Coed y Brenin 9

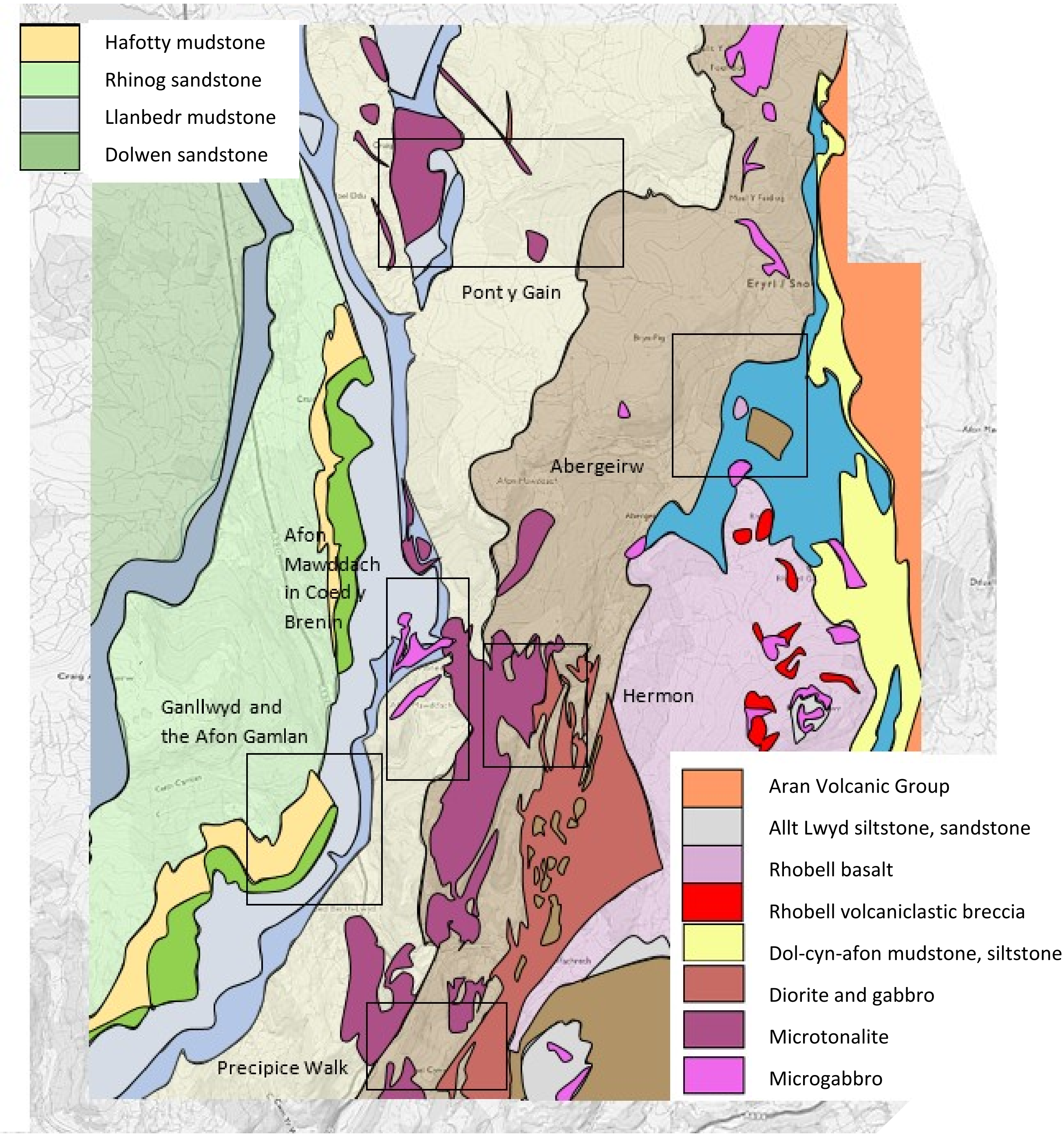


Figure 235: Field excursions.

In this chapter we focus on the Mawddach Group of sedimentary rocks. These occur towards the top of the Cambrian succession, and are composed mainly of mudstones and thinly bedded siltstones and sandstones. The rocks represent a mixture of shallow water shelf sediments and deeper water turbidites.

The outcrops lie on the eastern edge of the Harlech Dome, along the north-south Rhobell fracture zone. As a consequence, the outcrops are cut by a series of major north-south faults. The faults have often been eroded into deep, gorge-like river valleys in the Coed y Brenin area, as in the case of the Afon Wen between Glasdir and

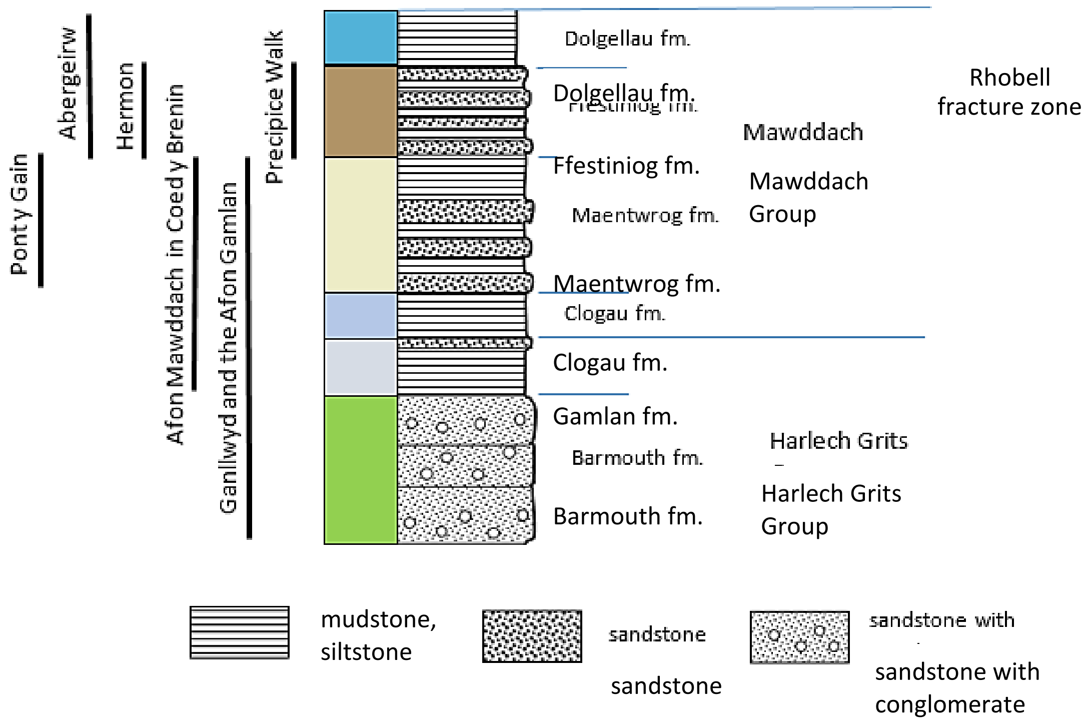


Figure 236: Strata examined during field excursions.

Hermon. The excursions taken together cover the sequence from the Barmouth Grit Formation to the Dolgellau Formation (fig.236).

The Mawddach Group of sediments were followed by the Rhobell volcanic episode, which marked the start of a long sequence of eruptions at other volcanic centres around the Harlech Dome, and in central Snowdonia and the Lleyn peninsula. By late Ordovician times, volcanic activity ceased. Mud and sands continued to be deposited in the Welsh Basin throughout the Silurian period during final convergence of the Avalonian microcontinent with Laurentia. We will examine this huge succession of volcanic and sedimentary deposits in later chapters.

By Devonian times, closure of the Rheic Ocean began to the south of Britain. Subduction of oceanic crust beneath the Welsh Basin caused the Acadian orogeny in which the basin sediments underwent additional folding and faulting. Low grade regional metamorphism produced slaty cleavage in mudstones, and hydrothermal fluids released during metamorphic reactions released heavy metals which were carried to higher levels in the crust and deposited as quartz sulphide vein deposits. Sites of gold mining on several mineral lodes of Acadian age are visited during the excursions in this chapter. We will return to examine the Dolgellau gold belt in greater detail later in the book.

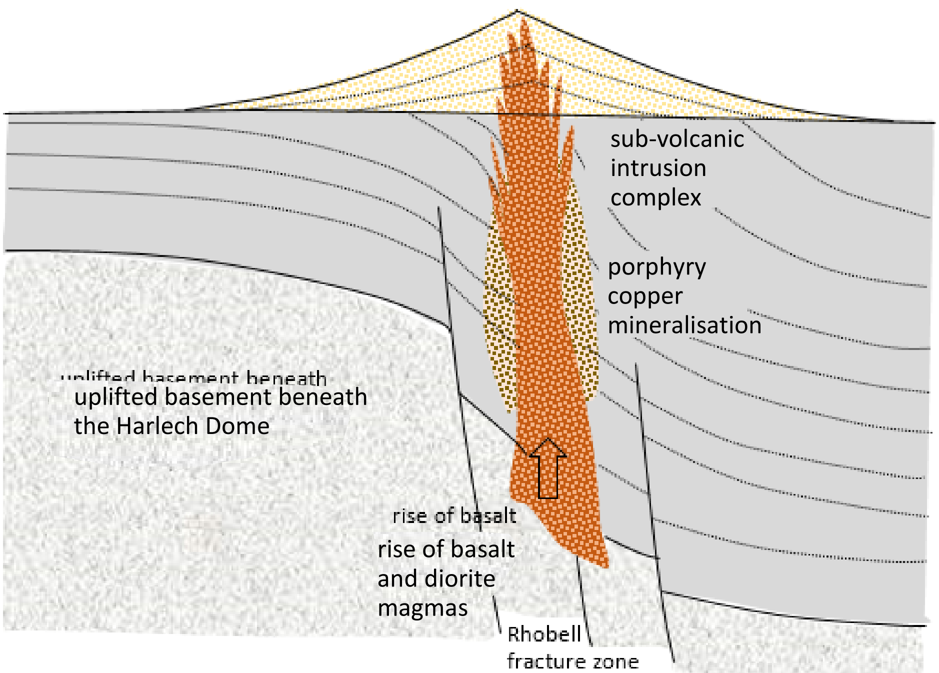


Figure 237: Cross-section of the Rhobell volcanic centre.

Precipice Walk

3 miles: approximately 1½ hours

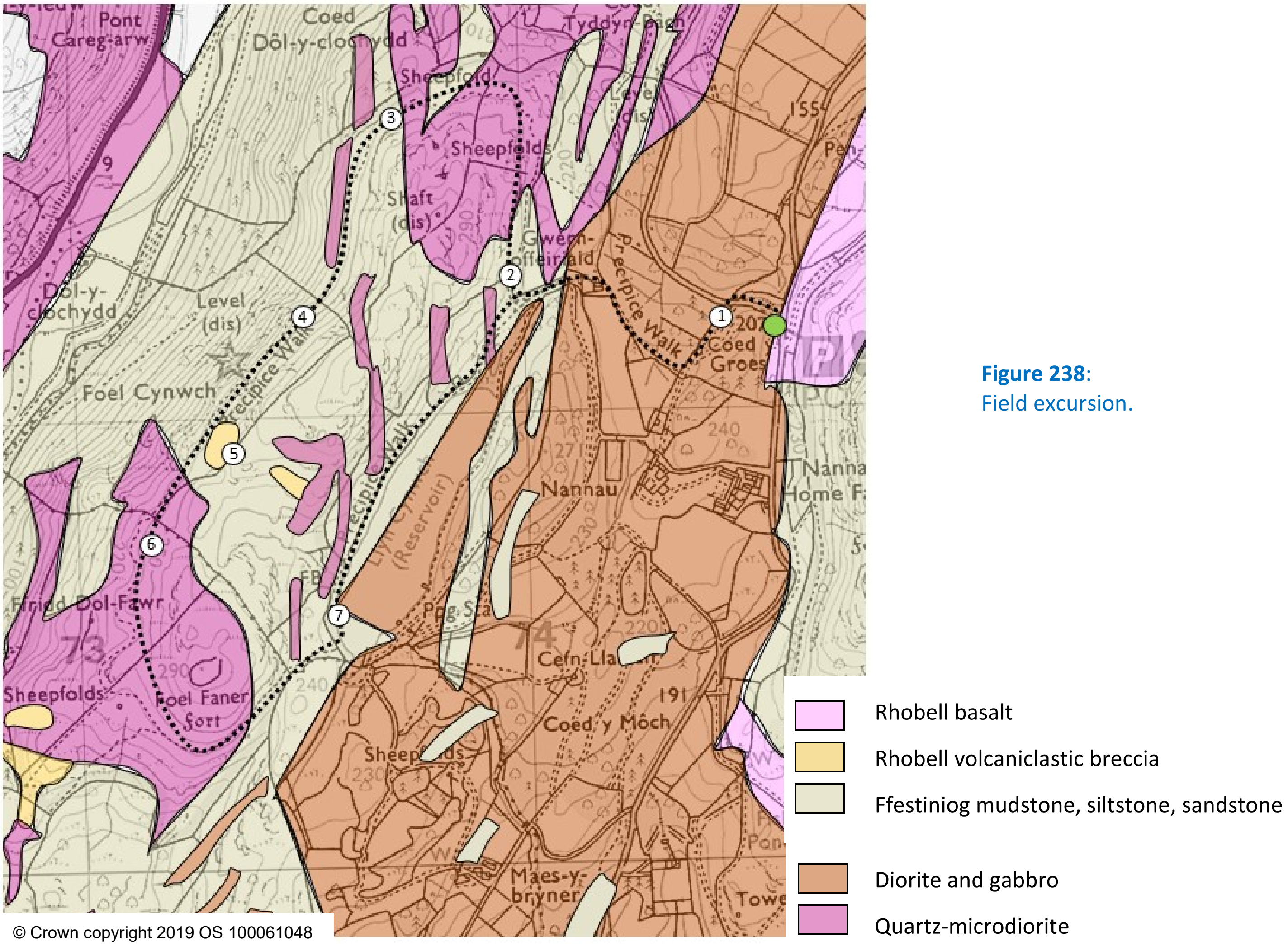


Figure 238: Field excursion.

We begin in the south of the Coed y Brenin area with an excursion to examine Ffestiniog sediments, igneous intrusions of the Rhobell fracture zone, and a large breccia pipe associated with the Rhobell volcanic episode.

Start: Take the minor road from Dolgellau to the car park at the start of the Precipice Walk near Llanfachreth village [SH746212].

1: Follow the footpath towards Llyn Cynwch

2: As Llyn Cynwch comes into view, take the footpath which branches to the right and rises up the hillslope to follow a dry stone wall.

3: Continue around the end of Foel Cynwch and follow the hillside path high above the Mawddach valley. By the side of the path, outcrops of Ffestiniog sandstones and microdiorite intrusions are visible.

The Ffestiniog Formation consists of hard, light grey, fine sandstones and siltstones which are interbedded with darker massive mudstones without visible bedding. The nature of the sediment and the depositional structures suggest that the Ffestiniog beds were deposited in a relatively shallow coast or estuary environment, either intertidal or within storm wave depth.

The relative proportions of sandstone and mudstone vary between different stratigraphic levels in the succession, representing changes over time in the nature of the sediment supply, the transport direction of bottom currents, and the location of sediment deposition relative to the shore line.

The sediments are cut by a number of sheet intrusions, generally of fine grained microtonalite which weathers to a light grey colour due to a high silica content.

Figure 239: Sedimentary structures in the Ffestiniog beds. (left) ripples, (right) flaser bedding.

4: Continue along the path, observing outcrops of Ffestiniog laminated mudstones and siltstones.

The siltstones vary between thin lenses and thick beds of up to quarter of a metre. They are interbedded with mudstones which have a cleavage at a steeper angle. Ripples, often symmetric in cross section, are developed on bedding planes and within thicker beds. A particular feature of the rocks is **flaser bedding**. Isolated sand ripples are found, separated horizontally by mud. This structure is characteristic of some tidal environments where sand ripples form during periods of fast high energy water flow, and are then infilled by mud during quieter low energy flow.

Figure 240: Breccia pipe above Precipice Walk
(above right) pinnacle produced by the breccia outcrop.
(below left) tight vertical folds in the sediments alongside the breccia pipe.
(below right) breccia within the pipe.

5: Pass through two gates to reach a point where a large rock pinnacle can be seen on the hillside above the path (fig.240). This is a volcanic breccia pipe. It is possible to climb up the heather hillside to inspect the outcrop. As the breccia pipe is approached, outcrops of Ffestiniog siltstones show tight vertical folds, suggesting that the sediments were forced outwards by the expanding breccia intrusion.

The breccia within the pipe is a mixture of Ffestiniog siltstone fragments in a matrix of mud and ash with flow foliation. Veins of calcite and sericite are present, cementing some of the fragments. There is no evidence of heavy metal mineralisation of the kind seen at Glasdir, so the pipe may simply have formed an escape route for high pressure steam generated at the margins of the sub-volcanic magma chamber in the later cooling phase of the Rhobell volcanic episode.

6: Return to the Precipice Walk footpath and continue around the hillside. Examine outcrops of grey microtonalite in the cuttings alongside the path, and view the exposures on the cliff faces above the path.

Flow foliation is present in the rock, indicating the directions in which the viscous magma was intruded. A point can be found where an upwards transition occurs between vertical and horizontal flow.

At a number of localities around the Harlech Dome, we find that the orientation of sheet intrusions is strongly controlled by sedimentary strata. Hot magma moves upwards due to its low density compared to the cold rocks surrounding it at depth. Flow often takes place along deep crustal fractures. As the magma rises, it passes through sediments which have been less compressed and are less dense. A point of **lithostatic equilibrium** is reached, where the densities of the magma and surrounding crustal rocks are equal, and further uprise of the melt is inhibited.

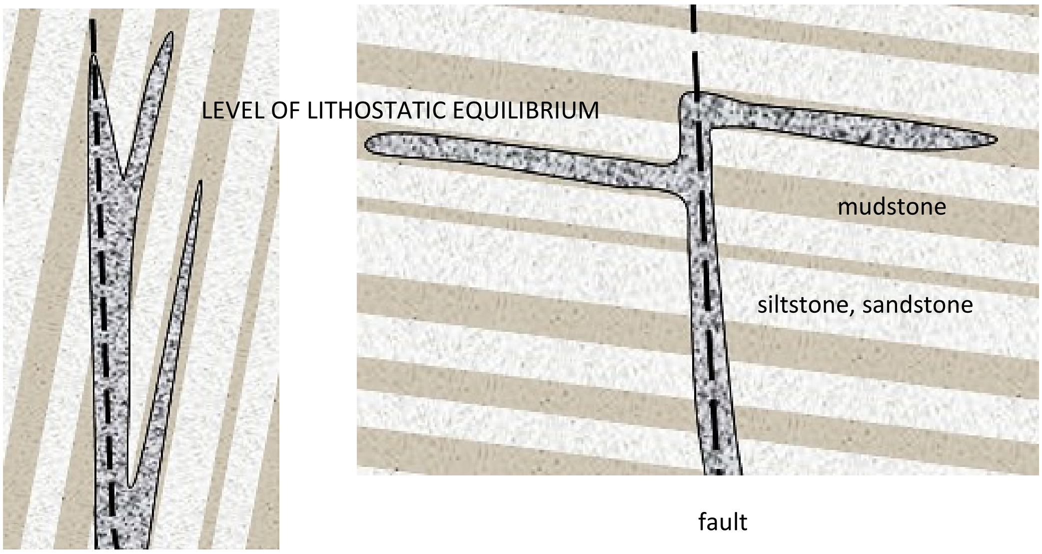


Figure 241: Orientations of sheet intrusions in relation to bedding.

Magma will move preferentially along softer mudstone horizons rather than through harder, more consolidated siltstones and sandstones. Where bedding is at a steep angle, multiple dyke intrusions are common, as in the intrusion complexes below the Rhobell volcano. However, in an area such as Precipice Walk where beds lie at a gentler angle, magma can flow more easily outwards to produce sill sheets.

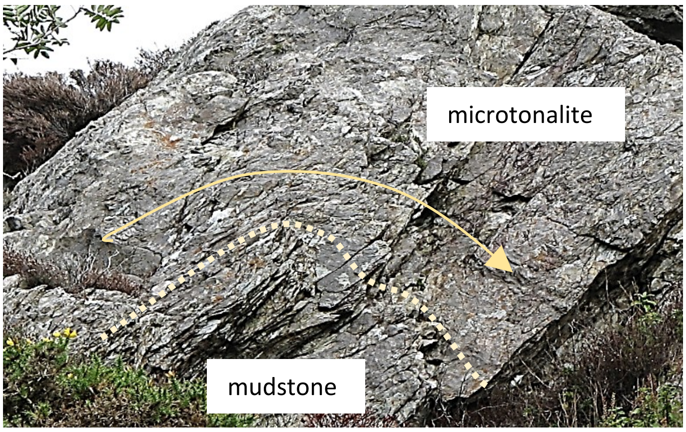
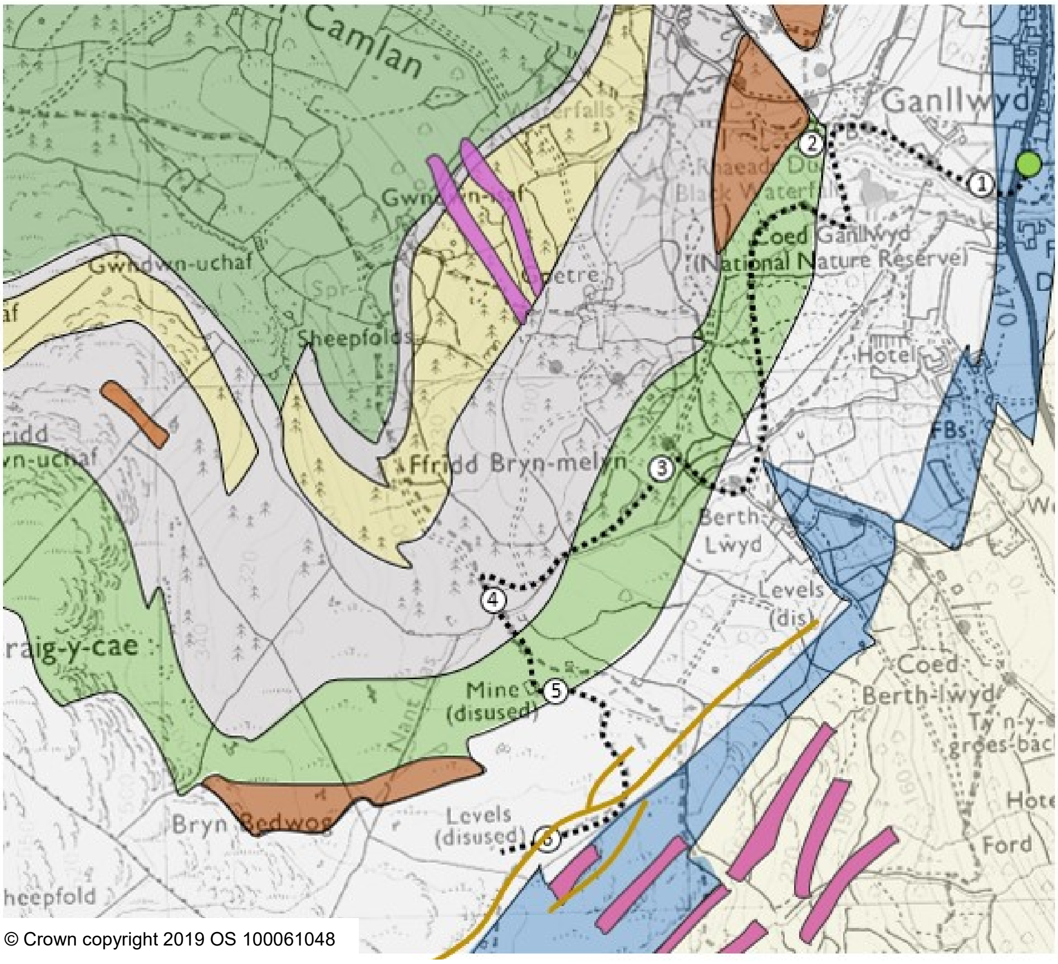


Figure 242: Orientation of an intrusion in relation to bedding of the country rock, at the point where a vertical dyke spreads laterally to form a sill.

7: Continue along the path beside the lake to return to the car park

Ganllwyd and the Afon Gamlan

3 miles: approximately 1½ hours



- Maentwrog mudstone, siltstone
- Clogau mudstone
- Gamlan mudstone, siltstone
- Barmouth sandstone, mudstone
- Hafotty mudstone
- Hafotty sandstone
- Rhinog sandstone, mudstone
- Quartz-microdiorite
- Diorite and gabbro

Figure 243: Field excursion.

In this excursion, we examine sediments of the Gamlan formation around their type locality of the Afon Gamlan. We again see sheet intrusions associated with the Rhobell volcanic centre, which at this point form the picturesque waterfalls of Rhaeadr Ddu. We complete the excursion by walking up the mountain to the site of the Cefn Coch gold mine.

Start: A car park is available in Ganllwyd village [SH727244].

1: Take the road uphill next to the village hall.

Beds of the Gamlan and Barmouth Formations are exposed in the river bed. The Gamlan Formation consists of grey silty mudstones, which may contain small particles of iron pyrite, and thin beds of coarse-grained sandstone. Similar sandstones occur at intervals throughout the Gamlan formation in Coed y Brenin.

Within the predominantly silty mudstone succession are four major sandstone members, including the Cefn Coch Grit. The beds are turbidite sandstone, greywacke to quartz wacke in composition, up to 2 m thick, in places with pebbly bases; they resemble the sandstones in the lower formations.

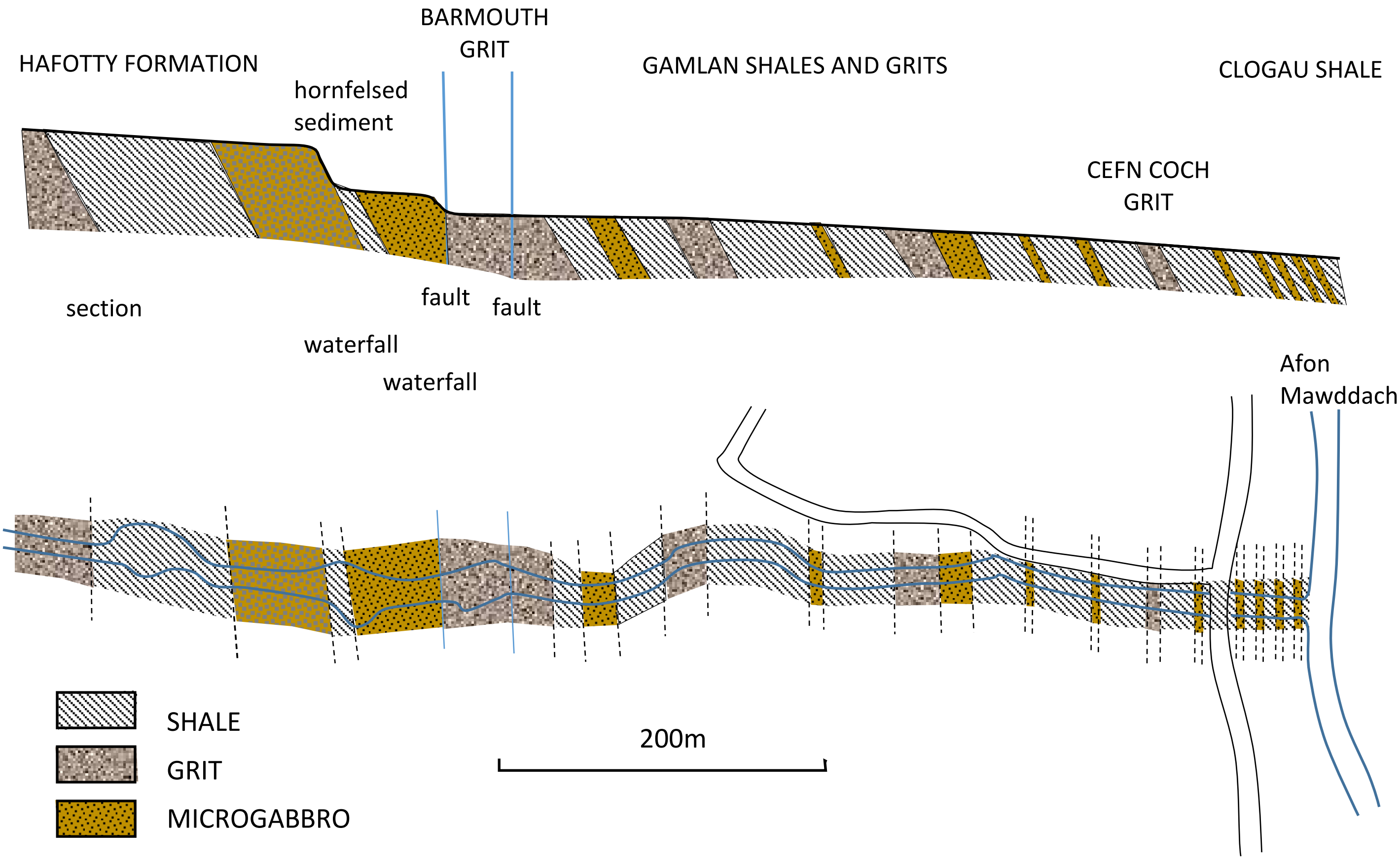


Figure 244: Outcrops along the Afon Gamlan, Ganllwyd.

Coarse-grained turbidite sandstones persist to the top of the formation, but interbedded with them in the upper half are laminae and thin beds of the coarse quartzose siltstone and fine sandstone which characterise the Mawddach Group. They are rare except in the top 20 m where, in some areas, they exceed coarse sandstone in proportion.

Figure 245: Gamlan quartz granule conglomerate and grit, Afon Gamlan.

2: Turn into the woods at the sharp bend in the road, taking the footpath to Rhaeadr Ddu waterfalls.

The lower and upper falls occur over sills of microgabbro. The lower fall is at the faulted contact with the Barmouth Grit. The upper fall is the upper surface of a sill intruded into hornfelsed sediment of the Hafotty Manganese Formation.

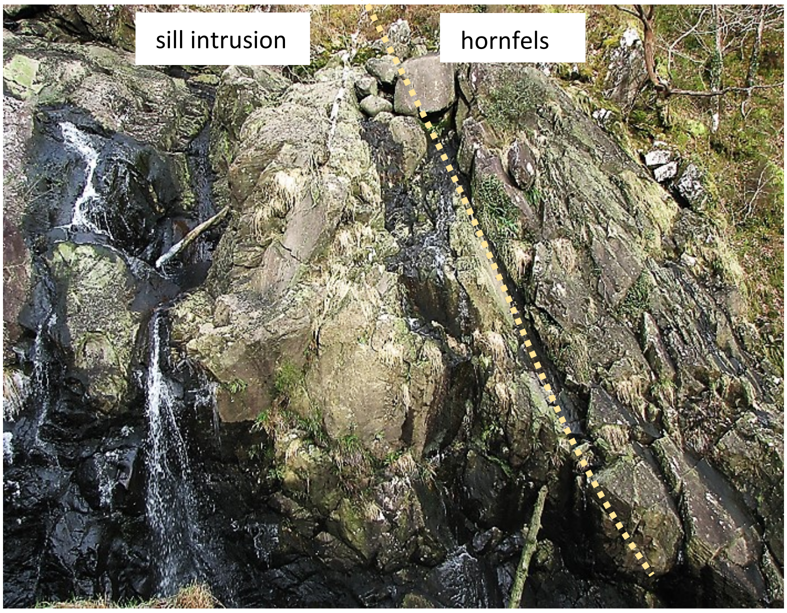


Figure 246: (above) Waterfalls over microgabbro sill intrusions at Rhaeadr Ddu. (below) Hornfelsed sediments above the microgabbro sill at the upper waterfall.

3: Cross the bridge over the river and continue up through the woods to Berth Lwyd, observing the remains of the gold mine site.

4: Continue upwards through the wood and turn onto the mine track. The cliffs of Craig-y-Cae to the west are composed of proximal turbidite grits of the Barmouth Formation. The Barmouth grit outcrop swings around in the nose of an anticlinal fold at this point and returns down to the waterfalls, with the Hafotty Manganese group underlying the grits.

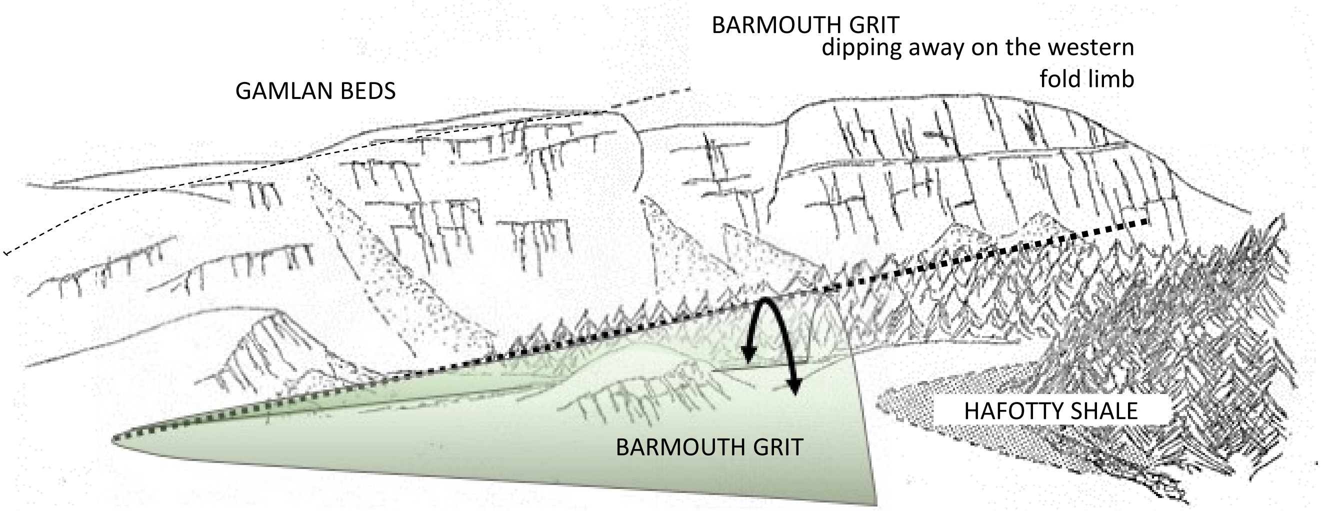


Figure 247: View looking west from Cefn Coch mill.

The anticline at Craig-y-cae is one of a series of parallel north-south oriented folds incorporated in the larger Dolwen Pericline structure at the centre of the Harlech Dome.

5: Observe the ruins of the Cefn Coch mill.

6: Examine the series of adit tunnels on the hillside.

Cefn Coch, and the adjacent Berth Lwyd mine lower on the hillside, worked several branching mineral lodes oriented approximately north-east to south-west which can be traced for about 2 kilometres. The mines were active from the 1860's. The heavy metal content declines with depth in the Gamlan formation, so the workings are close to the surface. Open trench workings and a series of adit tunnels have been excavated. When adits reached the mineral lode, the ore was extracted in stope workings which often extended up to the surface. Gold and other heavy metals were found in the quartz lodes, in addition to the lead ore galena, the copper mineral chalcopyrite, and the zinc mineral sphalerite.

The mineral lode often has the form of multiple parallel branching sheets of quartz emplaced along the cleavage planes of the enclosing shales.

The gold and other heavy metals were found in the quartz lodes close to the junction between the Gamlan shales and the overlying Clogau mudstones. The junction between the Gamlan and Clogau formations is transitional, with a gradual decline in turbidite grits and siltstones and an increase in the proportion of dark mudstones containing carbonaceous material and pyrite. The Clogau Formation represents a change in basin conditions, with turbidite events dying out and quiet deposition of muds becoming dominant. Deep water anoxic conditions preserved carbon and iron sulphide in the muds, derived from the decomposition of marine organisms. It is the presence of carbon and pyrite in the mudstones which is likely to have precipitated heavy metals at this point, as we will discuss in a later chapter about the Dolgellau Gold Belt.

Figure 248: Cefn Coch mine:
(left) Adit tunnel at Cefn Coch mine.
(above) Multiple quartz lenses in the vein.

Return to Ganllwyd by retracing your route down through the forest.

Afon Mawddach in Coed y Brenin

4 miles: approximately 2 hours

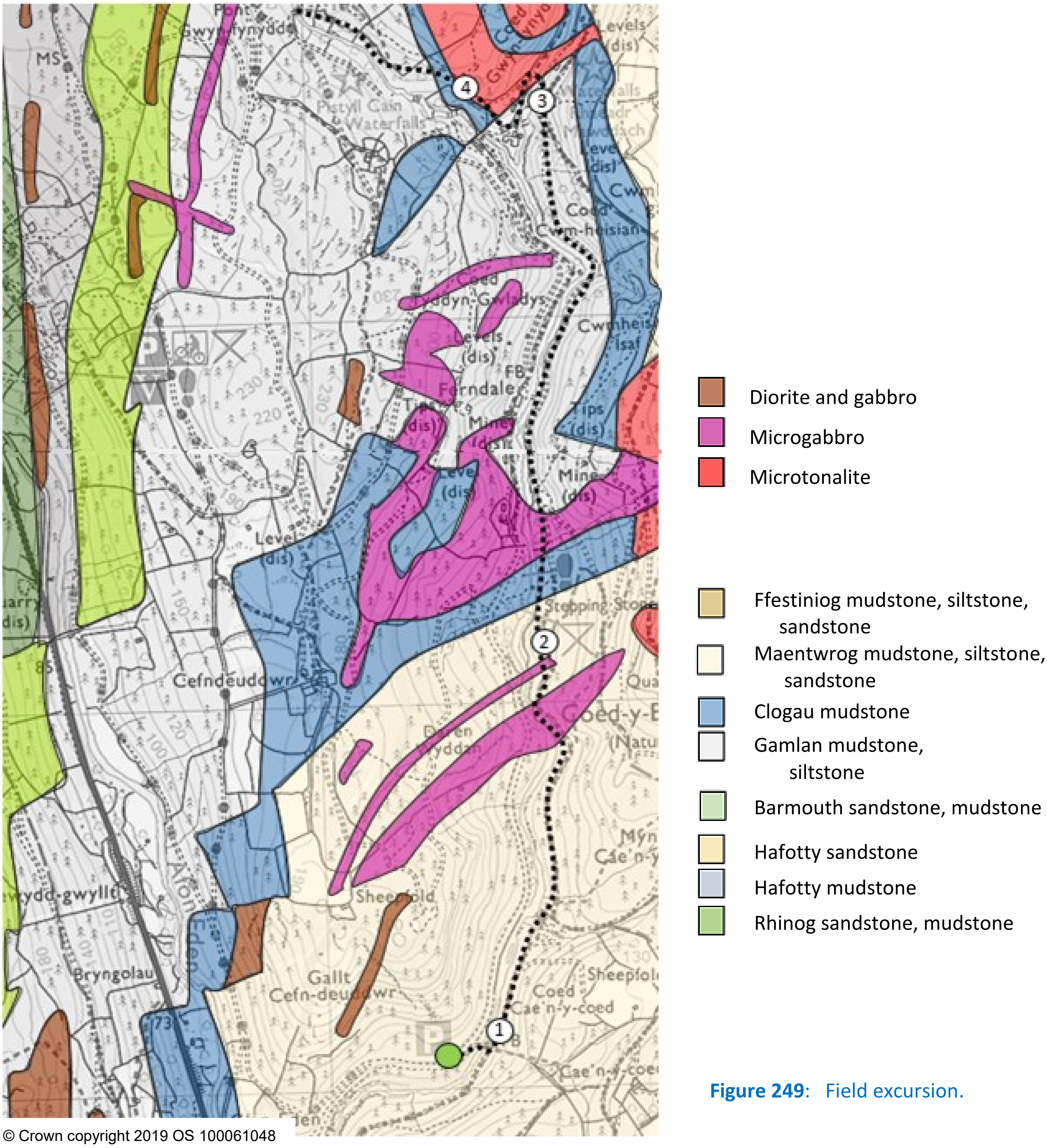


Figure 249: Field excursion.

In this excursion we move downwards in the Mawddach Group succession, examining outcrops of the Maentwrog, Clogau and Gamlan formations, along with intrusions related to the Rhobell volcanic episode and later Ordovician volcanicity.

Start: Leave the main road at the north end of Ganllwyd village. Continue along the minor road to the Forestry Commission car park in the Mawddach valley below Cefn Deuddwr [SH733251].

1: Cross the footbridge and follow the east bank of the river. Examine outcrops of the Maenwtwrog formation. These rocks represent a sudden return to turbidite deposition following the quiet low energy conditions under which the muds of the Clogau Formation were laid down.

Figure 250: Afon Mawddach Ganllwyd.

At this point, the Maentwrog Formation consists mainly of well-bedded coarse turbidite siltstones and fine sandstones, composed of quartz grains and some very small lithic fragments produced by weathering of earlier igneous rocks. The rocks are similar to the distal turbidite succession seen at Panorama Walk, Barmouth.

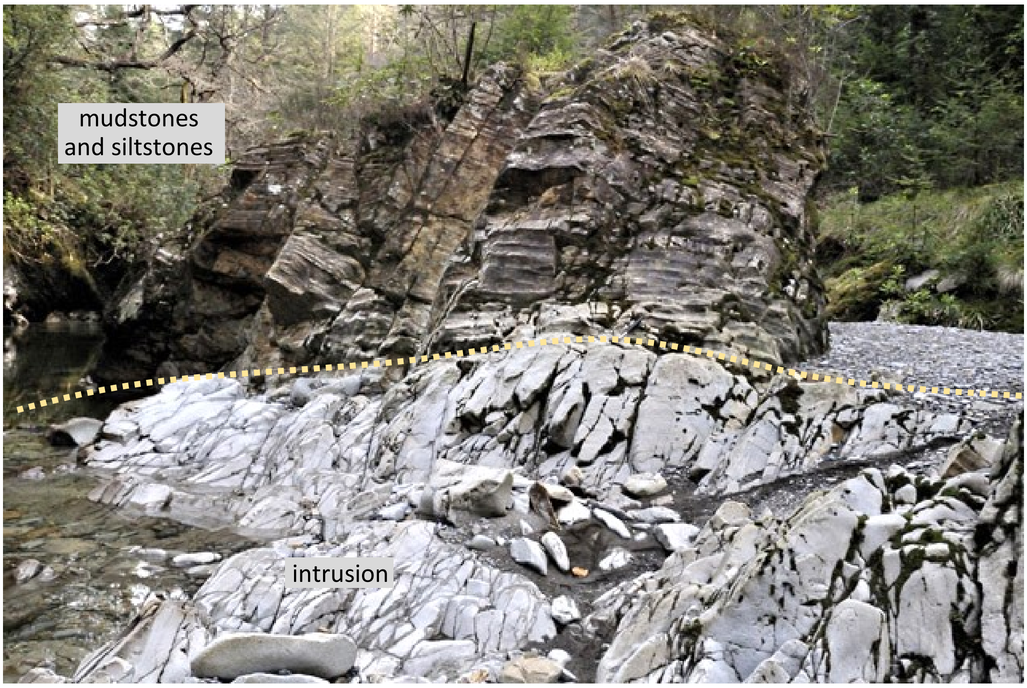
2: Several intrusions of microgabbro and microtonalite are exposed in cuttings along this section of the forestry track, and can be seen in the river bed and banks below.

Continuing along the forestry road, we see outcrops of Clogau mudstone and then Gamlan siltstone and sandstones.

The Gamlan Formation is of interest because of its variation across the area. Around the Mawddach estuary between Bontddu and Barmouth, and also at St Tudwal's peninsula in Lleyn, the formation consists mainly of thinly bedded siltstones and mudstones characteristic of distal turbidites, with ripples and cross-bedding indicating redistribution by bottom currents in the basin between turbidite events. By contrast, the Gamlan beds outcropping in Coed y Brenin in the east of the Harlech Dome contain a greater proportion of sandstone and coarse siltstone, and individual beds are much thicker. These rocks are more characteristic of proximal turbidite deposition, with minor quantities of mud accumulating between turbidite events.

During Gamlan times it is likely that turbidity currents discharged down submarine slopes in the area of Coed y Brenin, with sediment flowing into deeper waters to the west towards Barmouth and northwards towards Lleyn. The location of the submarine slope seems to be related to the north-south Rhobell fracture zone. Subsidence of the central Harlech Dome crustal block along this

Figure 251: Microtonalite dyke cutting Maentwrog strata in the Afon Mawddach.



fracture zone during Gamlan times may have produced deeper waters into which turbidity currents could discharge from the shallower shelf sea to the east.

3: Leave the forestry road and cross the Afon Mawddach by a stone bridge. Turn to the left and descend along the forestry track for a short distance to the site of the former processing mill for Gwynfynydd gold mine. From this point, Rhaeadr Mawddach can be seen.

Figure 252: Rhaeadr Mawddach, formed by a microtonalite intrusion within siltstones of the Gamlan Formation.

Rhaeadr Mawddach waterfall has been produced by a resistant microtonalite sill associated with the Rhobell volcanic centre which crosses the valley at this point.

Continue a short distance down the valley to the confluence with the Afon Gain. The similar but larger waterfall of Pistyll Cain is also produced where a thick microtonalite sill within the Gamlan Formation crosses the valley.

4: Return up the forestry road to the stone bridge over the Afon Mawddach. The road continues to the Gwynfynydd mine site, which we will visit in a later chapter.

Figure 253: Pistyll Cain, cut in Gamlan turbidite grit.

Take the footpath which climbs steeply up the valley side above Pistyll Cain waterfall, then continues along the valley to reach Pont Gwynfynydd.

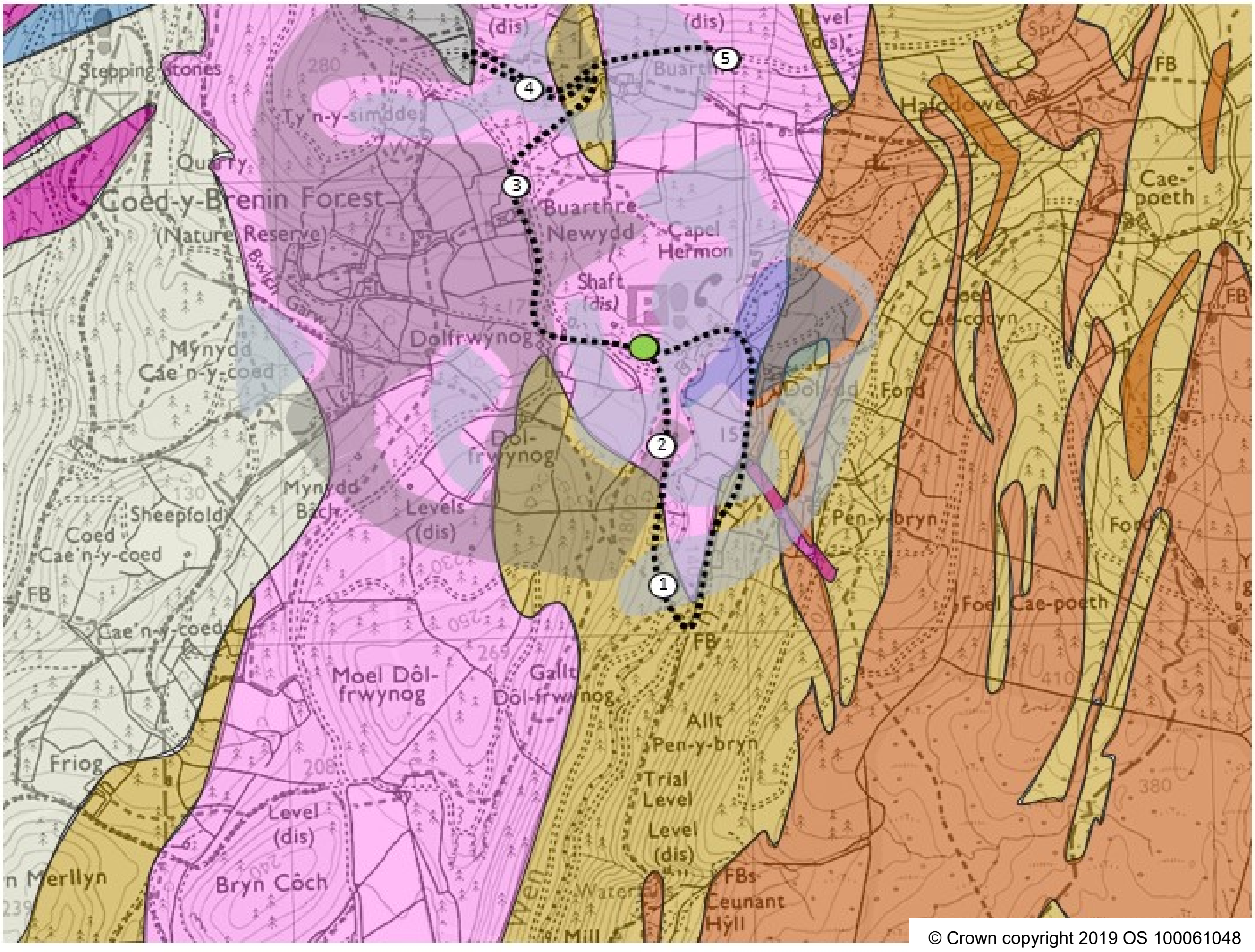
Descend along the valley side on the east bank of the Afon Gain. Waterfalls are cut in massive sandstones of the Gamlan Formation. A horizontally bedded sequence of fine turbidite sandstones and siltstones is well exposed in the gorge between Pont Gwynfynydd and the head of the Pistyll Cain waterfall (fig.253).

Figure 254: Afon Gain, cut in Gamlan turbidite grit.

Return by retracing your route down the valley.

Hermon

3 miles: approximately 1½ hours



Ffestiniog mudstone, siltstone, sandstone	Diorite and gabbro
Maentwrog mudstone, siltstone, sandstone	Microgabbro
Clogau mudstone	Microtonalite

Alteration zones of the Coed y Brenin porphyry copper deposit

propylitic   sericitic   argillic

Figure 255: Field excursion.

The objective of this excursion is to examine intrusions in the Rhobell fault zone around the village of Hermon. Intense hydrothermal alteration has occurred in both the igneous rocks and Cambrian sediments in this area, and has been accompanied by the deposition of large quantities of copper and iron minerals. Both the hydrothermal alteration and heavy metal mineralisation are associated with the Rhobell volcanic centre to the east.

Three different types of hydrothermal reactions have been identified in the rocks at Hermon, based on the secondary minerals formed:

Propylitic alteration, where biotite and plagioclase feldspar are broken down to chlorite and epidote:

$$\underset{\text{supplied in the fluid}}{\text{biotite} + H^{+}} \rightleftharpoons \text{chlorite} + \text{quartz} + \underset{\text{removed in the fluid}}{K^{+}}$$

$$\text{plagioclase feldspar} + \text{quartz} + H_2O + \underset{\text{supplied by the fluid}}{Na^{+}} \rightleftharpoons \text{epidote} + \text{albite} + \underset{\text{removed in the fluid}}{H^{+}}$$

Sericitic alteration, where orthoclase feldspar is converted to sericite:

orthoclase fledspar + H^+ ⇌ sericite + quartz + K^+
supplied in the fluid — removed in the fluid

Argillic alteration, where sericite has been further converted to clay minerals:

sericite + H_2O + H^+ ⇌ kaolinite + K^+
supplied by the fluid — removed in the fluid

Hydrothermal alteration takes place beneath the volcano during the late stages of cooling of the magma chamber when superheated steam is released, carrying heavy metals and other minerals in solution. In a simple volcano, the zones of alteration form concentric rings extending outwards from the magma chamber core. The argillic zone represents the most intense alteration of the original igneous rocks, whilst the sericitic and propylitic zones represent decreasing degrees of alteration.

The simple model of concentric alteration zones has been modified to some extent at Hermon, due to vertical movements of slices of crustal rock within the Rhobell fracture zone. The intensity of hydrothermal alteration increases from west to east across the fracture zone (fig.255), suggesting that the most altered rocks in the argillic zone in the east have been carried upwards from the greatest depth, whilst alteration in the propylitic zone to the west took place closer to the surface.

Figure 256: Mineralisation around Hermon. Locations on the field excursion are numbered.

The majority of alteration within the igneous intrusions of the Hermon area was produced by hydrothermal fluids released from the solidifying magma chamber of the Rhobell volcano. However, alteration in the surrounding sedimentary rocks was largely the result of circulating groundwater heated by the underlying magma chamber. Convection cells were active for a long period after the volcanic centre became extinct. Mineralising fluids moved through fractures in the rock, breaking down feldspars and depositing quartz and metal sulphides.

Start: A parking area is available at the forestry road junction above Hermon [SH748256].

1: Return along the road to the river bridge at Hermon. Follow the road southwards along the Afon Wen valley. After about 500 metres, leave the road and descend along a footpath to the waterfall pool and footbridge over the Afon Wen.

Siltstones and mudstones of the Ffestiniog Formation outcrop to the west of the river, with an intrusion of microtonalite on the east of the pool. The Afon Wen fault passes through the pool. This

Figure 257: (above) The Afon Wen fault is exposed in the outcrop to the right of the waterfall. (below) Cemented fault breccia.

is one of a series of north-south faults making up the Rhobell fracture zone. The fault is infilled by a cemented breccia containing large angular blocks of the adjacent igneous and sedimentary rock types.

2: Cross the footbridge and follow the path to reach a forestry road. Continue back along the road towards Hermon. After a short distance, a road cutting exposes a heavily altered diorite intrusion with prominent green colouration due to copper mineralisation. This is an outcrop of the Coed y Brenin porphyry copper deposit.

Figure 258: Sericitic alteration of diorite with copper mineralisation.

The original igneous rock has been heavily decomposed to sericite, although larger feldspar sulphide **chalcopyrite**, but this has been broken down by circulating groundwaters to produce the copper carbonate mineral **malachite.**

It is clear from examining the outcrop that the grade of the copper ore is very low, around 0.3% copper metal, but the deposit extends over an area of more than a square kilometre. If extracted and processed, it has been estimated that the Coed y Brenin deposit would provide around 600,000 tonnes of copper metal.

3: Return to the parking area and continue up the surfaced road. Take the right branch to Buarthre.

4: Continue up the forestry road and park at the T-junction at the top of the hill. Walk along the road to the left, where large road cuttings expose rocks within the alteration zone of the Coed y Brenin porphyry copper deposit.

Bedding is visible in siltstones and mudstones of the Ffestiniog Formation. The road cuttings lie in the sericitic zone, in an area of disseminated iron pyrite deposition. Alteration products are visible as orange colouration and development of soft mica-type minerals.

At this point there is evidence of the epithermal mineralisation processes which occurred in the late stages of the volcanic episode. Deep circulating groundwater at relatively low temperatures of 200-300^{0}C and pressures of a few hundred bars was able to dissolve silica and metals, then flowed upwards through fractures where deposition of quartz veins occurred. We see that rocks within a fault zone have been heavily decomposed, and pods of pyrite and quartz occur nearby. Brecciation has affected the

Figure 259: Hydrothermal alteration at Buarthre:
(right) Mineralised fracture cutting Ffestiniog siltstones.
(below left) Sericitic alteration of Ffestiniog shales.
(below right) Quartz and iron sulphide vein mineralisation.

overlying strata. This evidence gives us an indication of the conditions which existed in the deeper crust below the copper mineralised breccia pipe of Glasdir further to the south.

Figure 260: Stockwork of pyrite filled fractures in hydrothermally altered diorite.

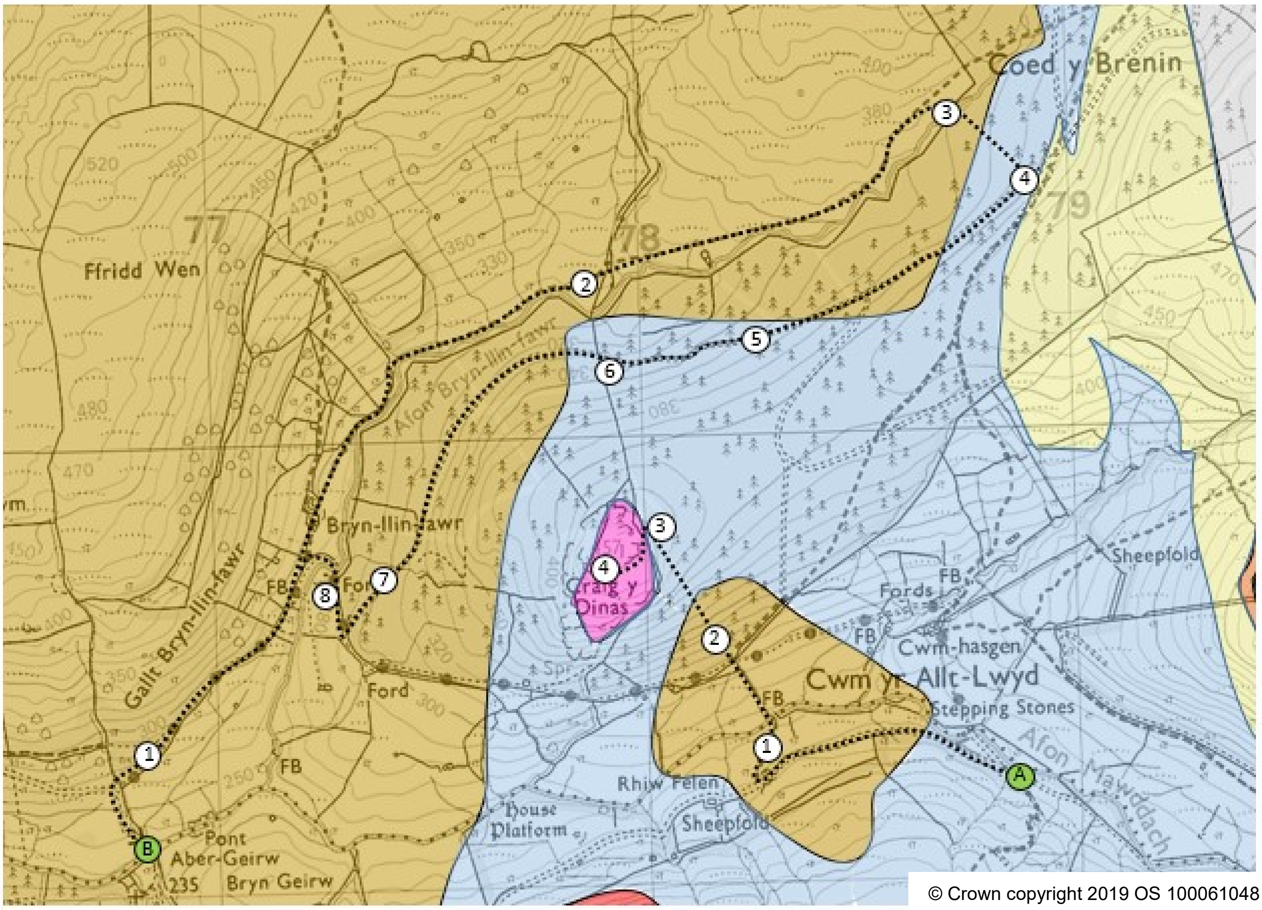
5: Follow the forestry road to the east, examining further outcrops of rock heavily impregnated by pyrite. We are within the zone of high iron precipitation which lies to the east of the porphyry copper deposit. Primary hydrothermal fluids released during cooling of the magma chamber caused decomposition and brittle fracturing of the overlying rock, creating a network of small fractures in which pyrite was deposited.

A small trial level has been excavated in a late epithermal quartz vein. This mineral vein was formed by groundwater circulation above the magma chamber.

Return along the forestry road to the parking point at Buarthre.

Abergeirw

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



- Allt Lwyd mudstone, siltstone, sandstone
- Garth Grit sandstone
- Dol-cyn-afon mudstone, siltstone
- Dolgellau mudstone, siltstone
- Ffestiniog mudstone, siltstone, sandstone
- Rhobell basalt
- Microgabbro

Figure 261: Field excursion.

In this section we undertake two field excursions: the first to Rhobell basalts which form an **outlier** at the summit of Craig y Dinas, and the second to visit fossiliferous localities in the Bryn-llin valley where brachiopods and trilobites may be found.

Excursion A Start: Take the minor road from Abergeirw to Cwm yr Allt Llwyd. Some parking space is available at the road junction near the river bridge at Cwm Hasgen [SH788292].

1: Return along the road and descend across the field to reach a footbridge across the river.

2: A prominent fire break will be seen in the forest ahead. Walk up the field, then follow the firebreak to the crest of Craig y Dinas hill.

Figure 262: Craig y Dinas. The hill is composed of Dolgellau mudstones, capped by an outlier of Rhobell basalt. The route to the summit is indicated.

3: At the top of the firebreak, turn to the left and work your way through the forest for a short distance until the open summit area of Craig y Dinas is reached.

Please note: the forest at this point is in an abandoned state with many fallen trees and thick growth of brambles and other vegetation. It is recommended that markers are placed on trees, using a biodegradable material such as paper, to help in finding the return route to the firebreak.

4: Outcrops of blue-grey Dolgellau mudstones are seen in the lower part of the open summit area (fig.263). A bedding plane dip of around 40^0 is observed, along with a near vertical slaty cleavage.

Continue westwards to reach a line of crags formed by Rhobell basalt. A lower angle of dip of around 20^0 is observed in the basalts, suggesting that an angular unconformity is present. Folding, uplift and erosion seems to have occurred in late Cambrian times before eruptions of Rhobell basalt began.

Figure 263: (left) Dolgellau mudstone, with bedding surface indicated. (right) Rhobell basalt grading upwards into agglomerate. Bedding surface indicated.

The basalts at this point have been weathered to a rough surface of large protruding feldspar crystals. The basaltic melt is likely to have contained these early formed crystals at the time that it was erupted, giving the rock a porphyritic texture. Individual lava flows can be identified which grade upwards into agglomerate, suggesting the incorporation of the rubbly surface of the flow as it advanced.

Return through the forest to the firebreak, then descend to the valley floor.

Excursion B Start:
Some parking space is available near Pont Aber-Geirw [SH768291].

1: Walk northwards up the road from the bridge take the farm road which branches to the right after a short distance. Continue through the farm to join a footpath which descends to the riverbank.

2: Follow the river bank to a small outcrop of dark coloured mudstone of the Ffestiniog Formation. Examination of the thin layers can reveal an abundance of small black shells of the brachiopod *Lingulella*.

Figure 264: Lingulella brachiopods in Ffestiniog mudstone.

Most of these shells appear intact with only a few broken pieces, suggesting burial in a low to medium energy marine environment. Growth lines on the shells were clearly visible on the larger pedicle valves and smaller brachial valves.

These brachiopods would have lived in a shallow intertidal marine environment. Although they can remain free lying on the sea bed, it is possible that they attached themselves via their 'fleshy stalk' the pedicle, onto something solid deep inside their burrow. When the pedicle was contracted Lingulella would return to the burrow for protection. The brachiopods fed on microscopic organisms and organic matter, collected through filaments extended from their open shells. The filaments were lined with cilia which generated currents to attract and trap food particles.

3: Continue along the river to reach a small waterfall. The Ffestiniog beds at this point are seen to be dipping eastwards at about 20^0.

Figure 265: Siltstones of the Ffestiniog Formation exposed in the Afon Bryn Llin Fawr.

4: From the waterfall, cross the valley floor and ascend through the forested area along a clear firebreak in a southerly direction for a couple of hundred metres until a forestry track is reached.

5: Walk back along the forestry track in the direction of Abergeirw. After a short distance, a shallow drainage ditch follows the bedding planes of dark grey Dolgellau mudstone (fig.275). The rock is fragmented, and the dark colouration indicates a high organic content. Pyrite is present.

A search can reveal an assortment of trilobite body parts. These include fragments of cephalon, thorax and pygidium which may have been discarded during moulting. The random orientation of the body parts suggests a lack of current in a low energy marine environment.

Figure 266: (above) Drainage channel exposing Dolgellau mudstone. (below) Fragments of trilobite exoskeleton.

6: Continue along the track to a quarry exposure of dark grey Dolgellau mudstone (fig.267). Well preserved trilobites can be found in this location including *Parabolina spinulosa* and *Peltura scarabaeoides*.

Figure 267:

(above) Quarry in Dolgellau mudstone.

(below) Slab split open to reveal casts of trilobites.

7: Continue along the forestry track to a cutting in Ffestiniog beds. Sedimentary structures typical of the Ffestiniog formation are well displayed. Ripples on bedding planes and cross bedding are indicative of moderately shallow water with currents able to transport sand and silt.

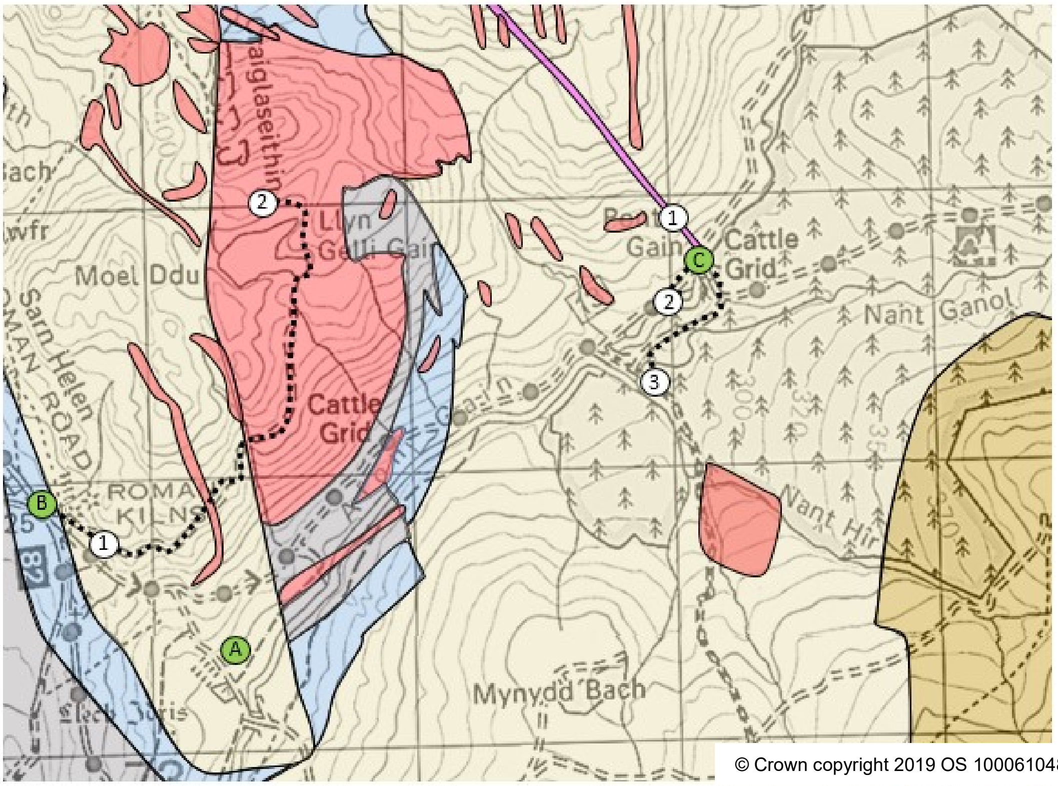
8: Return across the river to Bryn Llin Fawr farm, then descend along the road to Abergeirw.

Figure 268: Ffestiniog sandstones: (left) Cross-bedding. (right) Ripples on a bedding surface.

Pont y Gain

Excursion A: approximately ½ hour

Excursion B : 3 miles: approximately 2 hours
Excursion C : 1 mile: approximately 1½ hours



- Ffestiniog mudstone, siltstone, sandstone
- Maentwrog mudstone, siltstone, sandstone
- Clogau mudstone
- Gamlan mudstone, siltstone
- Microtonalite
- Microgabbro

Figure 269: Field excursion.

The objective of this excursion is to investigate geological structures affecting Maentwrog strata in the area of Pont y Gain, created by crustal movements within the Rhobell fracture zone. Before travelling to this location, we will gain a general impression of the local geology east of Bronaber by visiting a large quarry in Maentwrog siltstones, and a major intrusion of microtonalite.

Excursion A: From Bronaber, follow the road up through the holiday village and over the crest of the hill to reach the Afon Gain valley. Descend towards the river bridge. A large quarry in the Maentwrog Formation seen to the left of the road (fig.270) at SH732314.

Figure 270: Sill intrusion in Maentwrog siltstones.

Maentwrog siltstones and mudstones dip at a gentle angle, and are intruded by a sill of microtonalite in the western face of the quarry. The sill is slightly transgressive to the bedding of the sediments.

In the northern face of the quarry, a steeply dipping quartz-pyrite vein cuts the sedimentary succession. Quartz veins without metal sulphides are found in other parts of the quarry. All are oriented approximately north-east to south-west.

Excursion B: Return up the road towards Bronaber. After passing another quarry on the right, park near the start of the track to Llyn Gelli Gain [SH726318].

1: Walk up the track to the lake, which lies within the outcrop of the Craiglaseithin microtonalite intrusion.

Figure 271: Llyn Gelli Gain.

2: Examine exposures of microtonalite around the lake.

The Craiglaseithin intrusion has the form of a thick sill within the gently dipping Cambrian sediments in this area. The roof of the sill has been arched upwards as magma flowed into the intrusion, producing a **laccolith** structure. The intrusion lies at quite a deep level within the Cambrian succession, with Clogau and Gamlan Formation rocks along its eastern margin. This suggests that it is related to the Rhobell volcanic episode. Intrusions of the younger Aran Volcanic Group generally occur at higher levels within the upper Cambrian or Ordovician sedimentary sequence.

The western edge of the laccolith has been cut off by later movement along the Craiglaseithin fault.

Excursion C: After returning to the parking place above Bronaber, again take the road towards the Afon Gain valley. After a short distance, branch left along a minor road to Pont y Gain. A car can be parked at the road junction by the bridge.

1: A vertical microgabbro dyke outcrops on the hillside to the north of Pont y Gain. This dyke is remarkable in being almost constantly exposed as it runs in a straight line for more than a kilometre up the hillside. It is probably related to the Aran Volcanic Group of Ordovician age.

Figure 272: Microgabbro dyke intruded into Maentwrog sediments, Pont y Gain.

2: Walk down the road past the waterfall at Pont y Gain, then descend across the grassy slope to view the rock outcrops in the walls of the ravine below.

Whilst the general dips of the Maentwrog siltstones and mudstones are gentle in this area, we see several examples of tight monoclinal folds where the strata tilted into a vertical orientation for a short distance (fig.273). The axes of these folds run approximately north-south. It is likely that the folding occurred during vertical movements along the Rhobell fracture zone prior to the Rhobell volcanic event. The folds represent drape structures, as layers of sediment adjusted to changes in elevation of crustal blocks in the underlying basement.

3: Return to Pont y Gain, then follow the road across the bridge and up hill. After crossing a cattle grid, take the gravel track which branches to the right. Continue along the track to reach the confluence of two tributaries of the Afon Gain, the Nant Hir and the Nant Ganol. At this point, a rocky island in the river exposes a well developed monoclinal fold in the Maentwrog mudstones and siltstones.

Figure 273: Monoclinal folding in Maentwrog beds.

(above left, right) Pont y Gain.

(below) Confluence of the Nant Hir and Nant Ganol streams.