Ordovician of the Lleyn peninsula

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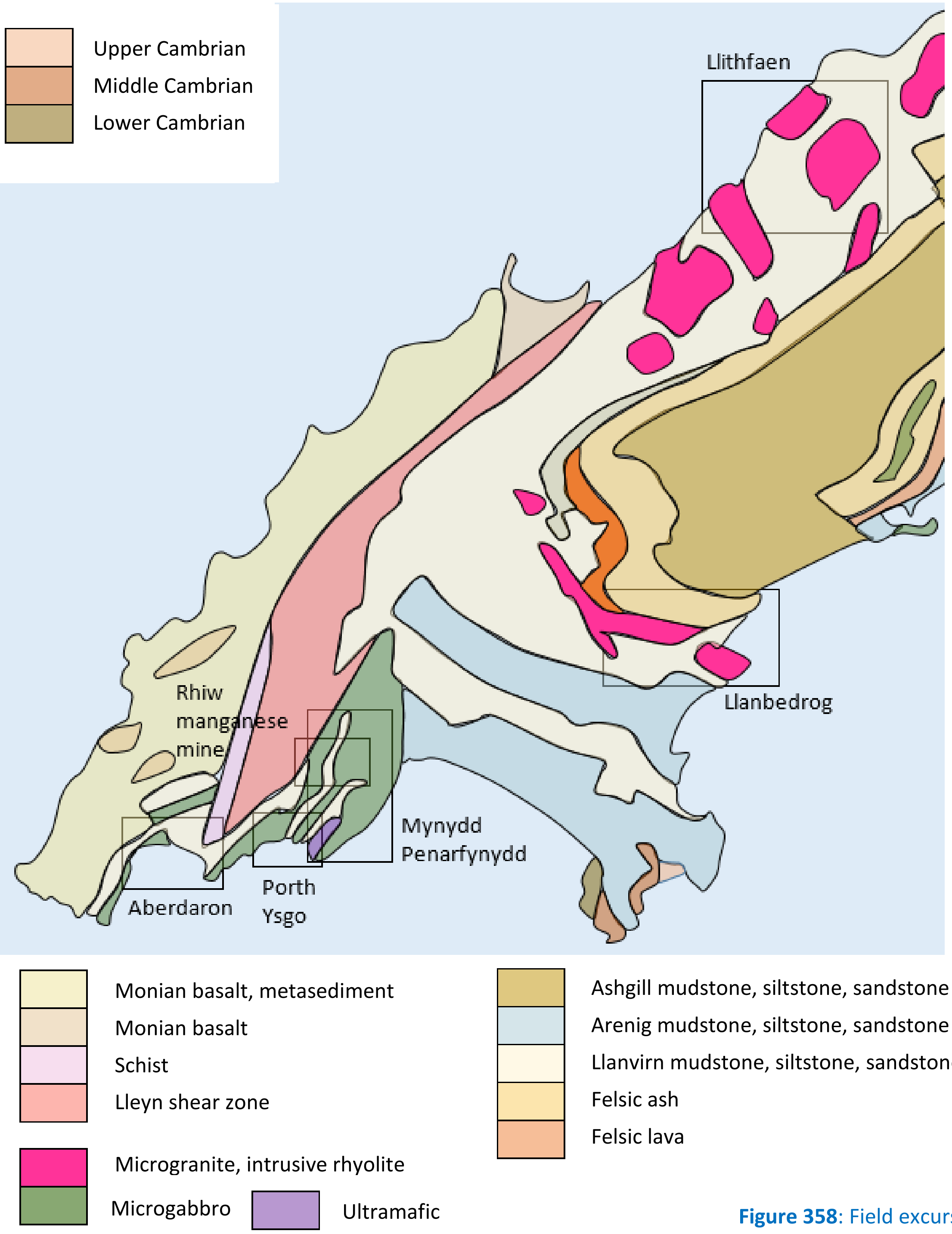
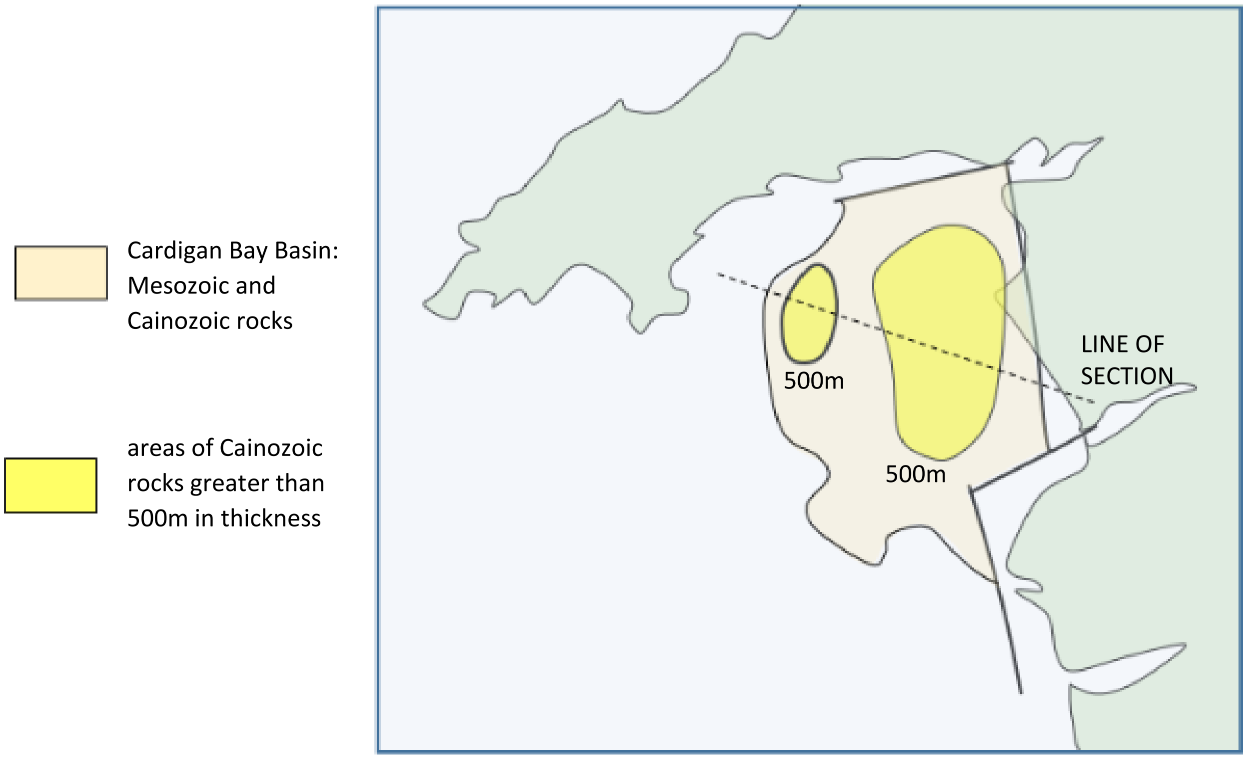


Figure 358: Field excursions.

In previous field excursions we have examined outcrops of Ordovician volcanic rocks around the Harlech Dome. However, volcanicity was widespread throughout the Welsh basin. In the current chapter we will be particularly investigating the Ordovician igneous rocks of the Lleyn peninsula.

We have discussed the importance of deep crustal fractures in controlling both sedimentary processes and the uprise of magmas. Although initially formed in Precambrian or Cambrian times, the major crustal fractures beneath Wales have remained as lines of weakness along which earth movements could take place. In the late 1960's, geologists began to suspect that a down faulted sedimentary basin might exist in Cardigan Bay containing much younger rocks than the surrounding coastal areas. An initial borehole was sunk at Mochras near Harlech, and this was followed by boreholes drilled offshore. A basin was indeed discovered, bordered by faults along which the underlying crustal basement was able to subside (fig.359).



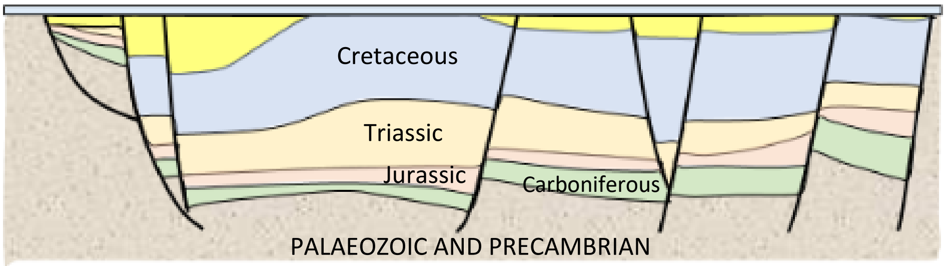


Figure 359: The Cardigan Bay Basin.

Combining evidence from onshore and offshore observations, we see that North Wales is underlain by two sets of deep basement fractures (fig.360):

- A set of fractures oriented approximately northeast to southwest, along which the fault motion has been mainly horizontal. These fractures separate blocks of crust which were successively pulled in the direction of central England as Avalonia broke away from Gondwana in Cambrian times. These fractures become more closely spaced towards the Menai Strait, as the margin of the Avalonian microcontinent was approached.
- A second set of major fractures have a roughly north-south orientation, and appear to have formed due to tension in the crustal slices during the pulling apart of Avalonia and Gondwana. These fractures exhibit mainly vertical fault movements.

As around the Harlech Dome, the locations of Ordovician volcanic centres in the Lleyn peninsula appear to have been strongly influenced by the deep fractures in the Precambrian basement which allowed the uprise of magma from the active subduction zone below.

We will begin our investigations by visiting the area of Trefor, where a series of large felsic intrusions occurs along the coast. This line of intrusions closely follows the orientation of the Menai fault system as it merges into the Lleyn shear zone at Nefyn. We move next to the area of Llanbedrog, where another series of felsic intrusions is found, this time associated with a north-south fracture zone. We finish our investigations in the area of Porth Neigwl, where large mafic intrusions occur at Mynydd Penarfynydd, again closely associated with a northeast-southwest transverse fracture.

An interesting aspect of the Lleyn intrusions is their grain size. At Cader Idris and Arenig we found very large felsic sills more than half a kilometre in thickness and several kilometres in lateral extent. These intrusions would undoubtedly have cooled slowly, at least in their central zones, but are uniformly of an extremely fine cryptocrystalline grain size. By contrast, all of the major intrusive bodies in the Lleyn peninsula have a larger grain size with individual quartz, feldspar and mafic minerals visible to the naked eye.

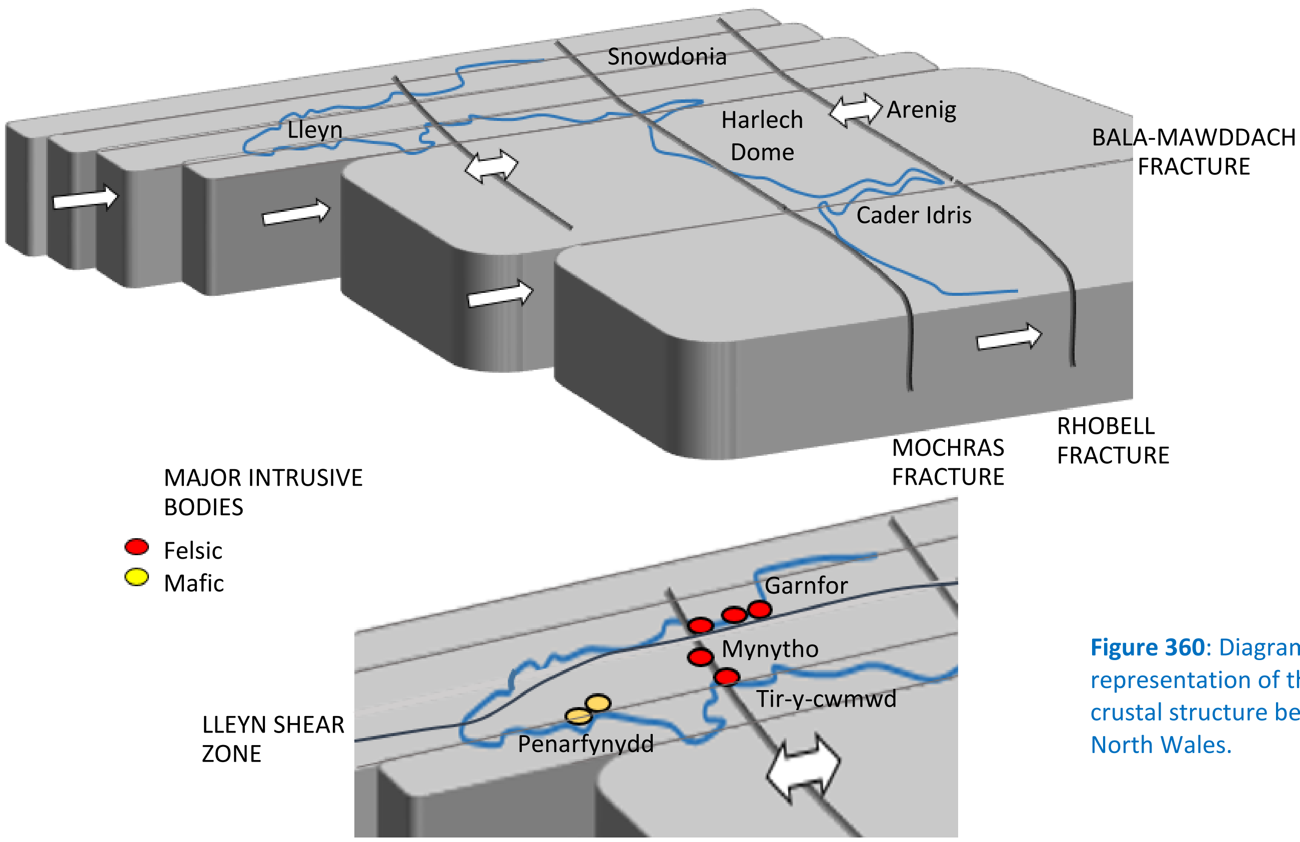
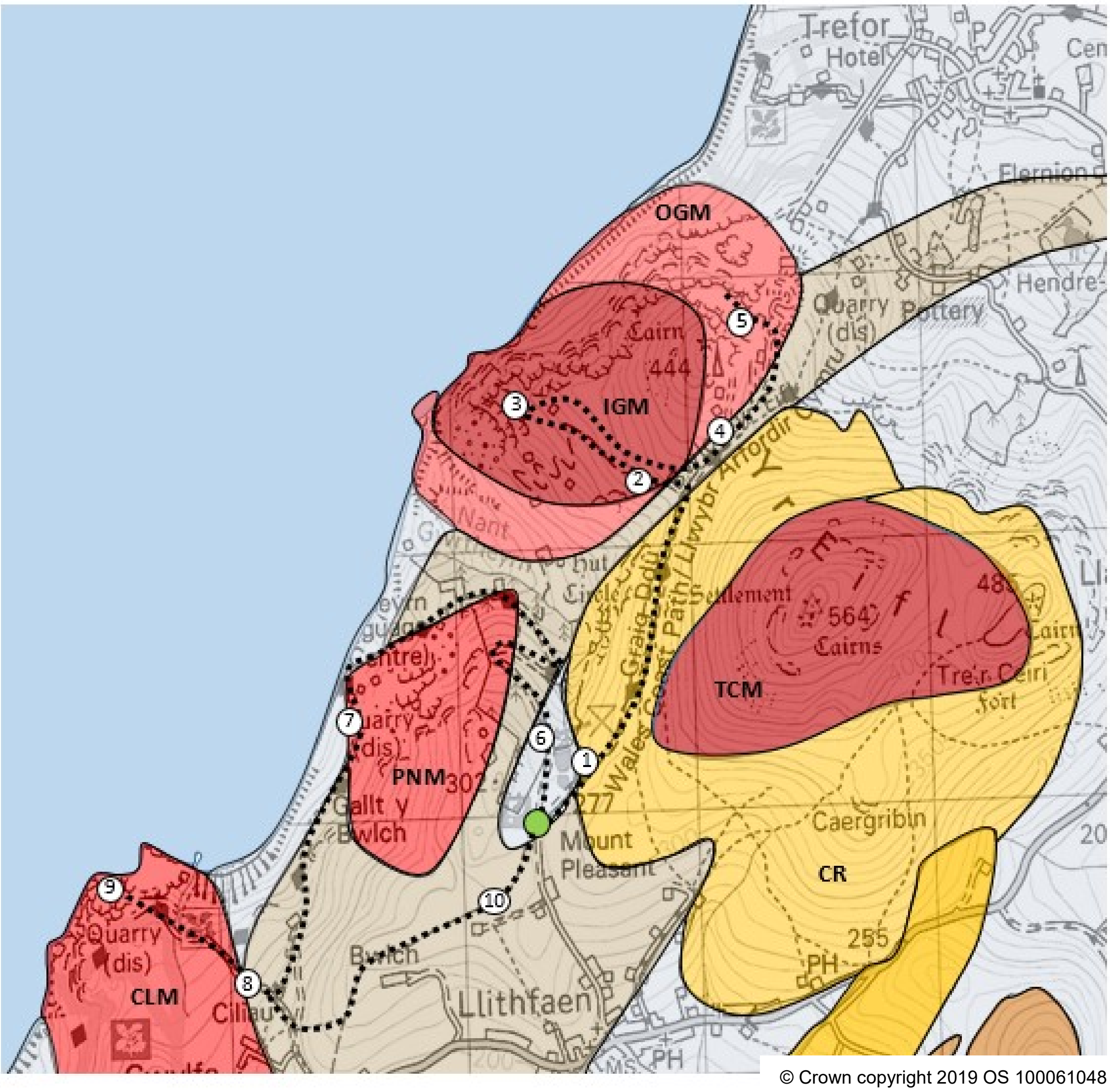


Figure 360: Diagrammatic representation of the crustal structure beneath North Wales.

An explanation for the difference in grain size may be the role of dissolved water in the melt, which is at least as important a factor as rate of cooling in controlling crystal growth. A larger proportion of dissolved water promotes the formation of larger crystals. The sills at Cader Idris and Arenig appear to have formed at very shallow depth beneath the seabed, allowing superheated steam to easily escape leaving a dry melt. The Lleyn intrusions may have formed at greater depth, where confining pressures could prevent loss of volatiles.

Trefor and Nant Gwrtheyrn

5 miles: approximately 2 hours



IGM	Inner Garnfor Microgranodiorite
OGM	Outer Garnfor Microgranodiorite
PNM	Porth Y Nant Microgranodiorite
CLM	Carreg-y-llam Microgranodiorite
CR	Caergribin Rhyolite
TCM	Tre'r Ceiri Microgranite
	Rhyolite
	Felsite
	Nant Ffrancon mudstone, siltstone
	Nant Ffrancon slate

Figure 361: Field excursion.

In this excursion we visit the series of large granitic intrusions along the coast around the villages of Trefor and Nant Gwrtheyrn. Whilst suggesting that these intrusions are associated with a northeast-southwest oriented deep crustal fracture, we have not yet considered their age. The intrusions were emplaced at approximately the same time, in mudstones which have been dated on fossil evidence as middle Ordovician. However, radiometric dating of the granites produces a mixture of widely separated late-Ordovician and Devonian ages. Geologists have variously suggested that the granites were emplaced during the Ordovician volcanic episode in Snowdonia, or alternatively during Devonian earth movements in the final stages of convergence of Avalonia with the Laurentian northern continent in the. No intrusions of definite Devonian age are found in North Wales, so an Ordovician origin is more likely.

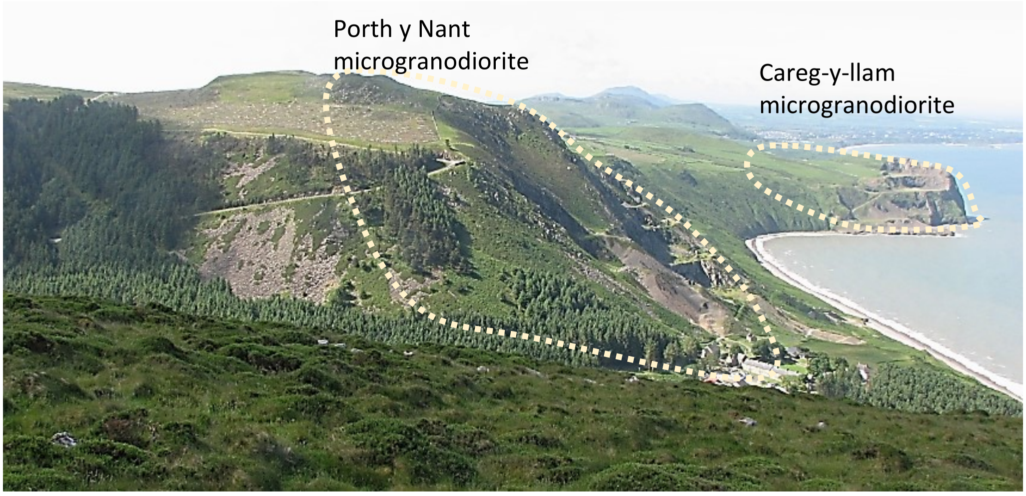


Figure 362: Micro-granodiorite intrusions at Nant Gwrtheyrn

We can explain the anomalous Devonian radiometric ages as the date at which the rocks were subject to metamorphism, and radiogenic daughter isotopes were lost from the rocks.

The quarries we will visit were first developed in the 19th century to produce 'setts', the small cubic blocks of granite which were used to pave roads in major towns and cities before the discovery and introduction of tarmacadam. The position of the quarries on the coast allowed rock to be transported away by sailing ship, and remains of piers and jetties still exist. In more recent years, crushed granite has been produced for use for road building and as concrete aggregate.

Start: From Llithfaen village, take the minor road towards Nant Gwrtheyrn. A large car parking area is provided before the road descends to Porth-y-nant [SH353441].

1: Take the track towards Bwlch yr Eifel. As the track ascends, we see a panorama of the quarried granite intrusions, stretching around the bay from the headland of Trwyn y Gorlech in the north, past the Porth y Nant intrusion, to Careg-y-llam in the south (fig.362).

Figure 363: Caergribin intrusive rhyolite.

The track passes outcrops of a pale-pink fine-grained felsic rock. This is the Caergribin intrusive rhyolite (fig.363), which forms the outer zone of a large intrusion centred on the peak of Yr Eifel. This outer zone shows evidence of flow foliation during forceful emplacement of the very viscous magma. The inner core of the intrusion can be examined by climbing to higher crags of the slopes of Yr Eifel, and is found to be a slightly coarser though still very fine grained microgranite.

2: Turn off the track through a gate and onto a footpath which leads around the hillside towards Trwyn y Gorlech.

In cuttings alongside the track, we find a medium-grey fine-grained microgranodiorite (fig.364). This lies in the inner zone of a large intrusion which forms the peak of Garnfor. We will be able to examine the outer zone of the Garnfor intrusion at Trefor quarry, where it is found to be lighter in colour, with a higher silica content.

It appears that the magmas which produced the inner and outer Garnfor intrusions were derived from the same parent melt in a deep crustal magma chamber. Over a period of time, the body of magma began to crystallise, with lighter quartz and feldspar crystals migrating upwards towards the top of the chamber, whilst denser mafic minerals such as pyroxene and amphibole sank towards the base. It appears that a quantity of the lighter felsic magma was able to migrate upwards through the crust first, to form the outer Garnfor rocks. This was followed by an injection of more mafic magma from lower in the chamber to produce the inner Garnfor intrusion.

Figure 364: (left) Trwyn y Gorlech quarry. (right) Inner Garnfor microgranodiorite.

3: Old quarry workings can be seen below the track, including an incline and large concrete storage bins for crushed granite. If time permits, you may like to examine these.

4: Return to the track leading to Bwlch yr Eifel. At the side of the track before the summit is reached, we pass a cutting exposing fragments of grey rock with rusty weathering on surfaces. Banding is present, but the rock is hard. The rocks were originally the mudstones into which the granitic intrusions were emplaced. Heat from the intrusions has baked the rock to produce **hornfels**, a process known as **contact metamorphism**.

5: Continue along the track, past the transmitter station, to the boundary of the Trefor quarry. Take the path to the left to reach an upper disused level of the quarry.

Figure 365: Outer Garnfor microgranodiorite.

The microgranodiorite rock exposed in the working face and loose blocks is a lighter and more silica rich variant forming the outer zone of the Garnfor intrusion (fig.365). The rock consists of visible crystals of plagioclase and biotite in a fine grained matrix of quartz, feldspar, hornblende and magnetite.

The outer Garnfor zone shows more evidence of late stage hydrothermal alteration than the inner zone. Some feldspar has been converted to sericite, and there is some alteration of mafic minerals to chlorite.

Figure 366: Rock face at Yr Eifl Granite Quarry illustrating the inland dip of the jointing. Photo by Eric Jones.

An interesting feature of the intrusion is the orientation of the main joints, which dip inland at an angle of about 45° (fig.366). It is possible that these joints were originally close to horizontal, forming parallel to the roof of the intrusion during cooling, but were then tilted into their current position by regional folding during the Devonian earth movements.

6: Return down the track to the car park, then take the road which descends to Nant Gwrtheyrn village. In the cutting just beyond the first hairpin bend, it is possible to identify the contact between the Porth y Nant microgranodiorite and the surrounding mudstones. Contact metamorphism has again converted the mudstone to hornfels.

7: Continue past the Nant Gwrtheyrn café to reach the coast path. The path descends past the remains of concrete storage bins for granite chippings, to reach the beach. The path then climbs again through ancient woodland to Gallt y Bwlch.

8: Follow the track to Ciliau, then the old road to the disused Carreg-y-llam quarry at Penrhyn Glas.

Figure 367: (left) Careg y llam quarry. (right) Careg y llam microgranodiorite.

9: Explore the old quarry and examine outcrops of the Carreg-y-llam microgranodiorite. The rock is of a more uniform fine grain than the Garnfor intrusives, but consists of similar minerals.

The variations in texture and chemistry of the different intrusions within the coastal group may represent a long period of evolution of a magma chamber at depth beneath the area during late Ordovician times, with periodic uprise of bodies of felsic magma to a high crustal level. There is no evidence that the magma actually reached the surface to produce rhyolitic eruptions. The lack any surface vents may have helped to maintain the dissolved water content of the melt, and promoted the formation of larger crystals.

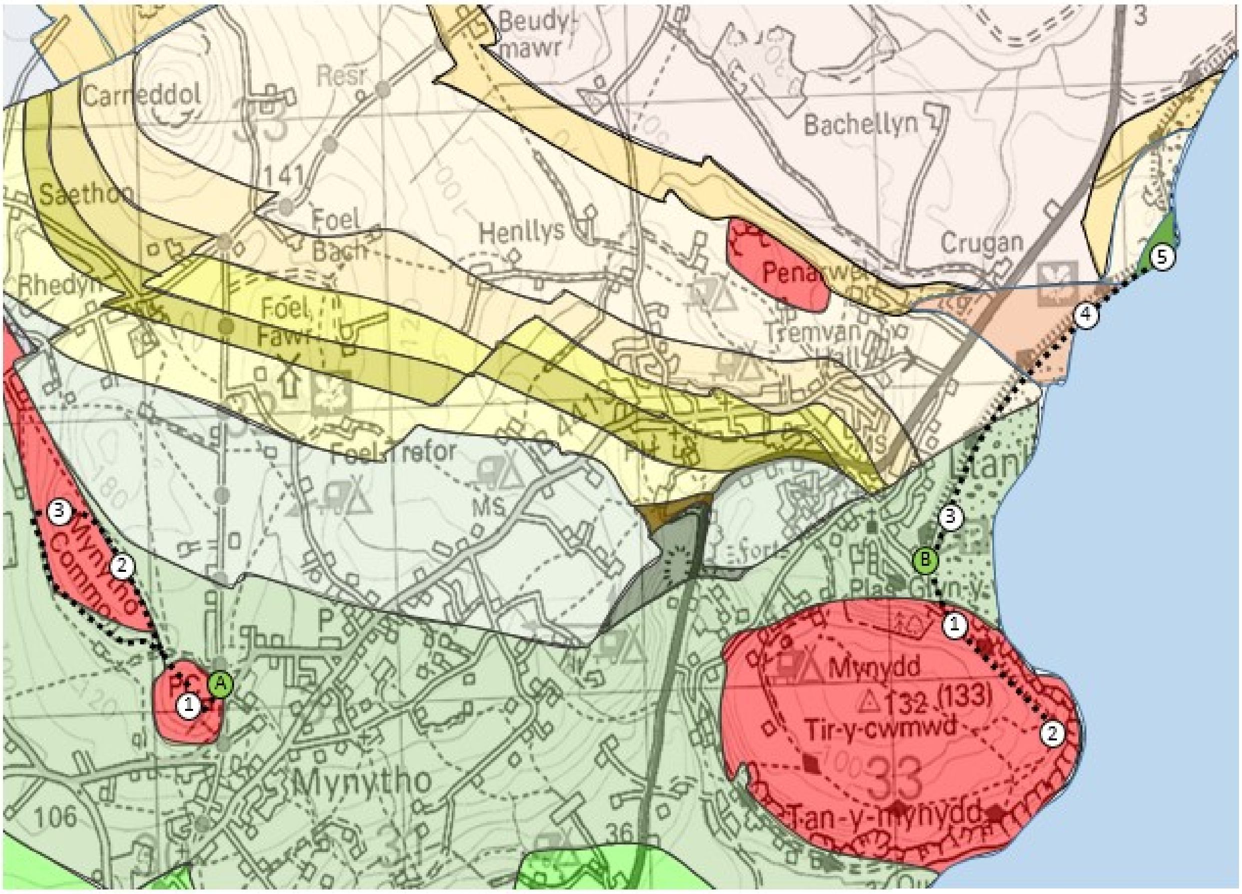
10: Return along the road to Ciliau, then take the footpath around the hill to reach the car parking area above Nant Gwrtheyrn.

Whilst crossing the fields near Bwlch, the path passes an outcrop of Nant Ffrancon mudstone, which represents unmetamorphosed country rock between the granitic intrusions (fig.368).

Figure 368: Nant Ffrancon mudstone.

Llanbedrog

Excursion A 1 mile: approximately 1 hour
Excursion B 2 miles: approximately 1½ hours



- Crugan mudstone
- Nod Glas mudstone
- Bodgadle rhyolitic ash
- Nant y Gledryd ash
- Foel Ddu rhyolitic Lava and ash
- Penmaen trachydacite ash and breccia
- Penmaen trachydacite lava
- Sill, dacite
- Nant Ffrancon mudstone
- Wig Bach sandstone, mudstone
- microgranite
- Dwyfach sandstone
- Penmaen andesitic ash
- Foel Ddu felsite

Figure 369: Field excursion.

In this set of excursions, we visit three areas: a series of felsic intrusions near the village of Mynytho; a large felsic intrusion at Llanbedrog; and outcrops at Carreg y Defaid. The rocks at Carreg y Defaid are most easily accessed at low tide, so the order in which the three areas are visited might be rearranged to allow this.

Start A: Following the road from Llanbedrog to Mynytho, a car parking area is reached in an old granite quarry at the base of Foel Gron [SH303310]. This isolated circular hill is formed by a dome-shaped intrusion of a pinkish-grey microgranite.

1: The microgranite can be examined in loose blocks in the quarry parking area, although the quarry working faces are now largely overgrown with vegetation.

A set of stone steps in the quarry leads to a footpath which ascends to the summit of Foel Gron. Loose blocks of microgranite at the summit illustrate its texture (fig.370).

Figure 370: Foel Gron microgranite.

2: Continue down the path on the northern side of Foel Gron to join a grassy track which follows a dry stone wall alongside the heather-covered Mynytho common. The track passes a large tor-like rock outcrop of white-weathering very fine grained microgranite (fig.371).

Figure 371: Microgranite outcrop alongside Mynytho common.

3: Leave the path at this point and make for rock outcrops visible in the heather moorland of Mynytho common, following the line of a series of electricity supply poles. From this view point, we can see the line of microgranite outcrops, stretching northwards to the peak of Carn Fadryn.

Compositional variations in the microgranite pick out a near-horizontal flow foliation which may represent convective overturning of the viscous magma within the magma chamber.

Figure 372: Microgranite outcrops on Mynytho common. Flow foliation in the microgranite is indicated.

Continue across the higher ground of Mynytho Common and descend past an old quarry to reach another grassy footpath. Follow the path back to the base of Foel Gron, then past the village school to reach the car parking area.

Start B: We begin by examining the Mynydd Tir-y-cwmwd microgranite which outcrops in the headland to the south of Llanbedrog bay. Park in the National Trust car park at Plas Glyn–y-weddw [SH330315].

Figure 373:

Mynydd Tir-y-cwmwd headland at Llanbedrog.

1: Enter through the main gate of Plas Glyn–y-weddw. Walk past the front of the mansion to reach a footpath which ascends through the woodland to the summit of the rocky headland.

2: The microgranite is exposed in outcrops alongside the path, and in a rock platform at the top of the headland. The microgranite contains phenocrysts of feldspar in a matrix of smaller feldspar, quartz and mica crystals. Some secondary alteration has converted mafic minerals to chlorite (fig.374).

The Mynydd Tir-y-cwmwd intrusion is a large circular boss. There is no indication that it broke the surface and formed an eruptive volcano. Indeed, the texture of visible crystals suggests cooling at depth under high confining pressure.

Figure 374: Mynydd Tir y cwmwd microgranite.

The intrusion occurs at the possible intersection of a northeast-southwest transverse fracture with a north-south tensional fracture in the deep crust.

This location might have facilitated the uprise of granitic melt.

3: Return to Plas Glyn-y-weddw, then take the road to the beach. Follow the beach northwards around the bay towards Carreg y Defaid.

Figure 375: Carreg y Defaid.

4: Examine the rock succession exposed in the cliffs at Carreg y Defaid.

Figure 376: Felsite, Carreg y Defaid.

The sequence of outcrops belongs to the Llanbedrog Volcanic Group, which is composed of felsic lavas and ashes, and a feeder vent from which these materials were erupted.

The first outcrops seen are of pink felsite, representing a dome shaped intrusion which broke the surface.

We next find a series of rhyolitic lavas. Nodular structures are present, and flow foliation can be found (fig.377). The rock structure in places is contorted and brecciated, suggesting that the very viscous rhyolitic lava was solidifying rapidly as it moved slowly away from the vent.

Approaching the point at Carreg y Defaid, we reach outcrops of an orange-weathering rhyolitic ash which shows evidence of welding. This material was deposited from ash flows erupted from a vent.

Figure 377: (above left) Felsite intrusion.

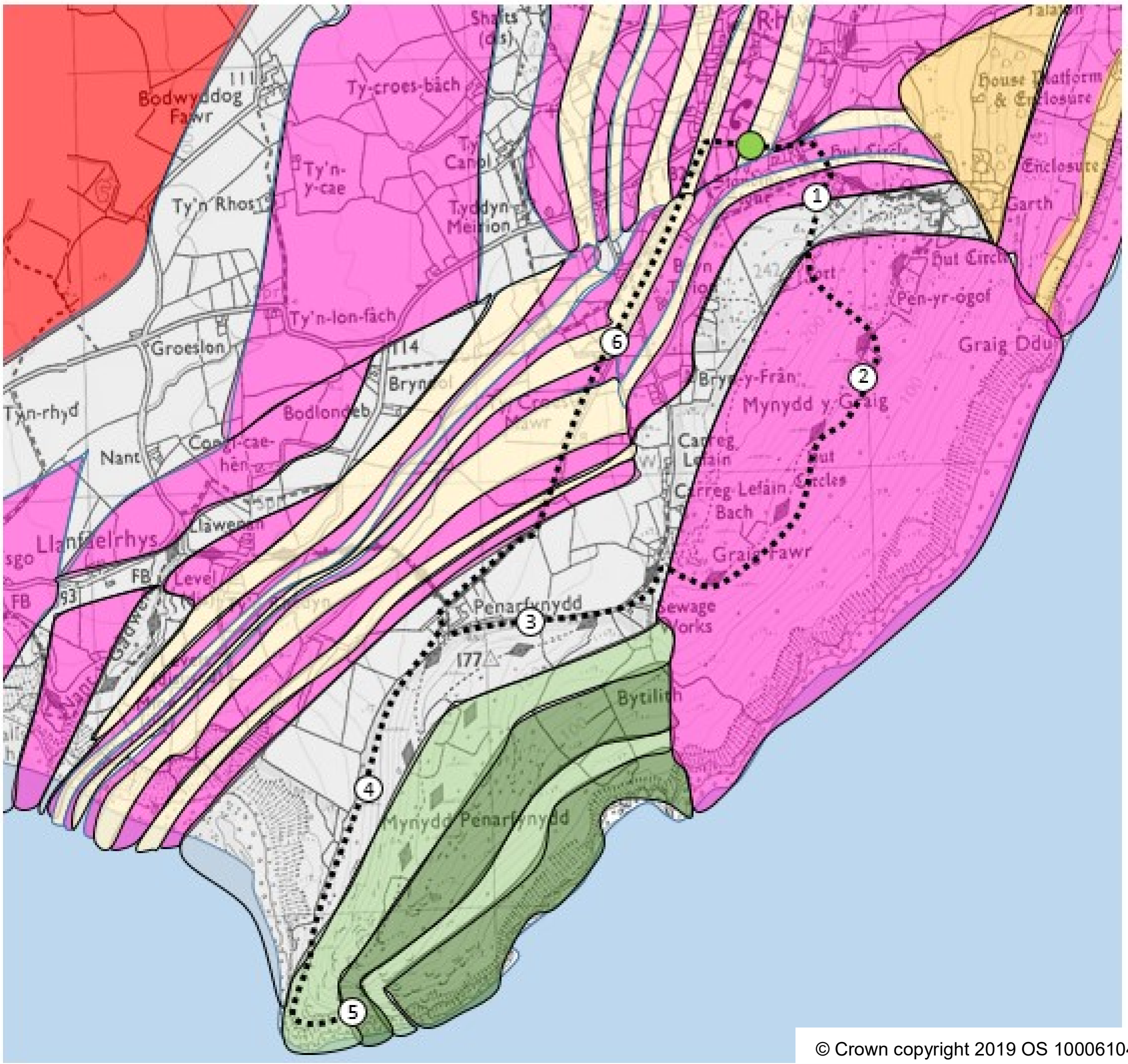
(above right) Rhyolitic lava showing flow foliation and a nodular structure.

(right) Rhyolitic ash with welding.

Return along the beach to the car park.

Mynydd Penarfynydd

5 miles: approximately 2 hours



Nant Ffrancon mudstone	Microgabbro
Trygarn sandstone	Picrite
Wig Bach sandstone, mudstone	Leucogabbro
Sarn Complex, igneous	

Figure 378: Field excursion.

In this excursion we will be examining rocks of the Rhiw igneous complex, which includes both sills and lavas. The volcanic rocks occur within a sequence of middle Ordovician sediments. In contrast to the igneous rocks of the Trefor and Llanbedrog areas, the Rhiw igneous complex is mafic in composition. We can conjecture that basaltic magma was able to rise rapidly along a northeast-southwest oriented deep crustal fracture. The flow of magma emplaced sills at a shallow depth beneath the sea floor, then erupted submarine basalts.

Start: From the crossroads in the middle of Rhiw village, follow the village street uphill to the north. Parking is possible on the road verge near the T-junction at the top of the village [SH226281].

1: Follow footpaths to the hill fort on the northern slope of Mynydd y Graig.

The scarp face below the hill fort is formed by a thick basaltic lava flow. This has a rough pillow structure in its lower part, with columnar jointing above.

Figure 379: Outcrop of basalt lava below Mynydd y Graig hill fort.

2: Continue towards the summit of Mynydd y Graig. Exposures of Ordovician mudstones are seen (fig.380). These rocks have experienced metamorphism due to heat from the surrounding igneous activity.

Figure 380: Ordovician mudstones exhibiting thermal metamorphism.

The broad summit of Mynydd y Graig is broken by ridges of hard igneous rock which run in a northeast-southwest strike direction. There has been some controversy as to whether these sheets are sills or thick lavas flows. It is probable that the coarsest of these microgabbros have been emplaced as sills.

3: Continue to the water treatment works, then follow the footpath which descends alongside a dry stone wall to Penarfynydd farm.

Figure 381: Microgabbro intrusion at Mynydd y Graig.

Figure 382: Detail of the Mynydd y Graig microgabbro.

4: On reaching the farm, walk southwards alongside a dry stone wall towards Mynydd Penarfynydd headland.

When the wall ends, continue along the sheep path at the same level to reach a flat grass area at the base of the headland above the sea cliff. Please be aware that the path from this point onwards is narrow and there is a steep drop to the sea. Care is needed.

The contact between Ordovician sediments and gabbro of the Penarfynydd intrusion is reached, which at this point is faulted (fig.383). The mudstone and siltstone beds have been heavily metamorphosed to hornfels by heat from the intrusion.

Figure 383: Intrusion contact at Mynydd Penarfynydd. The original bedding orientation in the hornfels is shown.

5: Continue along the sheep path around the headland to examine the Penarfynydd intrusion. The intrusion is a thick sill, with multiple layers of mafic and ultramafic composition. It is likely that a series of magmas were intruded over a period of time.

The first rock type we observe as we round the headland is an ultramafic picrite. This is dark grey to black in colour, containing a large percentage of olivine and hornblende amphibole but a low percentage of feldspar.

A variant of the picrite is a coarse grained rock which weathers with a curious honeycomb texture (fig.384). This is due to the different resistance to weathering of the feldspar crystals and the matrix of mafic minerals.

Figure 384: (left) Dark picrite outcropping at sea level at Mynydd Penarfynydd, with a honeycomb weathering variety seen on the hillside in the foreground. (right) Picrite, with feldspar crystals in a matrix of olivine and pyroxene minerals.

Continuing a short distance along the sheep path, we reach a cliff exposure of layered gabbro (fig.385). Multiple layers consist alternately of light feldspar-rich gabbro, and dark amphibole-rich rock.

Each layer pair may represent a separate inflow of magma from a nearby reservoir. It has been shown in recent petrology research that it is possible, under particular chemical and pressure/temperature conditions, for a basaltic melt to separate into two immiscible fractions. One fraction will be silica-rich and the other iron-rich. This mechanism is similar to the separation of a water-oil mixture. The two basaltic fractions can then crystallise to form a pair of contrasting layers of the type seen at Mynydd Penarfynydd.

It is possible, with care, to continue along the sheep path to examine further variants of gabbro which outcrop in the cliff face.

6: Return around the cliff path to Penarfynydd farm, then along the road to Rhiw.

Figure 385: Banded microgabbro in the Mynydd Penarfynydd intrusion.

Rhiw manganese mine

1 mile: approximately 1 hour

Figure 386: Field excursion.

The objective of this excursion is to visit the disused Benallt manganese mine, then to examine the thick basalt lava flow which forms the hill of Clip y Gylfinhir.

Start: As in the previous excursion, follow the main road to the crossroads in the middle of Rhiw village, then drive up the village street to the north. Parking is possible on the road verge near the T-junction at the top of the village [SH226281].

1: Take the minor road westwards, then the track to the manganese mine below Clip y Gylfinhir.

2: Examine the manganese opencast workings (fig.396). The manganese ore deposits occur within Ordovician shales. It is possible to deduce the irregular shapes of the ore bodies from the open pits which remain on the site. However, the Ordovician strata in this area were strongly folded and faulted during the Devonian earth movements, and it is possible that the ore body originally formed a more continuous layer within the sequence of shales and siltstones.

Figure 387: Opencast pits at Benallt manganese mine.

In previous chapters, we examined manganese deposits around the Harlech Dome. In that region, a sedimentary origin for the ore deposits seemed likely. A high concentration of manganese was dissolved in sea water, perhaps as a result of chemical weathering of basaltic rocks in the surrounding land areas. Manganese minerals, particularly carbonate, were then precipitated on the sea bed. In the Rhiw area of the Lleyn peninsula, however, the origin of the manganese ore is less certain. We may again have a sedimentary deposit from manganese-rich sea water. However, an alternative possibility is that the ore is hydrothermal in origin, and was deposited from hot manganese-rich fluids released from underlying basaltic intrusions. The hydrothermal fluids would have been channelled through particular soft unconsolidated mud layers below the sea bed, where manganese minerals could be precipitated.

3: Ascend the slope of Clip y Gylfinhir to reach outcrops of basalt lava. As at Mynydd y Graig, the lava flow has a rough pillow structure at the base, grading upwards into columnar basalt.

Figure 388: Clip y Gylfinhir.

4: Continue upwards to the top of the hill near the transmitter station. This upper zone of the basalt lava again shows a rough pillow structure. It is therefore likely that the lava flow was erupted from a sea floor vent and was of a huge volume. The upper and lower surfaces of the flow in contact with sea water developed a pillow structure, whilst the interior of the flow cooled more slowly to develop columnar jointing.

5: Return down the track from the transmitter station to Rhiw.

Porth Ysgo

1½ miles: approximately 2 hours

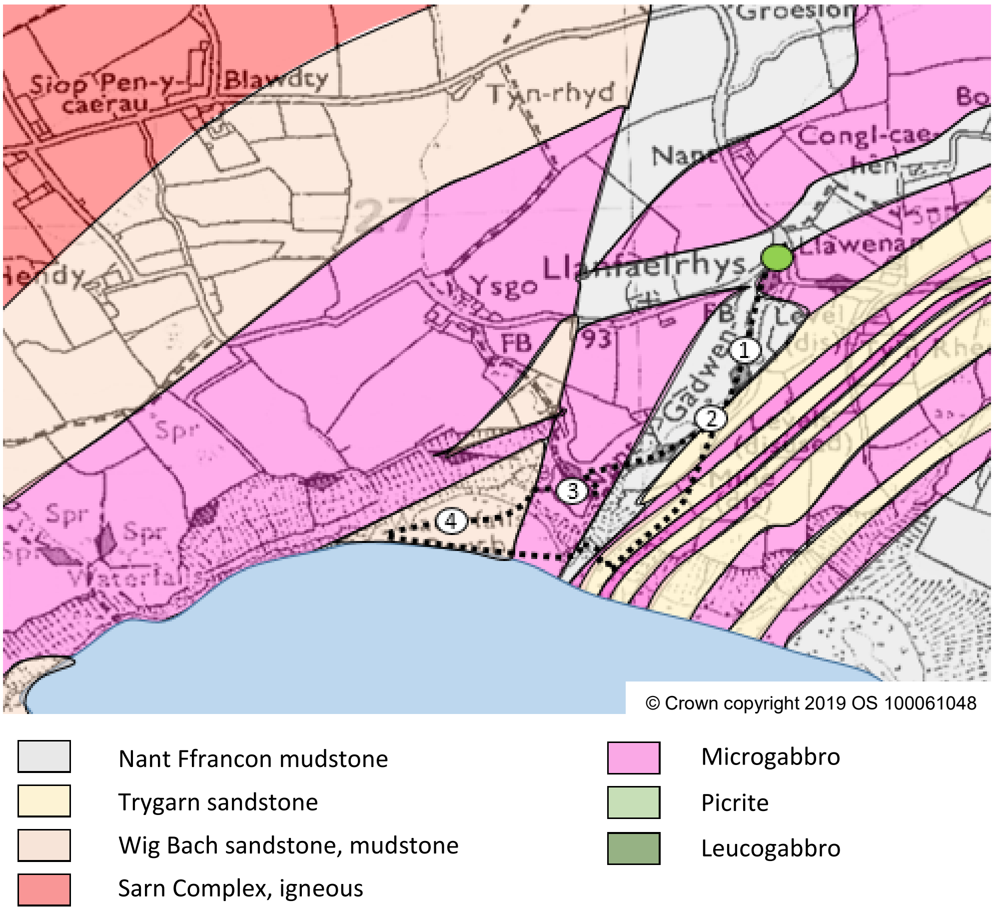


Figure 389: Field excursion.

In this excursion we will examine manganese workings in Nant y Gadwen, then descend to the beach at Porth Ysgo to examine microgabbro sills and Ordovician sediments.

Start: Parking space is available at the road junction near Llanfaelrhys, at the start of the footpath to Porth Ysgo [SH212269].

1: At the head of the valley a gate leads to a public footpath. Follow the path down the deeply incised valley.

Figure 390: Nant y Gadwen valley with manganese workings.

2: Examine the old manganese workings. Adit tunnels have been cut into the mudstones at the horizon where deposition of manganese carbonate minerals has taken place (fig.391). The manganese content of the rock varies, and the adits have been extended to reach rich pockets of ore. Shafts have also been sunk within the adits to reach lower layers of manganese-enriched mudstones.

As at Rhiw, the origin of the ore is uncertain. It may have a sedimentary source as a chemical precipitate, along with mud, onto the sea bed from sea water highly enriched in manganese. Alternatively, the manganese may have been emplaced by hot hydrothermal fluids released from underlying mafic intrusions, then channelled through permeable horizons within the Ordovician sedimentary succession.

The mines were active during the two world wars when mangnese was required for production of hardened steel for armaments. The ore was taken from the mines along a tramway to a gravity worked incline, where it was lowered to a jetty for loading onto ships.

Figure 391: Adit to manganese workings.

3: Follow the footpath down into the valley, then descend a long flight of wooden steps to the beach.

4: Cross to the cliffs at the western end of the beach. At this point, sandstones of the Wig Bach Formation overlie a large microgabbro intrusion (fig 392). The sandstones are bioturbated and contain trace fossils of worm burrows, indicative of deposition in shallow water near the shore.

The south-eastward regional dip of the strata indicates that the sill underlies the Penarfynydd gabbro intrusion, but they may share the same deep magma source.

5: Return along the beach to the rock promentary at the western mouth of the waterfall valley. This promentary is formed by another microgabbro sill, which shows rusty weathering and a structure of spherical nodules. The sill is underlain by mustones of the Nant Ffrancon formation, which are thermally metamorphosed to a band of hornfels along the contact.

6: Continue along the beach to the base of the old quarry incline. Ascend the old incline to reach the winding house on the clifftop, then return along the tramway path to the parking area.

Figure 392:

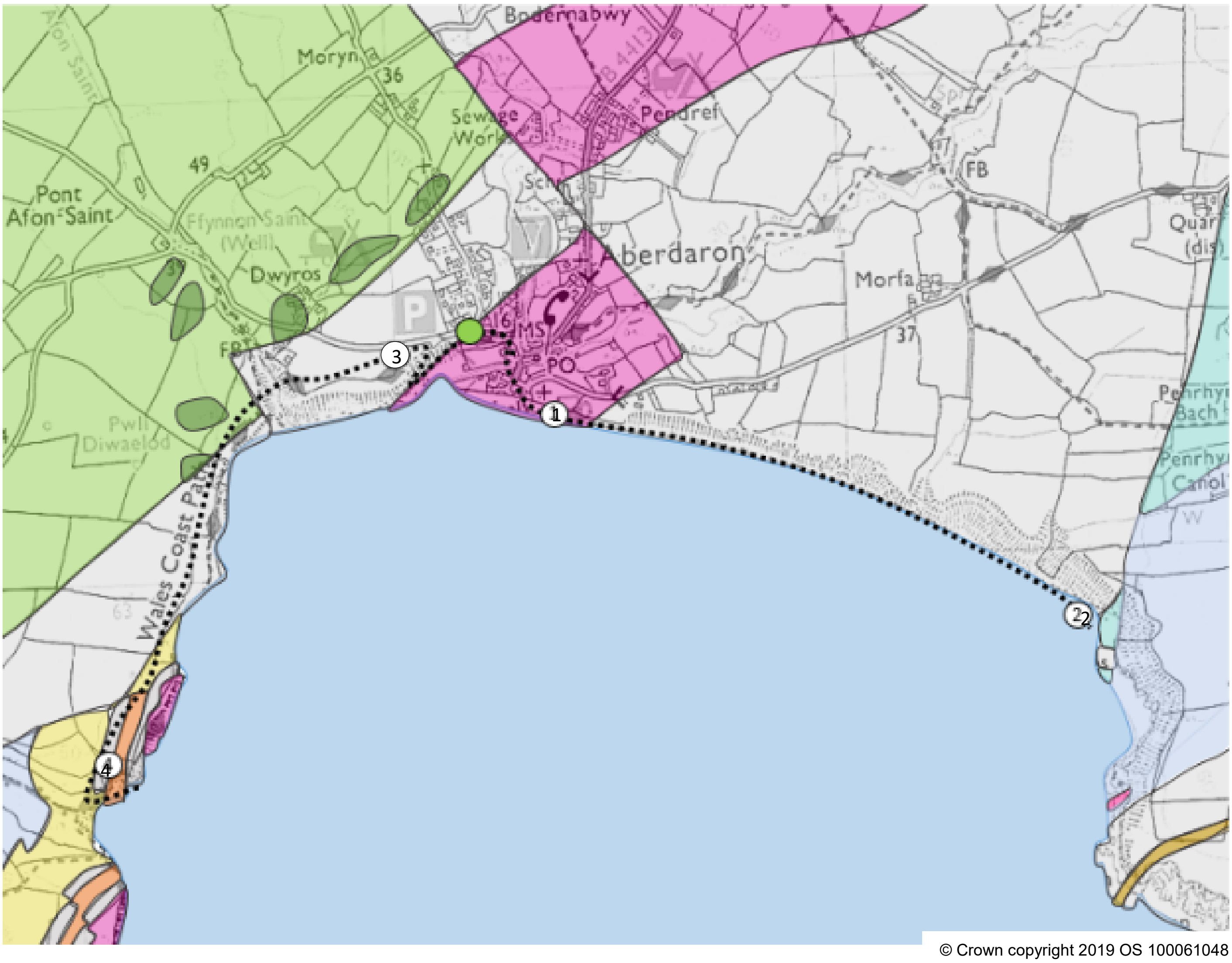
(above left) Bioturbated sandstones of the Wig Bach formation.

(above right) Microgabbro sill overlain by sandstones of the Wig Bach formation.

(below right) Microgabbro intrusion with nodular structure on the left, overlying Nant Ffrancon mudstones showing a lighter coloured zone of thermal metamorphism next to the intrusion contact.

Aberdaron

5 miles: approximately 2½ hours



- Nant Ffrancon mudstone
- Trwyn Cam sandstone
- Porth Meudwy sandstone, conglomerate
- Wig Bach mudstone
- Wig Bach sandstone
- Gwna mélange
- Gwna basalt
- Microgabbro
- Lleyn Shear Zone mylonite

Figure 393: Field excursion.

The objectives of this excursion are to examine the contact between Ordovician sediments and the Lleyn shear zone where this occurs in the cliffs in Aberdaron bay, and to study the turbidite sediments of the Porth Meudwy formation at their type locality of Porth Meudwy. Low tide is needed to reach the best exposures at each of these locations.

Start: A car park is available near the bridge in the centre of Aberdaron village [SH172264].

1: Walk eastwards along the beach to the rocky cliffs on the east of the bay. A faulted contact occurs between Ordovician mudstones and the first of two cliff sections where schists of the Lleyn shear zone are exposed.

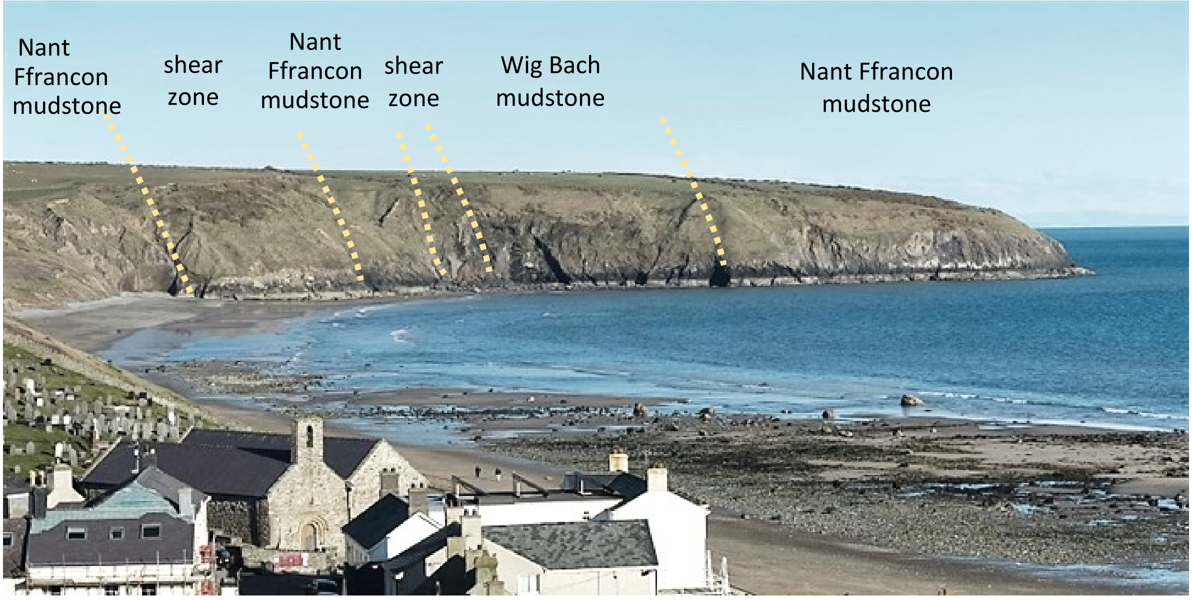


Figure 394: Aberdaron bay.

2: The Ordovician sediments at this point consist of mudstones and occasional siltstones of the Nant Ffrancon formation. The bedding of the sedimentary sequence is cut by the shear zone. Minor folding close to the contact may be the result of deformation during fault movent.

The fault zone separating the sediments from schists is filled by mylonite. This is rock which has been broken down mechanically during the transform faulting, and contains angular fragments of igneous and metamorphic materials in a matrix of clay and mica minerals (fig.395).

Continue around the headland to examine outcrops of schist unaffected by mechanical breakdown. These exhibit a sequence of foliated rocks with intense minor folding. Compositional variations are indicated by differences in colour between grey-green and red. It is likely that these

Figure 395:

(left) Bedded sequence of Ordovician mudstones and siltstones terminating at the shear zone.

(right) The mylonite layer separating sediments on the left from schist on the right of the photograph. A small fold terminates at the shear zone.

materials represent ocean plate stratigraphy and include basaltic ashes and deep water clays. The schists may have initially formed during the late-Precambrian subduction event which brought the Avalonian microcontinent to the coast of Gondwana, and were further deformed during transverse movement within the Menai Strait fracture zone.

Figure 396: Detail of schists in the Lleyn shear zone.

3: Return along the beach to the village, then follow the coast path westwards along the top of the cliffs to Porth Meudwy.

4: Descend the steps to the beach at Porth Meudwy, then walk back along the shore to examine rocks of the Meudwy formation outcropping in the cliffs and on the wave cut platform.

Although broken up by faulting, we can observe a sequence of sandstones and mudstones which have the characteristics of turbidite mid- to lower-fan deposits. The sandstones exhibit graded bedding of Bouma A units and parallel lamination of B units, typical of proximal deposition close to the sediment source. The mudstone layers represent D and E units, deposited in a more distal environment.

Rocks of the Meudwyn formation also outcrop in cliffs further south along the coast near the bay of Parwyd, where they are accessible only by boat. At this location, the sandstones have been found to include a slump deposit containing large angular blocks of igneous and metamorphic rock. This deposit may have been released from a shallow shelf near the shoreline, down a submarine slope into deeper water, perhaps as a result of earthquake activity.

Evidence from the sediments at Porth Ysgo and Porth Meudwy suggests that the end of the Lleyn peninsula lay close to a shoreline of the Welsh basin, at least during part of Ordovician times, with a landmass to the north or west.

Return along the cliff path, or along the road from Porth Meudwy to Aberdaron.

Figure 397:

Porth Meudwy:

(left) Thick turbidite sandstones outcropping in the cliff.

(right) Mudstone showing bioturbation.