Day 1: Monday

3rd September, 2018

Parys Mountain

We will look at the geology of this old copper mine and then run a geochemical survey on the surface waters to see how it varies across the site, why this might be and what its environmental impact is.

9am: Depart (*35 minute drive*)

9.45am: At Parys Mountain

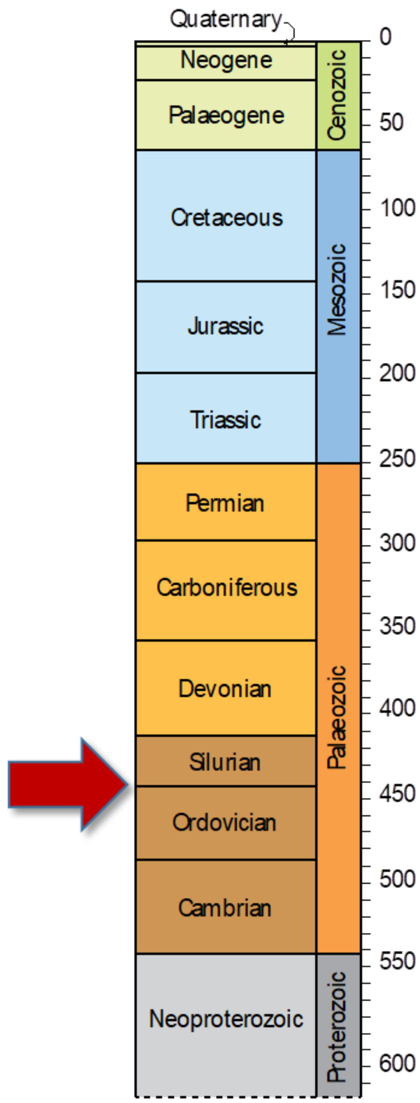
12.30pm: Drive down to Amlwch for lunch

1.30pm: Drive back to Parys Mountain

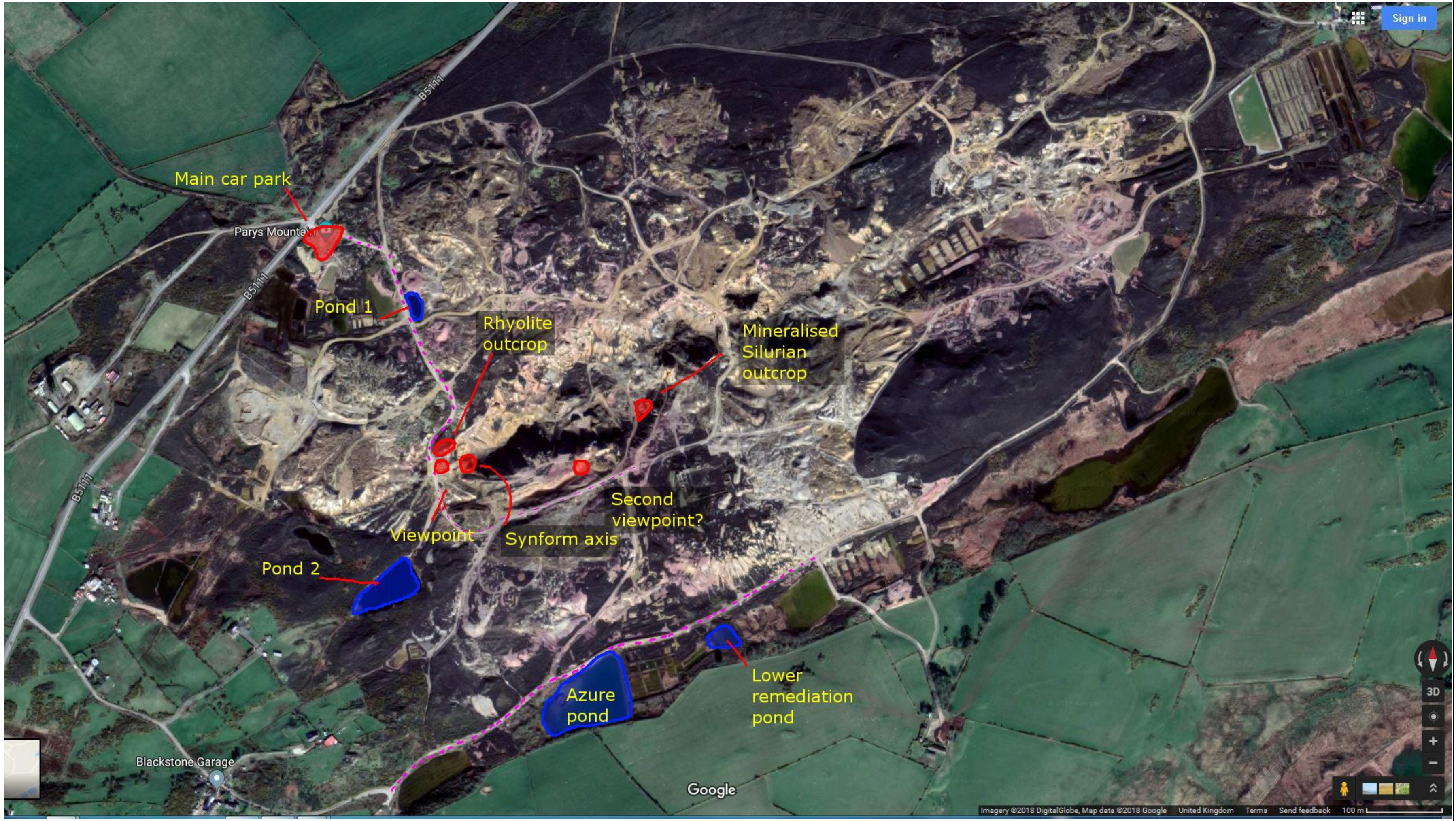
1.45-3.30pm: Water testing

3.30pm: Drive back to hostel

4.00pm: Back at hostel



Timings are approximate; it is difficult to judge how long activities will take, and conditions (eg the weather) may change.



Main car park
Parys Mountain
B5111
Pond 1
Rhyolite
outcrop
Mineralised
Silurian
outcrop
Second
viewpoint?
Viewpoint
Synform axis
Pond 2
Azure
pond
Lower
remediation
pond
Blackstone Garage
Google
Sign in
3D
Imagery ©2018 DigitalGlobe, Map data ©2018 Google United Kingdom Terms Send feedback 100 m

History of the site

Parys Mountain is the site of a former copper mine. In addition to copper, the mine also produced significant lead, zinc, sulphur (in the form of sulphuric acid) and accessory silver and gold. Mining on site goes back at least as far as the Roman era, due to the finding of crudely cast “cakes” of copper metal produced by the Romans during their occupation of Wales, and possibly further. Antiquity-age mining would have mainly been recovering what are called supergene deposits – produced by the weathering of deposits and interactions with the water table, which in the case of copper would produce minerals such as malachite, azurite, chalcanthite, cuprite and chalcocite. All of these are relatively high grade and relatively simple to smelt, but are only present as a cap atop the main deposit. Within the main deposit, would be minerals such as chalcopyrite, $CuFeS_2$, which is harder to process due to the associated iron.

Mining was at its most intense between 1768 and 1883, comprising both deep workings (beneath the Northern Carreg-y-Dol deposit, as well as centrally-sunk shafts down to >200m below surface) and the open cast pits of the “Great Opencast” and the “Hillside Opencast”. During this era twelve main lodes were mined, pursuing two main types of ore: a pyrite-chalcopyrite ore, and a less-common “bluestone” ore that contained considerable Galena (PbS) and Sphalerite (ZnS) with pyrite, chalcopyrite and chalcocite. The twelve lodes also form into six *associations*, which can be considered to be individual sets of conditions that may form multiple deposits.

In its heyday, the mine was the largest in Europe, and produced over 130,000 tonnes of copper in its working lifetime. Mining had effectively ceased by 1920, though low grade activity continued on site obtaining small amounts of copper by precipitation (pooling leachate from the ore bodies and displacing copper from solution using iron metal) until 1950. Since that time, the mining rights to the area have passed between a variety of companies and these have frequently conducted exploration, using drilling to a depth of 400-500m, surface sampling and geochemical analysis to refine models for the remaining deposits and their structure. It is interpreted that there at least another 10 ore bodies beneath ground, at depths of 100-250 metres below the surface, and the possibility of future mining activity is still very much alive, though it is dependent on economic market conditions.

Sadly, the opencast mining has largely exhausted the ore deposits at the surface, and redistribution of spoil has buried other areas. However, there is plenty to see in terms of mineralisation textures, and even to try and unravel the structure of the mine, which is absolutely critical in terms of developing and finding particular ore bodies.

Genesis of the ore body

Parys Mountain has been assigned to be a good example of what is called a **Kuroko-type Volcanogenic Massive Sulphide (VMS) deposit**.

VMS deposits are typically those produced by black smoker systems near mid ocean ridges, but although the mechanisms are similar – exhalation of hot (~300-400C) fluids onto the sea floor – Kuroko-type deposits form in a different environment. Most typically found in the modern Pacific Rim, Kuroko-type deposits are associated to the submarine extrusion and intrusion of evolved magmas (like rhyolites). In terms of the history of Anglesey, this type of activity occurred during the early Silurian, and we will explore that in the evening talk. Our morning will be spent looking at different rock types and trying to put them into a context. We do not intend to create a new model for the mine in one day, but rather to explore what kind of setting would allow all the rocks to form together! The afternoon will be spent looking at water contamination due to acid mine drainage, a sad consequence of mining activity.

Logistics

We will be parking at the upper car park and someone should be on hand with a key to let a vehicle through and into the mine site proper, which will allow everyone to get to the viewpoint. The upper ponds are both adjacent to the main pathway. For access to the lower ponds, it may be necessary to drive around to the far side where there is an area to pull in – we will see what access possibilities arise, but the afternoon work is likely to be split across two groups.

There are no facilities on site. Note that being a mining area, the levels of toxic elements (Pb, Cu, As) in various deposits means that local groundwaters are somewhat contaminated and are definitely not safe to drink nor bathe in. In addition, significant amounts of dust are mobile on site, and whilst exposure from examining the site is not harmful, if you have been handling samples, it is not recommended to handle food until you have had an opportunity to wash your hands and remove traces of mine dust. **Wash hands to decontaminate before eating**. If you drop food on site, I'm afraid that will not be something you should pick up again and eat. We will head to Amlwch town for lunchtime, and there will be a visit to a set of local toilets that do have a sink and give an opportunity to clean up.

Briefing for the exercises - Understanding the Great Opencast

The geology of this huge opencast pit is rather complex. It is not intended that we will be able to unravel it completely during the day. **Instead, our aim is to try to understand the type of environment and setting in which the Parys Mountain mineralisation has all been formed.**

To do this, we will need to get an overview of the area – by sketching the pit from a couple of different angles, and we need to investigate what rock types are present, and what it is that they tell us. As part of the evening debrief, I will go through what the current deposit model is, as well as an idea of what kind of geological setting was required to make the deposit. That deposit model is the result of many years work, but you will be able to get important key features from relatively straightforward field observations. Take it one rock at a time and feel free to discuss with field staff what your sample means.

There is a lot to take in here, and it could be quite overwhelming. As reassurance, understand that there is still some uncertainty about the precise structure of the area, and that is even with mining companies having cored boreholes throughout the deposit! A key feature of fieldwork is that observations drive interpretation. Your observations should be correct; the complexity of the model that you can build may however be limited by how long you could take observations. As scientists it is a case of observe, hypothesise, test via more observations, and make a new or improved hypothesis, and so on.

Viewpoint

The viewpoint is at the WSW end of the elongate main pit and is located adjacent to an outcrop of leached rhyolite (hand specimens are available) and overlooks the gaping hole of the Great Opencast. This hole was largely dug by hand!

Looking into the pit (the great opencast) there are a few things to identify and to say.

Geologically, the great opencast is only a small part of a larger system. The opencast we'll be working around samples only two of the main units, though we can actually find probably 4 lithologies in here.

Questions:

1. Looking into the pit from the view point, take a sketch. Note the colour changes, particularly the change from dominantly grey-green, to dominantly orange-yellow-red.

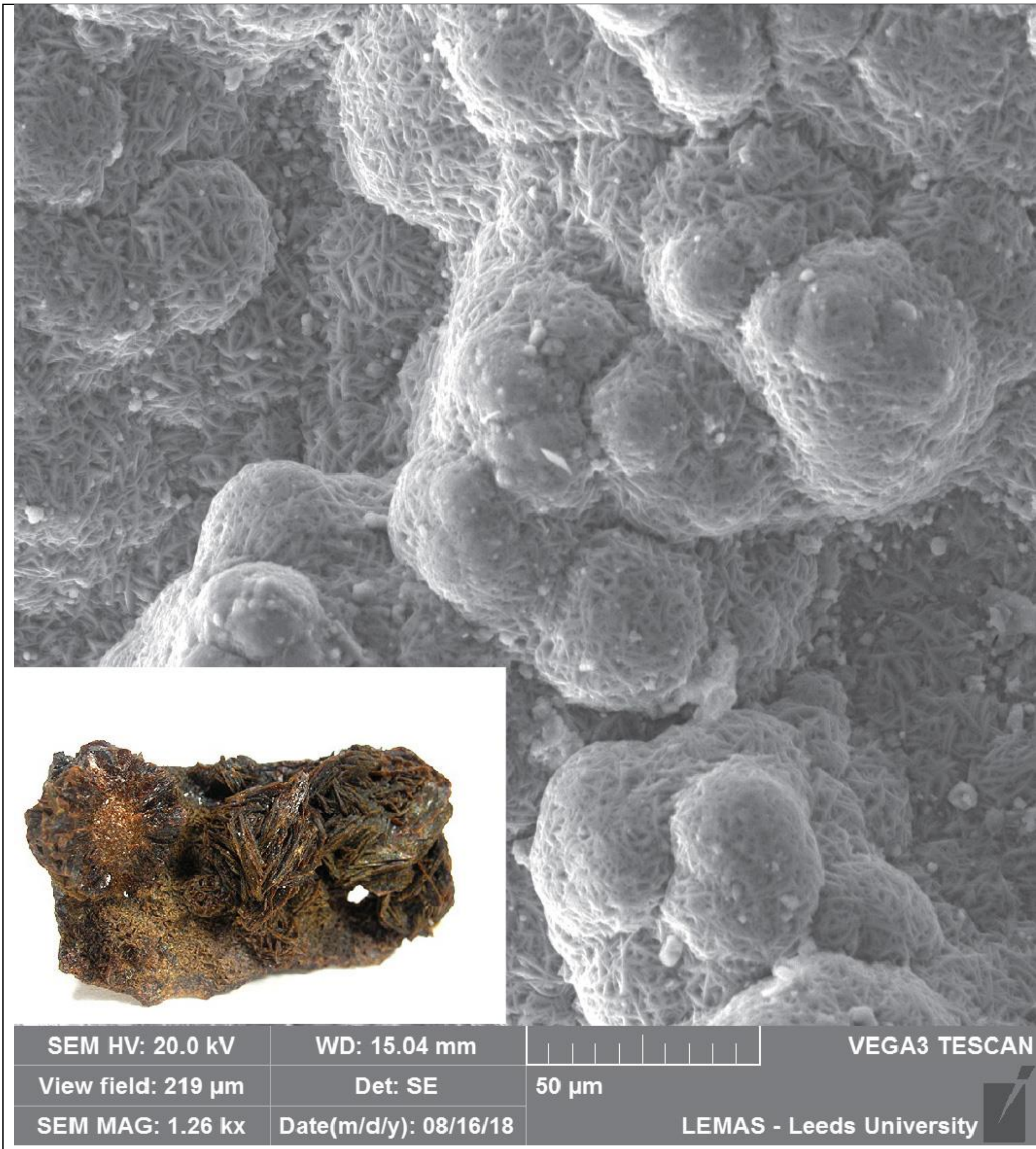
These changes refer to changes in the surface mineralogy of the pit, and to a lesser extent, reflect changes in host lithology for the mineralisation. Alteration minerals provide much of the colour.

Alteration minerals:

Jarosite $KFe^{3+}_3(OH)_6(SO_4)_2$	Limonite $FeO(OH).nH_2O$	Goethite $FeO(OH)$	Haematite Fe_2O_3
		 By Rob Lavinsky, iRocks.com – CC-BY-SA-3.0, CC BY-SA 3.0.	

Note that the degree of weathering can affect the colour – fine grained Jarosite is yellow, and coarse grained is brown, but intervening sized grains are variable shades of orange, particularly if they start to further alter to Limonite and Goethite.

For further proof, we have an image of a macroscopic jarosite specimen, and an SEM image of some Parys Mountain altered material:



An SEM shot of a jarosite crust growing on Parys Mountain Pyrite. Inset: a natural, coarsely crystalline specimen of Jarosite (photograph by Rob Lavinsky, iRocks, uploaded to Wikimedia Commons). Note the similarities in grain morphology as intergrown aggregate of platelets that form rounded, spherical masses.

2. Using the table of minerals above, think about what the colour changes might mean. We can see some red streaks in the left hand wall, so what might that reflect in terms of chemistry of what you are looking at? What mineral is dominant?

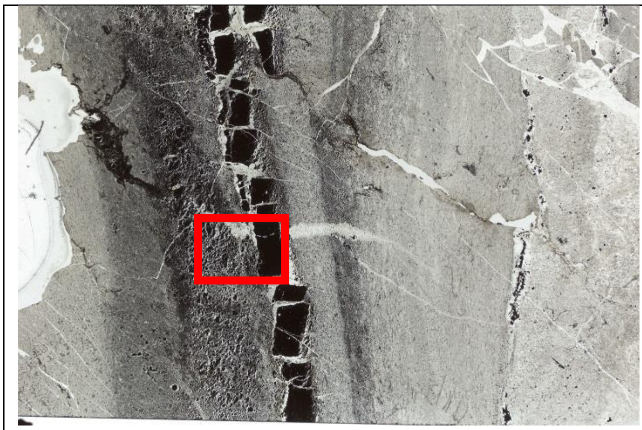
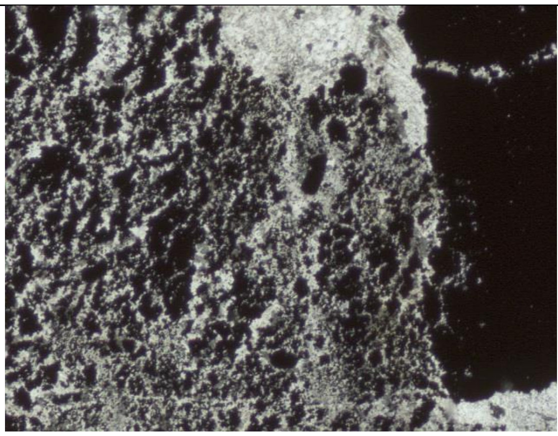
3. Investigating rocks. Have a look at the rock outcrop just to the W of the view point. Can you describe it? What minerals do you think it is rich in? Is there any evidence for a missing mineral or any evidence of alteration?

Having worked from the view point and made a sketch, then seen the rock type next to the viewpoint, we will move around the pit and have a sketching opportunity facing the rock face that makes up the N side of the Great Opencast. The reason to do this is to get a different perspective, on one hand, but also to get a handle on the structure of the mine. According to the history of the workings, there are **three significant faults** that cross that far wall, two of which hosted mineralisation. Faults, being fractures, can be significant fluid flow pathways and this allows both mineralisation and the mobilisation of elements. In the case of Parys Mountain, the faults were active after the mineralisation, but the fluids that they allow to move are capable of altering ore deposits.

Can you see any evidence for planes of weakness or a possible alteration zone? Can you record that on a sketch or an annotated photograph?

Some of the group will then descend into the pit to examine some further areas. These are the mineralised Silurian shales, the "central boss" and the far wall that we were sketching. **These are all hard hat areas and please do not wander away from the paths**. There is plenty of loose material to examine and no hammering is allowed. As you may appreciate, the walls of the opencast are not suitable for clambering up. For those who do not descend, relaying via iPad may be in operation, and there are a suite of hand specimens from these locations that can be looked at in addition.

Have a look at the mineralised shales. An interesting feature of this material is its density. Weigh a hand specimen in your hand. It should feel anomalously dense. This is an important observation, as when looking at this sample in hand specimen, it can be seen to be banded. This shows up quite well on a thin section scan:

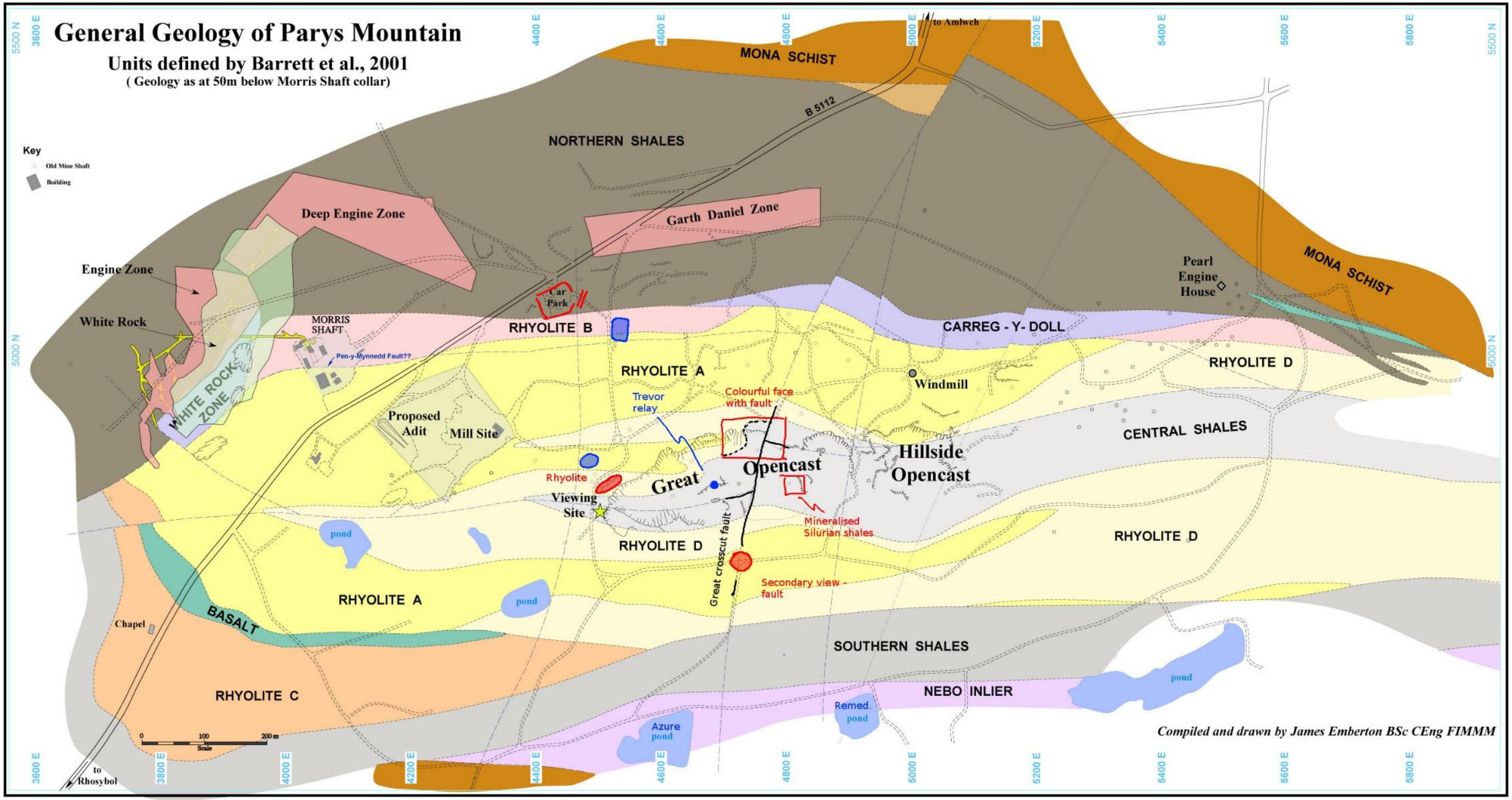
	
3cmx2cm thin section	5x4mm region, enhanced for clarity

The image above shows a dusty grey appearance, which is caused by masses of finely disseminated pyrite with a tiny grain size. Zooming in, aggregates of tiny pyrite crystals form this scaly texture. In the zoomed region about 50-60% of the rock mass is pyrite, though in other areas it is 10-15% or less. A broken layer of 100% pyrite crosses the whole slide, but it is very similar material and importantly is a ***layer***, parallel to bedding, not a vein. In these materials, pyrite was being emitted from black smokers as a very fine dust, at the same time as sedimentation of the shale was happening. This produces thin layers of pyrite in the shale, and this is what makes up much of the ore mass at Parys Mountain. In that sense we can describe ore masses like this as a form of *sedimentary-exhalative,* or *Sedex* deposit, and the pyrite can be referred to as *primary*, being in the rock mass since the beginning. Have a look at a hand specimen – is there any other type of pyrite or other mineralisation in the sample? Is that primary (layered parallel to bedding) or secondary (crosscutting, discordant features, so must be later?)?

From the mineralised shales, have a look at the **central boss** of the mine (the ridge in the centre of the Great Opencast). This has been interpreted by some as a *hydrothermal vent breccia*, comprised of fragments of exhalative vents. Can you find any evidence to back this up? Perhaps look and see if you can determine if the unit accumulated as rock fragments, or was subsequently mineralised via veins. It is quite possible that you may also encounter areas or pieces of *stockwork* – pieces of country rock that have been so heavily intruded by crosscutting veins and minerals from veins that they are more vein than rock! These can be worth a sketch or a photo.

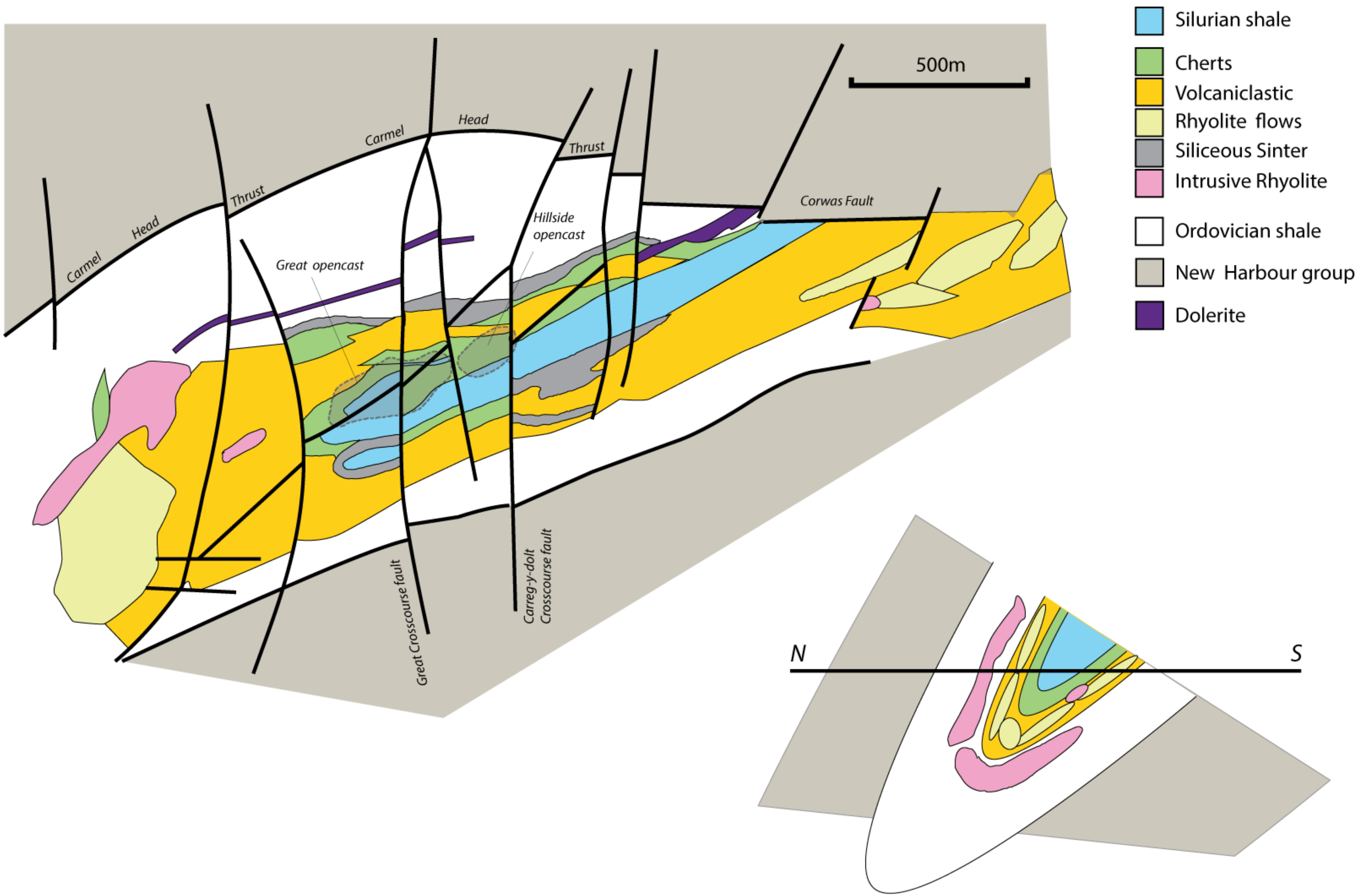
From the central boss area, look back towards the viewpoint. Can you see any interesting structures in the rocks beneath it? This is picked out by a large block of shale which projects just beneath the viewpoint and demonstrates the structural features. What type of structural feature is it? Can you locate it on the two maps which follow this page of text?

On the North wall of the pit, many shades of yellow, orange, red and brown can be seen which are to do with significant alteration to Jarosite (oranges and browns), with weathering to limonite (yellow) and haematite (pink) as well. Have a look at the low level fragments of rock that have accumulated down at the level of the path. Can you see any new rock types? Perhaps pick up a piece and retire to a comfortable point away from the slightly unstable North wall to make a rock description. How could this sample fit into the developing picture of the system that you are building? For those working with samples we have a hand specimen of the intensively leached rhyolitic material from the N Wall area.


General Geology of Parys Mountain
Units defined by Barrett et al., 2001
(Geology as at 50m below Morris Shaft collar)
Key
Old Mine Shaft
Building
MONA SCHIST
NORTHERN SHALES
B 5112
to Amlwch
Deep Engine Zone
Garth Daniel Zone
Engine Zone
White Rock
MORRIS SHAFT
Pen-y-Mynnedd Fault??
WHITE ROCK ZONE
Car Park
RHYOLITE B
CARREG - Y- DOLL
Pearl Engine House
RHYOLITE A
RHYOLITE D
Windmill
Colourful face with fault
Trevor relay
Proposed Adit
Mill Site
CENTRAL SHALES
Hillside Opencast
Great Opencast
Rhyolite
Viewing Site
Mineralised Silurian shales
Great crosscut fault
Secondary view - fault
pond
RHYOLITE D
RHYOLITE A
BASALT
Chapel
SOUTHERN SHALES
NEBO INLIER
RHYOLITE C
Remed. pond
Azure pond
0 100 200 m
Scale
to Rhosybol
Compiled and drawn by James Emberton BSc CEng FIMMM
3600 E
3800 E
4000 E
4200 E
4400 E
4600 E
4800 E
5000 E
5200 E
5400 E
5600 E
5800 E
5500 N
5000 N

Map of Parys mountain mine area

after Pointon, C.R. and Ixer, R.A., (1980) Parys Mountain mineral deposit, Anglesey, Wales: geology and ore mineralogy Transactions of the Institution of Mining and Mineralogy Section B, vol 89 p 143-155



Water testing

The afternoon at Parys will be spent water testing as we tour around. We will have four ponds to analyse, which we will be doing using a suite of analytical field kits designed for fairly accurate field analysis. These work by reacting particular analysis chemicals – supplied as compressed pellets – with the water being tested. An indicator in the pellet then produces a colour, which can be measured using a simple field absorption colorimeter. Everyone should have an opportunity to get involved.

We may divide into two teams to keep this moving fairly quickly; both Jacqui and Dan have had training in using the kits, which come with their own straightforward instruction sheets. One key point to note is that the levels of some pollutants are quite high at Parys Mountain, and it may be necessary to sequentially dilute samples for analysis with clean water to bring the concentrations down to a range that the kits can measure! **Definitely** do not drink any water from the mine!

We will combine the results this evening and compare them with various UK standards for water quality. Has the remediation been successful? We will find out!

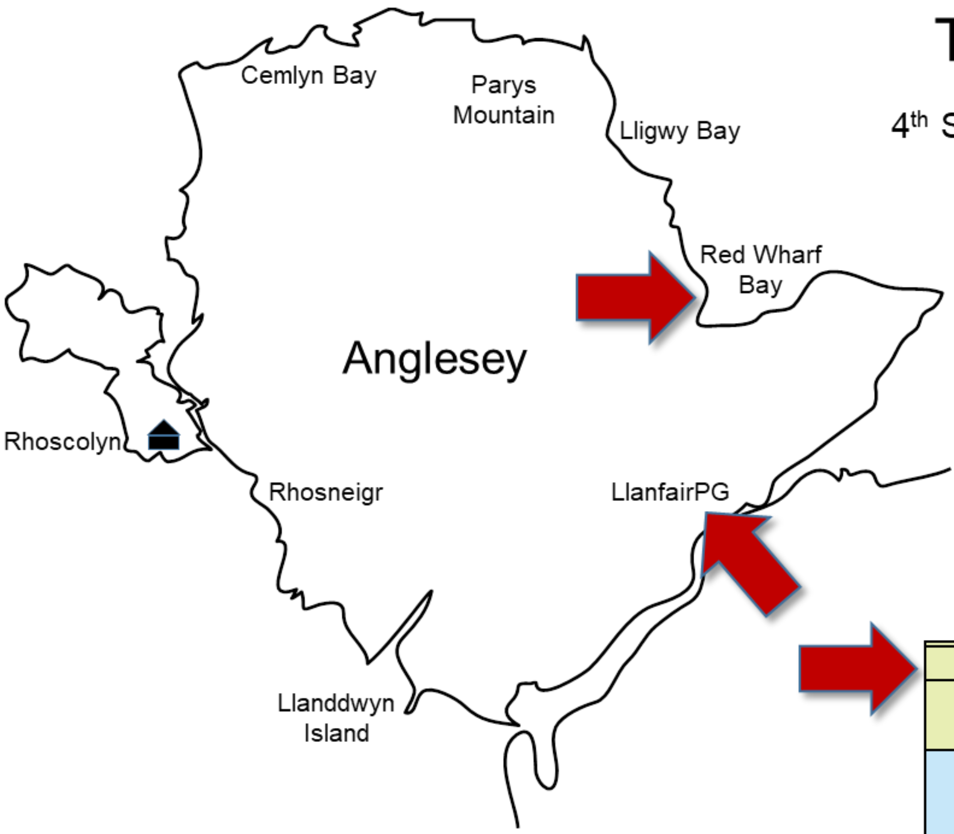
Analysis safety

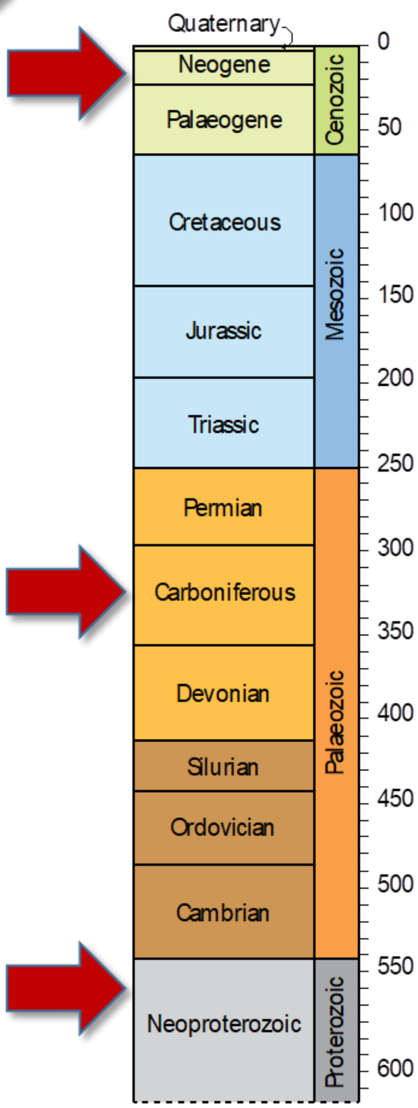
Each of the kits also has its own health and safety advice; this was given out as an update to the risk assessment on the first night. Simply put:

- wear gloves and safety specs,
- do not handle the pellets directly, use tweezers/forceps
- put all liquid waste after analysis into a waste vessel that we will have with us,
- do not ingest the pellets or get them into contact with eyes or skin. **If anyone does this tell us immediately**.

Day 2: Tuesday

4th September, 2018





Red Wharf Bay

Cliff and foreshore outcrops of Carboniferous limestone, sandstone and shales and a Miocene(?) aged beach deposit.

LlanfairPG

In the woods, beneath the Marquess of Anglesey's statue, are a series of Neoproterozoic blueschist outcrops.

9am: Depart *(40 minute drive)*

10.15am: At Red Wharf Bay

1pm: Lunch

2pm: Depart for LlanfairPG *(15 minute drive)*

2.30pm: At LlanfairPG

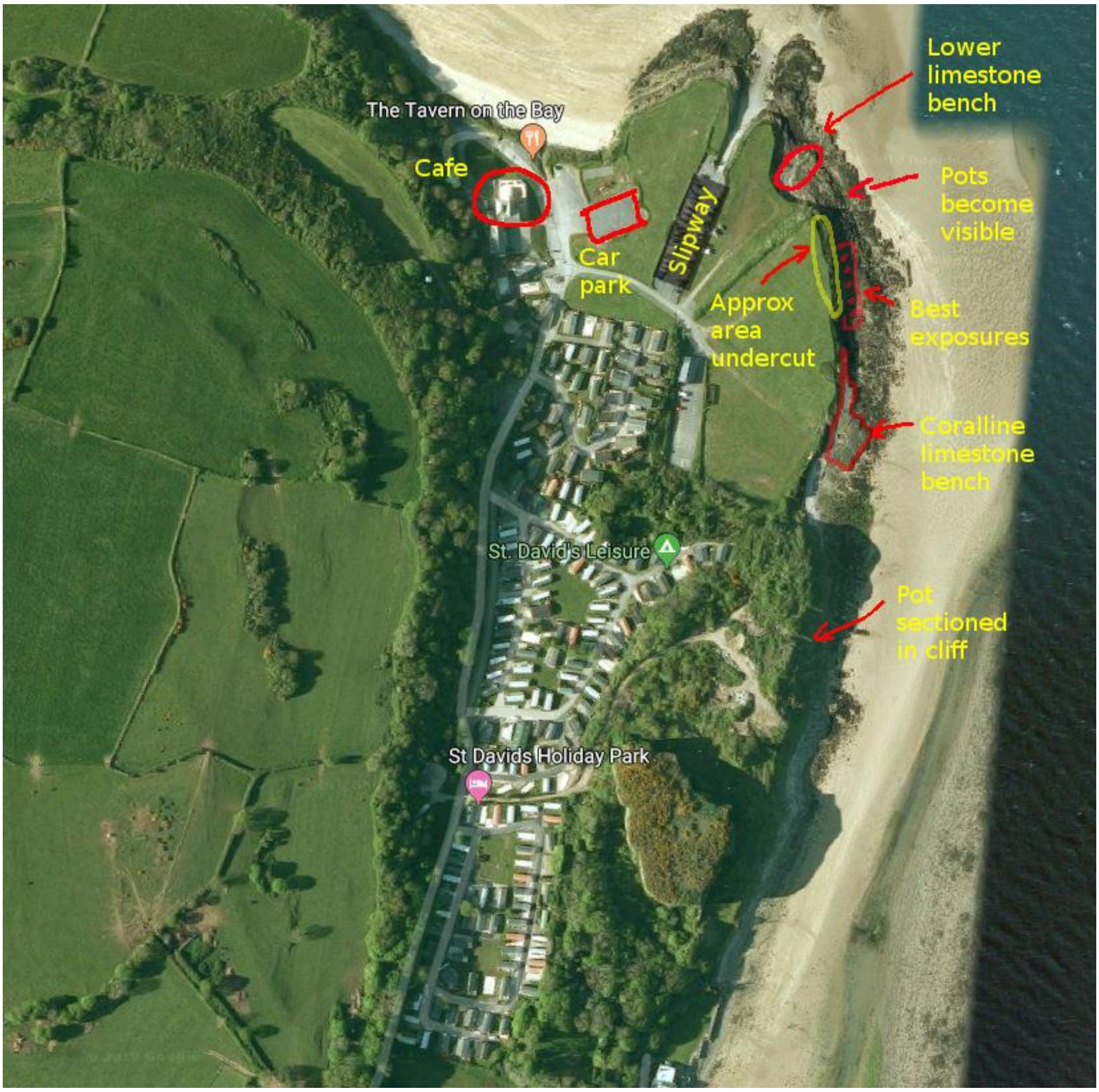
3.30pm: Leave for hostel

4.00pm: Back at hostel

Timings are approximate; it is difficult to judge how long activities will take, and conditions (eg the weather) may change.

Day 2: Red Wharf Bay and Llanfair PG

Red Wharf Bay (SH 5324 8192)



Summary

The morning will be spent examining a suite of carboniferous rocks, displaying an atypical Yoredale Bed cyclicity. Typically, full Yoredale cycles go Marine limestone – deltaic mudstone – deltaic sandstone – estuarine muds – palaeosol – coal – repeat (illustrated overleaf). These sequences are interpreted as representing the progradation of a deltaic system in a subsiding basin, which resets to marine limestones following lobe switching and prolonged subsidence, ready for the cycle to repeat.

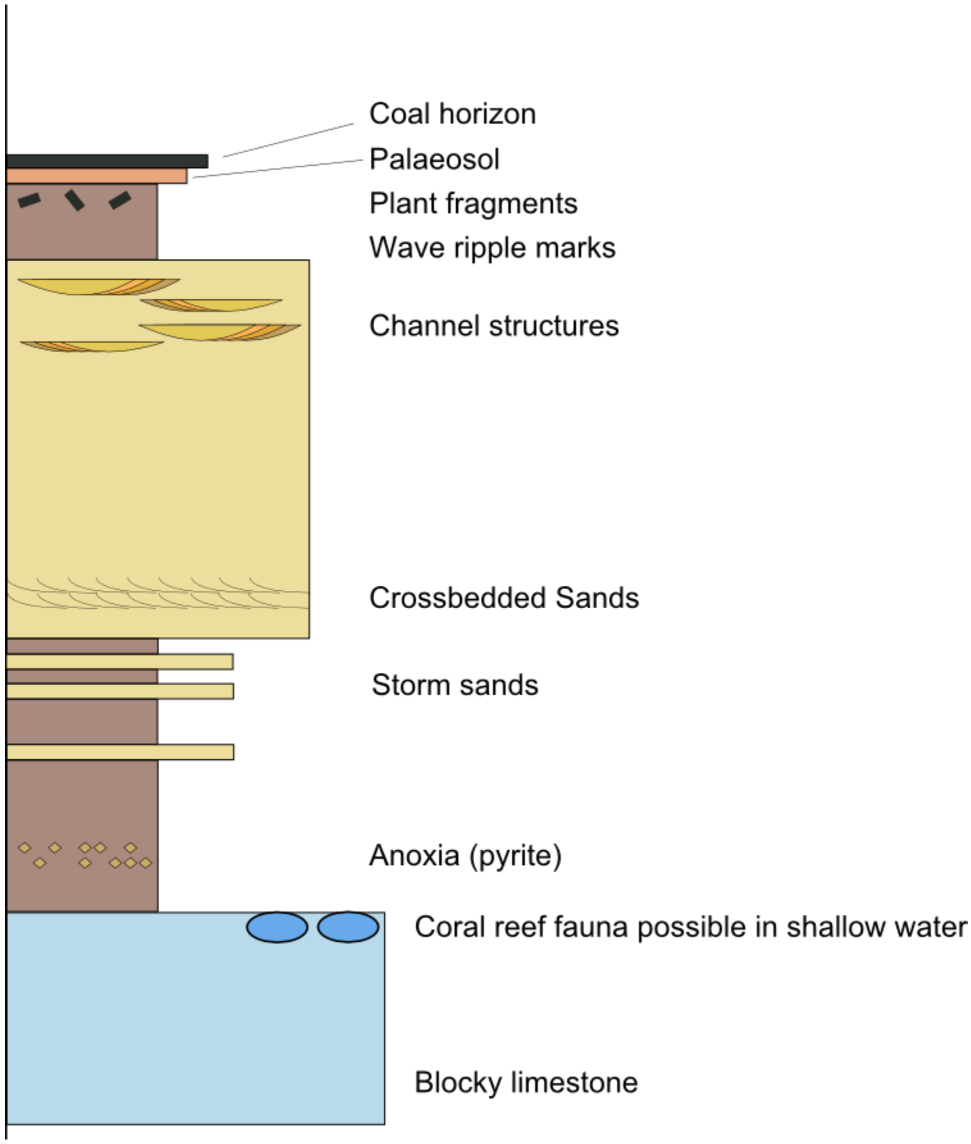
Here we will encounter a different order of lithologies that is produced by variations in sedimentary history and a set of events that causes the rock record to deviate from that simple order.

Background

Yoredale cyclicity – idealised.

The figure below gives an idealised version of a “typical” Yoredale cycle. Note that not all features may be developed (in particular the top of the system is prone to erosion), and the order of events can be varied by additional complications such as variations in sea level or lobe switching. Another useful thing to note is that the presence of coral in limestone indicates photic zone water depths, which may imply reef development adjacent to the delta.

Whilst we will see many of these lithologies, the rocks at Red Wharf Bay are definitely not typical Yoredale cycle. It will be necessary to consider how we can interpret events from the rock record in order to reconcile them as a sequence.



Logistics

The beach is public access but the car parking (SH 5324 8192) is not, being controlled by a camp site / spa resort – St. David's Leisure. They have given us permission to come on site and to use the slipway. The beach requires a certain amount of clambering over rocks, and is not so suitable for those who might be prone to stumbling or slipping on the extensive amount of bladder wrack and sea lettuce that coats the foreshore.

On the plus side, the café at the seafront is pretty well equipped and has an accessible loo.

Transecting from N to south

After arrival we will descend via the slipway and will work by transecting the area from N to S along the foreshore. Our first stop will be to look at the bench made of what we will call the **lower limestone**.

1. Have a look at a limestone surface. There are many of these which are smoothly polished with grooves, even higher up the beach. It can be helpful to splash a little water onto the rock surface, as this helps to make features in the rock more visible. Things to do: Give the rock a short description (5 -10 sentences). Consider gran size, presence or absence of bedding, and the presence of any fossils.

2. At its lower exposure, this limestone is smooth and striated, whereas in most areas near the sea a rough and pitted karstic appearance is typical. How do you think the smooth and striated appearance may have arisen? Is it likely to be old?

3. *Stretch activity: Closer to the sea, there* ***may*** *(if the tide is low enough) be an exposure of a different unit. We will see this under activity 5, if not, so don't worry if you don't see it here.*

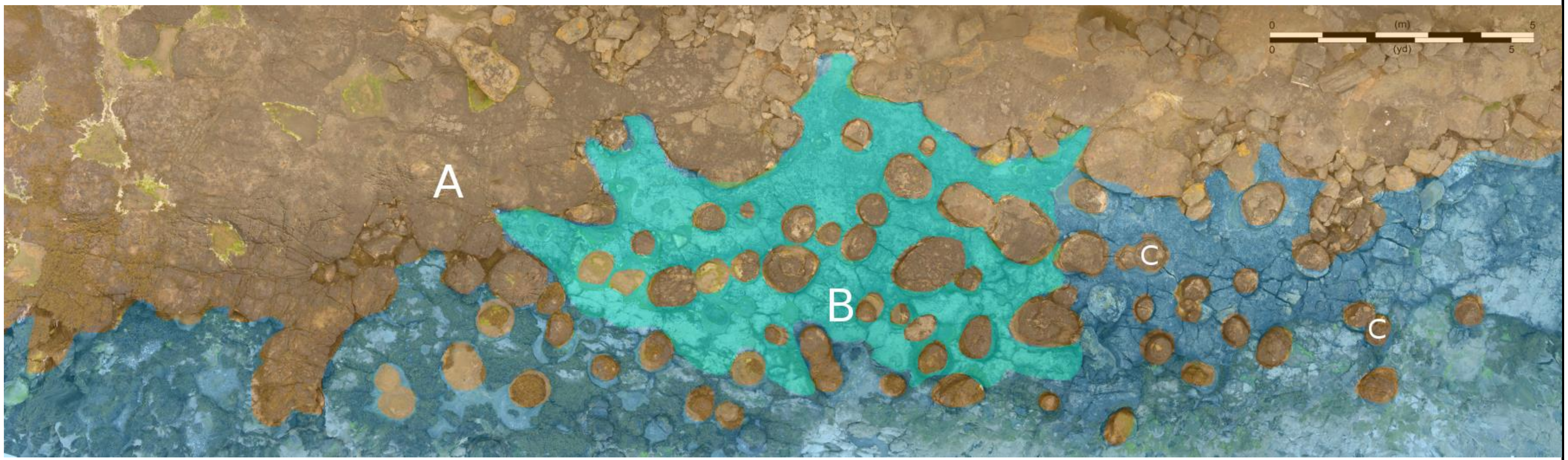
"Pot" Sandstones

As you move to the SE up onto a rougher bench, you will encounter "pot" sandstones, which have a columnar morphology. This is an interesting relationship between sandstone and limestone and is one of the ways in which Red Wharf Bay is different to typical Yoredale.

Continue to move SE, past the little headland. This opens out onto a larger surface where the pots are exposed. See figure overleaf. This area has plenty of things to look at.

This is a stitched composite image of the upper bench, with and without interpretation. As you can see, there are many of the sandstone pots exposed.


0 (m) 5
0 (yd) 5


0 (m) 5
0 (yd) 5
A
B
C
C

4. Sitting on one of the domal masses around **A**, and **<u>not</u>** under the overhang (which is dangerous, going by the mass of fallen blocks a bit further on), look back to the NW. This gives a good section through the cliff that makes a good sketch. Take a (full single page) sketch (or annotate a photo) of the cliff, and down onto the shelf of rock made by the lower limestone – this should give context to where we are in the stratigraphy and what is happening in terms of the order of units. At the base should be the lower limestone, with the pots in, and then the layers that successively cover them up. We will be annotating this, so leave space for more annotations or cross reference notebook observations to the photo. At this point you will not have had a look at all of these units, don't worry, we will have the chance to do this as we annotate the sketch. The key point here is to capture the layering and the relationships, picked out by the weathering.

5. Following on from the sketch, have a look in the turquoise area around B. There should be a different rock type exposed here, characterised by the presence of angular clasts of quartzite. It is not a thick layer in this location! Where does it sit in the stratigraphy? Is it cross cut by the pot sandstones, or does it sit on top? Check a few places. Describe it (a few sentences will suffice), and add it to your sketch from 3.

6. Next, take a sketch or annotate a photo of a pot sandstone column. There are some good examples around B, where you can see the top few tens of centimetres, and even see a bit into the side. Pay attention to the relationship with the host limestone. Is there any sedimentary layer between the limestone and sandstone? What does the bedding do within the pot sandstone? If present, what is the nature of the contact with any overlying unit? Can you see any fossil evidence?

7. On top of the sandstone pots is a layer of iron-stained sedimentary rock, which forms an undulating, domed surface. What is this layer's relationship to the pot sandstones?

8. *Stretch activity: If you are getting through this very quickly, have a chat with a staff member. If you have time, have a look at one of the areas marked C. In these areas, there are interactions between pot sandstones. How do they interact? Are there any kind of crosscutting relationships? Capture any that you find, and then consider what that adds to our order of events.*

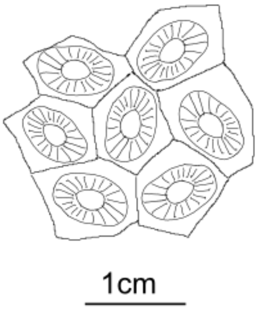
As we continue to move south from this area, we will gradually move up the stratigraphy. It should be possible to look at two further units. These are the softer layer that is prone to erosion that has formed the large overhang, and the unit that sits on top of that, which is harder and blockier.

9. Describe the softer layer. Again, only a few sentences are necessary; give it a name based on its apparent grain size and composition. Can you infer anything about conditions from this layer? Are there any obvious fossils within?

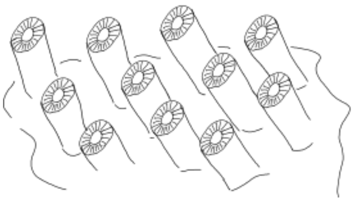
10. The blocky layer is exposed in a shallow cliff face, away from any overhangs. Have a look at it and do another brief description. Consider the following particular properties: grain size, bedding, and fossil content.

11. The blocky layer is exposed at its uppermost surface on a large bench of rock. This is a palaeontology stop!

See if you can find the following (there are others as well!):



Lithostrotion vorticale



Lithostrotion junceum

Pot transect in-situ

A couple of hundred metres further along, it is possible to see a pot developed higher up the stratigraphy. In this case, we see it in cross section, being fed into a higher-level limestone from a thin (0.6-0.8m thick) layer of pebbly sandstone that overlies it. Interestingly, there is a cave underneath it.

Note that the limestone here contains visible nodules of chert, and sits above the coralline bed you saw before.

12. Take a sketch or annotate a photograph of the location. What does this tell us about how the pots have formed? Look at the layering and the bed thickness in the sandy sediments above the pot. Does this tell us anything about how long it took for the pot to form?

Recent rock deposits (SH 5322 8165)

Yet further down, it is possible to locate a deposit comprised of limestone fragments.

13. Is there any evidence as to how old this deposit could be? Is it lithified, and if so, what is the cement?

As part of a thinking and wrap-up exercise, this evening we will work our way through our accumulated evidence to try to build a good picture of what happened during the formation of these rock units, and what the conditions and palaeoenvironment was at that time.

Marquess of Anglesey's Monument

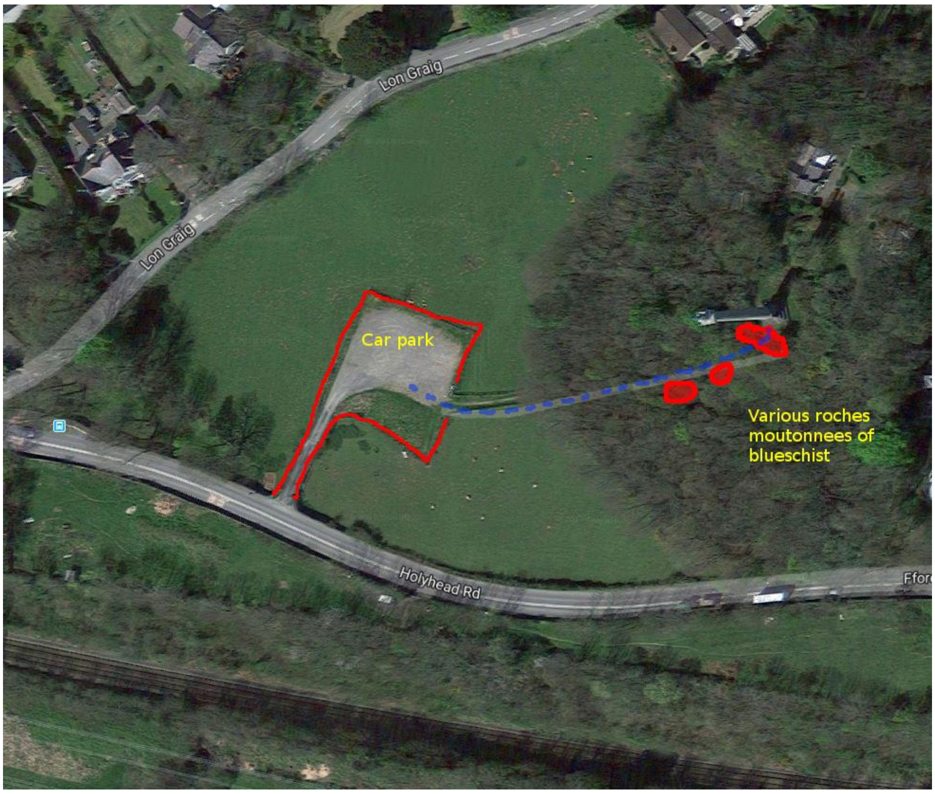
Summary: After a morning of looking at the Carboniferous of Anglesey on the beach, we will move on to the Marquess of Anglesey's Monument near Llanfair PG*, and on our timeline, back into the Precambrian. We are here to look at a suite of deformed metamorphic rocks, specifically **blueschist**.

The blueschist occurrence sits directly under the pillar that is the Marquess' monument (now roped off due to safety and maintenance concerns), as well as forming a couple of isolated outcrops nearby. Whilst the local moss means they are entirely green, the blueschists do demonstrate some good deformation textures. We do also have a pair of thin sections cut from this material back at the hostel, if anyone needs further convincing.

The purpose of coming here is to see this (relatively rare, certainly in the UK) rock type in the field, and to place it into a time context. Be aware that these rocks are somewhat complex and also difficult to examine based on their grain size and the inability to hammer

* Llanfairpwllgwyngyllgogerychwyrndrobwllllantysiliogogogoch, in full – yes, **that** place.

Logistics



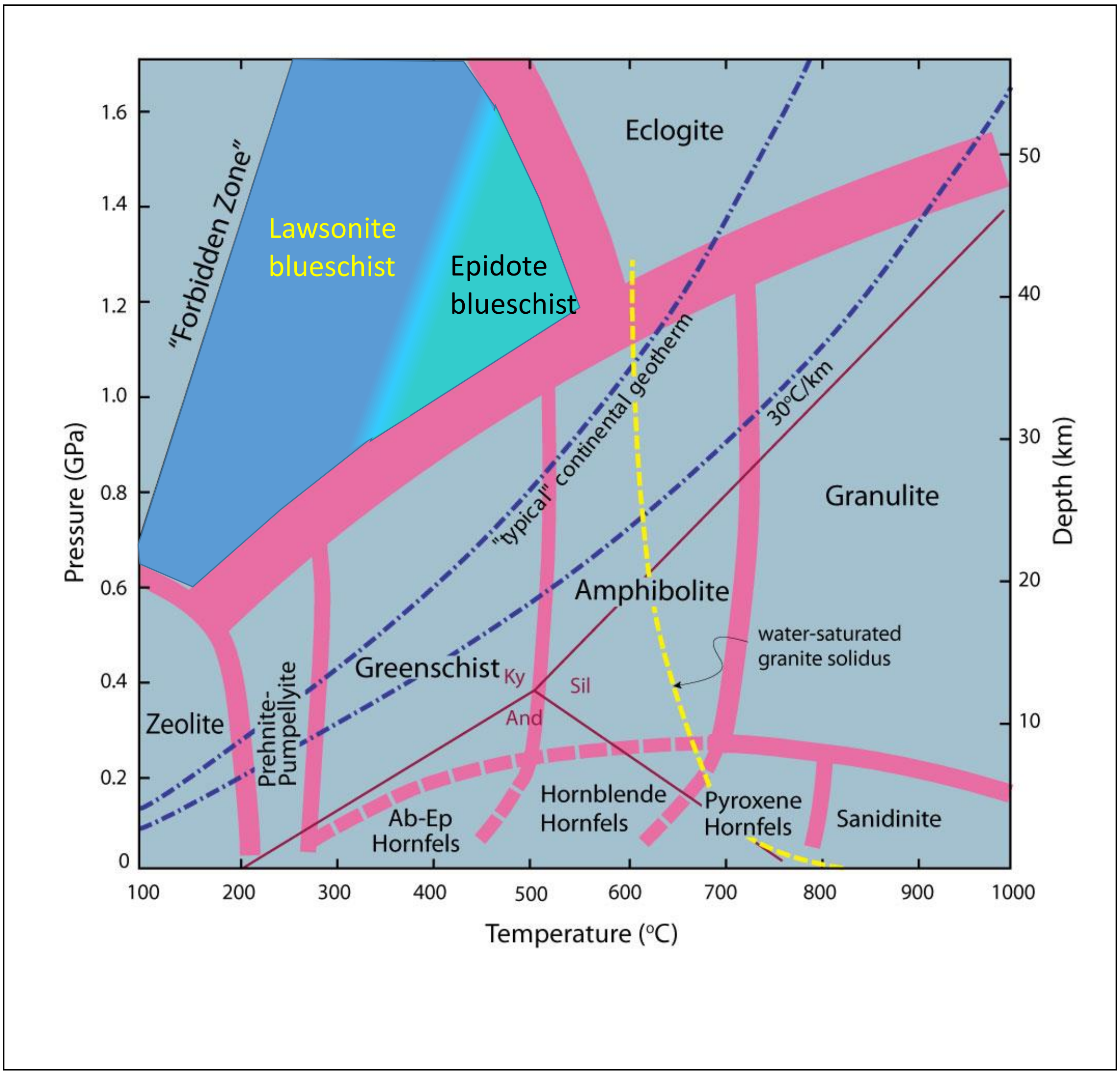
There is a car park though the angle onto the A5 road is a bit odd, and the car park is not big. The car park is in fact decidedly small. It's an incline up into the woodland, which may prove challenging to wheelchairs – the tree roots do stick out and it is an uphill incline, even if fairly subtle. There are NO facilities other than the odd tree.

Background

Blueschists are high-pressure, low-temperature metamorphic rocks, typically produced by metamorphism of basaltic igneous protoliths in a subduction zone setting. They obtain their blue colour from the mineral glaucophane ($Na_2(Mg_3Al_2)Si_8O_{22}(OH)_2$), a blue amphibole. In addition, they commonly contain epidote (a pistachio-green orthosilicate), lawsonite, and quartz. Other possibilities include the minerals zoisite and clinozoisite, which are related to epidote, but are colourless.

Blueschists are often seen altering to greenschist, which has a characteristic assemblage of green amphibole (actinolite), epidote, chlorite and sodic plagioclase. Greenschists are lower-grade metamorphic rocks than blueschists, formed at the same temperatures, but lower pressures, and greenschists are also more hydrated (as you go up grade, rocks tend to get drier, formed from minerals with progressively less water in their structures). The presence of blueschists is often taken to imply rapid exhumation (rate of ascent back to the surface) from the conditions of formation.

A P-T grid for metabasic rocks is shown below. This shows the P-T region (highlighted) in which blueschists can form.



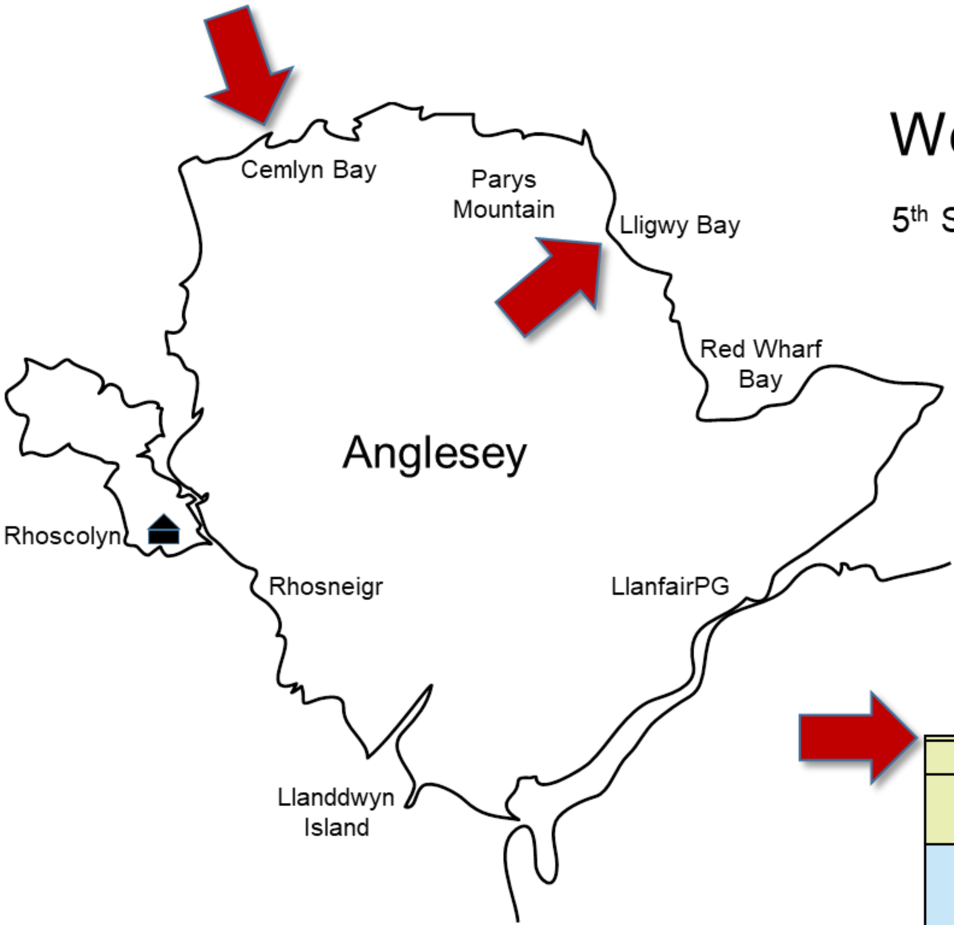
Tasks:

1. Approach one of the outcrops and have a look at a surface of the rock. Make a short description of it. Note that the lack of hammering and consequent lack of fresh surfaces may mean that the description is very limited. We have some fresh and polished specimens, which will be in the field but which are limited in number. It may be worth looking at one if you have the opportunity, or they will also be available back at the hostel.

2. The rocks do display some strong foliation and some spectacular folding. Choose a face of an outcrop and sketch it, or make an annotated photograph.

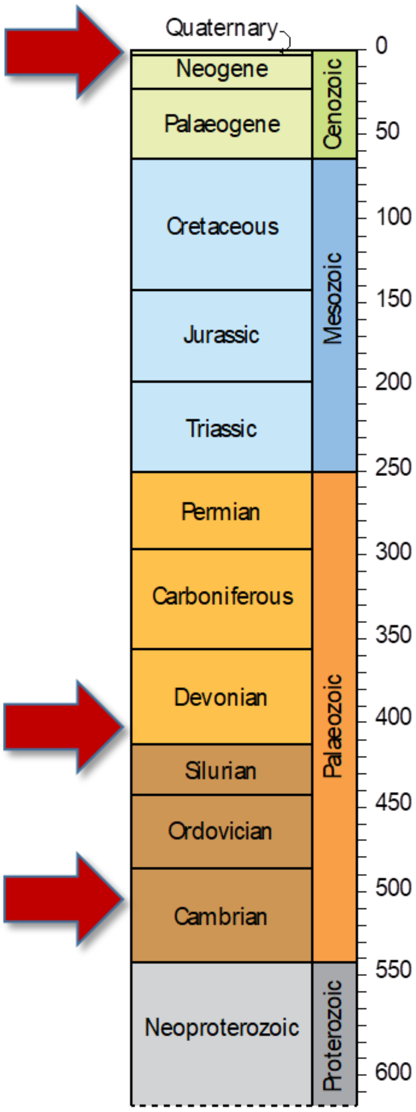
3. You may notice that there are some relatively harder, or more competent, blocks within the outcrop faces that the foliations wrap around. If you can locate one, have a look at it (as long as you are not disturbing anyone else's sketch work). Is it any different to the host rock in terms of minerals? Is it a feature controlled by rheology and mineralogy or developed by chance?

4. Finally, take some measurements using your compass clino and add these to your sketch at the correct points. Things to measure might include fold limbs (dip-strike of surfaces there) or hinge lines (plunge-azimuth). Are the readings consistent across outcrops, within a single outcrop, or chaotic? Is it possible to infer a compression direction for the folding?



Day 3: Wednesday

5th September, 2018



Lligwy Bay

Foreshore outcrops of Devonian Old Red Sandstones. Also Devensian (last ice-age) boulder clay deposits.

Cemlyn Bay

Outcrops of deformed Cambrian meta-sediments and a Devensian drumlin.

9.30am: Depart – late start due to tides *(40 minute drive)*

10.45am: At Lligwy Bay

12.45pm: Lunch

1.45pm: Depart for Cemlyn Bay *(30 minute drive)*

2.30pm: At Cemlyn Bay

4.30pm: Depart for hostel

5.00pm: Arrive back at hostel

Timings are approximate; it is difficult to judge how long activities will take, and conditions (eg the weather) may change.

Day 3: Lligwy Bay and Cemlyn Bay

Lligwy bay

Summary: Our Morning will be spent at Lligwy Bay, where we will be looking at part of the Devonian succession of Anglesey. The Devonian of the United Kingdom includes a specific set of sediments referred to collectively as the ***Old Red Sandstone***. These Devonian rocks sit between the Ordovician and Silurian shales and the Carboniferous. The rocks here therefore fill in some parts of the history between the Parys Mountain successions (late Ordovician and early Silurian) and the Carboniferous successions that you saw at Red Wharf Bay. As a first order approach to these outcrops, after noting and describing their properties, think about the palaeoenvironment in which they could have formed, and consider how this has been changing in Anglesey over geological time. A second thing to consider, particularly as we progress further along the beach, is to consider ***deformation***. By observing and measuring the units here, we may be able to place constraints on the tectonic history of the area.

Logistics: This is perhaps one of the most difficult beaches for access purposes. The beach is unsuitable ground for those with mobility difficulties and/or wheelchairs, with quicksand a very real hazard. It will be possible to work in the viewpoint area, and we have a parallel exercise for this purpose which looks at the rocks in detail and in comparison to other ORS outcrops nationwide.

SAFETY WARNING

As the warning signs in the car park note, Lligwy Bay does feature **quicksand patches** due to interaction between glacial boulder clay and beach sand. These are not terribly deep (about knee depth) but **are** a notable hazard. **Do NOT run on the beach**, as if a foot sinks in, your own momentum can break your leg. We will generally walk fairly high up the beach, but do be aware of your footing and avoid areas where the sand seems to shift oddly. Beware of the area marked out by the blue barrels and do not wander off.

Approach to the outcrops

We will largely be working in three separate areas along the back of the beach. The first is a sketching / annotated photo locality, to look at a particular surface developed in the sediments, and is also an opportunity to get a first rock description. The second is a more extensive bench of rock (bench 1), which gives clues to the lithological variety in the unit, and which will support a quite detailed investigation of the sedimentology of the unit. The third outcrop (bench 2) is an area that shows a development of the sedimentology and also shows some tectonic features.

First rock

This outcrop comprises a layer of weathered rock that dips towards the sea and which has a very interesting surface texture.

1. Take a sketch or annotated photograph, and try to get a short (5-10 sentences) rock description for the unit at this place – is that layer a sand, silt or mud? Are there any interesting features besides the surface texture? What do you think could have formed the surface texture?
2. Measure the strike and dip of the bed!

Bench 1: sedimentology focus

Moving along to bench 1, it is possible to see that the rock unit here is more variable than it was at the first stop, comprising several different sub-lithologies layered together.

3. Before sketching, have a look at the outcrops and decide how many sub lithologies you feel you could reasonably identify, based on field characteristics. This may include colour or texture variations, grain size, mineralogy, or other key distinguishing features such as fossils or the presence/absence of indicator minerals such as calcite.

4. Describe at least **three** lithologies at this location based upon that initial reconnaissance (again, short rock descriptions of 5-10 sentences). Are there any characteristic properties that seem to be useful, but which you cannot easily explain? Do remember to talk to demonstrators if so.

5. Next, sketch their relationship. In doing the sketching, be careful that you have determined the behaviour of the individual sedimentary layers. It may be useful to trace some from the cliff towards the sea. Are they continuous, or intermittent? Is there any evidence for syn-sedimentary erosion? (*Hint – it can be advantageous to view the rocks along strike but at a shallow angle, from a crouching position or sighting along the layers; the foreshortening of perspective can throw gradual changes into sharp relief*).

6. When you are comfortable with what you can identify as layers, what do you think is responsible for them and for the alternations in rock type? Can you think of any type of sedimentary environment where such things might form? Can you infer anything else about the palaeoenvironment? Perhaps take a dip and strike reading for the bedding.

7. Progress further along to the NE. Are there any changes to the overall nature of the sediments as you carry along? Are any of your sub-lithologies becoming more or less abundant?

Bench 2 tectonics focus

The furthest bench contains both sedimentary and tectonic features, with folding and faulting evident, as well as the development of cleavage.

8. An annotated sketch or photograph of the bench will be useful, which you can then populate with data. The rocks are still layered (hence the sedimentology from the previous outcrop will be useful), but you can see different responses to deformation between the fine-grained and the coarse-grained layers.

9. Measure the limbs of the fold and the plunge-azimuth of the fold hinge line. If you can find a good example, measure also the cleavage in the finer-grained horizons, where it is developed most strongly. If you can find a fault plane, also measure that. Be sure to keep your measurements clear as to what you have measured, and ideally, link it to a sketch or photo so you have the context of where your measurement was taken.

10. We will compare the data this evening against other tectonic orientations that you have obtained from Parys Mountain and The Marquess of Anglesey Monument (Blueschists). In addition, there will be other localities that we will visit that also preserve information on potential compression directions, which we can also compare.

Cemlyn Bay

Cemlyn Bay is a small bay in on the northwest coast of Anglesey. A shingle bar separates a lagoon from the sea. During the summer, it is home to an important nesting colony of terns (which can be very noisy, although they should have moved on by now). There are also fine views across the bay to Wyfla nuclear power station. The rocks here are part of the Cambrian New Harbour Group, which are probably younger than the South Stack Formation seen at Rhoscolyn, although relative ages are disputed. They have been cut by various dykes.

Locality 1: Large outcrops on beach

Task 1:

- Identify and describe the three different rocks types here.
- Consider the structure. Small-scale folds are clear, but consider these closely. Are there faults associated with them? Measurements of the hinge lines of the folds are useful here.
- Find a good example to sketch.
- There are some dykes on the beach. Can you identify the rock types? Have the dykes been emplaced before or after deformation?

Locality 2: About 250m north along the beach

Smaller outcrop of the same lithology as seen at locality 1. The main interest here is the structure.
Task 2:

- Identify the structures here.

- Take readings for comparison with structures seen elsewhere.
- Draw an annotated sketch.
- How do these structures relate to those seen at locality 1?

Locality 3: Over the headland and back on to the beach

During the Late Devensian, Anglesey was located close to the eastern margin of the Irish Sea Ice Stream. Ice flowed southwest from Scotland through the Irish Sea Basin where it joined the Welsh Ice Sheet centred on Snowdonia and flowed SW across Anglesey.

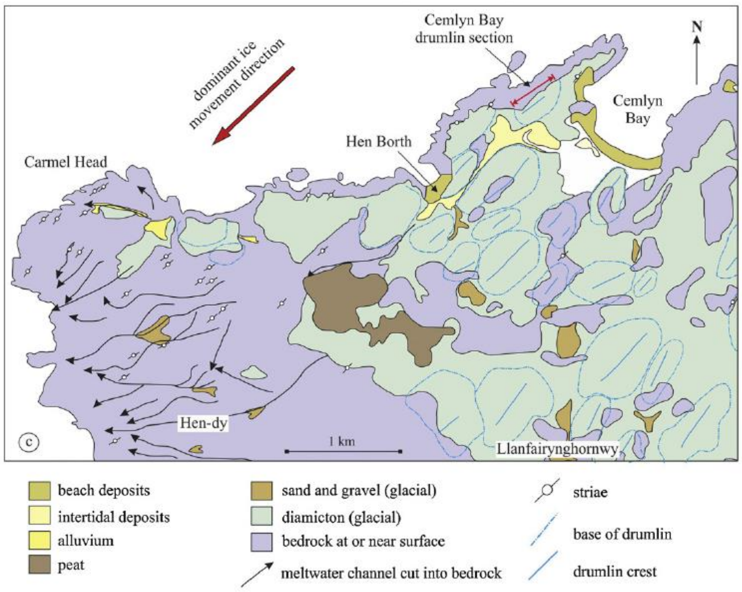


Figure 1: Glacial features around the NW coast (Phillips and Hughes, 2014).

The drumlin at Cemlyn Bay has been eroded back by the sea so its internal structures can be seen in cross section. Its long axis is oriented NE-SW consistent with the direction of the ice stream. It is composed of diamicton (glacial till).

Task 3:

- Describe the lithologies in the drumlin
- Draw an annotated sketch(s) of the drumlin.
- What do you think might have caused the layering in the drumlin?

Day 4: Thursday

6th September, 2018

Llanddwyn Island
(Newborough Forest Reserve)

Beautiful outcrops of Neoproterozoic pillow lavas on the beach, and melange on the far side of the island.

9am: Depart (*40 minute drive*)

10.15am: At first locality

11.00am: Move on to second locality

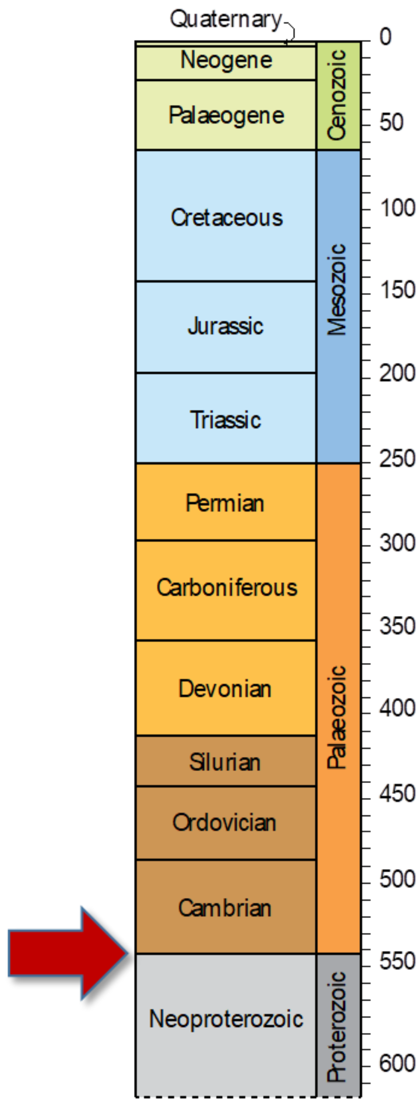
11.30am: At second locality

12.30-1.30pm: Lunch (flexible as at locality)

3.15pm: Walk back to carpark

3.50pm: Depart for hostel

4.30pm: Arrive back at hostel



Timings are approximate; it is difficult to judge how long activities will take, and conditions (eg the weather) may change.

Day 4: Llanddwyn Island (Newborough Forest Reserve)

Llanddwyn island: Pillow lavas and the melange complex

Summary

The purpose of this day is to conduct an exploration of some of the older rocks in the area, part of the Precambrian sequence. These rocks have been heavily tectonised, and form what is called a mélange unit, from the French for “mixed”, or more literally, “scrambled”. The aim here is to investigate the different rock types and to place them into context – where could all of the different rock types in the mélange have formed? What type of environment would allow them to be in relatively close contact prior to intense deformation, and what environment might be consistent with the deformation that they show?

Logistics and arrival

Access to Llanddwyn is via Newborough National Forest, which means paying a £5 toll per vehicle at the access gate and driving down to the car park (SH 4057 6350) which contains quite a lot of parking, as well as loos, an accessible loo, and some kind of catering van that does tea and burgers. From the main car park, if one has a key, access can be gained to both a further car park adjacent to the beach and the beach (and island) itself.

Access the island, and hence the mélange unit that is between the two lighthouse towers, needs low tide. It’s quite a bit of walking along the beach and island to the mélange, but a car can drive over the beach and up the island as far as the pilot’s cottages, provided someone from Newborough accompanies the party.

Background

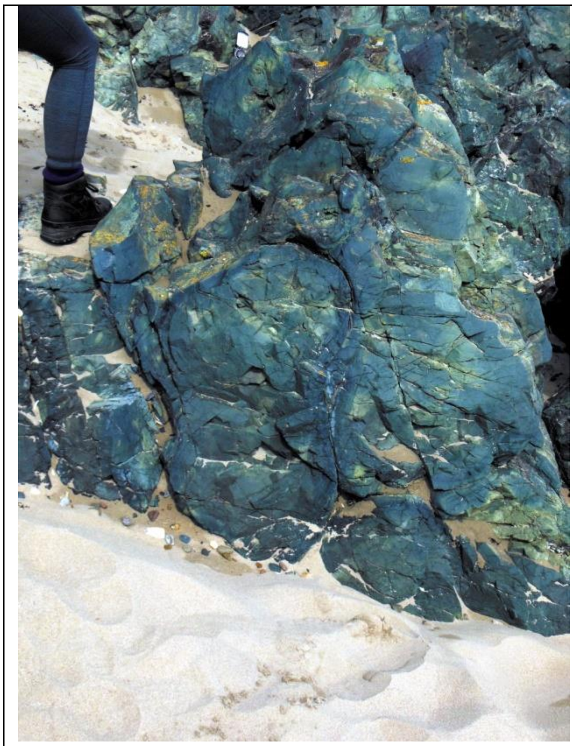
The rocks here are part of the Precambrian Mona complex, which represents the oldest rocks of Anglesey. The rocks that you have seen at the Marquess of Anglesey Monument (the blueschist), and the rocks that you will have seen at Cemlyn yesterday, are also part of this complex, as are the rocks of Rhoscolyn that you will see for the last two days of the trip.

The rocks we see here are from a lithologically different part of the Mona complex to anything that you have seen so far, in part because of the tectonic activity that they have been affected by. The precise story that these rocks can tell you is parallel, but not identical to, that of the rocks at Cemlyn and the Blueschists. It is educational to look establish their context and also to take structural measurements for comparison with other locations. In addition, differences between the rocks here and in other locations can give you important *geodynamic context* in that it allows you to place rocks found here into a tectonic framework relative to other places you have seen. This will be part of the aim in the evening wrap up.

Pillow lavas

The early morning will be spent examining a suite of pillow lava outcrops. They are variable in quality, dependent on the amount and type of weathering versus colonisation by plants and marine creatures. We will look at two areas on the way out to the island, with a possible stop at a third if it is not occupied by tourists. For the reasons of possible crowding of the beach and lack of access if someone has set up camp for the day, some photographs will be supplied here.

Small recent exposure (SH 3930 6358)



This particular outcrop is regularly blasted by wind-blown sand, which keeps it smoothly polished and clean on the seaward face, though the rest is gradually being colonised by dune plants. We will experience this first hand if it is windy! The polished faces give some really nice aspects to investigate and to either sketch or produce annotated photographs of. In terms of examining these outcrops it is useful to focus on the different shades of green that they display.

There are two characteristic green minerals in this outcrop that are very visible purely due to their colour. The most obvious of these is epidote, which is a shade of pistachio-nut green: ■■■■■. Also present and green is the mineral chlorite, which is a much darker, powdery blue-green: ■■■■■. Colour variations in this outcrop also map out the edges of individual pillows (why?)

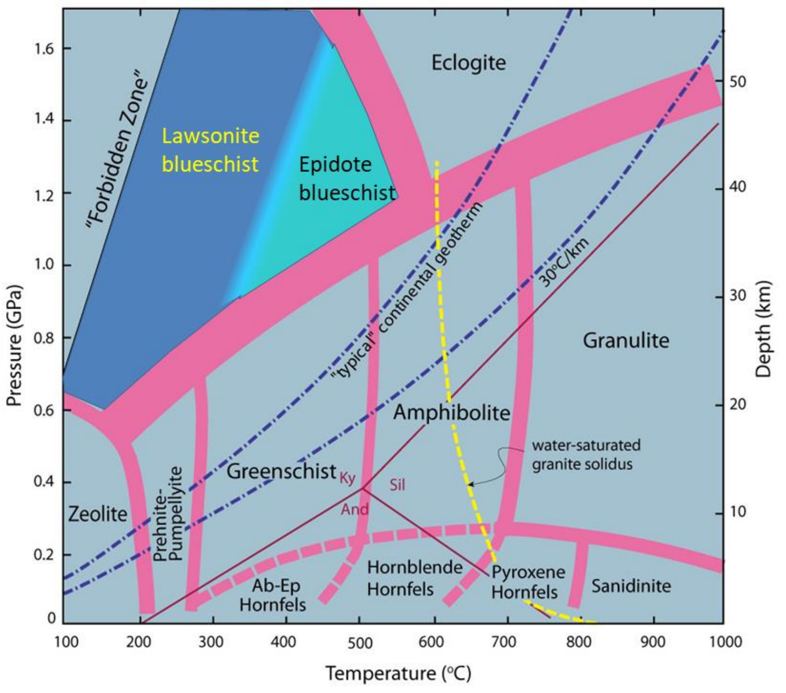
Tasks:

1. Make a sketch / annotated photo from one of the polished surfaces of the pillows in cross section. Can you trace the edges of individual pillows, and determine why these are visible?

2. Are there any other rock types present in the outcrop, e.g. between pillows?

3. Can you infer anything about the way up of the rocks from the shapes of the pillows? Remember that the pointed tails on pillows are usually on the lower surface as they squidge into gaps, whilst the tops are usually domed. *(Note that if you look and can't find anything, "no" is a perfectly acceptable answer, but since this rock type **can** give way up information it is worth trying)*. If you can see a way up, a slightly harder proposition is to determine if you can then see bedding. **This is much harder to see**, so, as above, do not get worried if you cannot, especially from a relatively small outcrop such as this.

4. The coloured minerals, when found together, are two indicative minerals for a particular metamorphic facies of basaltic igneous rock protoliths. Use the diagram below to work out what kind of P-T conditions we are considering as the metamorphic history of these rocks.

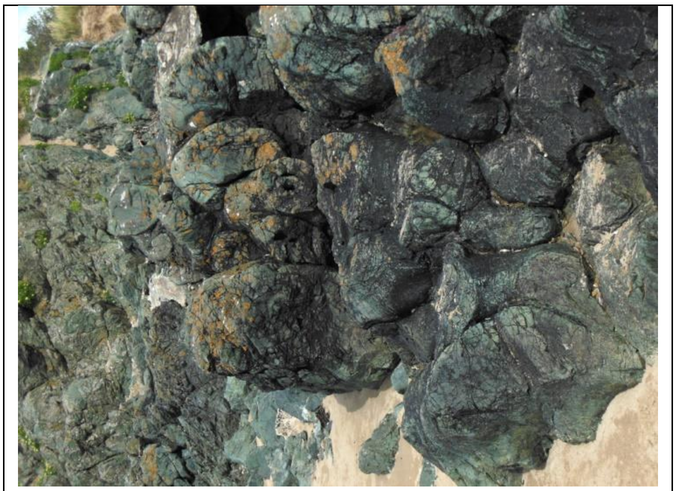


Temperature-pressure diagram showing the generally accepted limits of the various facies used in this text. Boundaries are approximate and gradational. The "typical" or average continental geotherm is from Brown and Mussett (1993).

Image and above caption taken from powerpoints supplied by Winter, J.D. (2010), from the textbook: Winter (2010) An Introduction to Igneous and Metamorphic Petrology. Prentice Hall.

Pillows with nice angles (SH 3911 6349)

Around this grid reference there are two outcrops that can be looked at. One outcrop is low lying and has some broken up pillows at one end, but also displays some good morphologies. These can be used to add to your observations from the previous outcrop.



The second outcrop nearby is a much larger face and gives a much better and representative idea of what a large pile of pillow lava would look like. Seeing way up structures and potentially bedding should be easier in this outcrop, and a sketch might be worthwhile.

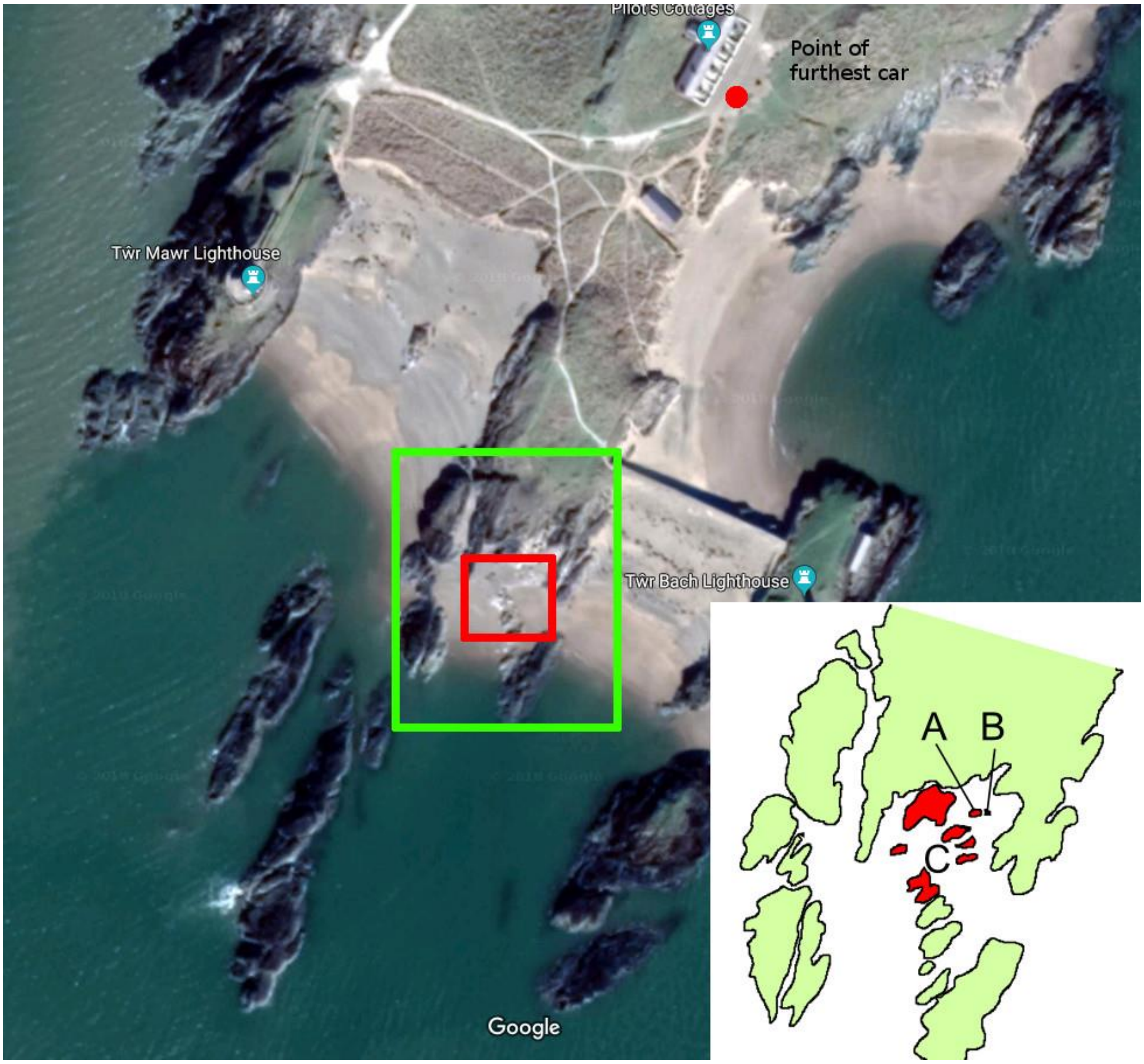
Llanddwyn Island

Following the exploration of pillow lavas, we will head up onto the island itself to locate the mélange unit. The island is composed of mélange, but the twin effects of erosion and colonisation by lichens and coastal organisms means that it is very hard to spot the different lithologies unless the outcrops are being eroded by the sea. This means we will walk to the far end of the island and descend onto the shoreline to examine outcrops in the intertidal zone that have been continually pounded by the sea to keep them clean. On the way, we will walk past a Geomôn information board that summarises the geology according to one of the prevailing models.

We will walk past the board, and along to the area that sits between the two lighthouses. A track goes as far as the pilot's cottages which is where the support vehicle will park up. The plan is to use the local area relay to allow those who cannot physically descend to the beach to have a virtual presence with the group.

Mélange unit (SH 3858 6241 and around)

This is high-resolution, lithologically complex geology. We will have to work with that, and indeed the purpose of coming here is to practice ***how to deal with complexity***.



As noted above, the mélange unit is an exercise in locating, identifying, recording and dealing with complexity.

It is fair to say that the unit is highly complex, and this in itself is potentially problematic. In many areas where there has been strong tectonic activity, such complexity is unavoidable. As geologists, we have to develop appropriate strategies to accurately record what we find without going too far or making the task of mapping and understanding it impossible. As it is the first time that you will have encountered the rock types, our first task is to break down the problem into smaller bite-sized problems that are individually solvable.

Tasks:

1. **How many rock types are there present on the beach section**? Starting from one end, investigate the outcrops that poke up out of the beach and define on very loose, simple terms, the different rock types that can be discerned. In terms of a scale of working, work at the metre-scale for rock identification – these rocks are typically fragmental materials made of other units, so it is necessary to work at a scale where the mixture is representative. This process can be difficult, because you will have to some extent ignore the details. If you are finding it overwhelming, ask for some advice.

2. Once you have defined how many you have – and you should ideally have no more than 4 or maybe 5 different rock types – **produce a sketch/annotated photo and a very short description of each**. For the purposes of this description, what are the **key properties** that make it what it is? Usually this would be covered by the following terms: colour, components, composition, clasts, fabric and matrix.
   *[**Hint:** you may find acid tests to be useful for at least one of the units].*
   *[**Hint 2:** one of the units that you may find is much less deformed than the others – why is that the case, and what is its relation to those other units?]*

3. From this point, use the high-resolution field slip to map out where these units are found and the boundaries between them.

4. If you have time, also take some measurements. Good possibilities would be any foliations that you might find in finer-grained, softer rock types, and also the orientations of the boundaries between rock types, since these should define planes. Add these to your map.

Note that if this was a mapping project, the level of complexity that the overall unit poses means that apart from having the separate rock descriptions that describe the components of the mélange, the mélange itself would probably be mapped as a single unit, even if it has different components, because distinguishing and mapping them at 1:10,000 is not really feasible – the unit is too internally variable. Only at very high resolution is it really feasible to separate them, and that is prohibitive for working across a large area (though fine for our purposes today).

Rationalising the rocks

When you have some small rock descriptions and relationships, you are much better placed to think about these rocks in terms of what they mean. Can you break your mapped lithologies down further? Are there components in these rocks that are distinct and identifiable? What environments might they be found in?

5. Some of the rock types here have common components, albeit in different proportions. Produce a little table that breaks down the rock types into the component parts.

6. Looking at your table of components, can you think of an environment where they might all have formed originally?

7. You can add pillow lavas as a further component / rock type, as these are also part of the mélange. Does this change your view about the environment, or reinforce it?

8. Considering the deformation, are these rocks deforming in a brittle or ductile way? What is your evidence?

9. Considering the metamorphic history that you determined from the pillow lavas in the early outcrops, and what you have determined in 6, 7, and 8 try to think of a way in which you could bring them all together as a mélange.

Optional extras: Hyaloclastite / Pillow breccia (SH 3924 6395, by track)

An extra possibility should we finish early or need something else to look at if access proves difficult is another facies of sea floor igneous crustal construction – hyaloclastites and pillow breccias. As pillow lavas pile up on top of their vent, it is possible for a considerable local topography to develop, a small mound up to 50-100m high called a ***tumulus***. Pillow lavas that do not accrete to the pile can roll off the top, and cascade down the sides of that mound, forming a pile of detritus around the mound composed of broken pillows and fragments of glassy material, a **pillow breccia**. This commonly underlies pillow lava deposits, as later eruptions advance the pillow lavas on top of the breccia.

In addition, the glassy, chilled margins of pillows can commonly ***spall*** off following thermal contraction to produce a sediment of glassy shards, a ***hyaloclastite***. This type of material is typically found as a ***talus slope sediment*** at the base of a pile, or ***tumulus***, of pillow lavas, associated with pillow breccias.

In an outcrop next to the access trackway, it is possible to see some evidence of these processes. Some pillow lavas are distinctly not intact, and have been disrupted into fragments within an even more fragmented matrix. This is a pillow breccia or (if taken a long way) a hyaloclastite, assuming that these textures are original and not tectonic.

Day 5: Friday

7th September, 2018

Rhoscolyn

Deformed Cambrian metasediments in a series of exposures across the headland.

Rhosneigr

Folded Ordovician shales and siltstones set in the sand at the popular beach resort.

9.00am: Depart hostel *(10 minute drive)*

9.15am: At carpark

9.30am: At Rhoscolyn coastguard hut.

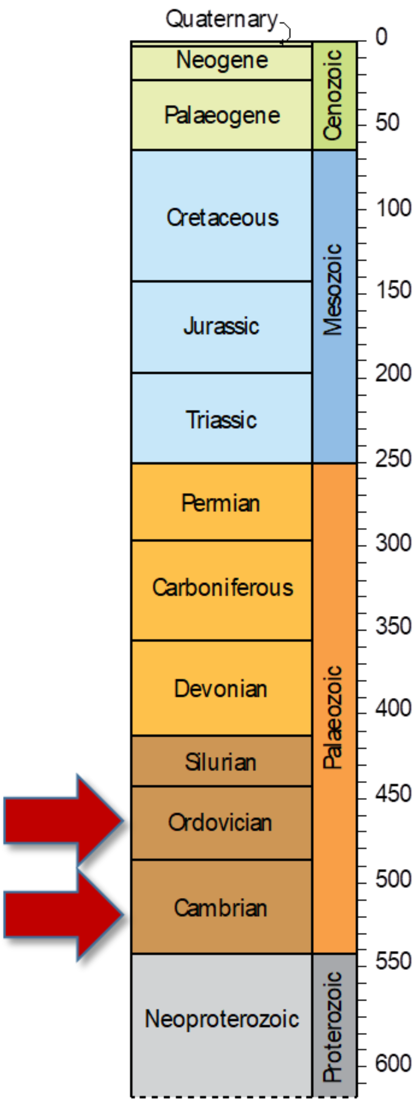
1.00pm: Lunch

2.00pm: Depart for Rhosneigr *(25 minute drive)*

2.30pm: At Rhosneigr

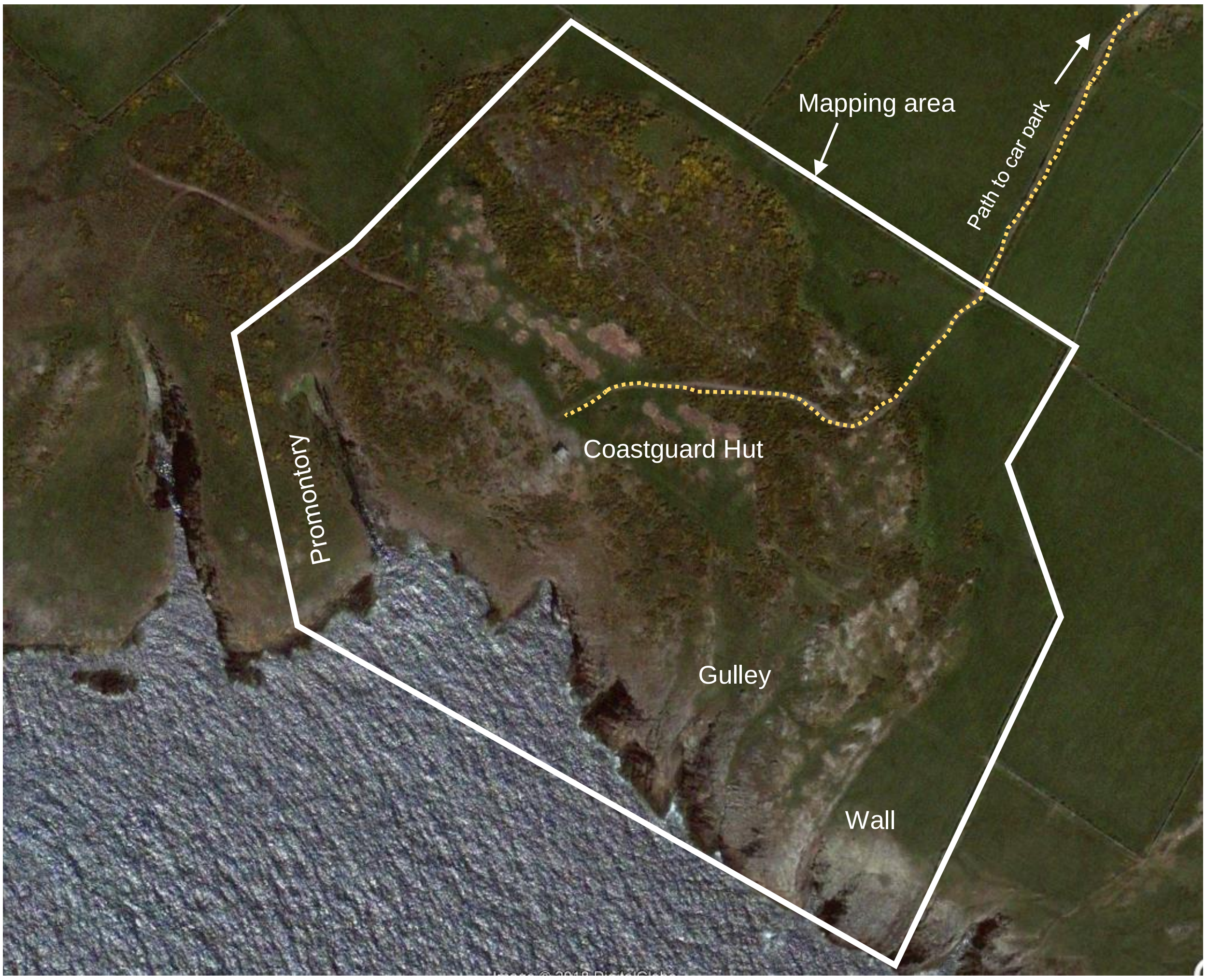
4.00pm: Depart for hostel

4.30pm: Arrive back at hostel



Timings are approximate; it is difficult to judge how long activities will take, and conditions (eg the weather) may change.

Rhoscolyn



Summary and context

This is our first visit to Rhoscolyn, we will be here again tomorrow to do a mapping exercise. The Rhoscolyn headland is ~300x400m in area. It consists of sheep grazed pasture, areas of gorse bushes and rocky outcrops. The area is best described as rolling hills with steeper drops along the coast.

Logistics:
Most vehicles will park at the Chapel or in a layby just down the road and we will walk to the localities along the track (about 10-15 minutes). The 4x4 will drive right up to the Coastguard Hut (Locality 1). There are no facilities here, but we are only a short drive to the hostel and will arrange a trip back there if needed.

The geology:
The area is made up of three Cambrian-age formations: the South Stack Formation, on the promontory and beneath the Coastguard Hut; the Holyhead Quartzite across the middle of the area; and the Rhoscolyn Formation on the southern side. These three formations are made up of similar lithologies, but in different proportions. The tectonic setting in which these sediments were deposited is disputed as to whether they were deposited in an accretionary prism representing continued subduction from the Neoproterozoic or whether they were deposited in a strike-slip setting post subduction.

Locality 1: The Coastguard Hut

The rocks here are part of the Holyhead Quartzite Formation. The outcrop on the landward side of the coastguard hut is a gentle slope. This has probably been sculpted by the movement of ice across it, however, it is a good approximation for bedding. The outcrops to the seaward side form a series of beds down the hill. The hill drops away quite quickly so be aware of where you are and do not go too far down.

Task 1:

- Do a brief description of the lithology.
- Take some readings: bedding readings, cleavage readings, B/C lineation readings (see appendix 1).
- Look at the bedding cleavage relationship:
    - What is the vergence (see appendix 1) of the cleavage with respect to bedding – if this is an axial planar cleavage, where are we on the fold?
    - If we are on a fold, use the cleavage reading to predict the orientation of the axial plane. Why might this be inaccurate (you might find it easier to answer this question once you have visited more of the localities).
    - Again, if we are on a fold, use the B/C lineation reading to predict the plunge of the fold.

Locality 2: "The Promontory"

The Promontory is accessed via a steep grassy slope and lies between to gullies. For those who cannot access it a relay system will be set up from the top of the hill. The rocks on the promontory and in the cliff face are from the South Stack Formation.

Task 2:

Sketch the view of the cliff from the promontory looking back towards the coastguard hut.
At first sight this looks very complex. Some of the beds have folded quartz veins within them, which draw the eye, but treat these as single beds. Don't worry about the detail too much here, we are interested in the overall picture. You may find it helpful to walk along the promontory so you can see all of the cliff. Pay particular attention to the beds and their dip direction.

Task 3:

Briefly describe the lithologies here, both in the cliff and in the rocks that lie along the coast. Obviously, it is not possible to examine the lithologies in the cliff close up, but what can be said about them from a distance?

Task 4:

There are a series of small scale folds along the coastal edge of the Promontory. Many are well exposed in three dimensions.

- Find a good example and do a sketch. What is the vergence of the folds?
- Take some readings – with such small scale folds measuring the hinge lines is often more useful than collecting lots of bedding readings. Cleavage readings are also useful. How do the readings compare with those at locality 1?

On the way to locality 3, we will visit the locality 1 again to look at the view back on to the promontory.

- What do you notice about the orientation of the folds down on the promontory relative to the cleavage here?

Locality 3: “The Gulley”
The Gulley is formed where a less resistant series of beds, within the Holyhead Quartzite, that have been weathered out. The top part of the gulley is safe to access; don’t clamber down too far as the cliff gets steeper. Again, a relay system will be set up for those unable to access this area.

Task 5:
Briefly describe the two main lithologies here and take some readings.

Task 6:
Look at the structural features:

- How many cleavages can you see here?
- Is there any pattern to the folded quartz veins – can you see vergence for example?
- Is there a relationship between the cleavages and the quartz veins?

Location 4: “The Wall”
As its name suggests this locality is dominated by a small cliff extending up the hill. Provided the ground is not too wet, this locality should be accessible. Between the cliff and the fence at the edge of the area is nearly continuous outcrop of the Rhoscolyn Formation.
Task 7:
Briefly describe the three main lithologies. There are more folded quartz veins here. How do they compare to the folded veins seen in at Locality 3? On the plateau near the wall are a series of folds. These are not easy to see and are best viewed looking back up the hill.

Task 8 (can be done back at hostel):
Summarise the different lithologies seen in the three different formations and consider the palaeoenvironments in which they were deposited.
Plan how you intend to go about mapping the area. What are the mappable units? A mappable unit is one that is large enough to be shown on a map – the Rhoscolyn field slip is 1:2,500 so 1cm=25m. Hint: It is possible to map some of the variations within the formations, so more than the three formation boundaries can be mapped. Think about the structures you have seen today and how they might look on a map. Have a look at the aerial photograph of the area for clues.

Rhosneigr

South of Rhoscolyn, Rhosneigr beach is home to large, low outcrops of Ordovician shales (and their interbedded sands).

Logistics: The main car park is a short walk from the beach. It should be possible to drive onto the beach, although only the southern outcrops will be reachable by car. Those to the north are in a no drive zone. The outcrops are mixed in quality, but essentially all show the same things. There is no need for everyone to visit every locality.

Regional linkage: The Ordovician black shales here are the same shales that have been mineralised at Parys Mountain. Here we get to see them without that overprint.

Task 1:

- Collect structural data to compare with data we have collected from elsewhere to see if we can determine information on the relative timing of deformation.

- Do a brief rock description, then collect measurements of fold hinge lines, cleavages, and bedding (this is limited to the larger fold limbs). The folds are not that easy to find. They are best observed looking down plunge, which in this case, is towards the northeast / east (towards the land). Some examples are given below. Note: In places, the cleavage is stained white with sea salt; this is not a lithological feature, but a product of the seater permeating the fractures, which then dries out to leave the salt behind.


Day 6: Saturday

8th September, 2018

Rhoscolyn

Deformed Cambrian metasediments in a series of exposures across the headland. Geological mapping of the folded Cambrian metasediments with the aim of producing a map and cross section of the area.

9.00am: Depart hostel

9.15am: At carpark

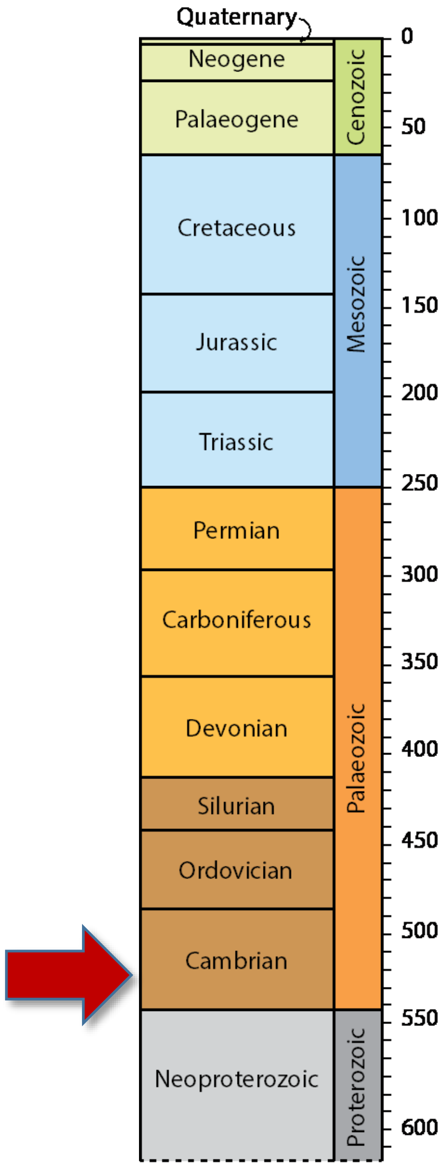
9.30am: At Rhoscolyn coastguard hut.

12.30-1.30pm: Lunch (flexible as at locality)

2.30pm: Leave field

2.45pm: depart for hostel

3.00pm: arrive back at hostel



Timings are approximate; it is difficult to judge how long activities will take, and conditions (eg the weather) may change.