# The Rhinog mountains

# 4

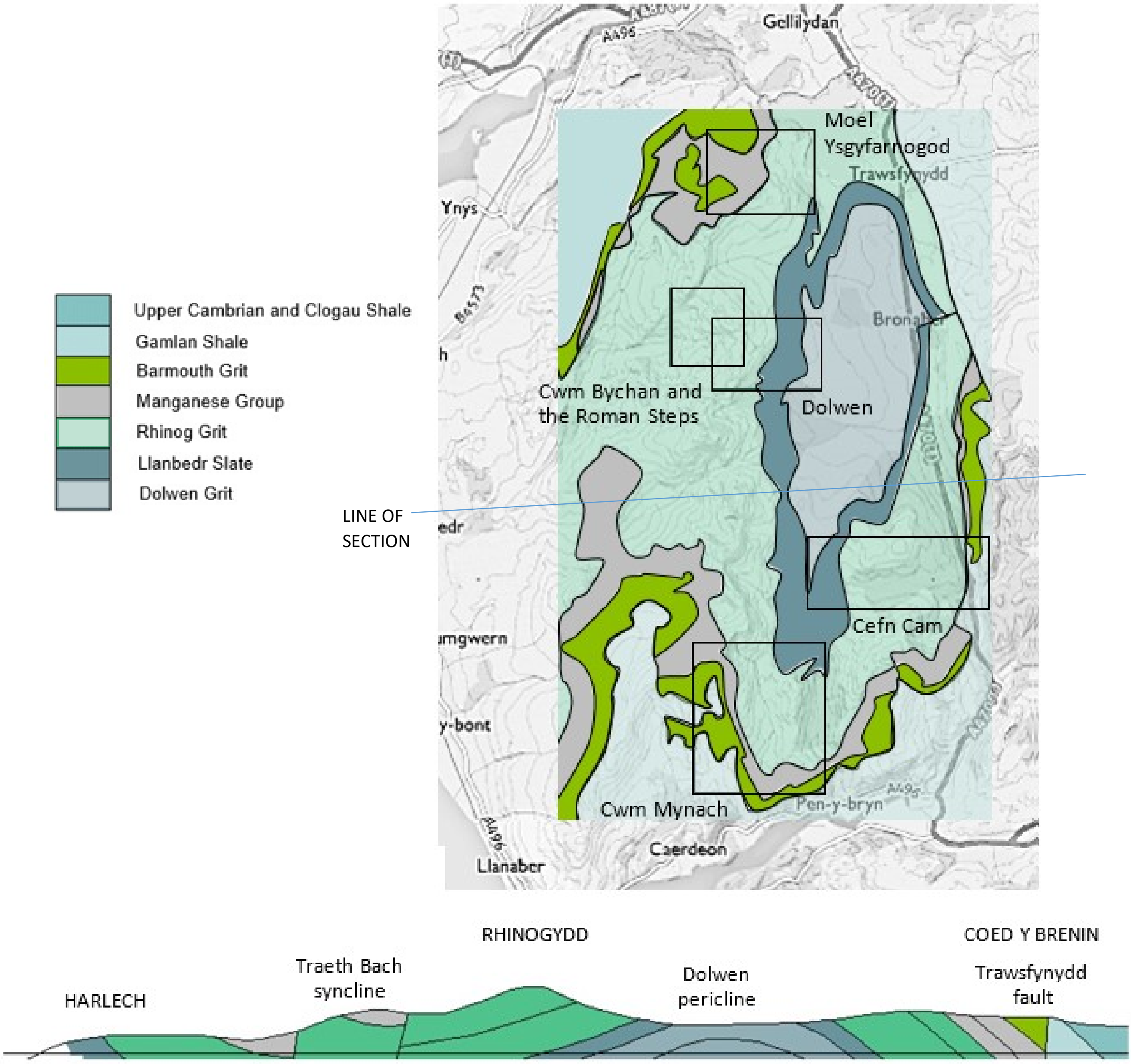



**Figure 105**: Field study locations

In chapter 1 we outlined a plate tectonic model developed by Pothier et. al. (2015) for the early evolution of the microcontinent of Avalonia alongside the great continental mass of Gondwana. During Cambrian times, Wales is believed to have formed part of the Megumia marine basin, along with Nova Scotia, Canada.

Megumia was bordered by the land areas of eastern Avalonia including England, and western Avalonia including part of Newfoundland. The Welsh and Canadian sections of Megumia were separated and carried to their present relative positions by sideways movement along the Menai Straits fracture zone during late Cambrian times.

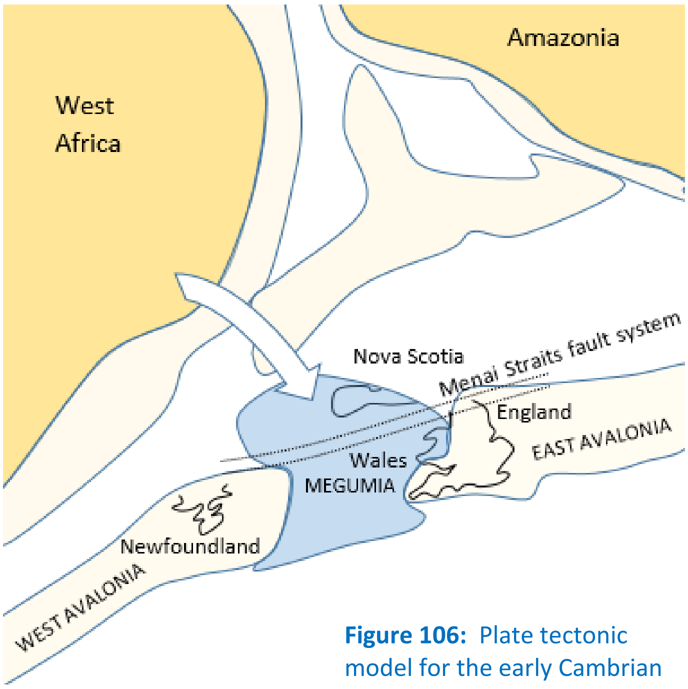



**Figure 106:** Plate tectonic model for the early Cambrian

It is thought that the Megumia basin was supplied by sediment carried by rivers from a region of West Africa. This is consistent with the Precambrian ages of zircon grains found in Cambrian sediments of Wales which correspond with the ages of granites outcropping in the core of the African continent.

We begin by examining the central area of the Harlech Dome, dominated by the Rhinog mountain range. Rocks in this area belong to the ***Harlech Grits Group***, of lower to middle Cambrian age, which includes a variety of sandstones, siltstones and mudstones, along with coarser conglomerates. An objective will be to determine the environmental conditions in which these various strata were formed, including the deposition mechanism and the water depth.

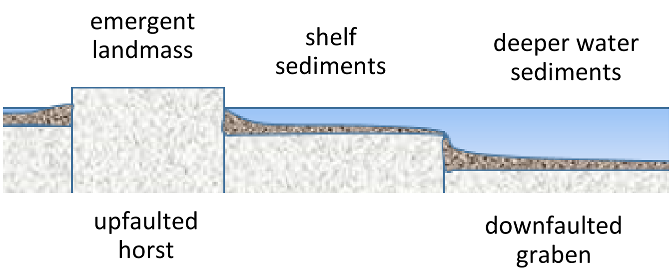



**Figure 107**: Block faulting below the Welsh Basin

Throughout Cambrian times and beyond, the Welsh basin was underlain by a mosaic of crustal blocks which were able to move both horizontally and vertically relative to one another along major crustal fractures in response to plate tectonic events. A consequence was that sea depth could change over time, and areas may become emergent land masses. Steep sea bed slopes may have separated the shallower shelves from the deeper basin areas.

The Cambrian succession begins with sandstones of the ***Dolwen formation*** and muds of the ***Llanbedr Slates formation*** (Allen, Jackson & Dunkley, 1985). These sediments were the first to be laid down in the Megumia marine basin. Sedimentary structures such as current bedding can provide evidence of the transport direction of the sediment. We find that the sand and mud were supplied from the north and west, probably carried by rivers draining the Gondwanan continent which lay beyond.

Above the Llanbedr slates lies a great thickness of hard and resistant grits, the ***Rhinog Grit formation***, which produces the highest peaks of the Rhinog mountain range. These rocks originated as turbidite deposits.

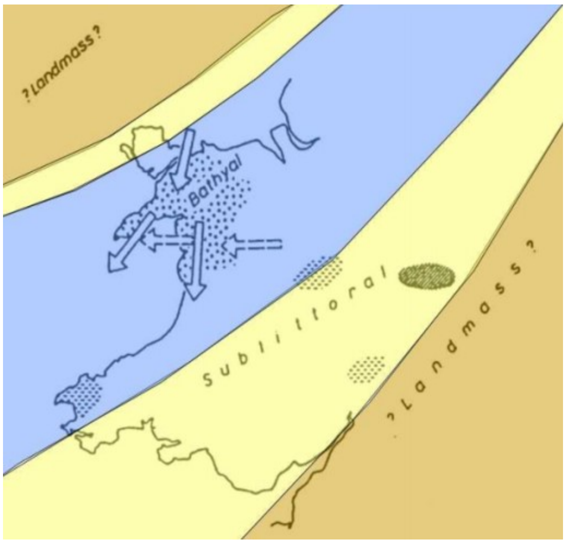



**Figure 108**: Paleogeography of the Rhinog Grits

The coarse and poorly sorted nature of many of the massive beds indicates a nearby source of sediment where a coastline and shallow marine shelf may have existed. Turbidity currents were discharged at intervals into the deeper waters of the marine basin. The turbidite flows of the Rhinog formation had a source area to the north of the Welsh Basin, perhaps in an upfaulted block bordered by the Menai Straights fault zone where it crosses Anglesey (fig.108).

After deposition of the Rhinog grits, environmental conditions in the marine basin changed dramatically. The supply of coarse sand ended, and a large thickness of mud began to be deposited as the ***Hafotty formation***. Chemical conditions were such that manganese minerals were deposited along with the mud, and at one horizon the concentration of manganese reached ore grade. This deposit, forming a continuous bed around 40cm in thickness, has been worked at a number of small opencast quarries and mines around the Harlech Dome area. The ore consists of bands of manganese oxide, carbonate and silicate minerals. The origin of the manganese ore is uncertain. One possibility is as a precipitate from sea water which had been highly enriched in manganese by erosion of basalt and other mafic igneous rocks. We have evidence that large quantities of basalt were accumulating at this time in the Monian subduction complex to the north east of the Welsh Basin (chapter 3).

The Hafotty formation is overlain by the ***Barmouth Grits***, which represent a return to the deposition of coarse sands by turbidity currents. Barmouth grits are seen in only a few outcrops within the central Harlech Dome, but we will be examining these rocks in more detail in chapter 6 in the coastal area of Ardudwy between Barmouth and Harlech.

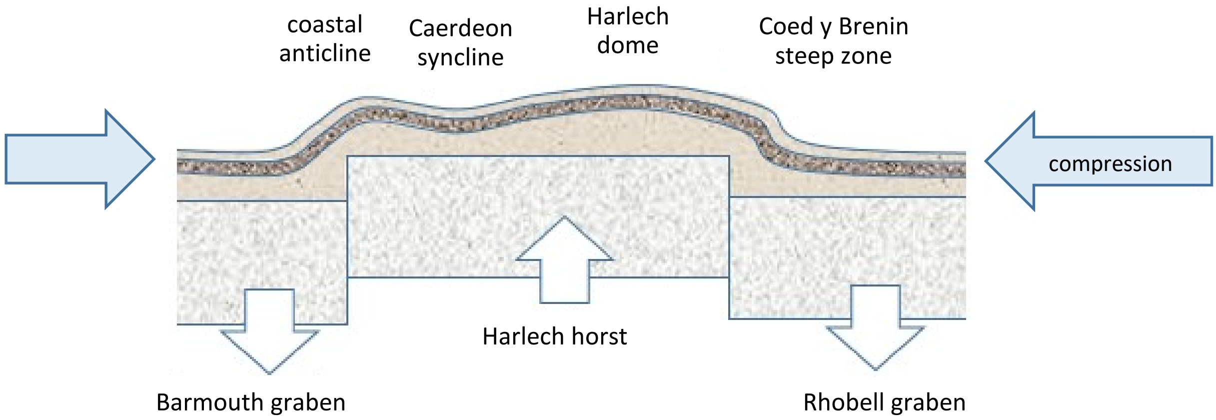



**Figure 109**: Formation of the Harlech Dome by block faulting and compressional folding.

The Harlech Dome is an uplifted area, exposing the oldest strata in the core of an elongated dome-shaped fold known as the **Dolwen pericline**. This structure developed during the Acadian orogeny in Devonian times, when plate convergence caused crustal compression in the Welsh area. Blocks of the Precambrian basement experienced vertical movements, and the overlying sedimentary succession was also compressed laterally.

The origin of the Harlech dome is due to upfaulting of the ***Harlech horst***, combined with folding to produce the dome (fig.109). West of the dome, compression formed the ***Caerdeon*** and ***Traeth Bach synclines***, and the ***coastal anticline***. To the east, drape folding of the sedimentary succession over the edge of the upfaulted crustal block has produced steep dips in Coed y Brenin and at Rhobell Fawr, with strata vertical or overturned in some locations.

## Dolwen

7 miles: approximately 4 hours

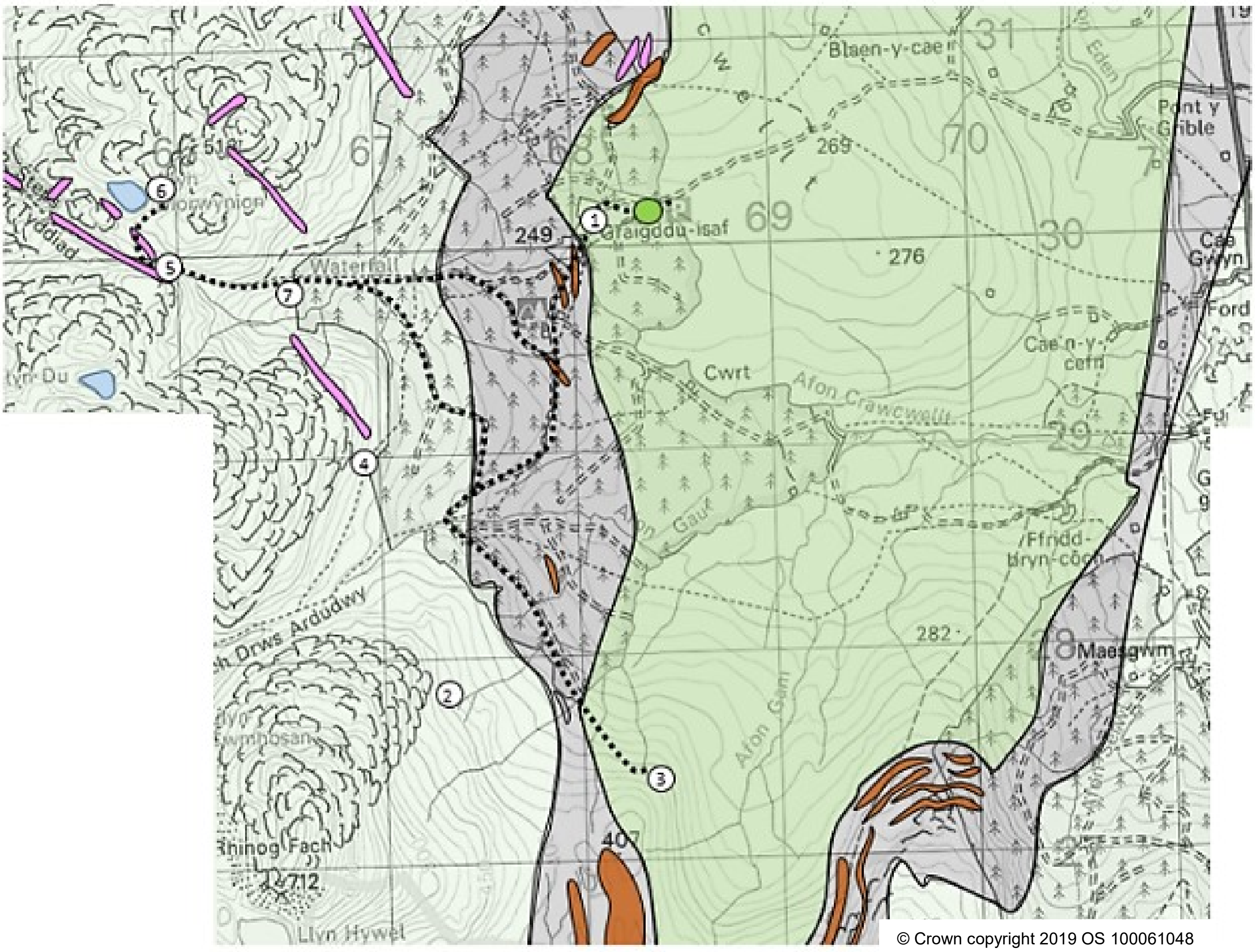



**Figure 110**: Field excursion

- Rhinog sandstone, mudstone
- Llanbedr siltstone, mudstone
- Dolwen sandstone, sitstone
- Microgabbro
- Diorite, gabbro

**Start:** Leave the main Dolgellau to Trawsfynydd road at Pont y Grible, and follow the minor road to the edge of the forest at Graigddu-isaf where a car parking area in provided [SH684302].

**1:** Follow forest roads past Graigddu-isaf farm, crossing the Crawcwellt and Gau streams, to reach the southern edge of the forest.

**2:** Leave the forest along a footpath, across a style, then cross a small stream.

A prominent outcrop with prominent bedding is visible about 500m away across a shallow wetland depression. Skirt around the hillside above the wetland to reach the outcrop.

**3:** Examine the outcrops of Dolwen grit.

The Dolwen Grits consist of sandstones interbedded with thin mudstones. The sandstones at this location show prominent bands of pebbly conglomerate which vary in thickness and wedge-out across the rock face.

The sandstone layers have a uniform grain size, and do not exhibit the fining-upwards that would be expected in turbidite deposits. Cross bedding is present in some strata (fig.111). Taken together, these sedimentary characteristics are similar to present day shallow coastal deposits. Sediment may be supplied by rivers to a shelf sea or delta.


**Figure 111**: (left) Dolwen formation, showing pebbly bands in sandstone. (right) Current bedding in Dolwen Grit.

**4:** Return to the forest and retrace the route for about 1km, then take a left turn where the forest road branches. Continue to the point where a footpath leaves the road on the left and climbs up the hillside towards Bwlch Tyddiad.

**5:** Climb the path to the head of the Roman Steps across Rhinog Grit.

**Figure 112**: Rhinog Grit outcrops around Bwlch Tyddiad.

The Rhinog Formation consists mainly of grey, greyish green or bluish grey **greywacke**. This term refers to a dark coloured sandstone which is poorly sorted, containing angular grains of quartz, feldspar, and small rock fragments in a muddy matrix. The grits are interbedded with thin layers of siltstone and mudstone. Quartz pebble conglomerates are found and can be traced for long distances along the outcrop, suggesting submarine channels lined with pebble debris. Taken together, these characteristics suggest deposition from turbidity currents in the upper parts of a submarine fan.

Geologists have investigated modern turbidite deposits discharging into deeper waters from submarine shelves at the mouths of major rivers such as the Mississippi and St Lawrence. It is found that flows of mixed sediment are initially confined within channels, but then spread through a series of distributaries to produce fan lobes on the sea bed. Deposition begins in the upper channel with the coarsest gravel sinking to the bed. Finer grit may be deposited above the gravel. After passage of a turbidite flow through the channel, the walls may be steepened and unstable and layers of finer sediment may slump into the channel.

**Figure 113**: Conglomerate composed of well rounded quartz pebbles.

Further down the slope, as the turbidity cloud spreads beyond the confining channel, a characteristic sequence of graded grit, parallel bedded sandstone, current bedded sandstone may be laid down. Over a period of hours or days, silt and mud may also settle on top of the coarser sediment (fig.115).

**Figure 114**: Several fining-upwards sequences from grit to sand and silt, representing deposition from successive turbidite flows.

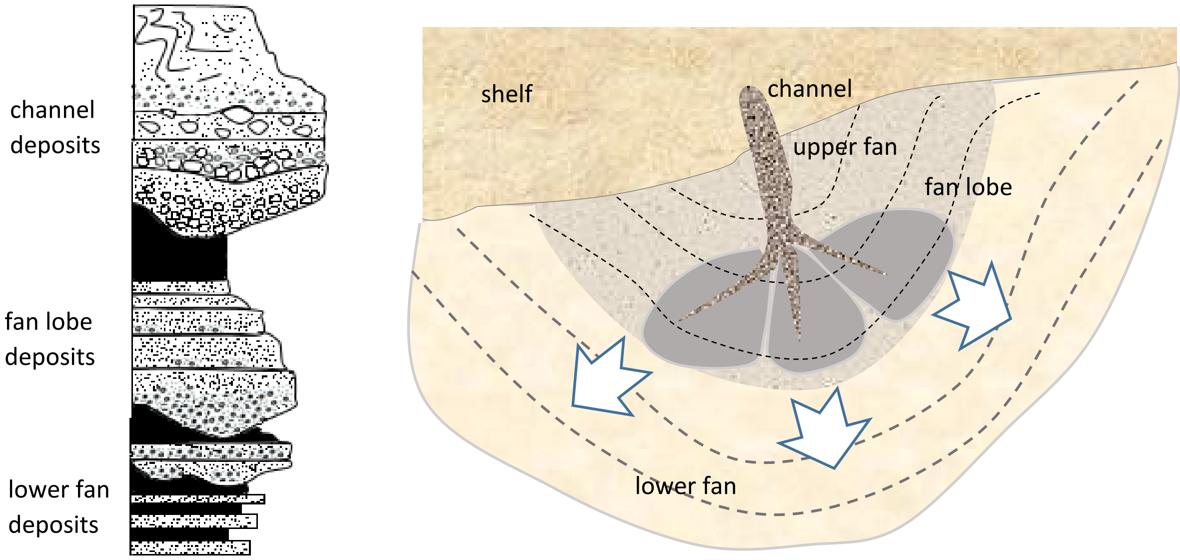



**Figure 115**: Turbidite fan deposits.

**4:** Cross the moorland to the grit crags above Llyn Morwynion where further examples of turbidite sequences are well displayed.

**Figure 116**: Rhinog Grit outcrops above Llyn Morwynion.

The Rhinog Formation is dominated by thickly bedded sandstone in which single units are up to 5m thick, although common amalgamation of adjacent sandstone beds locally makes the deposits of single turbidite events difficult to recognize. Beds are often graded and contain complete or partial **Bouma sequences** of sedimentary structures. Soft-sediment deformation structures, such as convolute lamination, are common. Sole marks such as flutes and grooves are found, indicating palaeocurrent flow mainly from the north in the Rhinog Formation.

**5:** Return down the footpath, crossing the forest road and continuing to Graigddu-isaf past the Pistyll Gwyn waterfall.

## Cwm Bychan and the Roman Steps

4 miles: approximately 3 hours

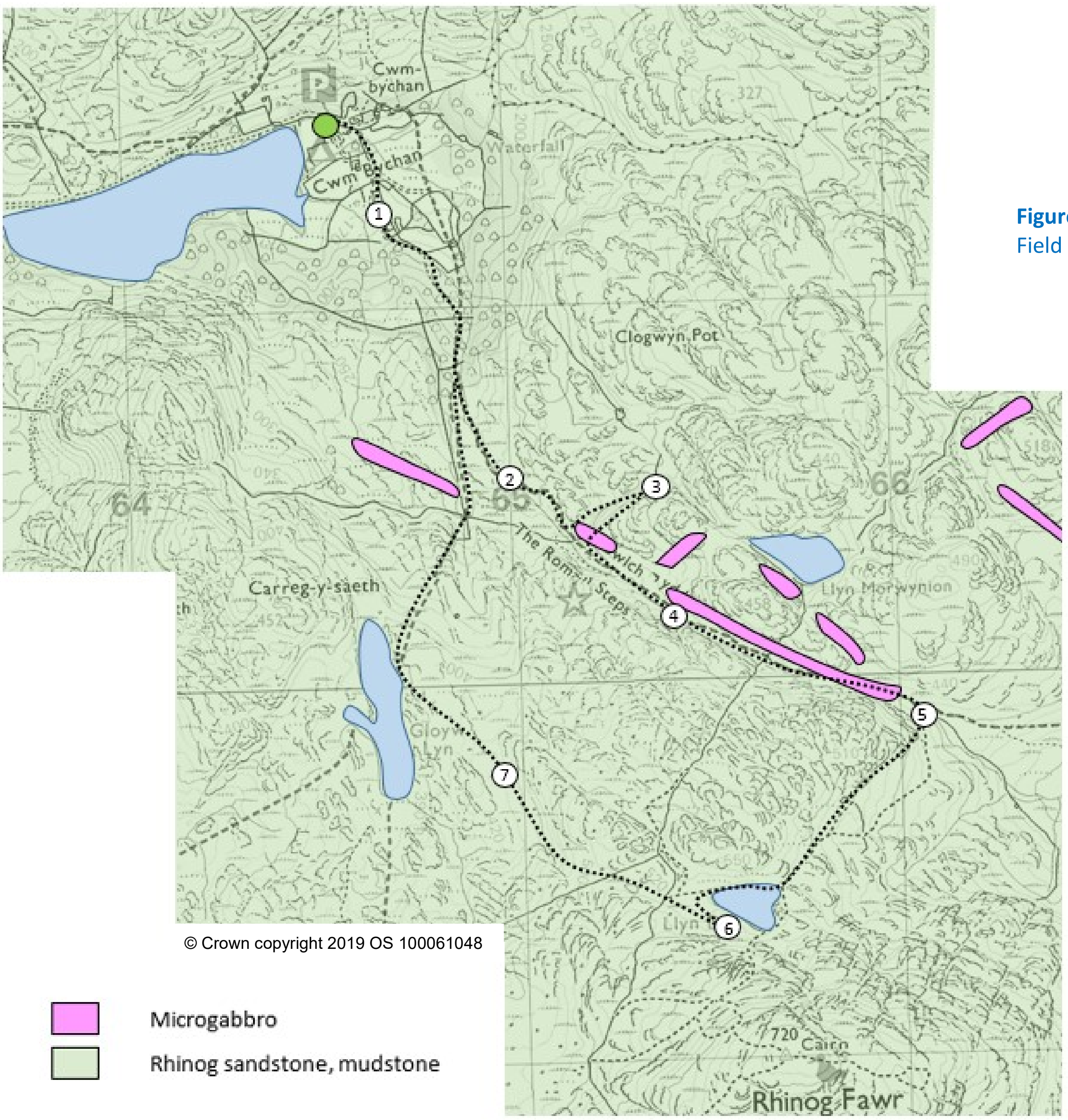





**Figure 117**: Field excursion.

**Start:** Follow the minor road from Llanbedr to Cwm Bychan. Car parking is available for a small fee in a field at the head of the lake [SH646315].

**1:** Follow the footpath to the Roman Steps.

Walk up to the top of the car park field and through a gate. Turn right onto a gravel track over the stream.

**2:** Continue up the valley towards Bwlch Tyddiad.

**3:** Examine the large cliffs of Rhinog Grit to the left of the path.

This is a good point to make a record of the sedimentary features of the turbidites, either by measurement or photographically. The measured section in fig.119 illustrates a variety of sedimentary structures:

A: cross-bedded sandstone, representing a Bouma C unit.

B: slump, formed as wet sediment overturned as it slipped down a slope.

C: an antidune in a Bouma A graded grit, formed during very rapid deposition when a dune migrates upslope against the flow as material is deposited against its leading edge.

D: a channel scour which has been infilled by further sand deposition.

E: soft sediment deformation within a laminated silt and mud Bouma D unit. The sediment has overturned as it slid downslope whilst saturated with water.

**Figure 118**: Rhinog Grit outcrops, Bwlch Tyddiad

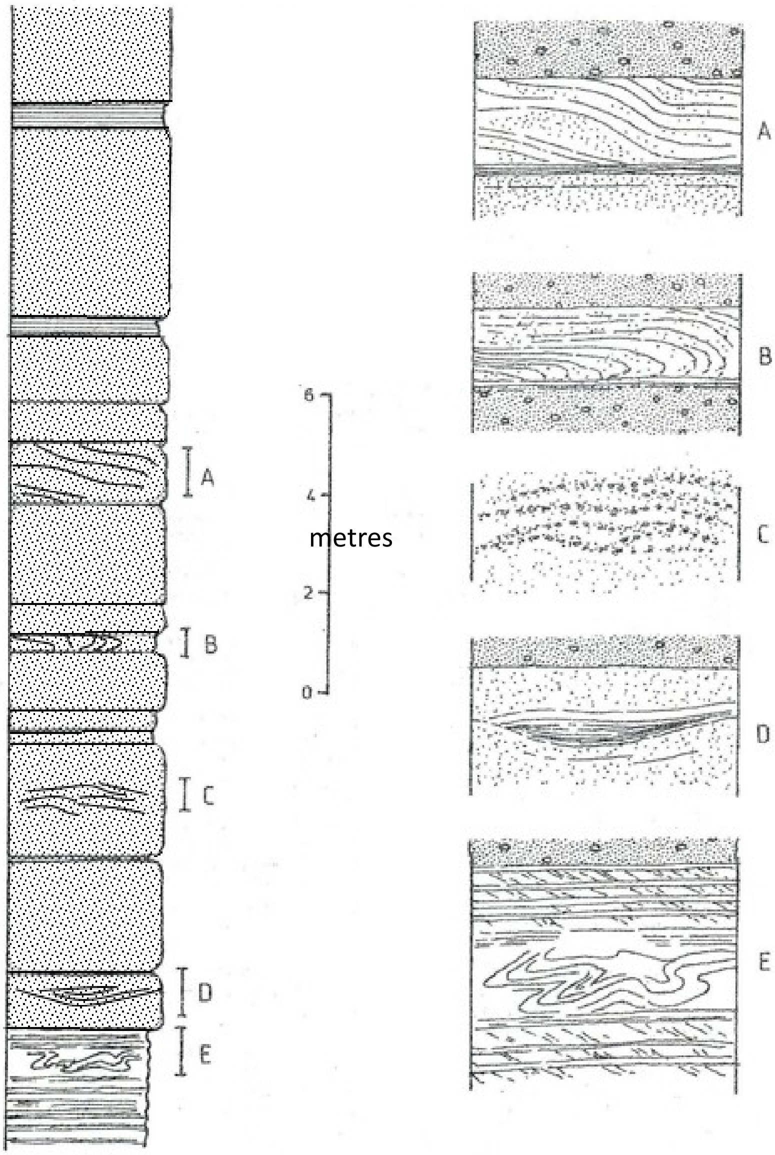



**Figure 119:** Sedimentary structures in the Rhinog Grits. Section near the Roman Steps.

**Figure 120**: Sedimentary structures in Rhinog Grit outcrops, Bwlch Tyddiad:
(top left) infilled channel in sand deposits,
(top right) slump folding in a silt-mud unit,
(bottom left) current bedding,
(bottom right) overturned slump fold in the lower sandstone bed.

In places, considerable thicknesses of finer Bouma D (mud-silt laminae) units and E (mud) units are found. These represent the last deposits from suspension as the turbidity current passed, with possible reworking by bottom currents which picked up and redeposited the material. These layers show a prominent slaty cleavage which is often at a much steeper angle than the bedding. The cleavage is axial-planar to the large fold structures which developed during the Acadian orogeny, as low grade regional metamorphism led to recrystallisation of platy mica minerals.

Continue to the head of the pass, climbing the narrow valley between crags of Rhinog Grit. The valley has been excavated by river and glacial action along the line of a microgabbro dyke.

Numerous cooling joints in the intrusion allow the rock to break easily into fragments, presenting less resistance to erosion than the massive beds of grit.

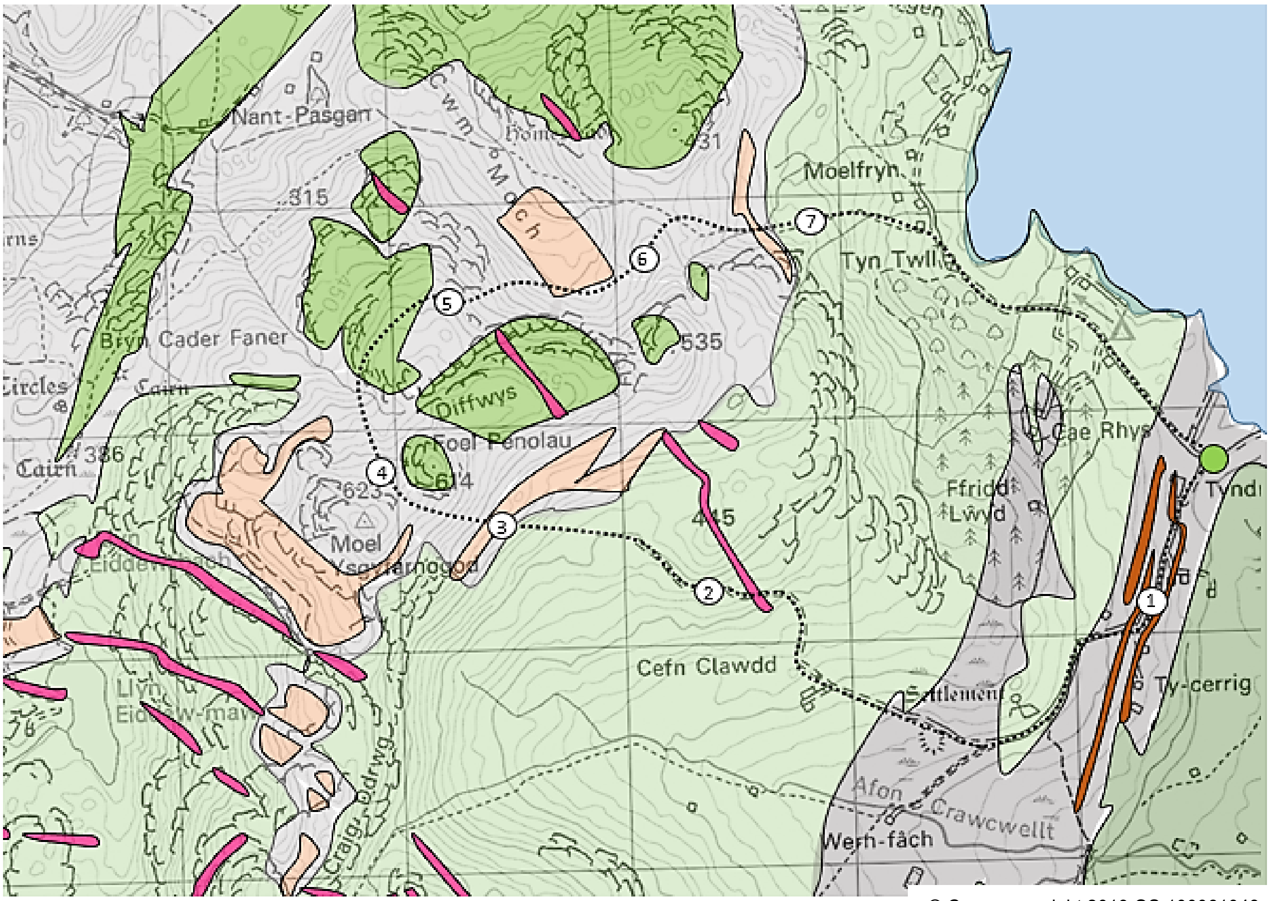
**5:** Before reaching the top of the pass, take a footpath up the mountainside to the right to reach Llyn Du.

**6:** Examine outcrops around Llyn Du, where numerous examples of Bouma sequences, dominated by thick A units, can be seen. Some A units have a compound structure, showing erosion surfaces and a repetition of the upwards fining sequence. These would have been produced by multiple turbidity currents discharging into the basin in rapid succession, perhaps initiated by earthquake activity.

**7:** Take the footpath which descends eastwards to Gloyw Llyn, and then to Cwm Bychan.

## Moel Ysgyfarnogod

7 miles: approximately 4 hours






- Barmouth sandstone
- Hafotty sandstone
- Hafotty mudstone
- Rhinog sandstone, mudstone
- Llanbedr siltstone, mudstone
- Dolwen sandstone, sitstone
- Microgabbro
- Diorite, gabbro

**Figure 121**: Field excursion.

In this excursion, we will carry out a transect across the northern edge of the Dolwen pericline from Trawsfynydd lake to the mountain escarpment of Moel Ysgyfarnogod. Beginning on Llanbedr slates, we climb over Rhinog Grit to reach outcrops of the Hafotty formation manganese shales, then pass the peaks of Foel Penolau and Diffwys which are capped by turbidites of the Barmouth Grit formation.

**Start:** Park on the road verge near the road junction at the south west corner of Trawsfynydd lake [SH699349].

**1:** Walk up the minor road to Cefn Clawdd.

**2:** Continue up the track towards the mountain escarpment.

**3:** Examine the manganese mine workings. Manganese ore formed a gently dipping band, about 40cm in thickness, just above the junction between the Rhinog Grits and the Hafotty formation. The ore is composed of cream layers of the manganese carbonate mineral **rhodochrosite**, red layers of the manganese silicate **spessartine**, and black layers of manganese oxide **pyrolusite**.

**Figure 122**: Manganese workings on the eastern flank of Moel Ysgyfarnogod:
(above left) Excavated ditch extending along the outcrop of the ore bed.
(above right) Collapsed workings, showing overhanging beds of shale above the removed ore band.
(lower right) Manganese ore: sample collected at Diffwys mine, Cwm Mynach

**4:** Continue to climb towards the gap between Moel Ysgyfarnogod and Foel Penolau. When the crest of the escarpment is reached, cross to the cliffs of Foel Penolau and examine the outcrops of the Barmouth Grit formation.

The Barmouth Grit formation is composed mainly of coarse sands deposited from turbidity currents in a channel and fan complex in a similar manner to the Rhinog Grits. In places, quartz pebble conglomerates occur at the base of graded grits, marking the first sediment deposited as a turbidite flow spreads out across the submarine fan. We will consider the palaeogeography of the Barmouth Grits in more detail in chapter 5.

**Figure 123**: (left) Barmouth Grit turbidites outcropping in the cliff of Foel Penolau.
(right) Pebble layer at the base of a turbidite grit.


**Figure 124**: Cwm Moch: (left) outcrops of Hafotty sandstones and shales. (right) mud and silt laminae of a turbidite Bouma D unit.

**5:** Contour northwards around Pen Olau and Diffwys to reach the deep glacial valley of Cwm Moch.

**6:** Descend the steep grassy slope into Cwm Moch, then skirt around the cliffs at the head of the valley.

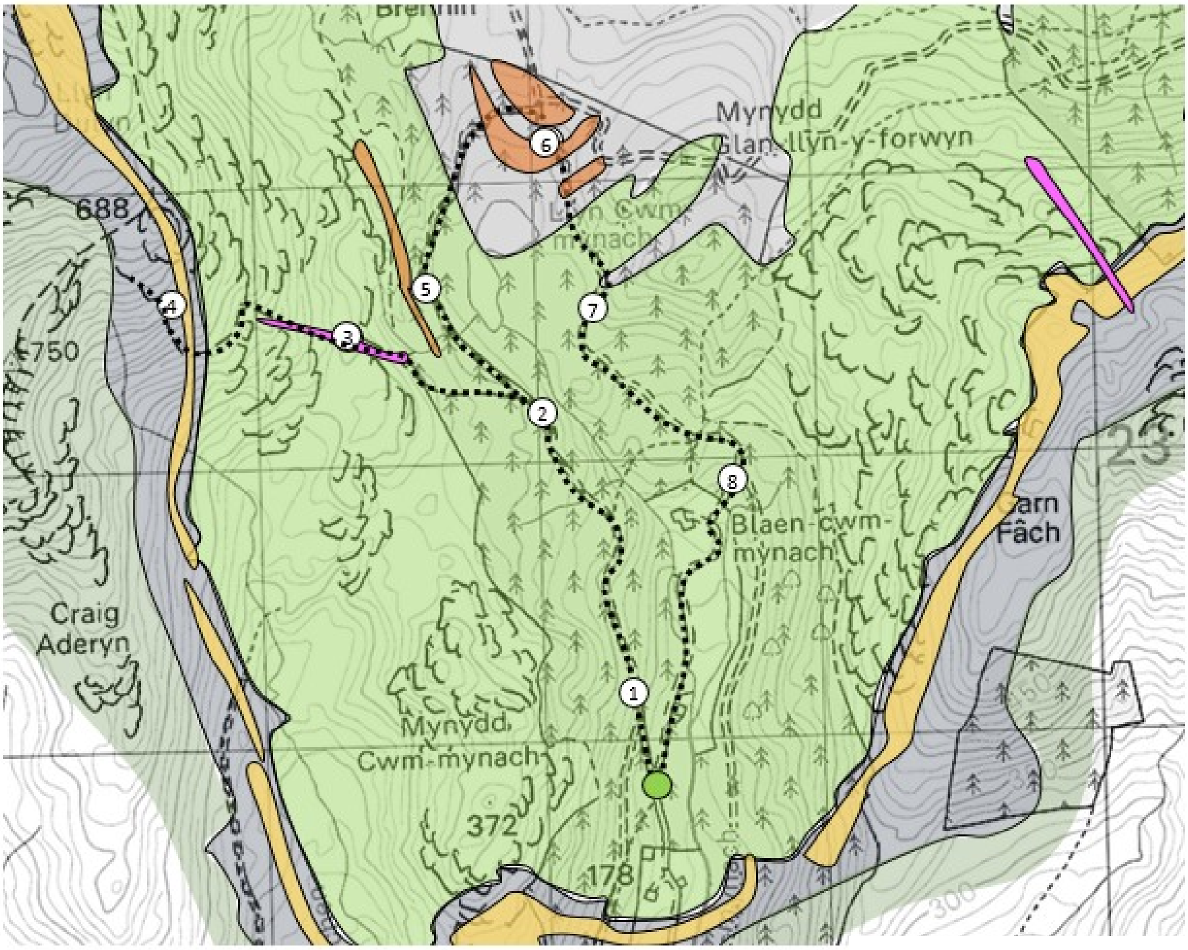
Cwm Moch is cut in sandstones and shales of the Hafotty formation. Examination of the rocks reveals sand units interbedded with mud and silt laminae units, characteristic of distal turbidites deposited by sediment flows which have travelled a considerable distance from their source, have a reduced transporting power, and have already lost most of their coarse sediment.

Whilst the Hafotty formation began with quiet chemical precipitation of manganese minerals in an enclosed basin, conditions appear to have changed to allow input of considerable quantities of turbidite sands, silts and muds. Sedimentary structures suggest a source area to the south of the Welsh Basin, perhaps from a landmass in the area of Bristol.

**7:** Cross the pass towards Llyn Trawsfynydd, descending by footpath to the road at the edge of the lake. Return around the lake to the car parking area.

## Cwm Mynach

6 miles: approximately 3 hours






- Barmouth sandstone, mudstone
- Hafotty sandstone
- Hafotty mudstone
- Rhinog sandstone, mudstone
- Llanbedr siltstone, mudstone

**Figure 125**: Field excursion.

The objective of this excursion is to make another transect from the Rhinog Grit to the Hafotty formation, this time on the southern edge of the Dolwen pericline. For part of the route, we will follow the system of old tramways and inclines which led to the manganese mine high on the side of Diffwys mountain.

**Start:** Take the minor road up into Cwm Mynach through the village of Taicynhaeaf. Continue to the parking area at the end of the public road at Blaen Cwm Mynach [SH684219].

**1:** Follow the forestry road up towards Llyn Cwm Mynach.

**2:** After about 1km, leave the forestry road and take a footpath to the left, leading through the woods along the old tramway towards the manganese mine.

The Diffwys mine was worked in the 1880's, providing manganese for the manufacture of steel mainly for armaments. A series of inclines descended the steep mountainside from the mine, with an aerial ropeway carrying the trucks of ore in a final descent to the lower tramway.

**Figure 126**: Tramway connecting the first and second inclines, Diffwys mine.

**3:** Continue to the left around a prominent crag, then follow the footpath as it climbs through the grit outcrops to the rock platform at the head of the aerial ropeway. This was once the location of a timber tower which supported the suspension cable.

Ascend the first incline, then follow the tramway which contours around the cliffs to reach the second incline.

Continue up the second incline to the site of the mine.

**4:** Examine excavations along the outcrop of the manganese ore bed

The ore bed occurs a short distance above the junction between the Rhinog Grits and the Hafotty formation. The ore was extracted from trenches and shallow tunnels which followed the dip of the strata into the hillside. The overlying soft shales have now collapsed into the workings. Waste rock has been piled in front of the workings, and has a characteristic dark grey colour indicating manganese enrichment.


**Figure 127**: Workings along the outcrop of the manganese ore bed, Diphwys mine.

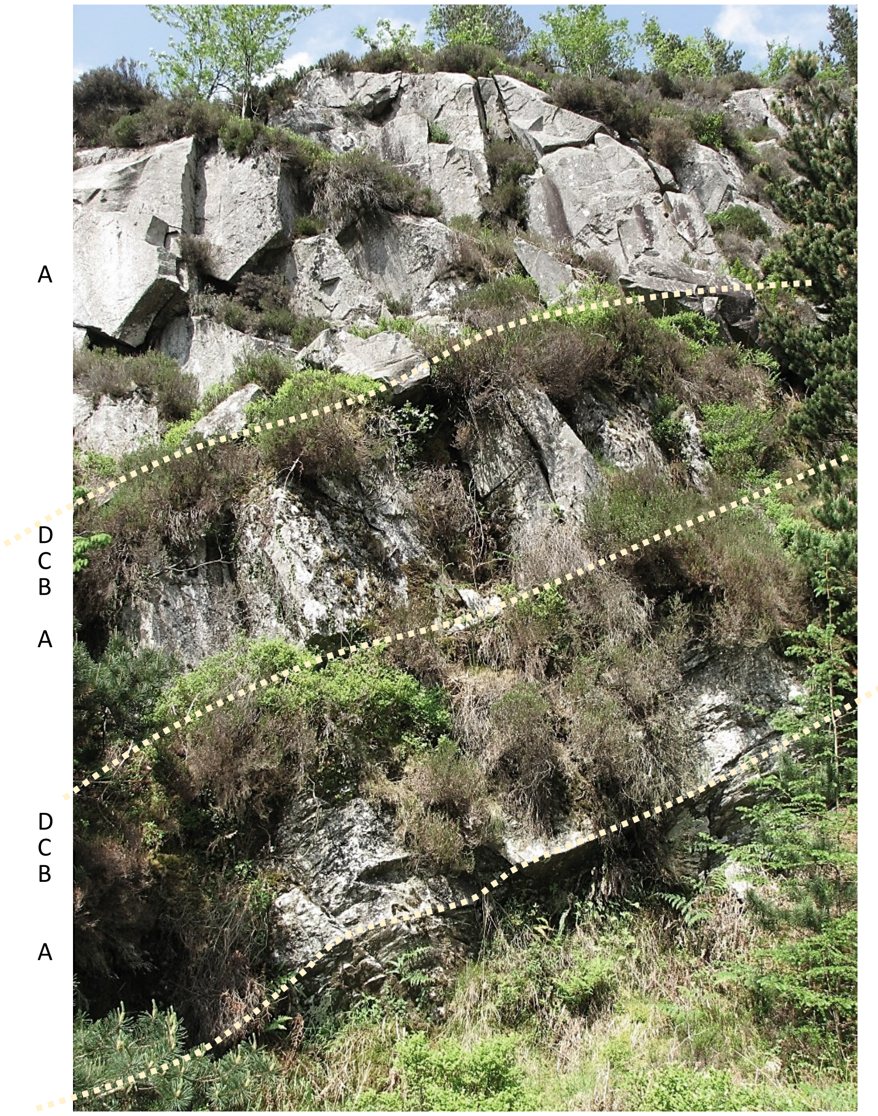



**Figure 128**:

Rhinog Grit outcrop alongside the forestry road at Garn Fach.

Bouma turbidite depositional sequences can be identified, with vegetation occupying ledges formed by the softer siltone and mudstone units.

**5:** Return down the inclines and tramway to the forestry road, then continue up the valley alongside Llyn Cwm Mynach.

After about 500m, a prominent outcrop of Rhinog Grit towers above the road. This exhibits a series of four Bouma turbidite events, each with a graded grit A unit overlain by a parallel bedded sandstone B unit, current bedded C unit, and laminated silt and mud D unit (fig.128).

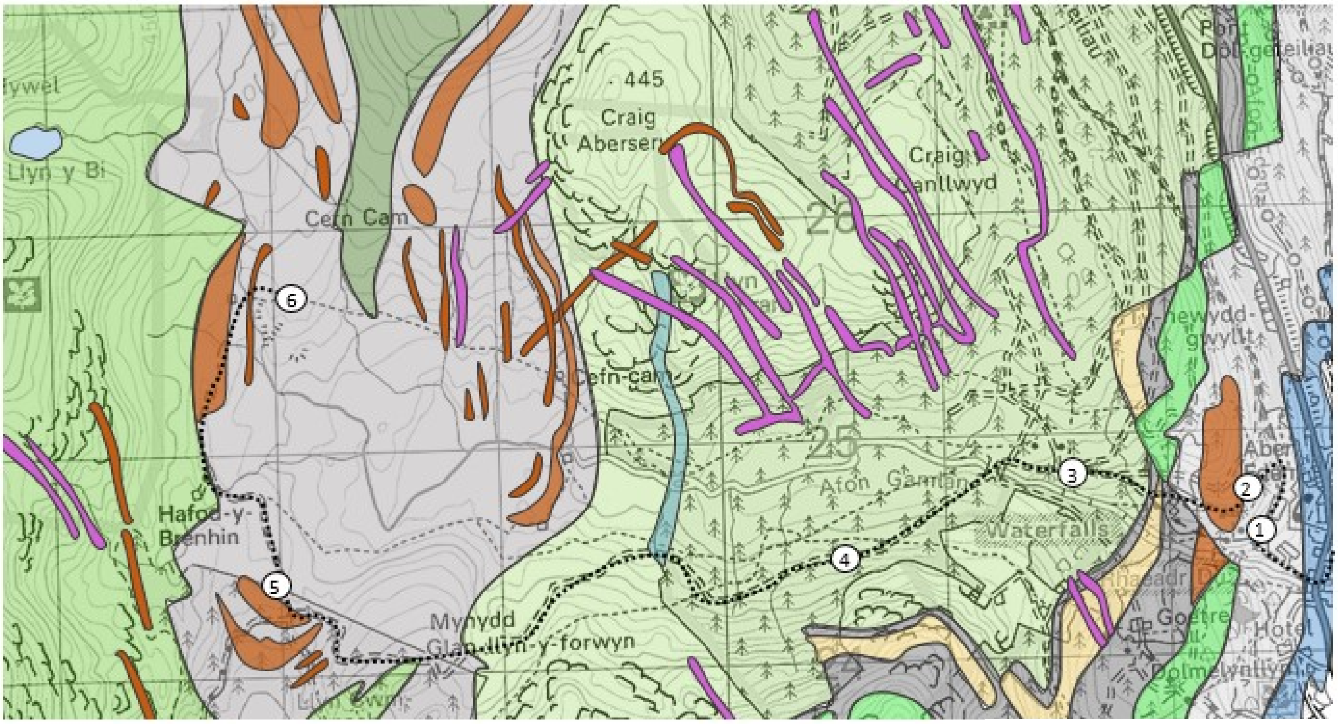
**6:** Continue around the head of Llyn Cwm Mynach, taking the forestry road which branches southwards to down the valley.

**7:** Examine further outcrops of Rhinog Grit which occur alongside the forestry road.

**8:** Return along the track past Blaen Cwm Mynach to the parking area.

## Cefn Cam

7 miles: approximately 3 hours






- Clogau mudstone
- Gamlan mudstone, siltstone
- Barmouth sandstone, mudstone
- Hafotty sandstone
- Hafotty mudstone
- Rhinog sandstone, mudstone
- Rhinog siltatone
- Llanbedr siltstone, mudstone
- Dolwen sandstone, siltstone
- Diorite, gabbro
- Microgabbro

**Figure 129**: Field excursion.

The objective of this excursion is to visit the Cefn Cam slate quarry, which was the largest quarry working the Llanbedr Slate formation within the central area of the Harlech Dome. This site is now abandoned. In the next chapter we will visit another quarry in Llanbedr Slate at Llanfair near Harlech, which is open as a visitor centre with underground tours of the workings available.

**Start:** A car park is provided in Ganllwyd village opposite the village hall [SH727244].

**1:** Follow the surfaced road up the hill past the village hall. A footpath branches to the left to the Rhaear Ddu waterfalls; we will visit the waterfalls in chapter 9. For the current excusion, continue along the road to its termination at a field gate.

**2:** Go through the gate and continue up the unsurfaced forestry track to a junction near a television relay mast. Take a turning to the left to continue up the Gamlan valley.

**3:** Continue to a junction with a larger forestry road. Follow the road up the valley and branch left to cross a bridge over the Afon Gamlan.

A series of outcrops of Rhinog Grit can be examined along this section of the forestry road.

**4:** Continue along the forestry road. A view of the Rhinog escarpment opens up ahead, with Llanbedr Slate underlying the marshy area of the valley floor.

**Figure 130**: Cefn Cam

**5:** The road leaves the forest at a cattle grid and skirts around moorland, before re-entering the forest at the head of the valley. After about 1km, take a left turn along the track to Hafod-y-Brenhin outdoor centre. Continue past the outdoor centre to reach the Cefn Cam slate quarry site.

**6:** Explore the Cefn Cam slate quarry.

The quarry was worked as a series of pits over a long period during the 19th century and into the 20th century. The slate was of a good quality, although not splitting as finely as slate from the Blaenau Ffestiniog and northern Snowdonia areas.

Remains of the splitting sheds can be seen where slates were split by hand, along with the workshop, office and miners' barracks, and the manager's house.

Continue around the buildings to reach the open pit workings of the quarry.

At this point, the dip of the slate beds is towards the west at about 60°, whilst the cleavage dips towards the east at about the same angle of 60°.

**7:** Return to Ganllwyd by retracing the outward route.

**Figure 131**: Cefn Cam open pit workings, looking south.

cleavage surface in the Llanbedr slate, dipping to the east

bedding plane in the Llanbedr slate, dipping to the west