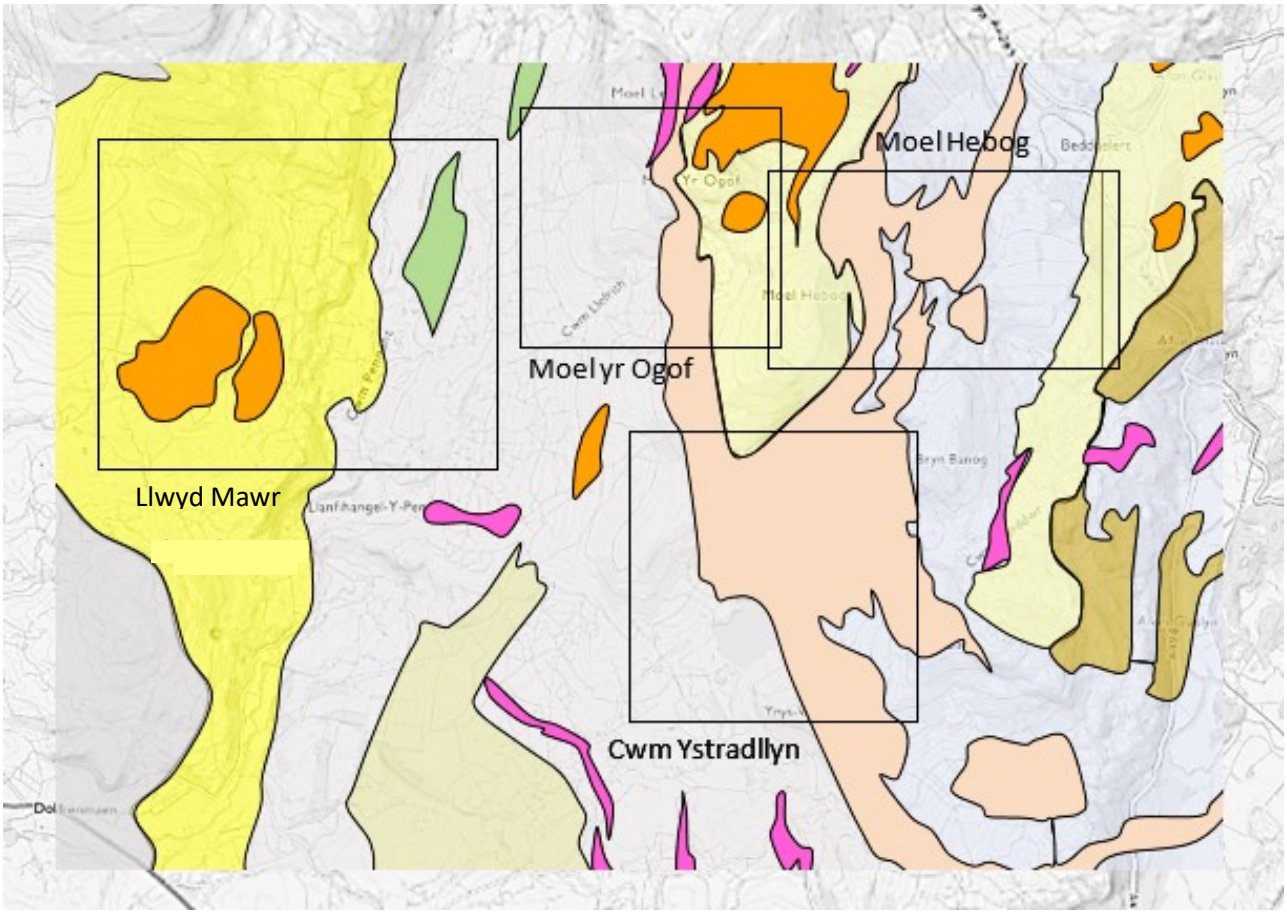
Moel Hebog

14



Cwm Eigiau Sandstone
Cwm Eigiau mudstone, siltstone
Moel Hebog Sandstone
Pitts Head felsic tuff
Nant Ffrancon siltstone
Marchlyn mudstone, siltstone, sandstone
Dol-cyn-afon mudstone, siltstone

Intrusive rhyolite
Microgabbro

Figure 398: Field excursions.

In previous chapters, we found that volcanic activity around the Harlech Dome and in the Lleyn peninsula reached its culmination towards the end of the Ordovician volcanic episode with the eruption of huge volumes of felsic ignimbrites and the emplacement of thick microgranite sills and large microgranite bosses. The climax of volcanic activity at this time also created a number of volcanic centres in central Snowdonia.

A long period of quiet sedimentation occurred in the north of Wales between the start of the Ordovician and the onset of major volcanic activity. During this time, mudstones of the Nant Ffrancon Formation and sandstones and siltstones of the Cwm Eigiau Formation were deposited in a marine basin. The outbreak of volcanic activity in the late Ordovician can be divided into two eruptive episodes; the Llewellyn Volcanic Group, followed by the Snowdon Volcanic Group.

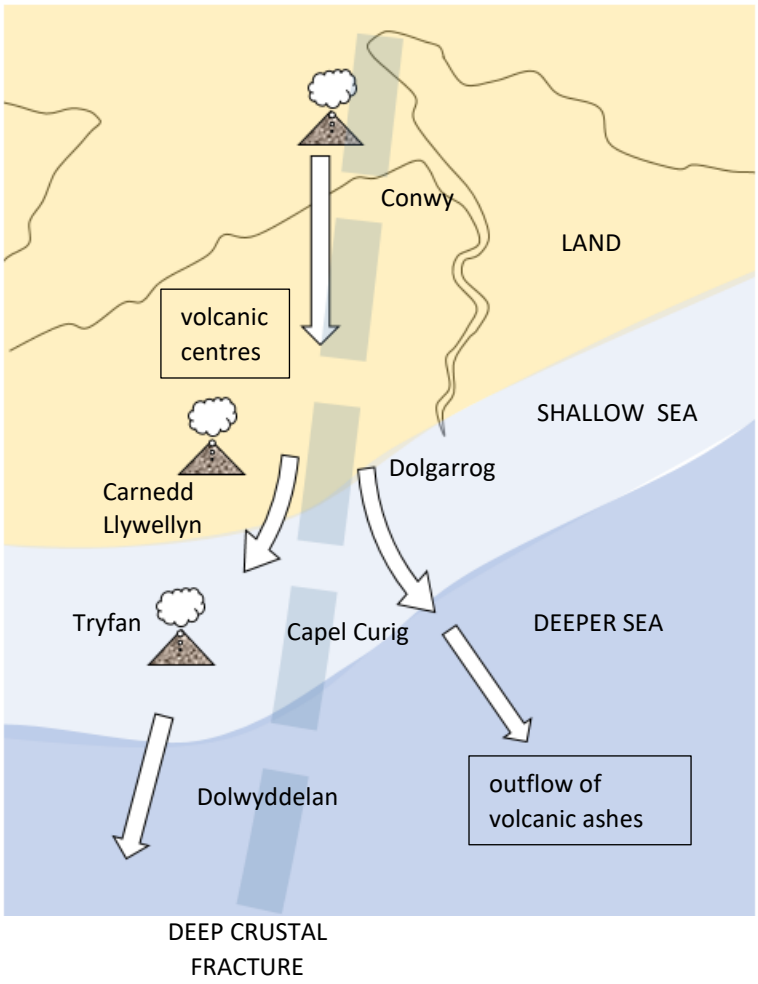


Figure 399:

Eruption of the Llywellyn Volcanic Group from centres near Conwy, Tryfan and the Carneddau.

As in other parts of North Wales, the distribution of volcanic centres in Snowdonia was controlled by deep crustal fractures. The Llewellyn Volcanic Group was erupted from centres located along a fracture zone from Conwy to Capel Curig (fig.399). This fracture forms a northerly continuation of the Rhobell fracture zone which we examined around the Harlech Dome. Rocks of the Llewellyn Volcanic Group consist mainly of felsic ashes, outcropping on the Carneddau mountains and Tryfan which lie to the east of the region included in this book.

Following the Llewellyn Volcanic Group eruptions, activity moved westwards into Snowdonia and was focussed at three centres: Llwyd Mawr near Tremadog, the Snowdon Centre around Beddgelert and Nant Gwynant, and Crafnant near Capel Curig. Eruptions took place from all three centres during the same period of time, so ash flows from the different sources became interbedded. In this chapter we focus on the Llwyd Mawr centre, whilst in the following chapter we will discuss the Snowdon centre in more detail. The Crafnant centre is outside the region covered by this book.

The Llwyd Mawr volcanic centre lies close to a series of faults along Cwm Pennant which are related to a deep crustal fracture. The Cwm Pennant fracture zone is unusual in having an orientation which is intermediate between the northeast-southwest transverse faults and the north-south tensional faults which we have encountered previously. Northwards, it runs into major transverse faults at Nantlle and Llanberis which form the boundary between Avalonia and the Arfon Basin terrane. Southwards, it runs into the tensional normal fault system which later allowed subsidence within the Cardigan Bay Mesozoic basin. The Cwm Pennant fracture zone may therefore exhibit both transverse and vertical fault movements.

Field evidence suggests that a subsiding trough existed around the Llwyd Mawr volcanic centre, into which up to half a kilometre thickness of ashes accumulated. Ash flows also travelled outwards from Llwyd Mawr across a neighbouring shore line into a shallow shelf sea, reaching the present day locations of Moel Hebog and Snowdon (fig.400). The deposits of the Llwyd Mawr centre have been divided into an **intracaldera facies**

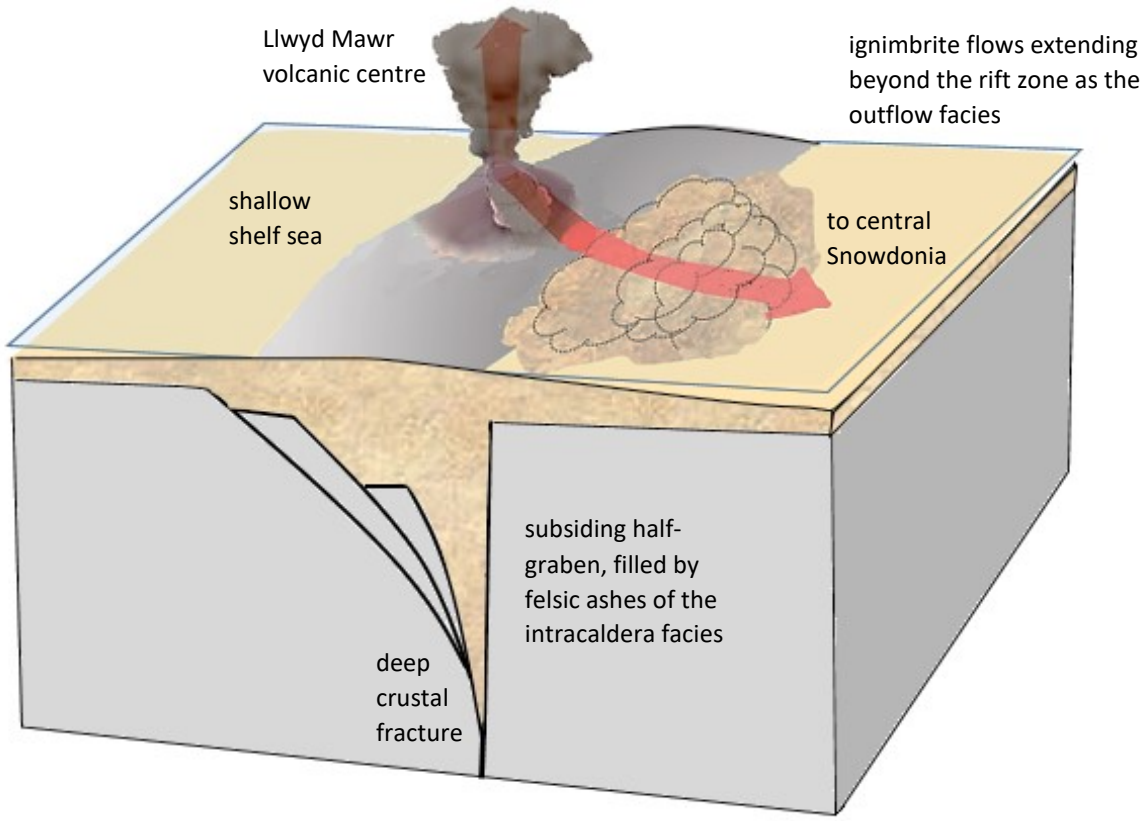


Figure 400: Eruptions from the Llwyd Mawr volcanic centre.

which accumulated within the subsiding trough, and an **outflow facies** which extended beyond the trough.

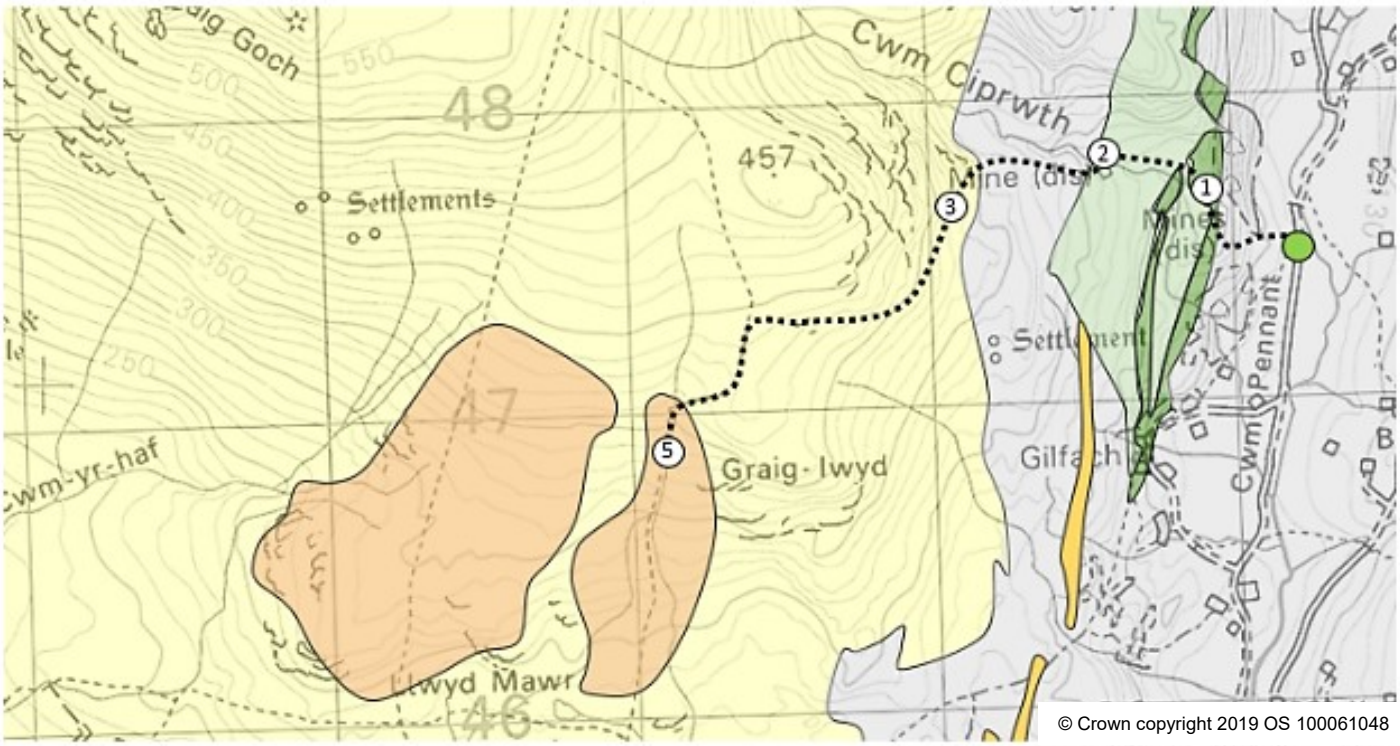
In the late stages of volcanic activity at Llwyd Mawr, a large mass of rhyolitic magma rose from an underlying magma chamber to form a dome-shaped intrusion at the core of the volcano. It appears that this very viscous magma did not break the surface to produce eruptions, but solidified in situ.

In this chapter we will visit the Llwyd Mawr volcanic centre, then move westwards to Cwm Ystradllyn to examine sedimentary rocks of the Cwm Eigiau Formation which were deposited in the marine basin around the time of eruptions from the Llwyd Mawr and Snowdon centres. Fine grained material has been converted to commercially workable slate deposits.

We then ascend the mountain of Moel Hebog. Here we find felsic ashes which flowed out from Llwyd Mawr, as well as ashes erupted from the Snowdon volcanic centre further to the east. A similar range of volcanic rocks are seen at our final destination of Moel yr Ogof, where we can also examine a felsic intrusion which lay on the rim of the large caldera associated with the Snowdon volcanic centre.

Llwyd Mawr

3 miles: approximately 2 hours



- Pitts Head Tuff, felsic
- Nant Ffrancon siltstone
- Carnedd Y Filiast Grit sandstone, conglomerate
- Marchlyn mudstone, siltstone, sandstone
- Allt Lwyd sandstone, siltstone
- Intrusive rhyolite
- Microgabbro

Figure 401: Field excursion.

We begin this excursion by visiting the site of the Gilfach and Cwm Ciprwth copper mines. Excellent restoration work has been carried out at Cwm Ciprwth on the water wheel and pumping system. The mine worked quartz lodes carrying copper and other metal sulphides. The mineralisation is likely to have occurred at the end of the volcanic episode in late Ordovician times. Residual heat from the magma chambers beneath the Llwyd Mawr and Snowdon volcanic centres produced convection cells of saline ground water which dissolved silica and heavy metals, particularly copper, from the overlying Ordovician ash deposits. The metals were carried upwards in solution through fissures in the rock, then deposited as the temperatures and pressures reduced with depth.

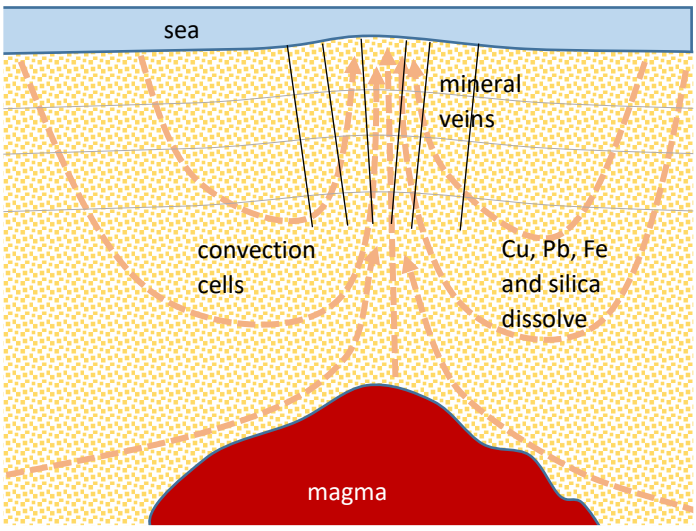


Figure 402: Copper mineralisation associated with volcanic centres in Snowdonia.

Start: Take the road up Cwm Pennant, past Plas-y-Pennant, parking at the river bridge [SH532476].

1: From the parking area, go through the field gate to join a very well waymarked path up through woodland towards the copper mines.

At the top of the wood, a waste tip is reached with a fenced adit of the Gilfach mine in the rock face. The rocks at this point belong to the Carnedd y Filiast Grit of the Marchllyn formation, and are exposed in a tight anticline (fig.403). They exhibit a variety of sedimentary structures characteristic of deposition in a shallow intertidal environment, including current bedding.

The Marchllyn formation is of Cambrian age, belonging to the rock sequence of the Arfon Basin. The tight anticlinal fold we see here is similar to the tight folds along the eastern margin of the Harlech Dome which were formed at the end of Cambrian times before the first eruptions from the Rhobell volcanic centre. This tight folding is very different in style to the broad open folds which were produced during later Devonian earth movements. Taken together, this evidence is consistent with a slice of the Arfon Basin crust being carried southwards into Cwm Pennant by transverse faulting in late Cambrian times. The strata were then subjected to east-west compression and folding, followed by a reversal of crustal stresses to produce east-west tensional rifting during the Ordovician volcanic episode.

Figure 403:

(above right) Tight minor fold in Marchlyn Formation rocks.

(below left) Adit of the Gilfach copper mine.

(below right) Current bedding in Carnedd y Filiast Grit.

2: Follow the waymarked path to the Cwm Ciprwth copper mine. Examine the mine workings and remains of machinery. The mine was active between 1850 and 1894, employing up to 18 men at its peak of production. Several shafts and levels can be seen, along with the ruins of the mine office and workshops.

Figure 404: Cwm Ciprwth copper mine site. (left) Rod system connecting the water wheel to an angle bob which operated pump rods in the mine shaft. (right) Water wheel providing power for pumping, and a geared winding drum for raising buckets of ore from the mine shaft.

3: From the mine, continue westwards above the river gorge following the line of the leat which carried water from the stream to the mine waterwheel. Cross open country formed by slates of the Nant Ffrancon formation. These slates have been quarried at several locations in Cwm Pennant.

Go to the rock face ahead, where rocks of the Llwyd Mawr volcanic centre are outcropping. The massive beds exhibiting columnar jointing are welded ignimbrite flows of the intracaldera facies (fig.405). Ignimbrites erupted from the Llwyd Mawr centre are known as the Pitts Head Tuffs, after a prominent rock outcrop called Pitts Head near Snowdon.

Ignimbrite is an ash flow deposit formed from pyroclastic material, ejected during an explosive volcanic eruption as a dense cloud which travelled outwards close to the ground surface. Much of the flow consisted of pumice fragments. As the pyroclastic material settled, it built up thick layers with an internal temperature above 500°C which is sufficiently high to weld the fragments into rock. The degree of welding depends on the weight of overlying material, so the tops of flows are often vesicular and of low density, while at depth the overlying weight crushes the pyroclastic material to form a dense, non-vesicular rock.

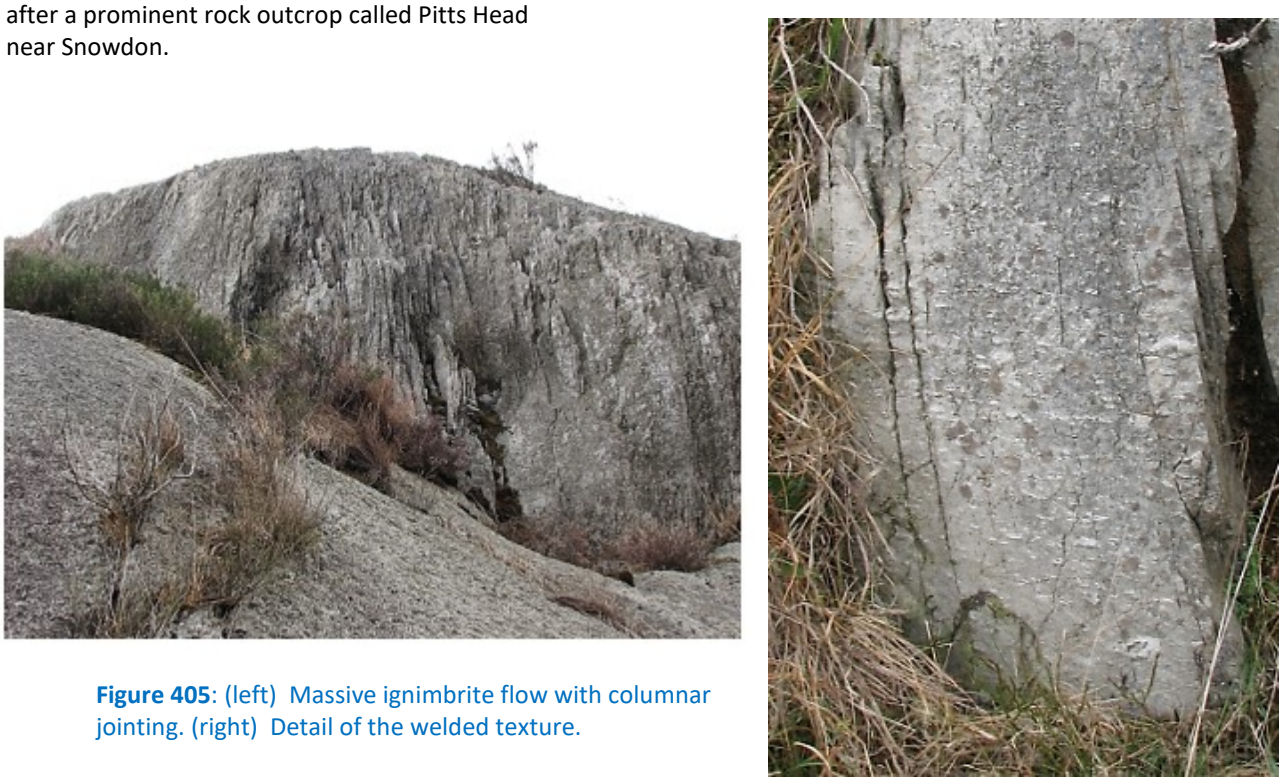


Figure 405: (left) Massive ignimbrite flow with columnar jointing. (right) Detail of the welded texture.

4: After examining the ignimbrites, we move to the central area of the Llwyd Mawr volcano where a late rhyolite intrusion has been emplaced. To reach location 5, it is necessary to negotiate a network of very high dry stone walls which cross the mountain. The most suitable route, making use of gaps in walls and a stile and gate, is shown in fig. 406.

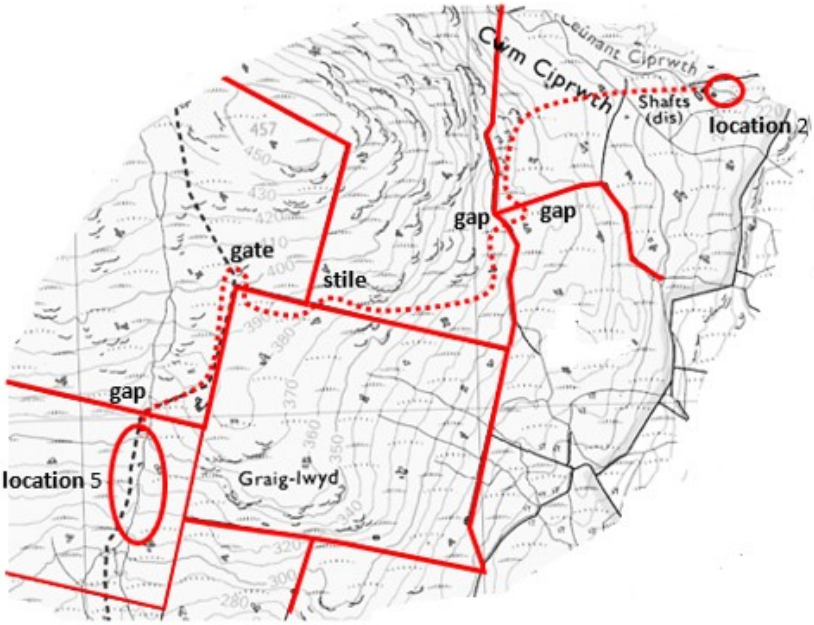


Figure 406:
Route to location 5. High dry stone walls are marked in red.

5: Outcrops of interest lie within an upland stream valley. Pink very fine grained felsite forms two dome-shaped intrusions, the first in this valley and a second on the slopes of Llwyd Mawr to the west. Also seen in the valley are outcrops of an unwelded ash which was deposited within the volcanic crater.

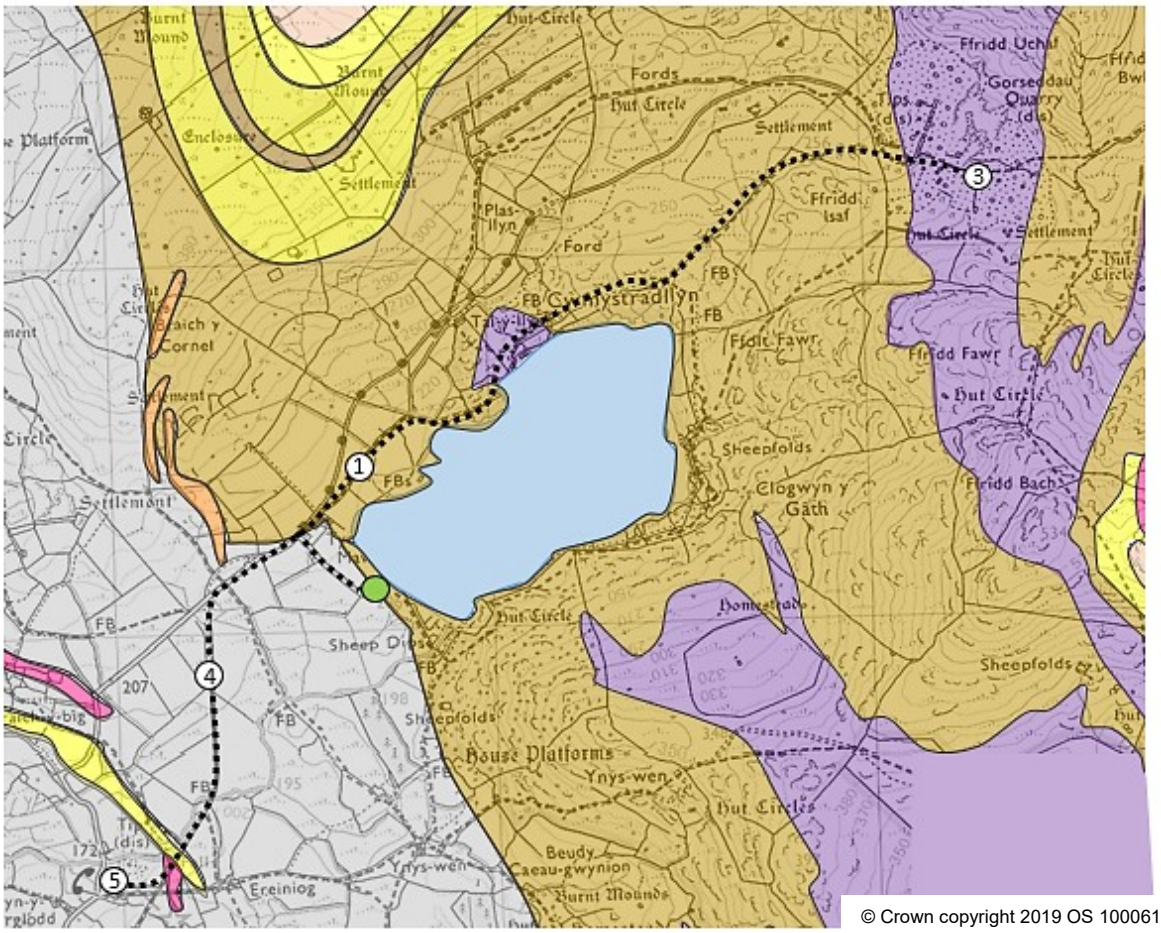
Return to Cwm Pennant by retracing your route.

An alternate route to Cwm Pennant is to follow the river for several kilometres downstream. However, the path is indistinct and crosses areas of thick heather and gorse, and wet marshland. This route is not recommended.

Figure 407:
(left) Intrusive felsite. (right) Unwelded ash deposited in the Llwyd Mawr caldera.

Cwm Ystradllyn

4 miles: approximately 2½ hours



- Nant Ffrancon siltstone
- Moelwyn tuffite
- Pitts Head Tuff, felsic
- Pitts Head Tuff sandstone
- Lower Rhyolitic Tuff, felsic
- Bedded Pyroclastic Formation
- Microgranite
- Microgabbro
- Cwm Eigiau mudstone, siltstone
- Cwm Eigiau sandstone

Figure 408: Field excursion.

In this short excursion, we visit Cwm Ystradllyn which was the site of substantial slate quarrying for a brief period between 1850 and 1870. In addition to exploring the quarry, we can follow the route of the horse drawn tramway to the enormous and well preserved processing mill.

Our objective is to examine Ordovician sedimentary rocks which were deposited in Snowdonia before and during the period of volcanic activity. The lower part of the Ystradllyn valley consists of mudstones and siltstones of the Nant Ffrancon formation. These deposits were laid down in the Welsh basin during the long period of volcanic inactivity in Snowdonia in early and middle Ordovician times. The mud and silt are likely to have come from neighbouring landmasses, carried into the marine basin by rivers. After initial deposition, the fine sediment may have been redistributed to deeper parts of the basin by bottom currents.

The upper part of the Ystradllyn valley contains outcrops of sandstone, siltstone and mudstone of the Cwm Eigiau formation. These materials were laid down during the volcanic episode in late Ordovician times. Cwm Ystradllyn lies between the Llwyd Mawr and Snowdon volcanic centres,

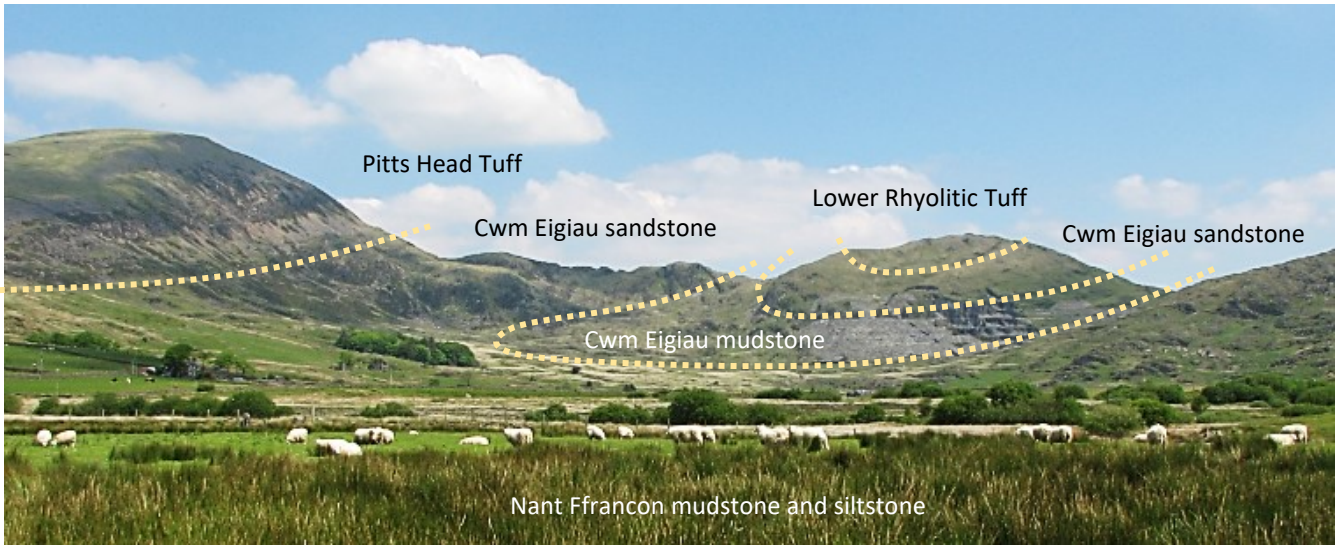


Figure 409: Geological succession at the head of Cwm Ystradllyn.

which both produced emergent islands in the marine basin during eruptions. The silts and coarser sands are likely to have been derived locally from erosion of felsic ashes deposited in the sea around these islands, whilst the muds may have been carried into the basin from further afield.

The mudstones of the Cwm Eigiau formation have been converted to workable slates at the Gorseddau quarry at the head of the valley. Low grade metamorphism affected the area during Devonian earth movements as the Avalonian microcontinent converged with Laurentia. In addition to the formation of chlorite and other slaty minerals, the rock has been penetrated by quartz veins. Silica was dissolved from the underlying felsic ashes by hot hydrothermal fluids during metamorphism, then carried upwards to be deposited in fractures in the slate beds.

Start: Follow the minor road to Cwm Ystradllyn, past the slate mill, and park by the reservoir dam [SH557441]. The reservoir was originally a natural glacial lake, but was deepened by construction of the dam between 1960 and 1970. It supplies drinking water to the Porthmadog and Lleyn areas.

1: Join the route of the former tramway which skirts around the western side of the lake. Pass the ruins of the manager's house and the tramway stables and workshop.

On the left, a track ascends the valley side to the ruined village of Treforys. This was built for quarry workers and their families, with 36 cottages which each had a small plot of land for growing vegetables or keeping animals.

2: Continue up the valley to the first of the quarry waste tips. The tramway was protected from falls of waste rock by a large concave dry stone wall. Next to the wall are outcrops of Cwm Eigiau grey sandstone. This exhibits cross bedding which is characteristic of accumulation as foreset beds on the face of an advancing sand delta. The sediment may have been carried down by rivers from the eroding subaerial cone of the Llwyd Mawr volcano.

Figure 410: Cwm Eigiau grey sandstone with cross bedding.

3: Continuing along the tramway, you reach the ruined barracks building of the Gorseddau quarry. The quarry extends above you, and was developed as a series of stepped galleries cut into the mountainside, with slate brought down by means of a gravity worked incline for transfer to the horse drawn tramway.

Walk past the incline to reach a valley between the slate tips which leads to the lower quarry.

Figure 411: Gorseddau slate quarry.

The slate, created by regional metamorphism of mudstones of the Cwm Eigiau formation, is not of the high quality seen at Llanberis and Blaenau Ffestiniog, so the Gorseddau quarry was only a limited commercial success and closed after 20 years. The main products were slate slabs for flooring, and producing slate tanks to hold milk in dairies or for use in chemical works.

The slaty cleavage at this point is close to vertical, produced by lateral pressure during convergence of Avalonia with Laurentia. The orientation of the cleavage is approximately north-south, parallel to the axial planes of folds in the west of Snowdonia. Quartz veining is found in the slate, which gives an indication of the metamorphic conditions which existed in the rock. Clay minerals in the original mudstones were recrystallized to chlorite and sericite, releasing hot hydrothermal fluids under high pressure. These fluids were able to dissolve silica as they flowed the rock. The silica could then crystallise as quartz in fracture cavities where pressures were lower.

If time permits, it is interesting to climb around the slate tips to the higher levels of the quarry, where remains of buildings and tramways can be seen.

4: Return along the tramway, past the access road to Cwmystradllyn dam, to reach the point where the tramway diverges across fields. Follow the old tack over a footbridge across the river, then southwards to the Ynysypandy Slate mill.

5: The remains of the impressive mill building can be explored. The mill was equipped with sawing and planing machines for preparing slate slabs, powered by a large waterwheel situated in the centre of the building which took water from the nearby river. Branches of the tramway led into the upper and middle floors of the mill, and waste rock was taken out and tipped next to the building. Completed products continued their journey by tramway down the valley to Porthmadog for transfer to sailing ships.

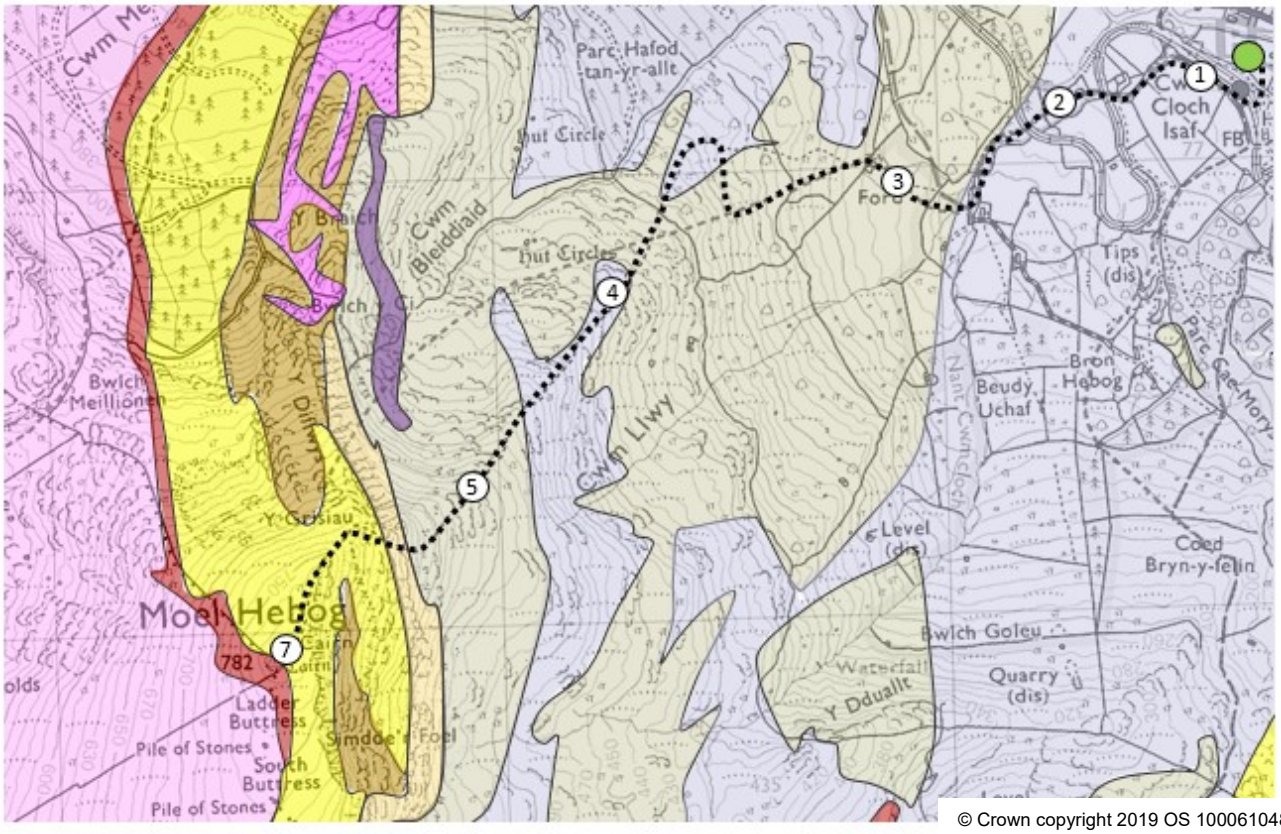
Leave the mill building and descend into the river gorge to examine outcrops of the Nant Ffrancon mudstones. These are grey, fine grained mud and silt rocks which have not developed a sufficiently good cleavage for slate production. The thin beds probably represent marine shelf deposits, laid down under quiet low energy conditions some distance from the shoreline.

Figure 412: Ynyspandy slate mill.

Return to the parking area at Ystradllyn reservoir by retracing the route along the old tramway, or by following the minor road up the valley.

Moel Hebog

3 miles: approximately 2½ hours



- Cwm Eigiau mudstone, siltstone
- Cwm Eigiau sandstone
- Pitts Head Tuff, felsic
- Lower Rhyolitic Tuff, breccia
- Lower Rhyolitic Tuff, felsic tuff
- Bedded Pyroclastic Formation
- Intrusive rhyolite
- Intrusive basalt
- Microgabbro

Figure 408: Field excursion.

The objective of this excursion is to examine the sedimentary and volcanic succession on the eastern slopes of Moel Hebog. This begins with sandstones and mudstones of the Cwm Eigiau formation which were deposited in the Welsh basin before the Snowdon volcanic episode. These are overlain by the Pitts Head Tuff, formed by outflows of felsic ash from the Llwyd Mawr centre to the west. We then reach the Lower Rhyolitic Tuff which was derived from the Snowdon centre to the east.

Start: A car park is available in Beddgelert [SH588482].

1: Leave the village on the path alongside the Welsh Highland Railway station.

2: Take the minor road uphill, crossing the Welsh Highland Railway several times as it loops up the valley side. After passing a small conifer plantation, leave the road and take the footpath towards Moel Hebog.

3: For the first section of the climb we ascend through steep grassy fields bordered by dry stone walls.

4: Outcrops of Cwm Eigiau sandstones can be examined alongside the path. These are coarse-grained, with fragments which commonly weather-out to leave small holes in the rock. This suggests that the clasts have a high carbonate content. The sandstone is cross-bedded in places, suggesting deposition in a delta environment.

Figure 423:
Cwm Eigiau sandstone. A set of cross beds is indicated.

5: We are drawing closer to a prominent cliff which is formed by a massive sheet of the Pitt's Head ignimbrite.

Beneath the ignimbrite are a series of bedded unwelded ashes of the Pitts Head formation (fig.425). The ashes contain flattened lenses of pumice, along with angular fragments of rhyolite. The rock has developed a faint vertical cleavage in response to the later earth movements.

As we approach the shoulder of the mountain where the ignimbrite sheet outcrops, we see that a layer of large spherical nodules of silica rock occur a short distance above the base of the ash flow. This is a common feature of thick ignimbrites in Snowdonia. Superheated steam is trapped within the lower layers of the ignimbrite flow when welding takes place in the layers above, producing an impermeable seal. The steam dissolves silica, which can then recrystallize to form large nodules within the ash.

Figure 424: Cliff face produced by Pitt's Head tuff, Moel Hebog.

6: Continue up the steep path to the top of the Pitts Head tuff outcrop, where ashes of the Lower Rhyolitic Tuff member are reached (fig.426).

These ashes were erupted from a vent within the Snowdon volcanic centre which we will discuss in more detail in the next chapter.

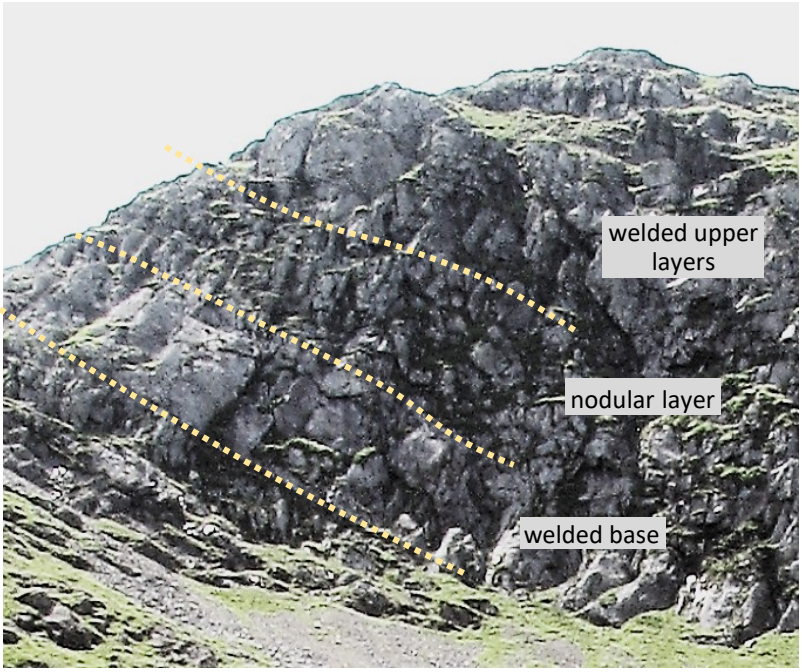


Figure 425: (above) Pitts Head Tuff. The cleavage direction is indicated.
(right) Structure of the Pitts Head ignimbrite flow.

The Lower Rhyolitic Tuff is composed of ashes and larger particles of pumice, with parallel or rippled laminations suggesting that they were laid down under water.

Continue to the summit of Moel Hebog, then return to Beddgelert by retracing your route.

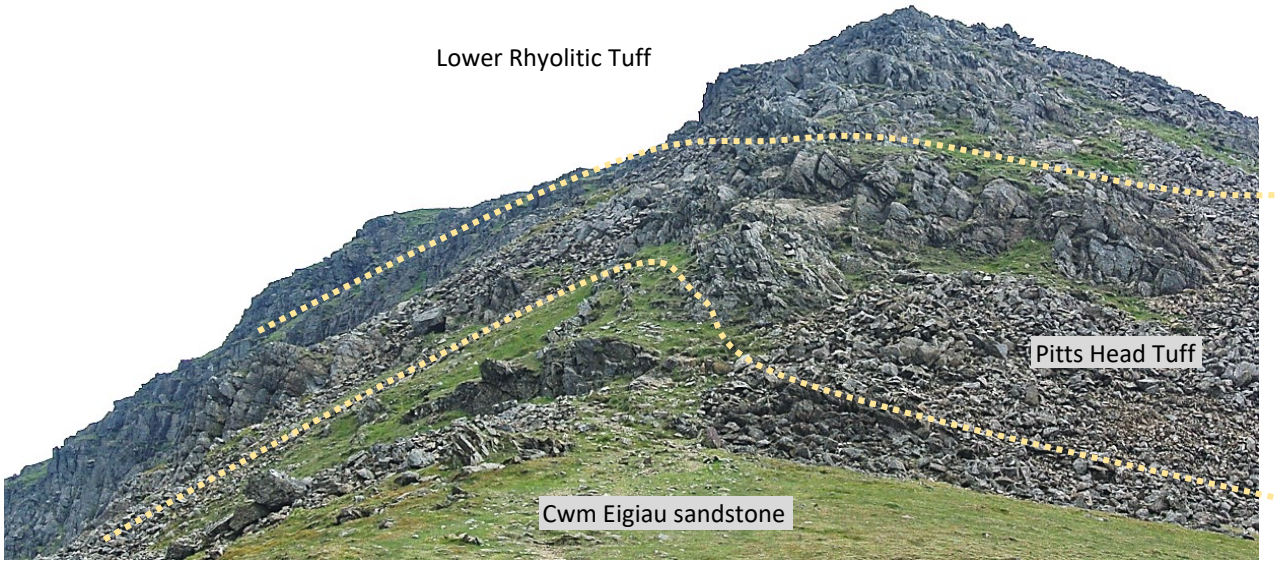
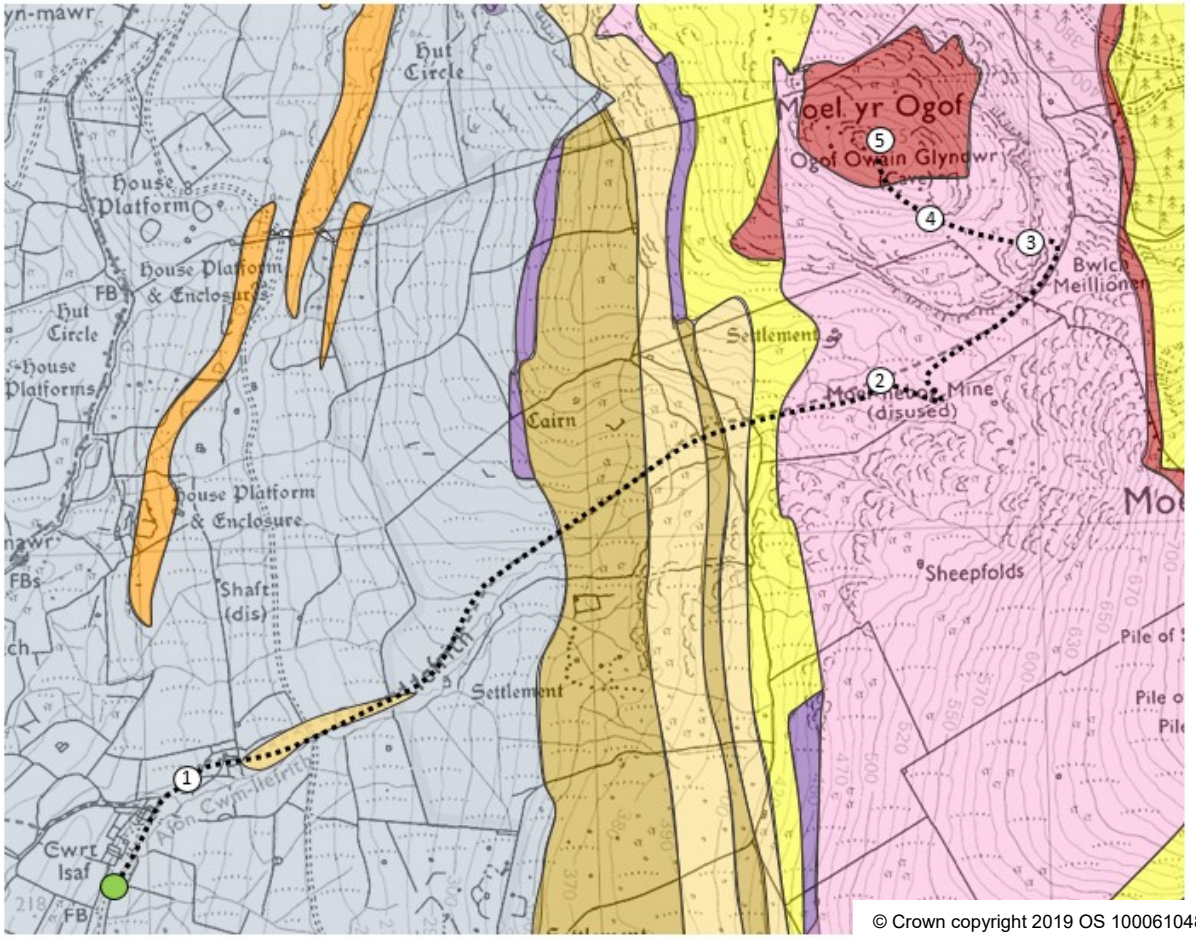


Figure 426: Outcrops below the summit of Moel Hebog.

Moel yr Ogof

3 miles: approximately 2½ hours



- Bedded Pyroclastic Formation
- Lower Rhyolitic Tuff, felsic
- Pitts Head Tuff, felsic
- Moel Hebog sandstone
- Moelwyn lower tuffite
- Nant Ffrancon siltstone
- Microgranite
- Microgabbro
- Intrusive rhyolite

Figure 427: Field excursion.

In this excursion, we begin by visiting the site of the Moel Hebog copper mine, then ascend Moel yr Ogof where felsic ashes and mafic lavas and pyroclastic deposits are outcropping. The summit of this small mountain is composed of intrusive rhyolite forming a vent on the margin of the Snowdon volcanic caldera.

Start: Take the road to Cwm Pennant, branching to the right at Pont Gyfyng. Park at Cwrt Isaf Farm [SH540463].

1: Continue on foot past the farm, then take the poorly defined footpath along the northern bank of the Cwm Llefrith stream. We cross the route of the old tramway which carried slate from the quarries at the head of Cwm Pennant. Follow the path alongside the stream to reach the Moel Hebog copper mine at the head of the valley.

2: The Moel Hebog mine (fig.428) operated on a small scale between 1837 and 1889. The main problem faced by the miners was the remote location, making the transport of ore difficult. The mine worked a vein of sulphide-bearing quartz emplaced in the late stages of volcanic activity at the Snowdon centre. The richest ore was found

Figure 428:

Moel Hebog copper mine.

around the junction of the Lower Rhyolitic Tuff with the overlying Bedded Pyroclastic formation. This is typical of copper deposits around Snowdon, and probably represents the crustal depth where pressure and temperature conditions were suitable for the crystallization of sulphides at that time.

3: Continue to the head of the valley at Bwlch Meillionen. Cross the wall which runs through Bwlch Meillionen, then go to the large cleft in the cliff face to your left. The cliff is composed of basalt pillow lavas.

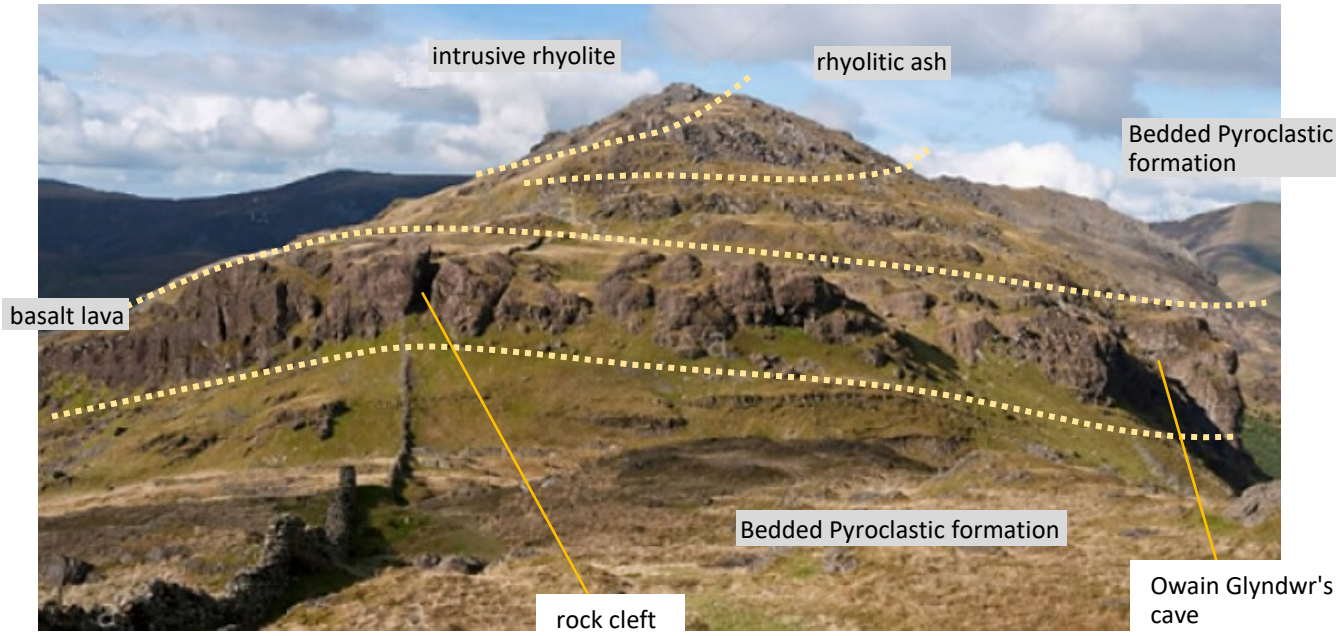


Figure 429: Bwlch Meillionen, with Moel yr Ogof in the distance.

Cross the wall which runs through Bwlch Meillionen, then go to the large cleft in the cliff face to your left. The cliff is composed of basalt pillow lavas.

3: Ascend through the basalt outcrop, observing the lava pillows exposed in the walls of the cleft.

Beyond the basalts are outcrops of pyroclastic agglomerate, with angular rhyolite fragments in a mafic matrix. These rocks are overlain by finer basaltic ashes with a poorly developed bedding. These deposits, as well as the basalt pillow lavas, appear to have been deposited under water.

4: Continuing up the mountain slope we arrive at the cliff where a cave, reputed to have been used by Owain Glyndwr, is situated. The cliff is

Figure 430: Basalt pillow lavas exposed in the rock cleft above Bwlch Meillionen. (right) Pyroclastic agglomerate overlying mafic ashes. The orientation of bedding in the ash is indicated.

composed of massive felsic ash. This is unwelded, and contains many larger fragments of pumice and angular rock fragments, suggestive of violent explosive eruption from a nearby vent. The bedding is again suggestive of deposition under water.

Close to Glyndwr's cave is a small mine. This very unusual mineral working follows a narrow seam of white chrysotile asbestos. This mineral is normally associated with ultrabasic intrusive rocks such as serpentine. It is likely that a layered magma chamber existed below the area during part of the Snowdon volcanic episode, with ultrabasic magma present in its lower part. Late hydrothermal activity allowed magnesium silicates to be dissolved and carried upwards, to recrystallize in the volcanic ashes near the sea bed.

Figure 431: (left) Cliff of felsic ash, Moel yr Ogof. Owain Glyndwr's cave is the larger opening on the left, with the asbestos mine to its right. (right) Entrance to the asbestos mine, with the vein visible in the tunnel wall.

5: Complete the climb to the summit of Moel yr Ogof. In the upper crags we find flow banded rhyolite which filled a vent intrusion. Felsic magma has a high viscosity, so is likely to have flowed only a short distance from the vent after eruption, forming a rhyolite dome. There is no evidence of explosive eruption, and this material may represent a late upwards flow of degassed magma in the closing phases of the volcanic episode.

From the summit of Moel yr Ogof, return by retracing your route down Cwm Llefrith.