The Mawddach estuary and Ardudwy 5

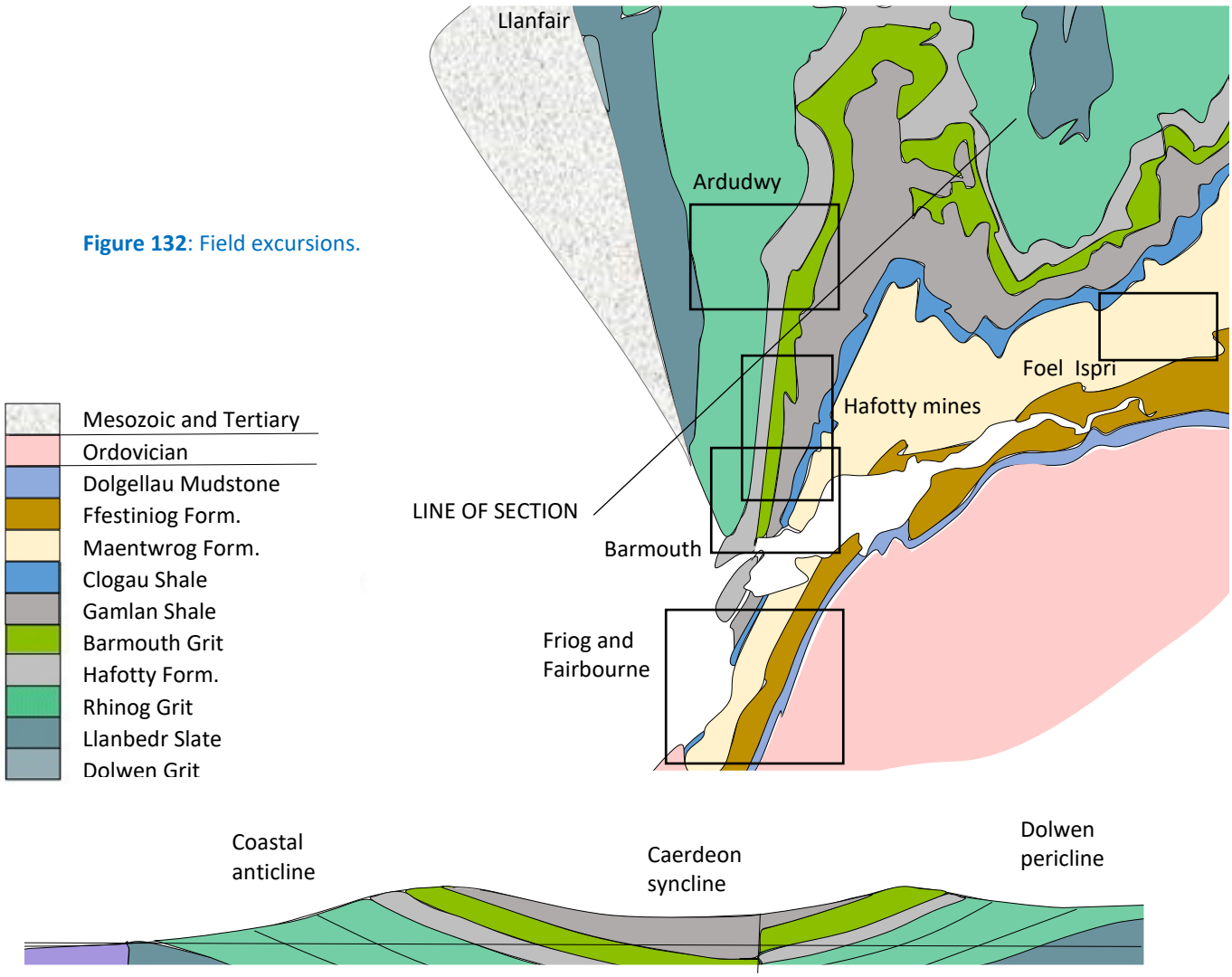


Figure 132: Field excursions.

The field excursions in this chapter continue our investigation of Cambrian sediments, looking at further outcrops of the ***Harlech Grits Group*** and also examining the overlying ***Mawddach Group***. Whilst the Harlech Grits Group is dominated by thick and resistant turbidite grits which form higher mountain areas, the Mawddach Group consists of softer mudstones, siltstones and thin sandstones which produce the lower hills and valleys around the Mawddach estuary and Coed y Brenin.

We begin by examining the Barmouth Grit formation on the Garn mountain headland above Barmouth. The Barmouth Grits appear similar in appearance and turbidite origin to the Rhinog Grits

Figure 133: Pebble filled channel in Barmouth Grit.

seen in the central Harlech Dome area. However, the Barmouth Grits are generally coarser, and channels infilled with pebble conglomerates are a prominent feature of many outcrops.

The pebble filled channels suggest that the grits were deposited in a proximal environment very close to the sediment source. The channels represent the branching distributaries in the upper turbidite fan.

Our fieldwork investigations have shown that the maximum pebble sizes and maximum widths of gravel filled channels in the Barmouth Grits vary around the Harlech Dome (fig.134). The largest pebble deposits and also the widest channels are found in outcrops close to the Mawddach estuary in the south, and in outcrops running northwards through Coed y Brenin.

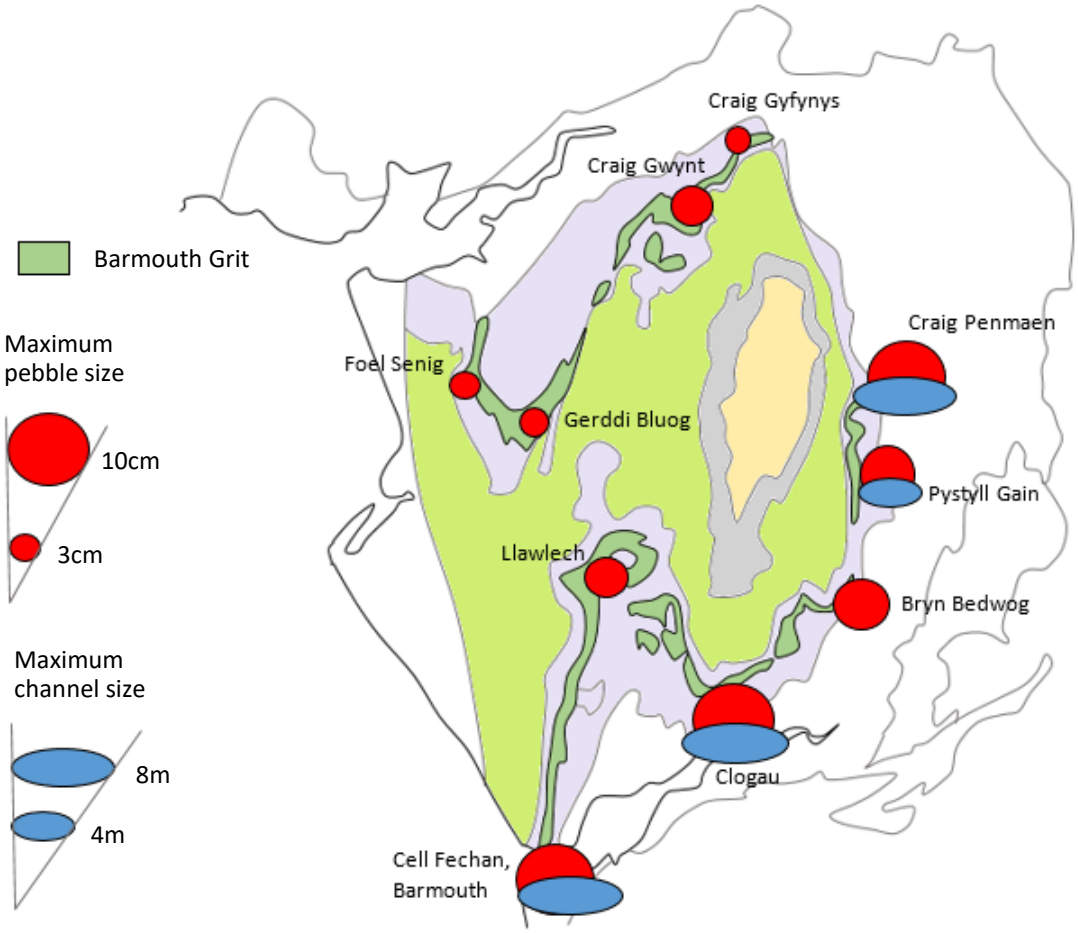


Figure 134: Pebble sizes and channel widths in the Barmouth Grit.

In the interior of the Cambrian outcrop area west of Trawsfynydd lake and in the Caerdeon and Traeth Bach synclines, the Barmouth Grits consist mainly of coarse to medium sands with only minor pebble inclusions at the base of fining up sequences.

During Cambrian times, Wales formed part of the Megumia marine basin bordered to the east by the Midland platform within the land mass of eastern Avalonia. Structures in the Barmouth Grits suggest that sediment was supplied predominantly from the direction of the Midland platform. After reaching a shallow shelf sea, mixtures of pebbles, sand and mud accumulated and intermittently discharged down a submarine slope onto the deeper seabed, perhaps triggered by earthquakes. The distribution of pebble sizes and channel widths in the Barmouth Grits suggest that submarine slopes lay roughly along the lines of the NE-SW Bala-Mawddach fracture zone and the N-S Rhobell-Corris fracture zone.

Following the deposition of the Barmouth Grits, occasional turbidite deposits still occurred in the overlying ***Gamlan Formation***, along with the quiet deposition of large thicknesses of mud and silt on the seabed. The Gamlan rocks are the uppermost strata of the Harlech Grits group.

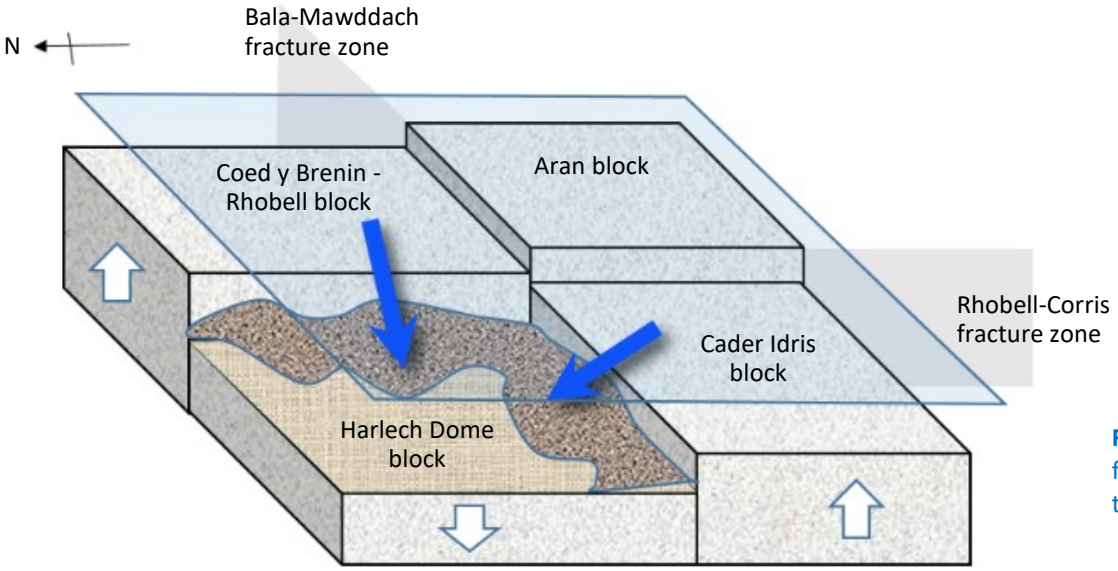


Figure 135: Model for deposition of the Barmouth Grits.

We now move upwards into the ***Mawddach group***. Mud deposition continued in the ***Clogau Formation***, with low oxygen levels on the seabed leading to carbon and iron sulphide being preserved in the sediments. As we will see later, the chemistry of the Clogau rocks has been important in determining the locations of gold deposits around the Harlech Dome.

After a brief period of shallow seas, the waters of the Welsh Basin deepened and turbidites were again deposited across the region. However, the source area appears to have changed to a southerly source in the area of the present-day Bristol Channel. Turbidite flows reaching north Wales had already lost most of their coarse debris, so only finer silts and muds were deposited in this **distal** environment. These rocks make up the ***Maentwrog Formation*.**

The Maentwrog Formation is overlain conformably by lighter coloured silty mudstones of the ***Ffestiniog formation***. Sedimentary structures such as tidal ripples indicate that deposition occurred in a shallow coastal or estuary environment.

The final deposits of the Mawddach group were the dark muds of the ***Cwmhesgen Formation*.** These strata begin with the carbon and pyrite rich ***Dolgellau mudstones*** and move upwards into the ***Dol-cyn-afon mudstones,*** where first traces of volcanic ash mark the commencement of the volcanic activity which affected the region throughout much of the Ordovician period.

Field excursions

In this sequence of field excursions, we have an opportunity to view rocks spanning much of the Cambrian succession from the Harlech Grits group at the base to the Mawddach group at the top. Dips are generally eastwards near the coast, in the eastern limb of the coastal anticline, changing to a westwards dip as we pass through the Caerdeon and Traeth Bach synclines and approach the Dolwen pericline in the central area of the Harlech Dome.

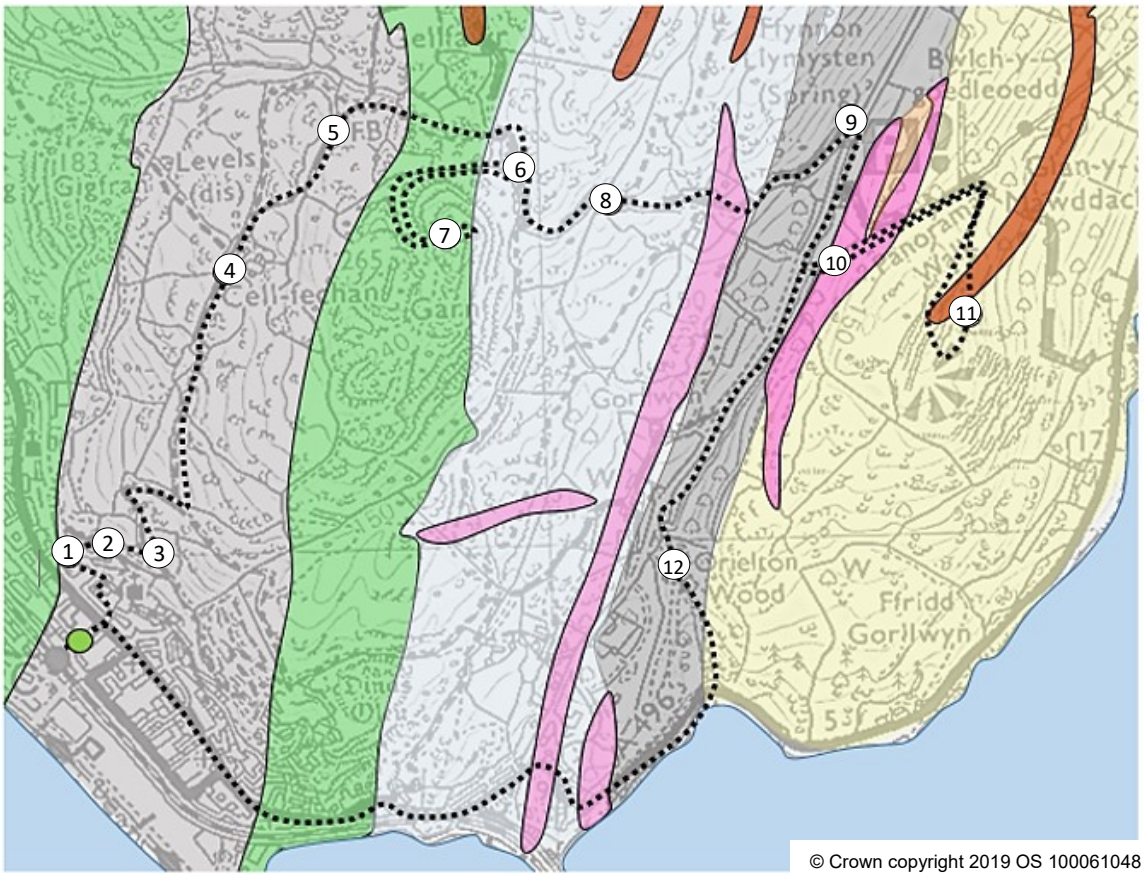
We begin at Barmouth with a transect upwards through the ***Hafotty*** manganese group and the proximal turbidites of the ***Barmouth Grits***, to reach the distal turbidites of the ***Maentwrog*** formation. Staying in the Barmouth area, our next excursion takes us to the historically important Hafotty manganese mines. Moving inland along the Mawddach estuary, we visit old gold mines around Foel Ispri in rocks of the ***Maentwrog*** formation.

Returning to the coast, we will examine outcrops of the ***Gamlan*** and ***Clogau*** formations in the cliffs of Friog, and visit the nearby slate quarries of Golauwern which worked beds of slate in the ***Dolgellau mudstones***.

Moving northwards along the coast to Ardudwy, we take a trip inland to view ***Barmouth Grit*** in the mountain outcrops at the head of the Ysgethin valley. We finish our fieldwork near Harlech where there is an opportunity to examine ***Llanbedr slates*** underground in the Llanfair slate caverns which are open as a visitor attraction.

Barmouth

3 miles: approximately 1½ hours



Maentwrog mudstone
Clogau mudstone
Gamlan mudstone, siltstone
Barmouth sandstone, mudstone
Hafotty mudstone
Rhinog sandstone, mudstone
Microgabbro
Microdiorite

Figure 136: Field excursion.

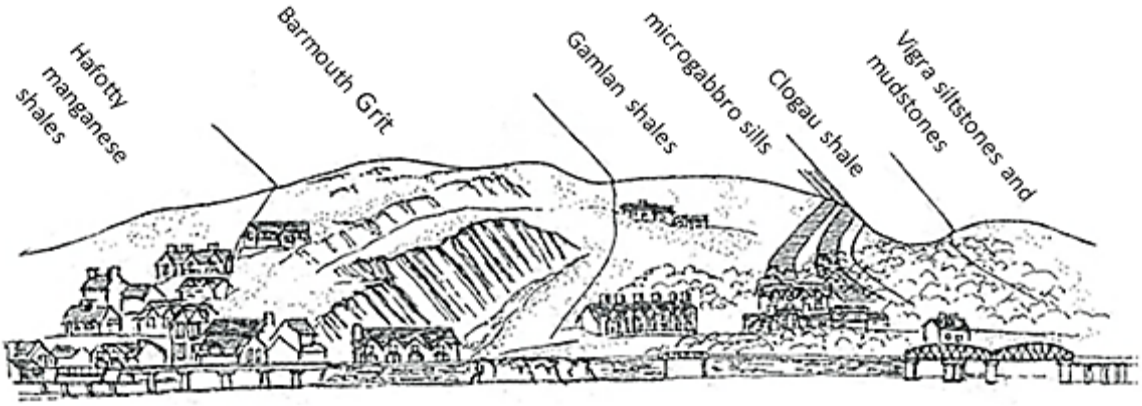


Figure 137: Sequence of outcrops of Cambrian strata above Barmouth.

Start: parking is readily available in Barmouth in car parks or along the promenade.

1: Follow the narrow road uphill next to the church until an outcrop of Rhinog Grit is reached. Branch to the right along a footpath.

2: The footpath passes onto the Hafotty Formation, and old manganese workings are reached.

The manganese ore bed lies about 10 metres above the base of the Hafotty formation, separated from Rhinog Grit by mudstones (fig.139). An adit tunnel (fig.138) marks the position of the ore-bed underlying a thin turbidite known as the ***bluestone grit***. The ore-bed is thinly banded, and often stained purplish brown from the weathering of the manganese minerals. It consists mainly of the red manganese silicate spessartine, the cream manganese carbonate rhodochrosite, and black manganese oxide pyrolusite.

It is thought that the ore formed as a chemical precipitate of manganese carbonate on the sea bed of a shallow marine basin; it was then partially oxidised, and partially converted to manganese silicate during metamorphism. The source of the manganese is likely to be chemical weathering of a landmass composed of mafic igneous rocks such as basalt or gabbro, or metamorphic schists or gneisses derived from these materials.

Figure 138: Managanese workings, Barmouth.

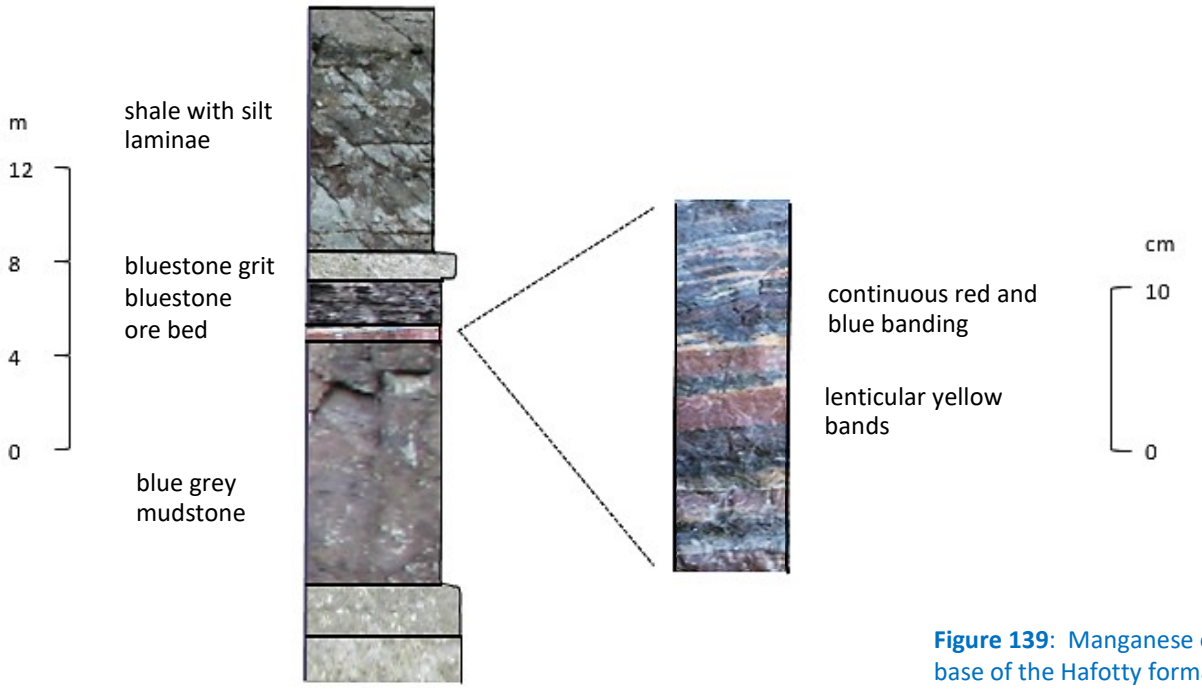


Figure 139: Manganese ore bed at the base of the Hafotty formation.

3: Continue past the mine adits and go through the gate to reach a path which leads uphill to the left past outcrops of Manganese shales. Continue up the path to the ruins of Cell Fechan farm.

The Hafotty mudstones show laminations, and ripple marks can be found on some bedding planes. Occasional turbidite grits with graded bedding are present, but it seems that most deposition occurred in a quiet, relatively shallow

marine basin. The considerable thickness of the formation suggests that subsidence of the fault blocks underlying the north Wales area was keeping pace with deposition. Sequences equivalent to the Hafotty formation in south Wales and the Welsh borders are much thinner and may have been deposited along the coasts of the marine basin.

Figure 140: Manganese shales at Cell Fechan.

5: Continue along the footpath as it skirts around the mountain of Y Garn until the road is reached.

6: Follow the road in the direction of the estuary and coast. After a short distance, turn through a gap in the dry stone wall and follow the path back around the base of Y Garn.

7: Leave the path and climb a small valley to examine outcrops of Barmouth Grit in the terraces of Y Garn.

Figure 141: Turbidite grits and conglomerates, Garn.

The rock outcrops spectacularly display a sequence of proximal turbidites, dominated by Bouma graded grit A units and parallel laminated sandstone B units. Cross bedded sandstone D units and finer silts and muds are sometimes present.

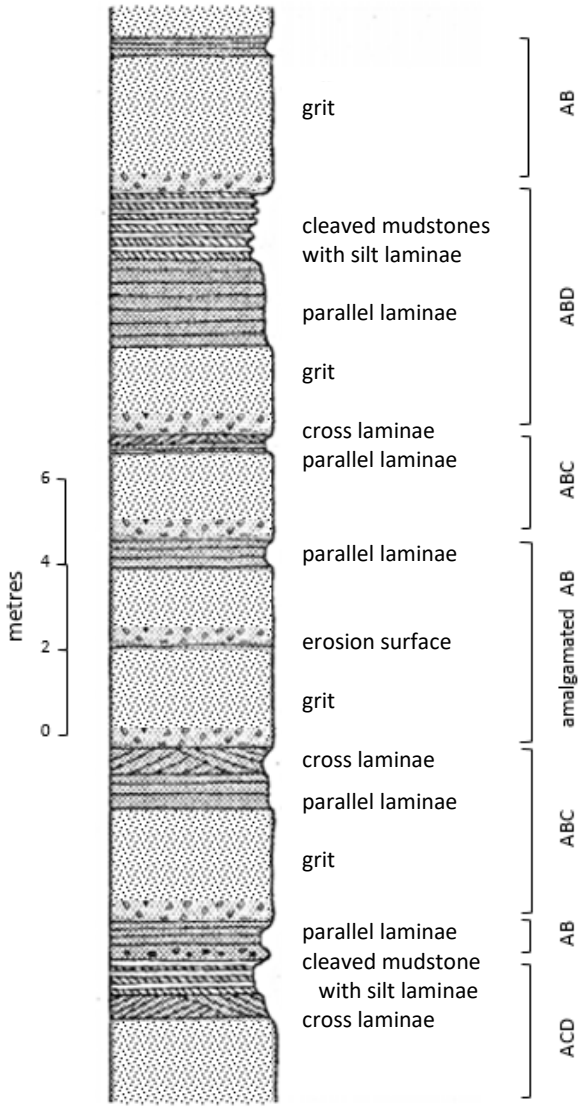


Figure 142: Turbidite sequences in the Barmouth Grits.

Amalgamated units occur where one turbidite flow has rapidly followed the previous flow, allowing no opportunity for the deposition of laminated or cross-bedded sands under lower energy conditions in the wake of the flow.

A particular feature of the Barmouth Grits is the presence of large distributary channels infilled with quartz pebble conglomerates (fig.141).

The turbidity cloud will have had a much higher density than sea water, so kept close to the sea bed as it moved out across the fan complex on the basin floor. Gravel filled turbidite channels in submarine fans exhibit similar features to the gravel streams seen in mountain areas on land, including: meanders, braiding, imbricate structures in which pebbles are deposited at a sloping angle as they accumulate against one another, and finer over-bank deposits extending beyond the channels.

8: Return along the path to the road, then descend past a prominent bedding plane which forms the face of Y Garn, and is a popular location for climbers to practice abseiling. Continue to a gate across the road. Here, the Gamlan formation is reached. Examine the shales in a small valley to the left of the road.

The Gamlan Formation consists of thinly bedded siltstones, mudstones and fine grained sandstones. Parallel lamination and cross-bedding can be present.

Figure 143: Gamlan mudstones showing tectonic rippling, Garn.

Prominent ripples on the bedding surfaces are not original sedimentary features, but have a later tectonic origin due to the intersection of the cleavage with the bedding. In the few locations around the Harlech Dome where sedimentary structures are found, the source of the sediment seems to have been from the south.

9: Continue down to the road junction at Ffynnon Llymysten, where Clogau Shales outcrop. The rocks are dark grey to black carbon-rich silty mudstones.

10: Follow the road downhill for a short distance to reach the gate at the start of the Panorama Walk footpath. Follow the footpath as it crosses a small valley and enters woodland.

11: Take the footpath to the Panorama Walk viewpoint.

Rocks exposed in cliffs alongside the path belong to the Vigra member of the Maentwrog Formation. These rocks are thin laminated siltstones and mudstone, and have a distal turbidite origin. The source of the turbidite flows is thought to be far to the south in the area of the present day Bristol Channel.

Figure 144: (above) Vigra distal turbidites, Panorama Walk. (below) Slump structure illustrating soft sediment deformation.

12: Return to the road and descend towards Barmouth, taking the footpath down through Orielton Wood.

Hafotty mines

5 miles: approximately 2 hours

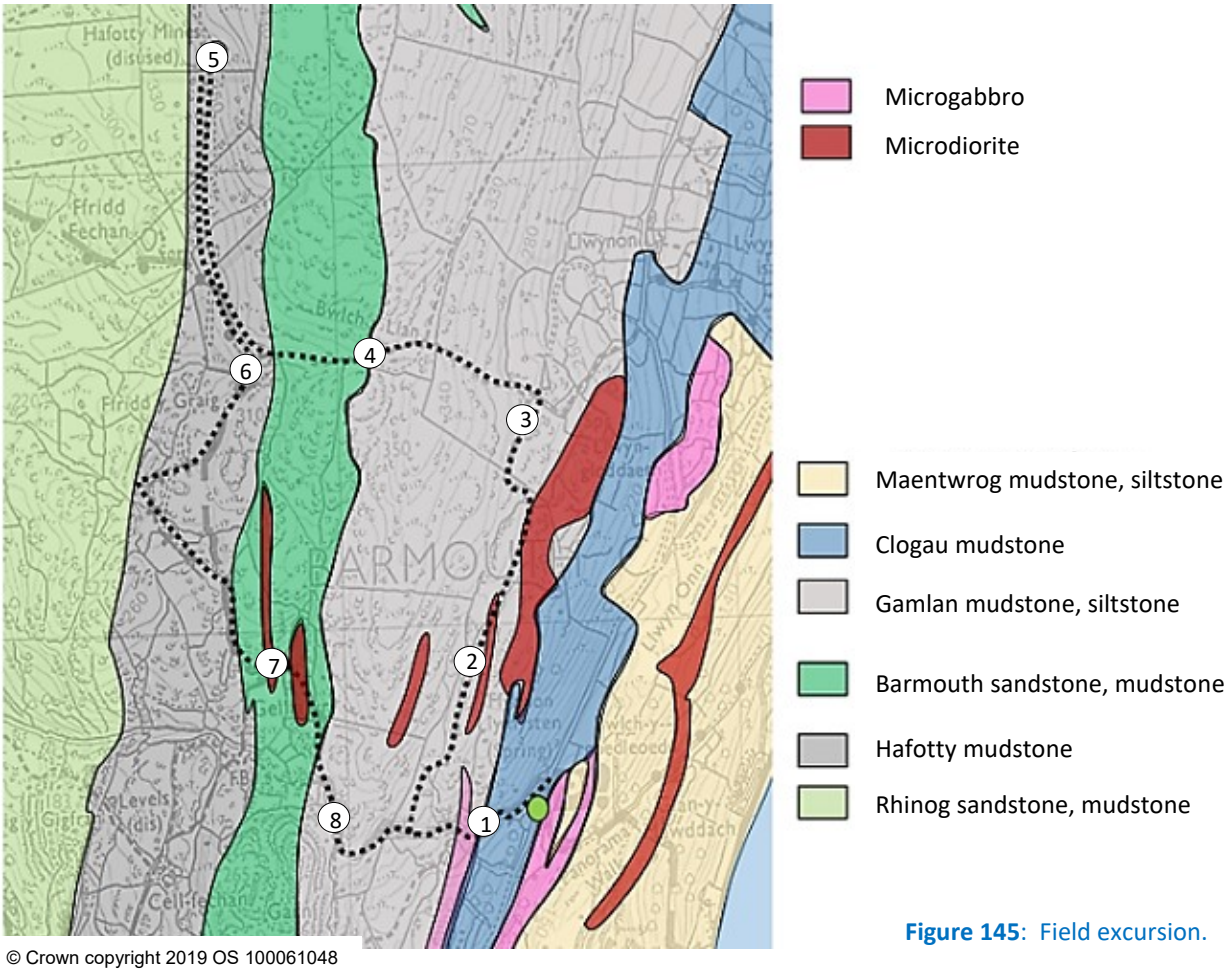


Figure 145: Field excursion.

Start: Use the parking area near the start of the Panorama Walk path above Barmouth [SH625166].

1: Follow the road uphill towards Y Garn, taking a footpath to the right before the gate across the road.

2: Continue along the footpath along the hillside until the telecommunications mast comes into view.

From this point, we have a panoramic view across the Caerdeon syncline. This downfold, lying **en-echelon** with the Traeth Bach syncline to the north, occurs between the western limb of the Dolwen pericline and the coastal anticline at Barmouth. All of these structures were produced in the Acadian orogeny during the Devonian period. Compression occurred as a result of east-west shortening in the Welsh basin, affecting sedimentary rocks to a depth of several kilometres. Shortening took place as fault blocks in the Precambrian basement slid past one another, accompanied by vertical uplift of the crustal block beneath the central Harlech Dome.

The Caerdeon syncline plunges southwards, exposing progressively younger strata towards the Mawddach estuary. The oldest rocks form the edge of the syncline, with resistant Barmouth Grit outcropping on the high mountain ridge of Llawlech. Within this ring, softer siltstones and mudstones of the Gamlan and Clogau formations have been eroded into valleys. However, the resistant turbidites of the Vigra member of the Maentwrog formation create a higher hill in the central area of the syncline. Finally, softer Penrhos shales form the slopes leading down to the shores of the Mawddach estuary.

3: Continue along the track, climbing to a gap in the hill line above the telecommunications tower. At this point, pass through a gate in a dry stone wall and follow the path which descends along a valley towards the Hafotty manganese mines.

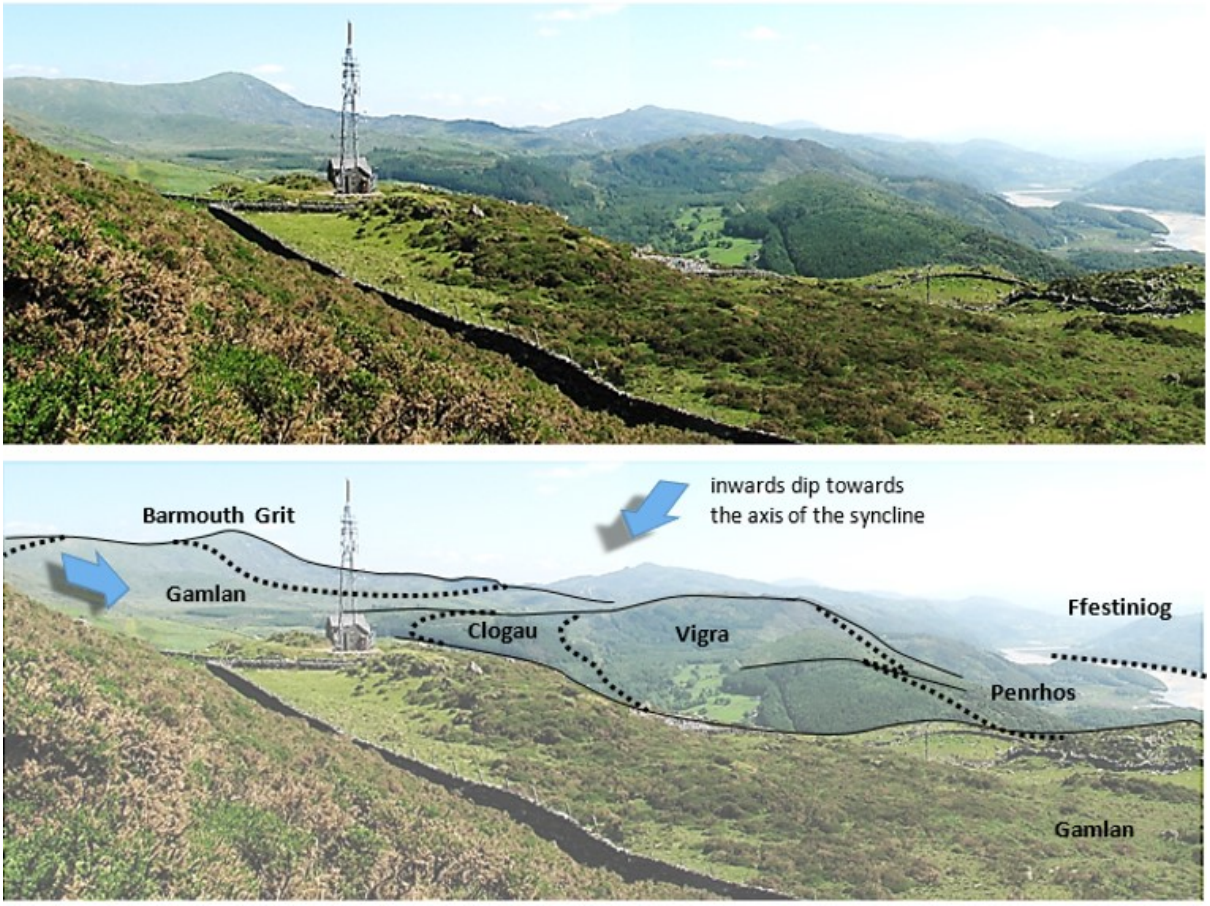


Figure 146: The Caerdeon syncline

4: The manganese mines come into sight as a long earthwork ditch, following the outcrop of the manganese ore bed northwards along the hillside.

5: Follow the path as it curves around the hillside to the right. Pass a fenced-off mine area, then continue along the line of the trench workings to reach a series of mine excavations at the head of the valley.

Blocks of manganese ore have been used in the construction of the dry stone wall around the workings – please do not remove these! The ore shows the familiar thin lenses of light coloured manganese carbonate and dark oxide and silicate.

Hafotty was the largest of the manganese mines in the Harlech Dome area, operating between about 1885 and 1924. A narrow gauge tramway and an incline were constructed to facilitate the movement of ore to a collection point, where it was loaded into horse-drawn carts for carriage to the railway station in Barmouth.

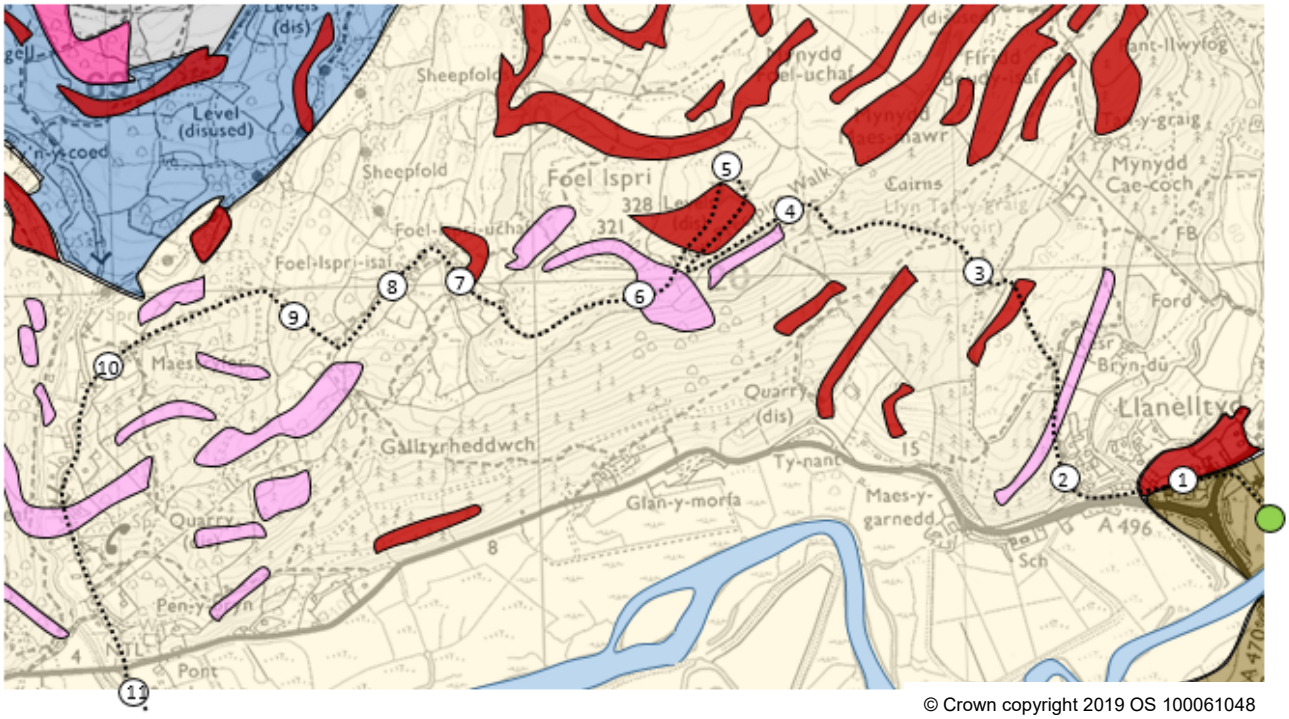
The narrow ore bed dips eastwards at about 60°. It was extracted by cutting into the hillside along a sloping excavation with the overlying soft shales supported in places by timber props. As the workings moved northwards along the outcrop, it seems that timbers were removed and the workings allowed to collapse.

Figure 147: Pieces of manganese ore in a dry stone wall.

7: Return along the footpath, taking a right branch to Cell Fechan. Descend past Y Garn to the car parking area at Panorama Walk.

Foel Ispri

6 miles: approximately 3 hours



- Ffestiniog mudstone, siltstone, sandstone
- Maentwrog mudstone, siltstone, sandstone
- Clogau mudstone
- Gamlan mudstone, siltstone
- Diorite, gabbro
- Quartz-microdiorite
- Microgabbro

Figure 148: Field excursion.

Start: Park at any convenient location in Dolgellau [SH728180].

1: Follow the Mawddach trail footpath alongside the river. Cross the footbridge and continue alongside the river to the roundabout on the outskirts of the town. Cross the main road at the roundabout, and walk northwards along the cycle path until you reach the old road to Llanelltyd bridge. Continue to the bridge, then on into Llanelltyd village.

2: Follow the minor road through the village past the turning to the village hall. Immediately before the car parking area at the end of the village, take a footpath with steps on the right leading up the valley side.

3: Climb the steep footpath to Llyn Tan y Graig.

4: Follow the path around the lake, then uphill through the coniferous plantation, past outcrops of Penrhos shales of the Maentwrog Formation. At the top of the forest, a style leads over the dry stone mountain wall.

Figure 149: Llyn Tan y Graig

Turn to the left and follow the wall to the derelict house. This lies adjacent to a small rocky gorge in which a series of quartz lodes are exposed within the Penrhos shales.

Continue across a wooden bridge over the stream, then along the grassy track. Beyond the dry stone wall, a rocky ridge is produced by a microgabbro sill intrusion.

An incline is reached. Ascend to the level of the New Panorama Walk footpath. Follow the path eastwards around the hillside to reach the Foel Ispri mines.

5: Continue along the path to an area of waste tips at the mouth of an adit tunnel. The rusty weathering blocks typically contain **marcasite** iron sulphide, along with grey **zinc blende** and occasionally lead sulphide **galena** and copper-iron sulphide **chalcopyrite**.

The Foel Ispri mines were mainly worked between 1860 and 1910, and have yielded a moderate production of copper and a small amount of gold. A series of quartz lodes outcrop on the upper slopes of Foel Ispri within the Maentwrog formation, running approximately east-west. The lodes were initially worked in open trenches, but adit tunnels were later driven from the hillside to intersect the veins at greater depth.

Figure 150: (left) adit at Foel Ispri mine. (right) Quartz with marcasite and zinc blende on the waste tip, Foel Ispri.

6: Return to the New Precipice Walk and continue westwards along the hillside.

Figure 151: Vigra siltstones and mudstones, showing soft sediment deformation.

Outcrops at the side of the track expose Vigra siltstones and mudstones, and Penrhos shales, belonging to the Maentwrog formation.

The Vigra rocks are of distal turbidite origin, representing mainly Bouma D units of laminated silt and mud. The materials show soft sediment deformation, with slump folds and lense-shaped thickness variations in layers. Coarser beds show parallel lamination and cross-lamination.

Within the sedimentary sequence are found thin sills of microgabbro, emplaced during the uprise of magma in Ordovician times when volcanic centres were active along the fracture zones around the Harlech Dome crustal block.

7: Continue past Foel Ispri farmhouse to reach the road.

8: Descend along the road to the first right-hand bend, then take a footpath down into woodland to the left. Vigra siltstone and mudstone turbidites are well displayed alongside the path (fig.152).

Figure 152:
Vigra siltstones and mudstones, Foel Ispri.

9: Follow the path downhill alongside a dry stone wall until a gate is reached. After emerging into a small grassy clearing, immediately cross the stream and look for a gate through the dry stone wall on the right side of the clearing. Go through the gate and descend along a path through the woods.

10: Join a minor road and descend through Taicynhaeaf to the Mawddach estuary.

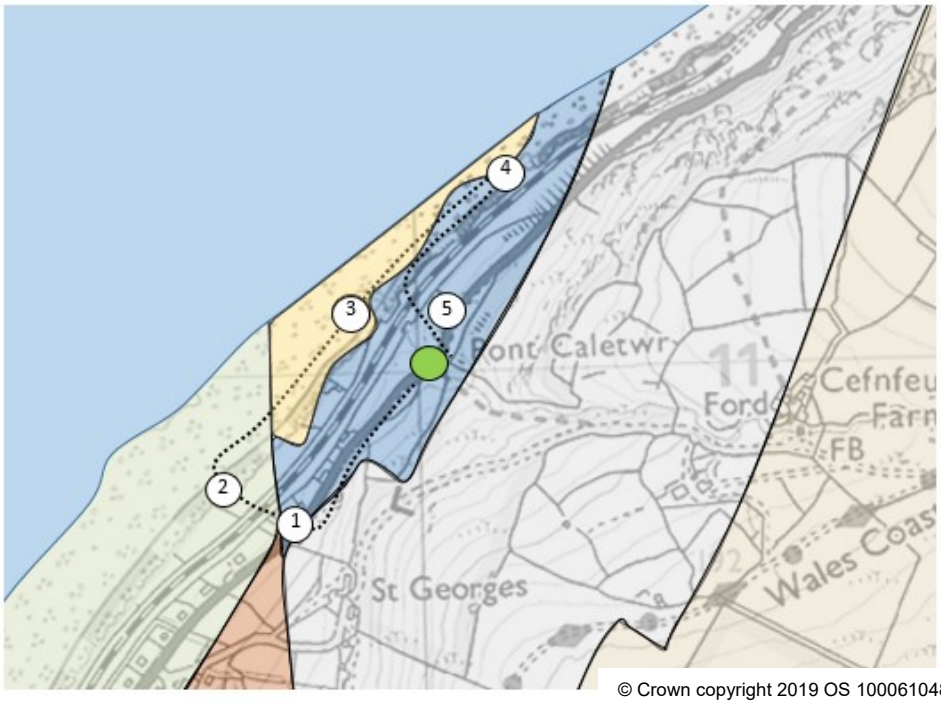
11: Continue across the Penmaenpool toll bridge to the George III Hotel.

The headland downstream from the toll bridge is composed of Penrhos mudstones of the Maentwrog Formation, overlain by Ffestiniog Formation sandstones which are exposed in the old railway cutting through the headland to the west of the hotel.

From this point, return along the Mawddach Trail which follows the track of the old railway back to Dolgellau.

Friog

1 mile: approximately 1 hour



Allt Lwyd sandstone
Dol-cyn-afon mudstone, siltstone
Penrhos mudstone
Vigra mudstone, siltstone
Clogau mudstone
Gamlan mudstone, siltstone

Figure 153: Field excursion.

Start: Park in the lay-by on the main road from Fairbourne to Tywyn at Pont Caletwr [SH600110].

1: Walk down the road to a row of houses. Turn down a footpath between two houses which runs down across fields to the beach.

2: Pass under the railway line, then descend to the beach down the low cliff of glacial till.

3: Walk along the beach to the outcrop of Gamlan siltstones and shales.

Figure 154: Gamlan siltstones and mudstones, showing minor folding.

The Cambrian strata along cliffs and wave cut platform are dipping generally south eastwards, but are affected by a series of faults and minor folds.

4: Continue past the mouth of the Caletwr stream.

The junction between the Gamlan siltstones and the overlying Clogau shales appears at the base of the cliff.

Near the top of the Gamlan beds, purplish and greenish stripes are present in the mudstones, suggesting variations in the oxidation state on the bed of the Welsh basin. A layer of concretions is present, indicating a high concentration of phosphate in the water. Beds are cut by hydrothermal quartz veins, probably associated with metamorphism during the Acadian orogeny in Devonian times.

The Gamlan Formation appears to be of distal turbidite origin, dominated in its upper parts by fine grained Bouma E mud units.

Figure 155: Gamlan formation at Friog. (left) Colour banding in mudstones. (right) Phosphate concretions within mudstones.

The Clogau Formation is exposed in the cliffs towards the north (fig.156).

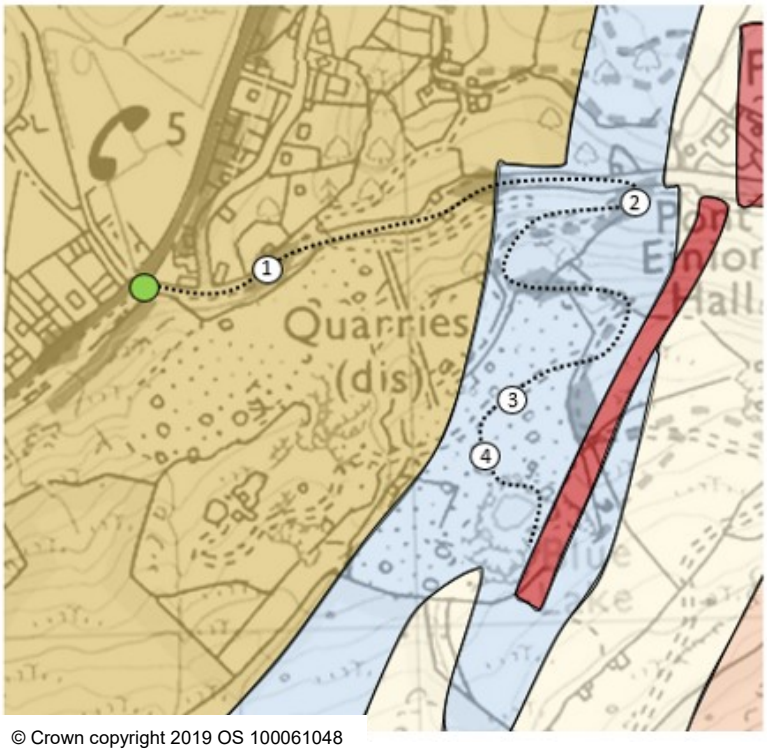
Figure 156: Clogau formation in the cliffs at Friog.
The line of a fault is marked. Masonry infill has been used to reduce marine erosion along the fault line, protecting the railway at the head of the cliff.

The lowest Clogau beds form a transition from the Gamlan Formation, with a mixture of the siltstones characteristic of the Gamlan and black mudstones characteristic of the Clogau formation. Inflows to turbidity currents ended. Reducing conditions with low levels of oxygen allowed the accumulation of organic carbon and iron sulphide within the sea bed muds.

5: Return by the outwards route. Alternatively, it is possible to take a short cut by scrambling up the path alongside the Caletwr stream and under the railway bridge to reach the road.

Friog slate quarry

1 mile: approximately 1 hour



Microdiorite
Allt Lwyd sandstone
Dol-cyn-afon mudstone, siltstone
Dolgellau mudstone, siltstone
Ffestiniog mudstone, siltstone, sandstone

Figure 157: Field excursion.

Start: Park on the main road verge at Friog, near to the junction with the minor road to Pont Einion [SH617123].

1: Take the minor road towards Pont Einion.

2: Leave the road and climb the footpath to the disused quarries, passing the inclines which were used to transport slate and waste rock from the quarry above.

3: Examine the remains of the mill area of Goleuwern Slate Quarry.

Figure 158: Flooded pit at Gloeuwern quarry.

4: Go through the tunnel to the flooded quarry known as the 'Blue Lake'.

The quarry opened in 1865, initially working slate from a series of levels on the hillside, but later developed as an open pit accessed by tunnels. Slate was transported down to Fairbourne, where it was transferred onto the railway.

The quarry was worked on four levels, the current lake being at floor 2. The higher floors 3 and 4 can be seen as ledges around the end of the pit workings (fig.158). A lower tunnel originally led to the base of the pit but was blocked, causing the pit to flood.

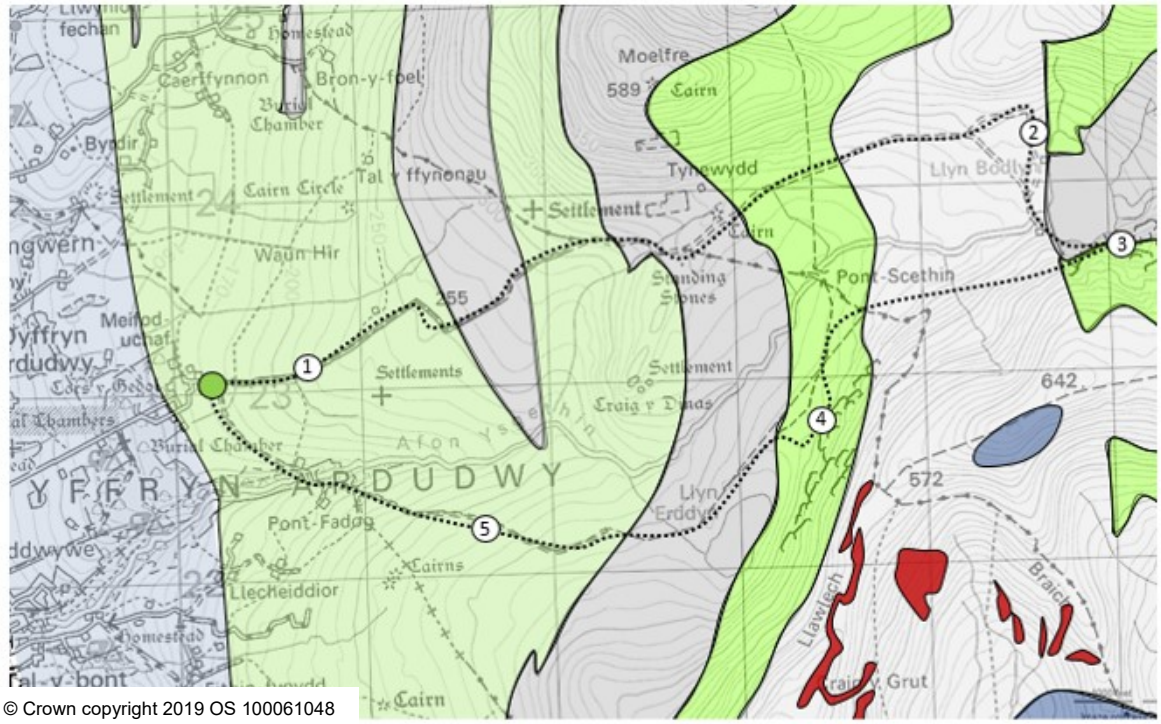
The quarry is developed in slates of the Dolgellau Formation. These mudstones have a deep water non-turbidite origin. The rocks have a gentle dip towards the south-east. A near-vertical axial planar slaty cleavage was produced by low grade regional metamorphism during the Acadian orogeny. The cleavage has a north-south strike, consistent with the compression and folding which affected the Harlech Dome crustal block.

It is possible to gain an overview of the quarry by climbing the incline to levels 3 and 4 above the flooded pit.

Return down the track to the road at Friog.

Ardudwy

6 miles: approximately 3 hours



- Clogau mudstone
- Gamlan mudstone, siltstone
- Barmouth sandstone, mudstone
- Hafotty mudstone
- Rhinog sandstone, mudstone
- Llanbedr mudstone, siltstone
- Microdiorite

Figure 159: Field excursion.

Start: Leave the main Barmouth to Harlech road between Tal y Bont and Dyffryn Ardudwy, taking a minor road past the historic house of Cors y Gedol. Park at the end of the village in a parking area close to the Dyffryn Neolithic burial chamber [SH602231].

1: Walk along the road to Llyn Bodlyn reservoir.

To the right, the route passes Craig y Dinas hill fort, located on an outcrop of Rhinog Grit proximal turbidites.

After crossing Hafotty mudstone, we move upwards into the Barmouth Grits and Gamlan formation. This sequence forms the eastwards dipping limb of the coastal anticline.

2: On reaching the reservoir, follow the track around the dam to examine Barmouth Grit exposed in the cliff face to the south.

Close to the reservoir, a north-south oriented fault associated with the axis of the Caerdeon syncline causes repetition of the sequence to produce the Barmouth Grit outcrop at this point. A sequence of massive proximal turbidites is seen in the cliff, with terraces marking the positions of thinner Bouma sandstone, siltstone and mudstone units between the massive graded grit A units (fig.160). A broad syncline can be traced in the cliff face with a north-south axial trace.

3: Examination of the grits at this locality indicates a lower pebble content and less channel development than in the outcrops at Y Garn above Barmouth, suggesting a greater distance from the head of the submarine slope and sediment source.

Figure 160: Llyn Bodlyn. Cliffs in the background are composed of Barmouth Grits.

4: Skirt around the hillside to examine further outcrops of Barmouth Grit above Llyn Erddyn.

5: Re-join the footpath leading down to a farm track and continue past the Neolithic burial chamber to the parking area above Dyffryn Ardudwy.

Figure 161: Llyn Erddyn.

Llanfair

approximately 2 hours

Rhinog sandstone, mudstone

Rhinog siltstone

Llanbedr mudstone, siltstone

Figure 162: Field excursion.

Start: Visit the Llanfair slate caverns, taking the access road from Llanfair and parking outside the visitor centre [SH580288].

Explore the underground workings of the quarry.

The Llanfair quarry was active between 1873 and 1906, extracting slate from the Llanbedr Formation. The upper limit of workable slate within the quarry is the base of the Rhinog Grit formation. Dip of the slate beds is at approximately 30° to the east, forming the landward limb of the coastal anticline. The slaty cleavage dips at a steeper angle of approximately 70°.

The method of working was to drive a horizontal access tunnel along the strike of the slate bed below the grit formation. A slanting **roofing shaft** was then extended upwards along the base of the grit, separating the slate from the overburden, and allowing the safety of the roof to be checked whilst it was still easily accessible. A chamber could then be developed by extracting blocks of slate from the working face using explosives, until a backwall height of around 30 feet was reached. A new chamber would then be developed along the dip, or at a lower level, leaving a pillar walls of slate in place on either side of the chamber to support the roof.

Figure 163: Llanfair slate quarry.

Chamber showing the excavation of a roofing shaft, prior to extracting slate from the working face.