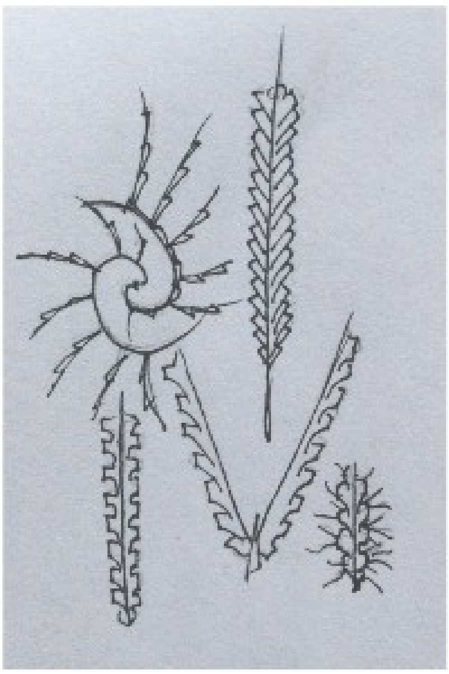


To find out which fossils you've found, turn to the back... but the most common (and useful!) are **graptolites**.

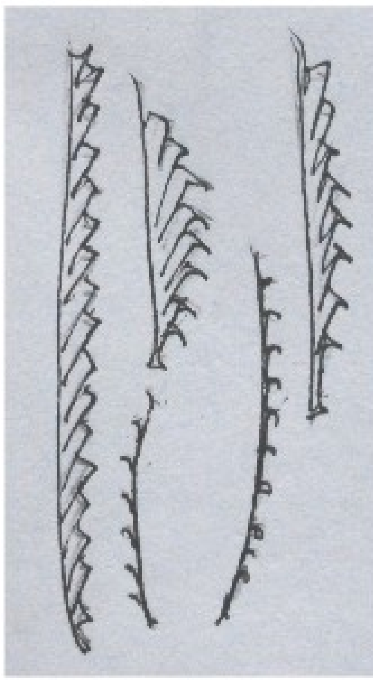
Graptolites resemble thin fretsaw blades, with teeth on one side. The teeth are actually compressed tubes, and inside each one lived a tiny, filter-feeding animal. Before we get to the environment, you can use the species you find to identify the age. The more you find, the better, but which of these sets of fossils is the right one for this quarry?



1. Early Ordovician



2. Late Ordovician



3. Late Silurian

You should have identified the fossils as representing a Silurian marine environment!
If you decided on 1 (open marine) and 3 (Late Silurian), then well done! The rocks are indeed late Silurian in age, specifically from the *Neodiversograptus nilssoni* Biozone of the early Ludlow Stage... in short, 427 million years ago. There is an error bar on that, but it's only around 0.4 million years, so it's fairly accurate!

The Silurian World
At this time, the world was a very different place. We were part of a small continent called Avalonia, in the southern subtropics; Scotland and Northern Ireland were attached to North America, beyond the last remnants of the Iapetus Ocean... which was sinking beneath us, driven by the forces of plate tectonics. The local sea was the Welsh Basin, and that was lost only about 5 million years afterwards, when continental collision pushed up the Highlands and the Welsh mountains... or, rather, the mighty mountain range of which those hills are the last, eroded stumps.

The world was also warmer (no ice at the poles), but life on land had barely begun; the first plants were taking over the riverbanks, and insects, millipedes and arachnids were following close behind. In the sea, there were reefs in shallow water, but not as we know them; and fish had barely evolved jaws by this time. It's a long way back in the history of animals.

Interpreting the environment
The fossils here prove that this area was marine at the time, but they also show more than that. These graptolites were planktonic creatures, drifting around the surface of the open sea. The nautiloids were active swimming predators, feeding mostly on small creatures that were too soft to be preserved. Sometimes there are crinoids ("sea lilies": relatives of starfish, with a stalk) attached to them, but those are very rare. But what was life like on the sea floor?

1. Are there any burrows? Look again at the sides of slabs... does anything disturb those fine layers?

2. Have you seen any fossils that might live on the sea floor? (If you found any clams, that would be quite convincing!)

3. Are there any ripple marks or other structures that imply water movement? Only if it was completely still would you expect to see just flat lamination.

Hopefully you've found that there was nothing much living on the sea floor. There are only a few reasons for why that could be, especially in the relatively deep water that has graptolites floating around at the surface. It can't be too cold, or too hot. Could it have been too salty? Unlikely, if the water above was OK for animals... and salt would have left a trace, in the form of crystals that grew in the sediment.

Only one answer really fits: *there wasn't enough oxygen*.

Lack of oxygen is very often a cause of a barren sea floor... and at this precise time, it was a pattern across the deeper seas around the world. This is probably because of a particularly warm climate, combined with the continental arrangement that shaped the ocean currents.

But there is one more question... how long did these rocks take to be deposited?

Counting layers

Let's go back to the laminations (part 2). They tell us that there was a regular shift in the colour of the sediment, between dark and light. The darker layers contain more carbon, from the remains of microscopic life. What could have caused this?

To answer that, you need to think of cycles that affect the open ocean on a regular timescale, and think which might change the amount of organic matter being deposited. You can use all the information you've accumulated so far to help you decide! Could the layers represent...

Tides?

Seasons?

Ice ages?

Now, we have all the answers we need to work out roughly how much time is represented in this quarry...

How many laminae are there in one centimetre thickness of rock, on average?

Therefore, how long does 1 cm represent, on average?

Roughly how thick is the rock exposed in the quarry? (Estimate this, in metres: it's quite a bit more than the height of the cliff, because of the way the beds are tilted – see part 1)

And therefore... how many years does this thickness of rock represent?

no. of years per cm x thickness of rock in m x 100 = ?

That should come out to a decent length of time. For comparison, the time between the first cave paintings and the modern world is around 45,000 years!

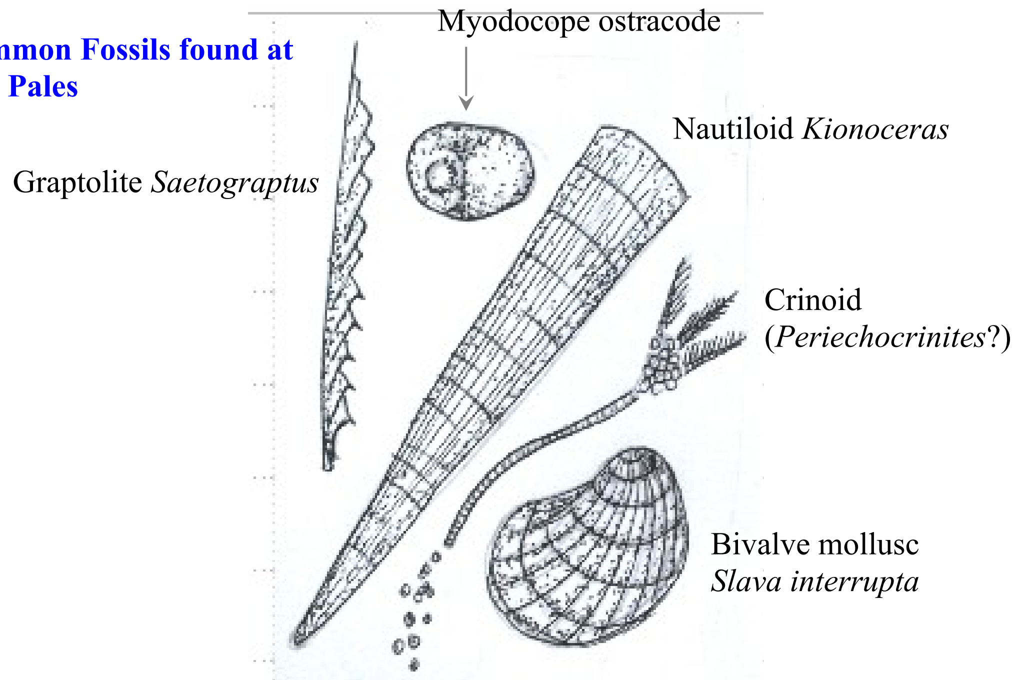
Answers: The laminae should be seasonal, because there is more algae in the spring and summer, giving you the darker laminae.
There are normally around 2-3 laminae per *millimetre* of thickness (i.e. 20-30 per cm), but this does vary, and can be hard to see.
The quarry exposes something like 15 m of rock.
The answer is therefore something like 50,000 years... but anything in the range 10,000-100,000 gives you the right sort of idea!

We hope you've enjoyed “doing some science!”

To find out more about the local rocks, there are displays in the Radnorshire Museum (Llandrindod) and the Kington Museum, and numerous books and websites. If you want to get more into the subject, there are also friendly local associations, such as the Mid-Wales Geology Club (www.midwalesgeology.org.uk) and the informal Mid-Wales Palaeontology Group (contact by email to Joe Botting at acutipuerilis@yahoo.co.uk).

Also, look out for the other geological activities, at Cefnllys and Llandegley Rocks!

Common Fossils found at The Pales



Graptolites of The Pales (most of them!)