The Vale of Ffestiniog

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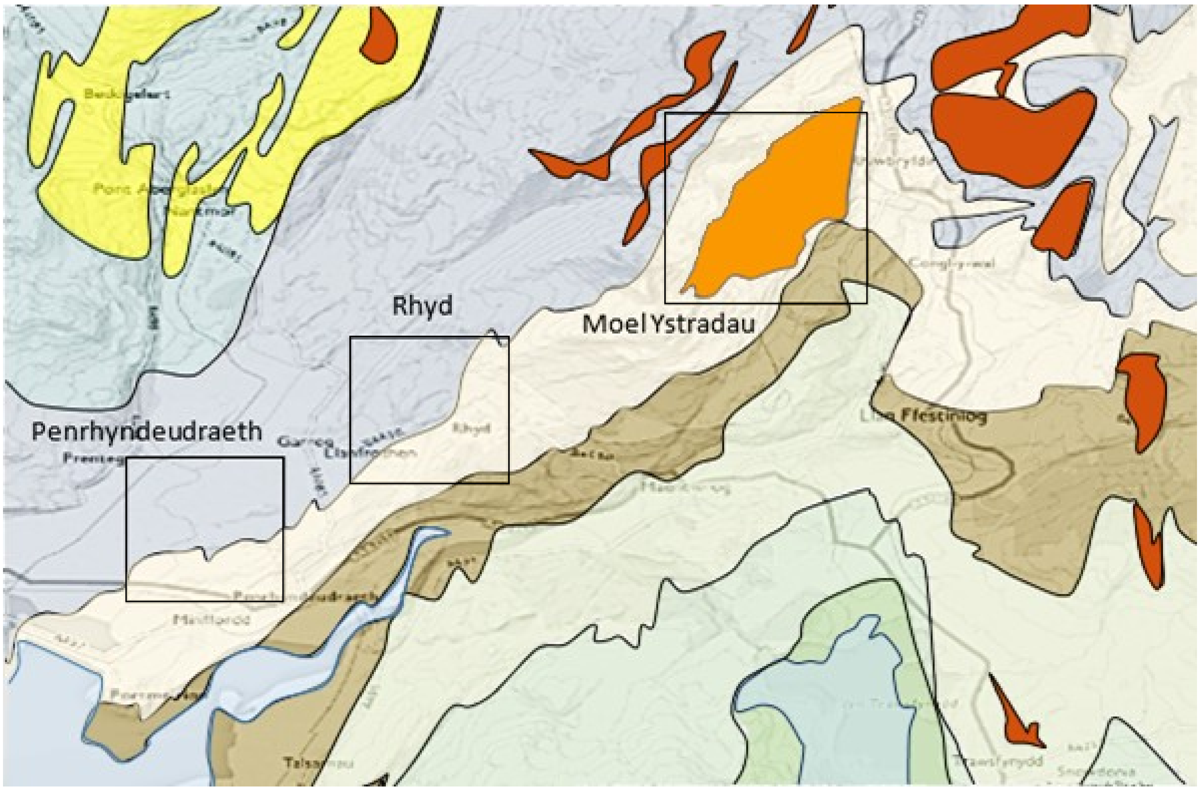


- Dol-cyn-afon sandstone, siltstone, mudstone
- Dolgellau and Ffestiniog formations
- Maentwrog formation
- Hafotty, Barmouth and Gamlan formations
- Rhinog formation
- Lower Rhyolitic Tuff
- Cwm Eigiau mudstone, siltstone
- Nant Ffrancon siltstone
- Microgranite
- Intrusive rhyolite

Figure 458: Field excursions.

In this chapter we examine the northern margin of the Harlech Dome, between the outcrops of the Cambrian Welsh basin sedimentary sequence to the south and the Ordovician Snowdon volcanics to the north.

The vale of Ffestiniog lies along the line of a presumed deep fracture in the crust. There is sedimentary evidence that this fracture formed a break of slope in early Ordovician times, with delta deposits produced by rivers flowing southwards into the marine Welsh basin (fig.459).

It is likely that the vale of Ffestiniog fracture zone became inactive by the middle Ordovician, perhaps as fault movement was transferred to the fractures which run through central Snowdonia and Cwm Pennant. The sea bed in the vale of Ffestiniog area was covered by uniform deposits of volcanic ashes, along with sand and mud sediments.

In the later Ordovician, volcanic activity reached a climax in Snowdonia. Magma rising from a deep reservoir could follow the fractures deep beneath the vale of Ffestiniog to reach the top of the Cambrian sedimentary succession and emplace the large microgranite intrusion of Tanygrisiau. This intrusion contrasts with the majority of Ordovician felsic intrusions in central Snowdonia in having a coarser grain size, allowing individual crystals of feldspar and mafic minerals to be seen with the naked eye, in contrast to cryptocrystalline intrusions elsewhere. This is evidence that the Tanygrisiau intrusion solidified beneath the ground surface without losing steam through a volcanic vent, promoting the growth of larger crystals in the hydrous melt.

A feature of the Tanygrisiau intrusion is a very large metamorphic aureole surrounding the microgranite, where mudstones have been recrystallized to hornfels by heat and the action of steam escaping from the solidifying intrusion into the country rock nearby.

The vale of Ffestiniog did not completely escape the effects of late Ordovician volcanicity, as a major volcanic centre developed nearby at Manod near Blaenau Ffestiniog, and ashes were erupted in the Moelwyn mountains above Tanygrisiau. These events will be discussed in chapter 17.

The vale of Ffestiniog is mainly underlain by Cambrian and lower Ordovician sandstones, siltstones and mudstones. This succession is intruded by a series of cone sheets originating from the Snowdon caldera. Lead mineralisation is present, associated with mountain building during the Devonian period, and has been worked in mines around the village of Rhyd, and in the Moelwyn mountains.

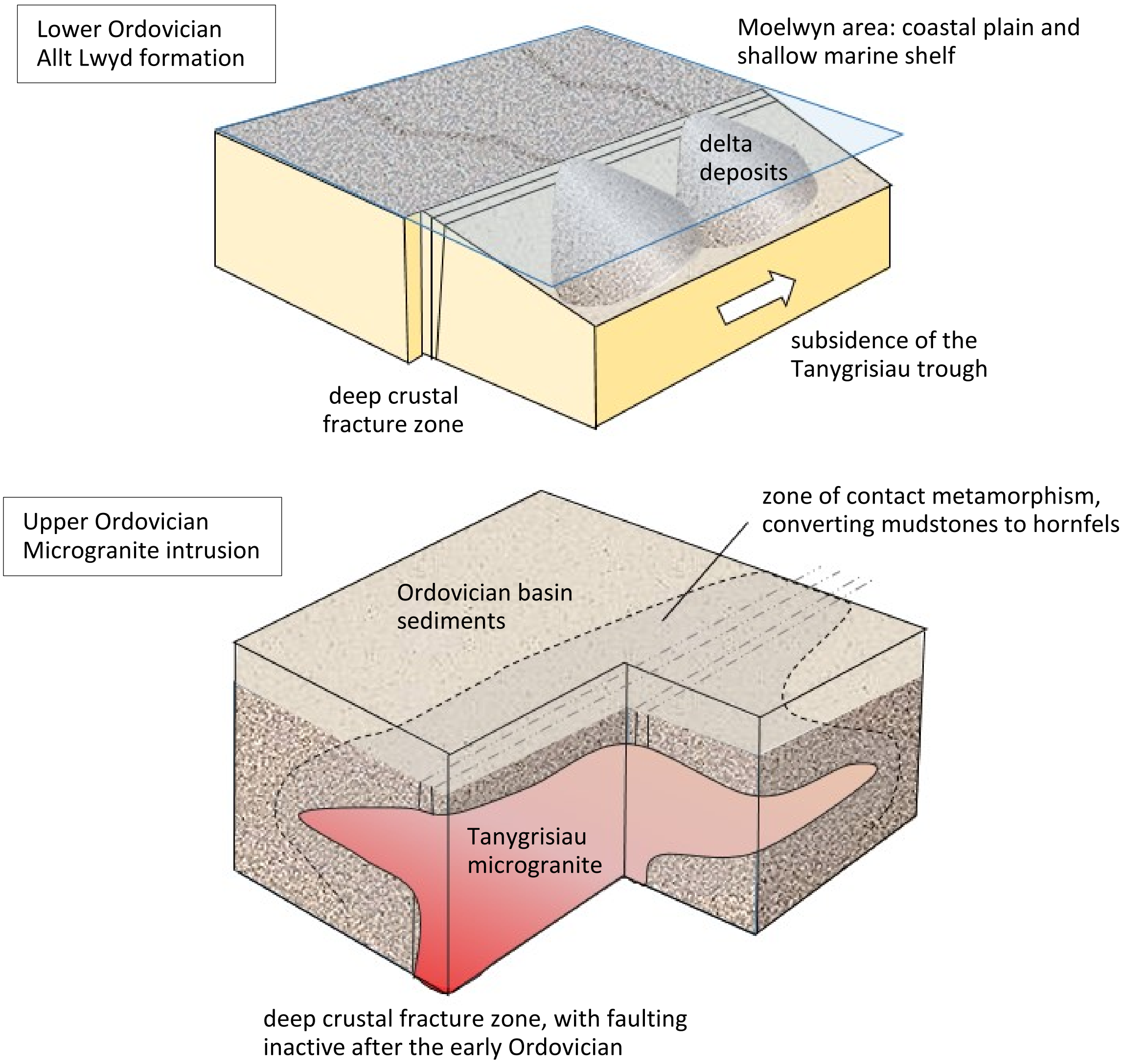


Figure 459: Evolution of the Vale of Ffestiniog.

By Silurian times, the microcontinent of Avalonia was converging with the major continent of Laurentia, assisted by subduction in the Rheic ocean to the south which was carrying oceanic crust northwards beneath Avalonia. The overall effect of these plate tectonic processes was to cause compression and crustal shortening in the Welsh Basin. These movements affected the thinner and softer bedded strata near the surface,

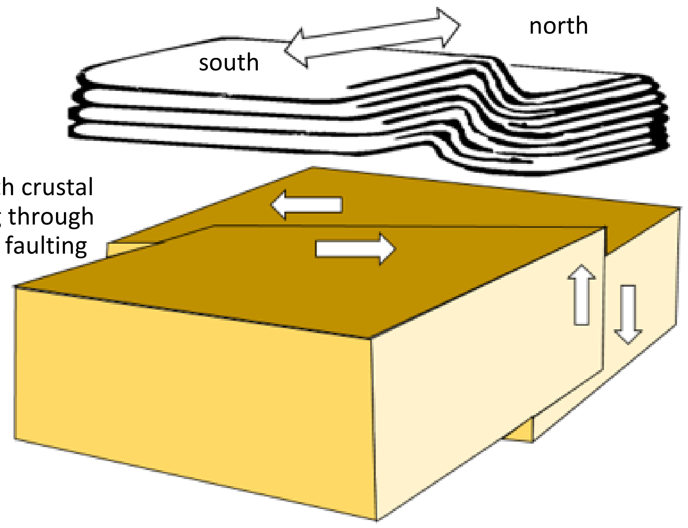


Figure 460: Crustal compression and folding in the Welsh Basin.

but were largely controlled by strong and massive blocks of the Precambrian basement underlying Wales. Both horizontal and vertical fault movements could occur between basement blocks (fig.460).

The Vale of Ffestiniog fracture zone appears to have played an important role as a boundary between the upfaulted crust of the Harlech Dome to the south, and downfaulted crust beneath Snowdonia to the north. In addition, crustal shortening occurred through transverse fault movements. Compression of strata in the Vale of Ffestiniog reached such an intensity that movements could no longer be accommodated by folding, and multiple low angle thrust faults developed. An example near the village of Rhyd is shown in fig.461.

Field excursions in this section include: Porthmadog and the coast of the Traeth Mawr and Traeth Bach estuaries; the mountains above Maentwrog; and the outcrop of the microgranite at Tanygrisiau.

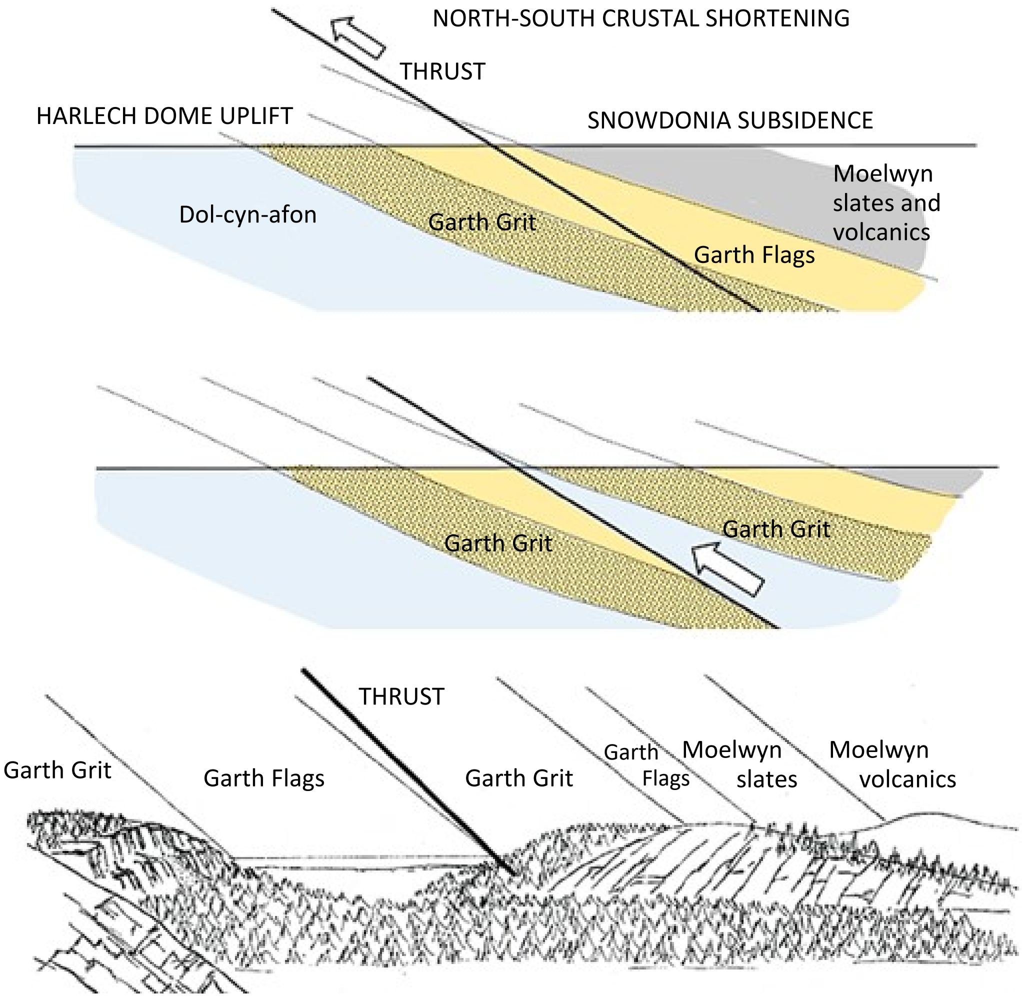
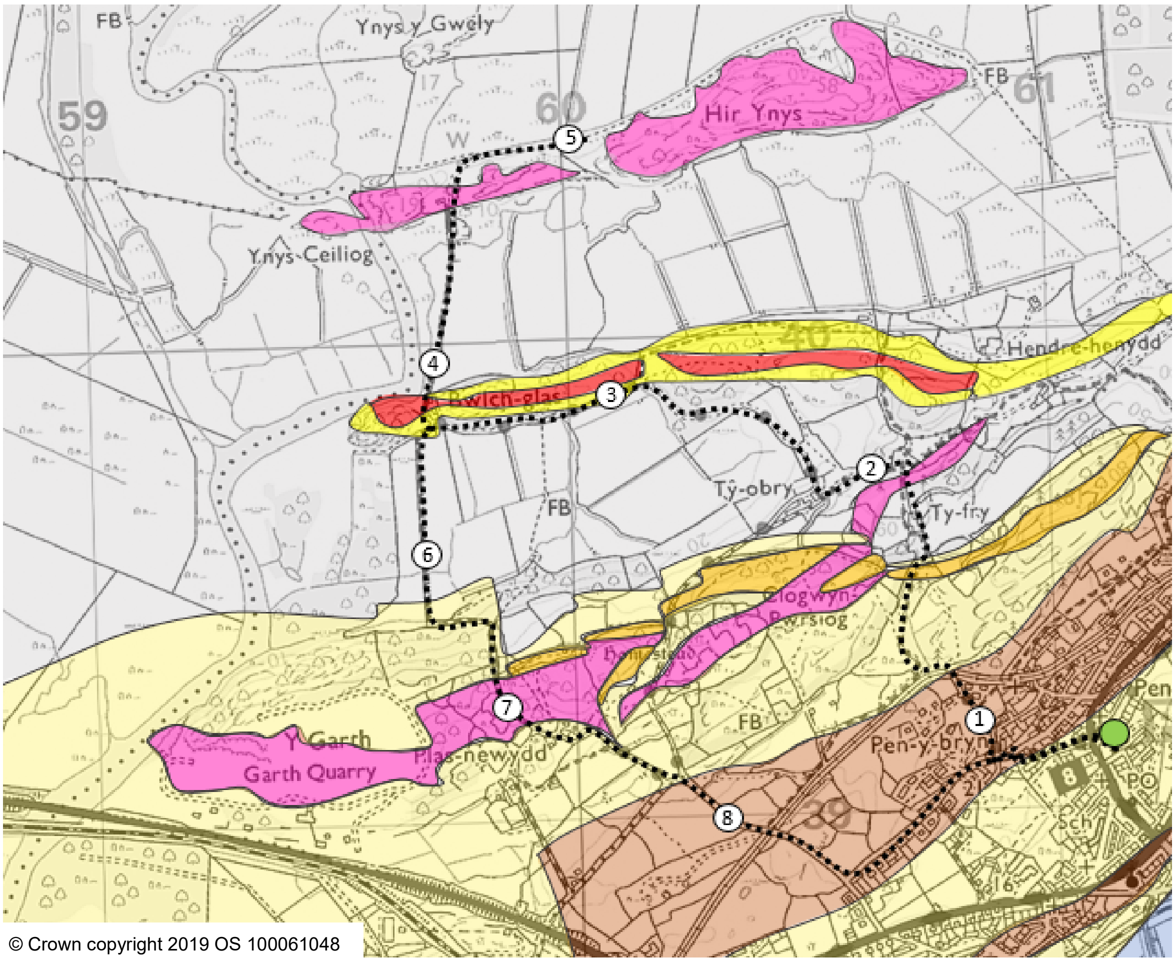


Figure 461: Thrust faulting at Rhyd, leading to repetition of the outcrop of Garth Grit.

Penrhyndeudraeth

3 miles: approximately 1½ hours



- Moelwyn tuffite
- Nant Ffrancon siltstone
- Garth Grit sandstone, conglomerate
- Dol-cyn-afon mudstone, siltstone
- Dol-cyn-afon sandstone
- Dolgellau mudstone, siltstone
- Microgabbro
- Intrusive rhyolite

Figure 462: Field excursion.

In this excursion we visit an area of former coastline of the Traeth Mawr estuary where a series of rocky ridges once extended into the sea as headlands and islands. These ridges are now separated by flat alluvial fields. We will see evidence of the enormous thrust faulting which occurred on a mountain building scale along the Vale of Ffestiniog during the late Silurian and early Devonian periods.

Start: A car park in available in Penrhyndeudraeth [SH611391].

1: From the car park, take a minor road westwards up a hill. At the junction, turn left to Pen-y-Bryn, then north along a minor road which passes under the Ffestiniog railway.

2: Take the footpath alongside the railway, then through the woods to Ty-fry. At the footpath junction, take the left branch over the hill to Ty Obry past outcrops of Garth Grit. This coarse grit occurs near the base of the Allt Llwyd formation. It was one of the first deposits laid down in the Welsh Basin as subsidence began again at the start of the Ordovician period, following uplift, erosion, and early volcanic activity at the Rhobell Fawr centre.

The Garth Grit at this point was deposited in a series of delta fans, extending from a shoreline along the northern margins of the Vale of Ffestiniog, southwards into deeper waters in the Harlech Dome. We see thickly bedded materials with pebbles present in places. Rates of deposition were high, as large quantities of coarse sediment were carried down large rivers during storm events over the mountains to the north.

3: At Ty Obry, join the minor road which skirts around the ridge of Ynys Berfed. Observe the outcrops in the roadside cuttings.

A panorama opens up across the valley (fig.463) at Ty Obry. The upper crags along the ridge of Ynys Berfed are formed by a thick sill of rhyolite. The sill is intruded into ashes of the Moelwyn Volcanic formation which dip to the north and overlie older Ordovician slates. As we shall see, the sequence has been strongly affected by earth movements.

Figure 463: Ynys Berfed ridge from Ty Obry

The first outcrops seen along the roadside are bedded fine rhyolitic ashes of the Moelwyn formation. These ashes were erupted in late Ordovician Caradoc times, but from a localised volcano not forming part of the Snowdonia caldera. A likely vent for this volcano, infilled with agglomerate, has been identified on the hillside to the north-east of the Ffestiniog Railway station at Tan y Bwlch.

The Moelwyn ashes are underlain by slates which are heavily deformed. In places the slate breaks into pencil-like fragments, and many small low-angle thrust planes cut across the cleavage. Blocks of rock from disrupted volcanic ash bands are mixed with the slates.

Detailed mapping has shown that Ynys Berfed is cut by several thrust faults, so that many of the geological boundaries we see are faulted. A boundary zone between slates and the sill intrusion contains a breccia composed of keratophyre fragments in a slate matrix, produced as the rock masses moved over one another in the thrust zone.

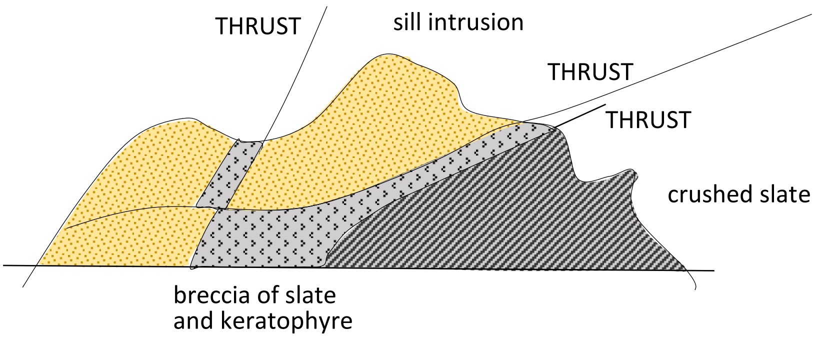


Figure 464: Geological structure of the western end of the Ynys Berfed ridge.

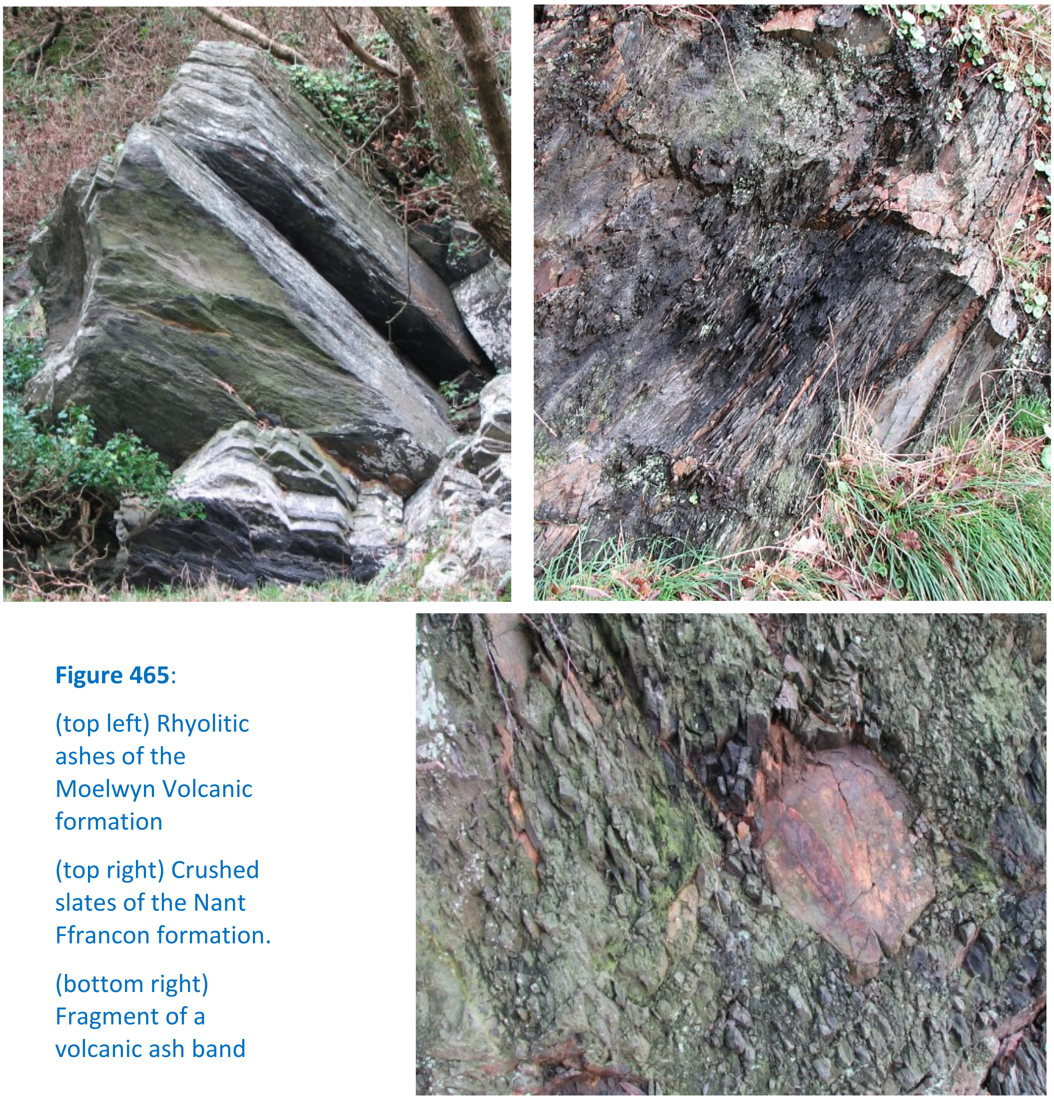


Figure 465:

(top left) Rhyolitic ashes of the Moelwyn Volcanic formation

(top right) Crushed slates of the Nant Ffrancon formation.

(bottom right) Fragment of a volcanic ash band

The upper crags of the Ynys Berfed ridge are formed by a felsic sill. This is a very fine grained rhyolitic rock containing phenocrysts of white albite feldspar. The rock type is classified as ***keratophyre*** due to high sodium content of its feldspar.

Figure 466: Keratophyre sill.


Figure 467: (left) The Hir Ynys ridge, formed by a microgabbro sill. (right) Detail of the microgabbro.

4: Follow the road through the hill gap at Bwlch-glas and continue north to Hir Ynys.

5: The Hir Ynys ridge is again formed by a northwards-dipping sill intrusion, this time of mafic composition. There is no evidence of the thrust faulting seen at Ynys Berfed, which may be due to the stronger, more massive nature of the microgabbro. Both sills are likely to have formed as cone sheets extending upwards and outwards from the magma chamber beneath the Snowdonia caldera, a short distance to the north.

6: Return southwards along the road through the gap in the Ynys Berfed ridge, then take the footpath which follows a drainage embankment across fields to the foot of the hill ridge of Y Garth.

7: Go through the gate to join the path which ascends around Y Garth. The first part of the ascent is across mudstones of the Upper Cambrian Dol-cyn-afon formation. This location is scientifically important as the location where specimens of the trilobite *Angelina sedgwicki* Salter were first found. The species is named in honour of the collector Mr Salter, a solicitor in Porthmadog and important amateur palaeontologist.

Figure 468: A museum specimen of *Angelina* collected at Y Garth.

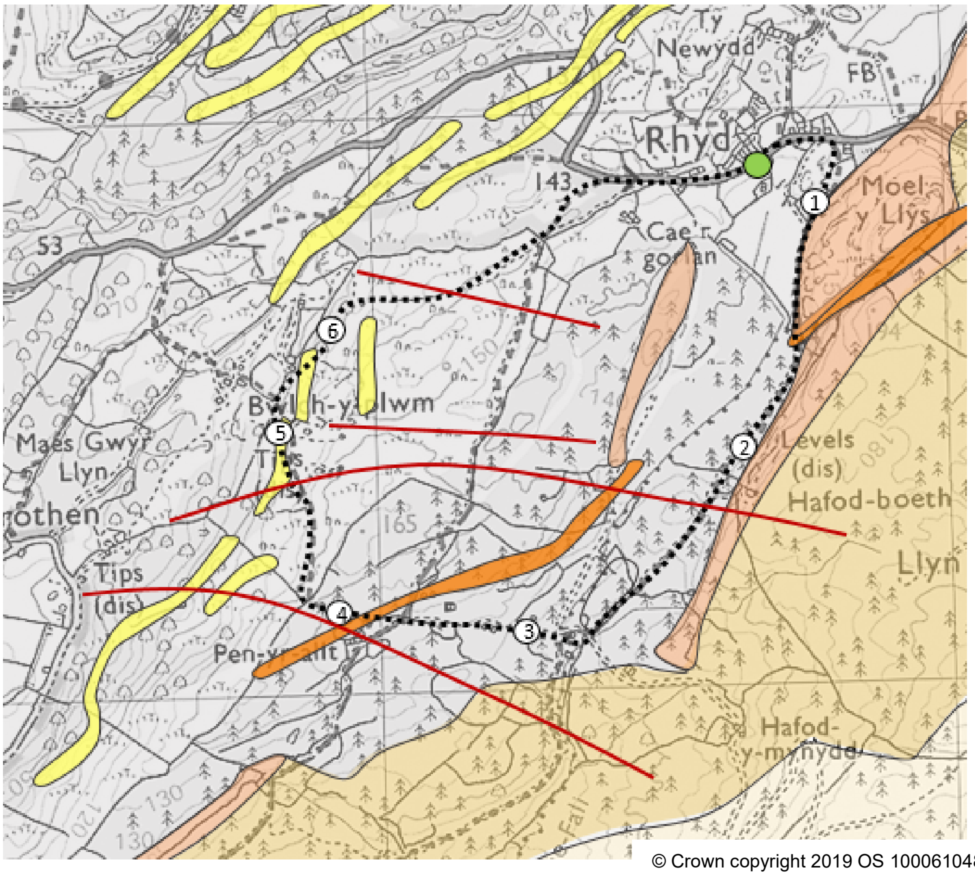
At the top of the ridge, observe the crags of microgabbro to the left of the path. The ridge of Y Garth is again formed by a cone sheet intrusion, similar in composition to sill at Hir Ynys. A short distance through the woods to your right, beyond the 'DANGER' signs, is the working face of the large Minffordd Quarry, which is prominently visible when travelling from Porthmadog.

Figure 469: Minffordd quarry, mainly producing rock chippings for railway ballast and roadstone.

8: Continue along the footpath over the summit of the ridge. Follow minor roads back to Penrhyndeudraeth.

Rhyd

3 miles: approximately 2 hours



- Moelwyn tuffite
- Nant Ffrancon metamudstone
- Garth Grit metasandstone, metaconglomerate
- Dol-cyn-afon sandstone
- Dol-cyn-afon mudstone, siltstone
- Microgranite
- mineral lode

Figure 470: Field excursion.

The objective of this excursion is to explore the area of thrust faulting affecting Ordovician sediments and volcanic ashes around the village of Rhyd, and to visit several disused lead mine sites.

Start: Park by the roadside in Rhyd village [SH638419].

1: Follow the footpath alongside the hill of Moel y Llys. Outcrops of Garth Grit can be examined.

The rocks are fan delta deposits, produced as sediment was discharged into deeper water to the south. The sands spread out across the delta apron on the sea bed, with currents producing rippled bedding in places. Grain size varies between fine and coarse grit, with quartz granules present at some horizons.

2: Continue along the footpath into the conifer plantation. When a gate is reached, follow the dry stone wall upwards through the forest to the left to reach the waste tip of the Hafod-poeth lead mine. Adit tunnels access the mineral lode on two levels, where galena lead ore has been extracted from a steeply dipping vein of quartz. This mine, along with others in the area of Rhyd, was active between about 1825 and 1860. Ores were taken by cart, and in the later years by the Ffestiniog Railway, to Porthmadog. Sailing ships then transported the ore around the coast to Swansea, where an important non-ferrous metal smelting industry had developed with the use of coal mined in the area.


Figure 471: (left) Garth grit outcropping on Moel y Llys. (right) Grit bed with quartz granules. A plane bed and a rippled bed are indicated.

In Snowdonia, in contrast to the copper ores of Ordovician volcanic origin, lead ores were emplaced during the Acadian orogeny in Devonian times. Mountain building took place as the Avalonian microcontinent came into collision with the continent of Laurentia to the north. Horizontal and vertical movements of the basement blocks beneath the Welsh Basin at this time were responsible for the major uplift of the Harlech Dome and subsidence of central Snowdonia, along with thrust faulting along the Vale of Ffestiniog. During a further phase of the earth movements, the crustal block of the English Midlands was compressed sideways into sediments of the Welsh Basin to produce a series of north-south folds. These folds are seen today in the Harlech Dome as the Dolwen pericline, the Caerdeon syncline and the Traeth Bach syncline. North-south oriented anticlines are found at Ffestiniog and Criccieth.


Figure 472: Hafod-boeth mine (left) Waste tip. (right) The deep adit.

As folding took place, the sedimentary sequence was thickened and pushed down to greater crustal depth. This led to heating of the lower layers under pressure, and low grade regional metamorphism was initiated. The clay minerals of mudstones recrystallized to mica-like silicates, particularly sericite and chlorite, producing slate. During the process, superheated steam was released. This hydrothermal fluid was able to dissolve silica, along with heavy metals such as lead, zinc and copper, as it passed through the surrounding beds of sediment.

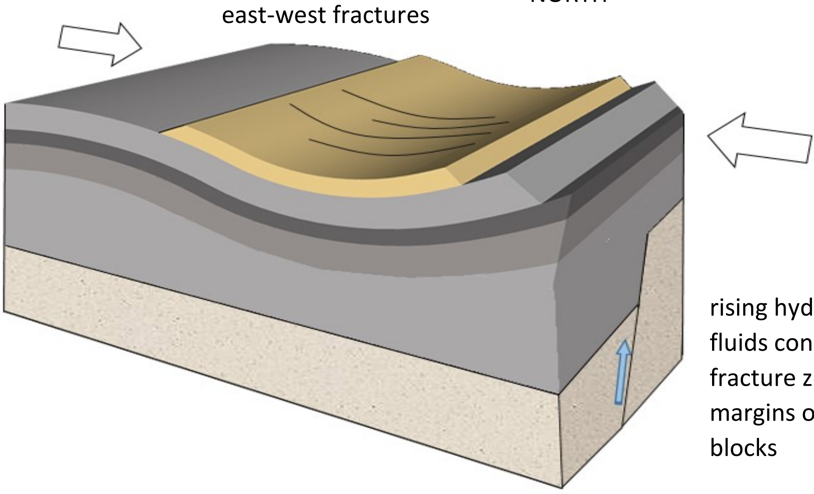


Figure 473: Hydrothermal mineralisation related to folding during the Acadian orogeny.

The easiest upwards pathways for hydrothermal fluids to follow were through the fracture zones surrounding major crustal blocks such as the Harlech Dome. On reaching the upper levels of the crust, temperatures and pressures reduced and minerals could precipitate. It is commonly the case that faults develop in the direction of least principal stress at right angles to a fold axis, which in this case is east-west. These faults provide locations for the crystallisation of quartz and heavy metal sulphide vein deposits.

3: Return to the forest track and continue up the hill. At the point where the track turns sharply to the left, take the footpath to the right towards Pen-yr-allt.

4: Follow the old tramway embankment past the adits and spoil tips of the Catherine and Jane Consols lead mine to reach the site of a former Cornish engine house which provided power for water pumps and the haulage of ore from deep levels of the mine.

5: Continue along the path to the end of the forest, then cross a style to emerge onto moorland overlooking the Traeth Mawr estuary and Porthmadog. Descend across the fields to the Bwlch-y-plwm lead mine site.

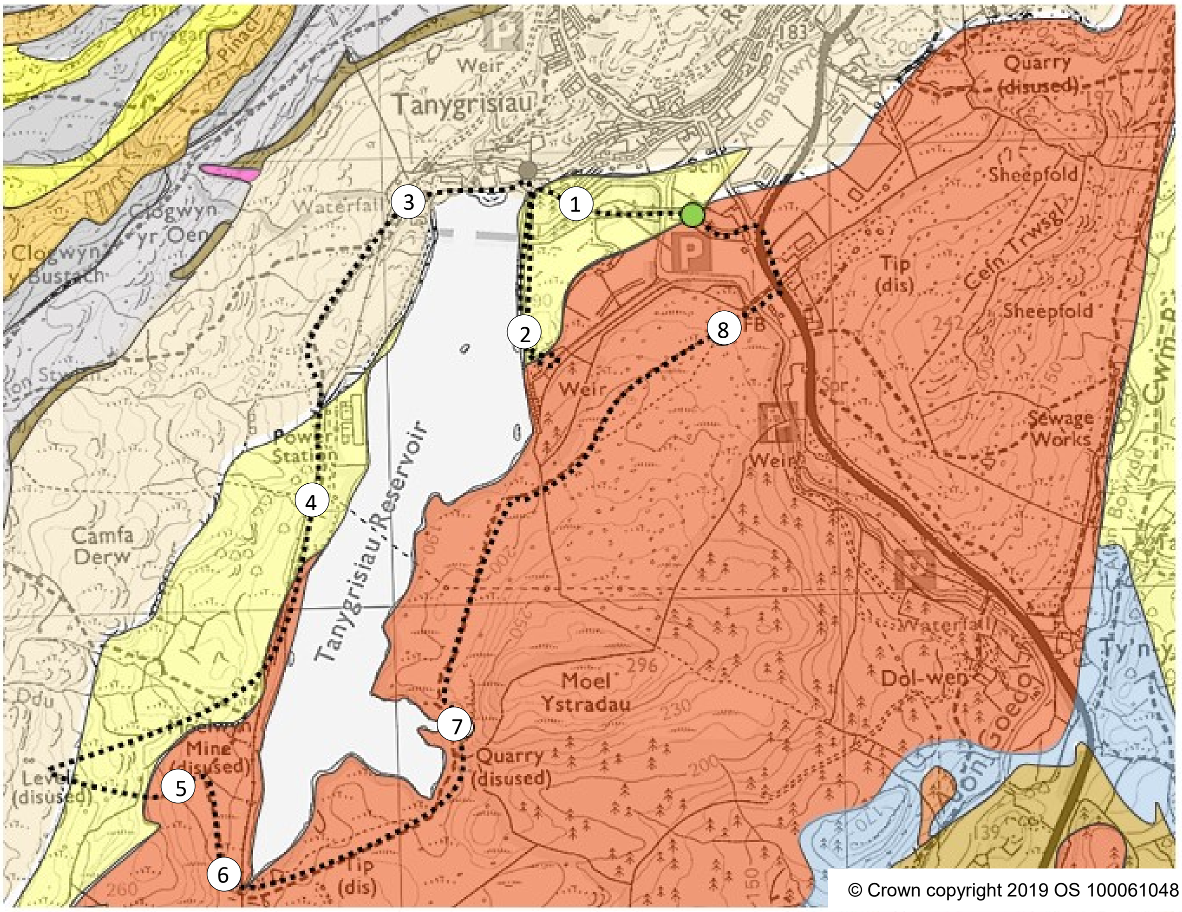
The mine worked a quartz lode cutting mudstones, and ashes of the Moelwyn Volcanic formation. The mudstones show evidence of thermal alteration to hornfels, which is evidence that the area is underlain at shallow depth by a westward extension of the Tanygrisiau microgranite intrusion.

Figure 474: Opencast workings at Bwlch y Plwm mine.

6: Return around the hillside to Rhyd.

Moel Ystradau

4 miles: approximately 2½ hours



- Moelwyn tuff
- Nant Ffrancon mudstone
- Allt Lwyd mudstone
- Garth Grit sandstone, conglomerate
- Dol-cyn-afon sandstone
- Dol-cyn-afon mudstone, siltstone
- Dolgellau mudstone, siltstone
- Maentwrog mudstone, siltstone
- Microgranite
- Microgabbro
- Intrusive rhyolite

Figure 475: Field excursion.

The objective of this excursion is to examine the Tanygrisiau microgranite intrusion, and investigate its relationship to the surrounding country rocks. We will also have an opportunity to visit the disused Moelwyn lead mine.

Start: Turn off the main road from Maentwrog to Blaenau Ffestiniog in Tanygrisiau, taking the minor road to the Ffestiniog power station. A parking area is provided to the right of the road after a short distance [SH685449].

1: Walk along the road to the concrete dam of Tanygrisiau reservoir. Cross a ladder stile and walk along the dam.

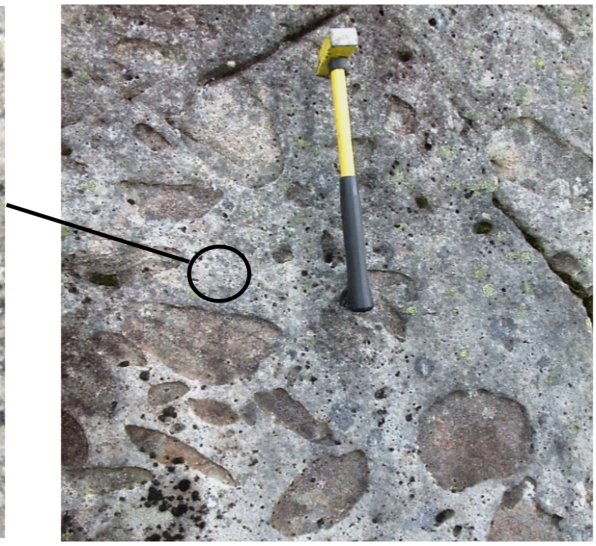
At this point, we are close to the contact between the microgranite intrusion and mudstones of the Upper Cambrian Dol-cyn-afon formation.

An outcrop of microgranite in the field below the reservoir dam contains angular and rounded xenoliths of mudstone, broken from the walls and roof of the intrusion and exhibiting various degrees of assimilation into the melt. (Please note

Figure 476: Tanygrisiau microgranite:

(left) Microgranite texture.

(right) Xenolithic margin of the microgranite.



that this outcrop is on private land, and permission should be obtained before entering.)

The Tanygrisiau microgranite exposed at the surface at the present day covers an area of about 4 km², but there is evidence that the intrusion extends at shallow depth from Cwm Penmachno in the east to Maentwrog in the west. Mudstones over this larger area show signs of contact metamorphism to hornfels, suggesting that they are underlain by a major igneous intrusion (fig.477). A second line of evidence comes from geophysics. A gravity survey over the region indicates a gravity low anomaly which roughly corresponds with the area of contact metamorphism. This is consistent with the presence of a large low-density granite body at a shallow depth below the surface.

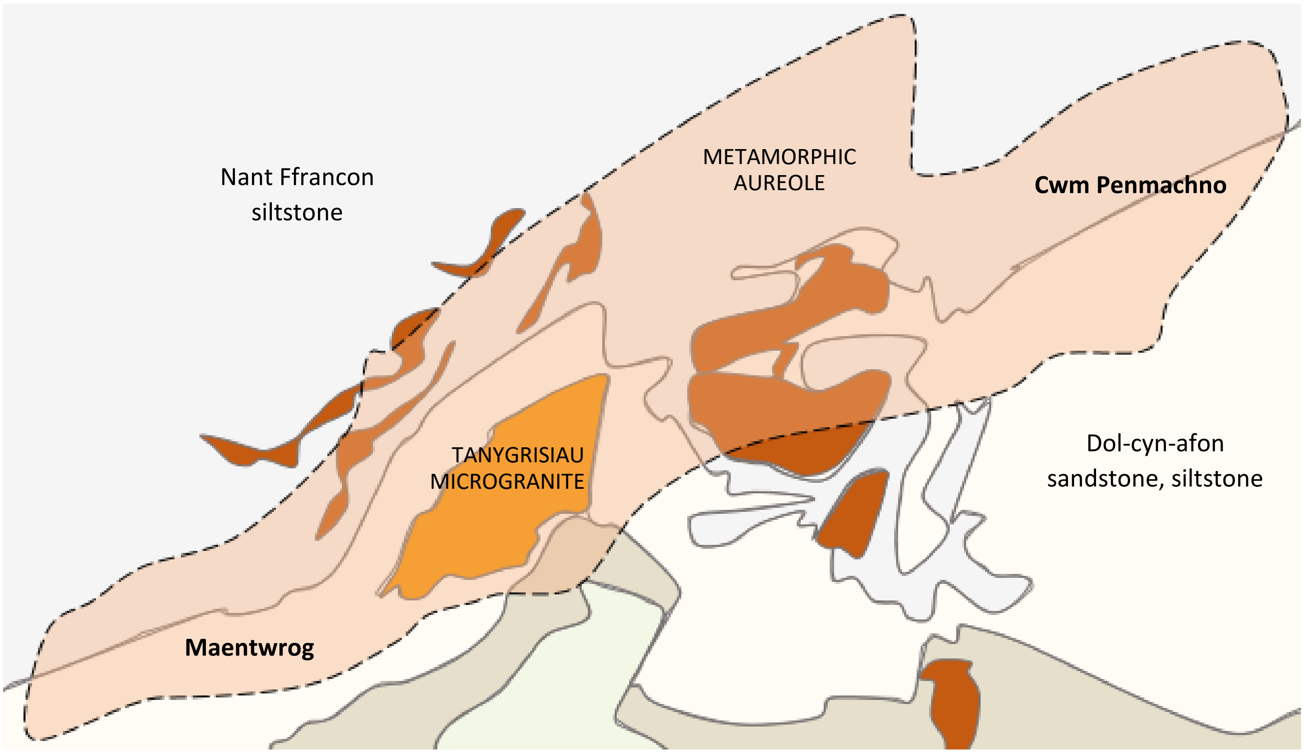


Figure 477: Evidence for a subsurface extension of the Tanygrisiau microgranite.

2: Continue along the concrete dam to reach a rocky outcrop on the left of the roadway.

Mudstones and siltstones have been converted to hornfels by heat from the microgranite intrusion. In the first outcrop you reach, the original sedimentary bedding can be seen. It is noticeable that the rocks show no evidence of the slatey cleavage which is normally present in similar sediments in Snowdonia. This is due to the contact metamorphism occurring during the Ordovician period, so that clay minerals were no longer present to create slatey cleavage during the subsequent Devonian earth movements.

Figure 478: Metamorphic aureole of the Tanygrisiau microgranite.

(above left) Outcrop of Dol-cyn-afon mudstone. The original sedimentary layering appears to be present, but no slatey cleavage has developed.

(above right) Banded hornfels. Silt bands have recrystallised to quartz, whilst mud layers have been converted to chlorite and sericite.

(below right) Higher grade spotted hornfels outcropping closer to the microgranite contact.

The first rocks observed are banded hornfels, with the original sedimentary composition reflected in the metamorphic minerals formed in each band. Rusty weathering can be seen in some layers, and is due to the formation of iron-rich chlorite from the original clay minerals.

Continue southwards along the rock outcrop. We see that the banding of the hornfels becomes less distinct, then disappears to leave a spotted hornfels with a crystalline texture similar to an igneous rock. This represents the highest grade of contact metamorphism where the rock was close to melting. Visible crystals of chlorite and sericite are present. It is likely that crystal formation was catalysed by superheated steam escaping from the nearby body of microgranite.

Descend along the roadway which leads to the spillway of the dam. Examine the rock outcrops in the cutting on the right of the roadway. The majority of the rock face is formed by the

Figure 479:

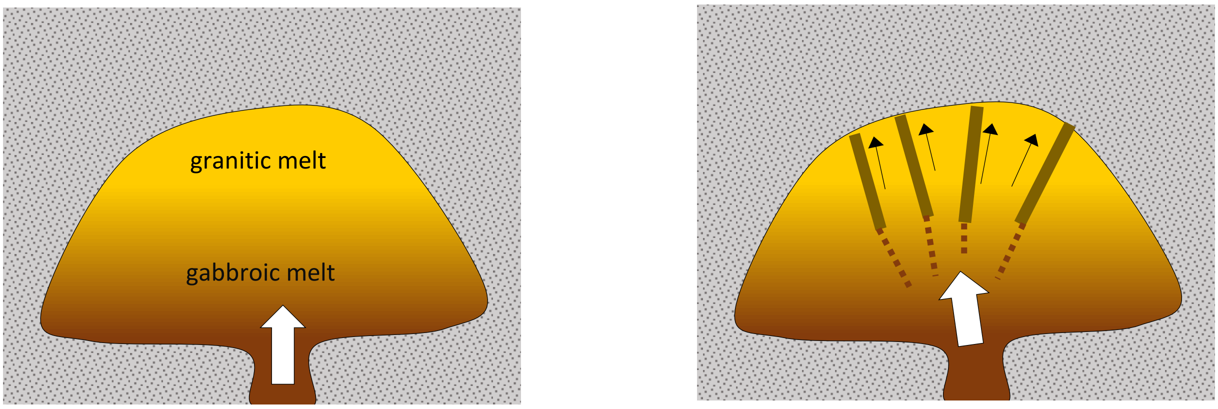
(left) Microgranite exposed in the road cutting next to the dam spillway.

(right) Mafic dyke and associated quartz veining cutting the microgranite.

Tanygrisiau microgranite. The microgranite is a pale greenish-grey fine-grained rock composed of plagioclase and orthoclase feldspar, quartz with dark spots of the secondary mineral chlorite. The chlorite is a product of low grade regional metamorphism during the Devonian mountain building event, and replaces biotite which was originally present in the microgranite.

Within the rock face, the light coloured microgranite is cut by a thin vertical dyke of a black gabbroic rock with a visible crystalline texture. This dyke is in turn cut by irregular veins of white quartz (fig.479). Similar thin mafic dykes and associated quartz veining have also been found in the roof zone of the microgranite intrusion at a number of other locations. A possible mechanism for the emplacement of these dykes is shown in fig.480.

The emplacement of the gabbro dykes whilst the microgranite was still hot is shown by blended boundaries between the rock types, with no sharp lines of contact. Hydrothermal fluids released from the crystallising microgranite are able to permeate through the hot crystal mesh of the gabbroic dykes to produce quartz veining.



The magma chamber becomes gravity fractionated, with the melt varying from gabbroic at the base to granitic at the roof.

Crystallisation begins in the upper granitic zone. Injection of further melt can displace gabbroic melt upwards into fractures in the roof of the solidifying intrusion.

Figure 480: Emplacement of gabbroic dykes in the roof of the Tanygrisiau intrusion.

3: Return across the dam to the road, then turn left towards the power station. At the road junction, take the branch which ascends southwards above the lake, crossing the Ffestiniog railway.

4: Take a footpath on the left of the road which skirts around the back of the power station, then continues alongside the reservoir to reach the disused Moelwyn lead mine.

5: Spoil tips, adit tunnels and opencast workings stretch up the hillside (fig.480). As in the case of the mines around Rhyd, these ore deposits were emplaced during the Acadian orogeny in Devonian times. Hydrothermal fluids produced by low grade regional metamorphism of the underlying sedimentary succession will have risen along the Vale of Ffestiniog fracture zone, crystallising in faults and fractures near the surface as the temperature and pressure were reduced.

Figure 481: Moelwyn mine.

6: Cross the Ffestiniog Railway and take the footpath which skirts around the end of the reservoir towards the Moel Ystradau granite quarry.

7: View the old granite quarry.

8: Continue along the footpath around Moel Ystradau to reach the main road at Tanygrisiau, and then take the power station road to reach the parking area.

Figure 482: Moel Ystradau granite quarry.