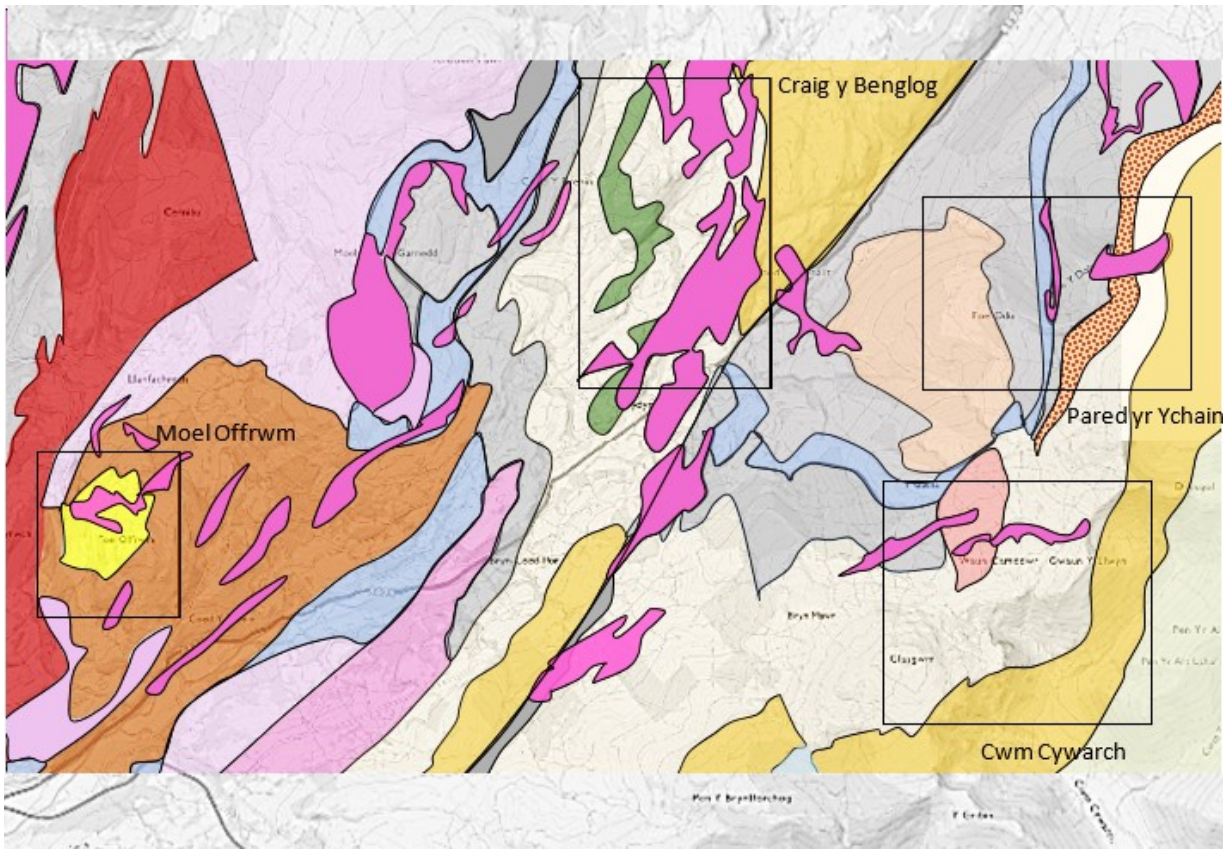
The Aran mountains

11



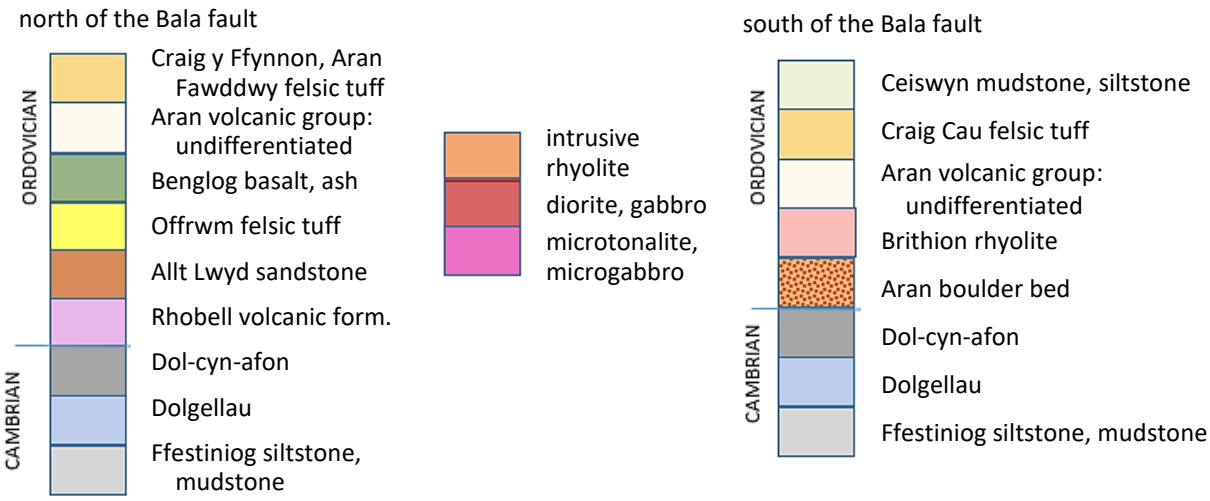


Figure 306: Field excursions.

In this and the next chapter we continue to examine the Aran Volcanic Group as the outcrop is followed inland from Cader Idris, through the Aran mountains and around the eastern margins of the Harlech Dome to Arenig. An important aspect of our investigation will be the role played by deep crustal fracture zones in controlling both sedimentation and volcanic activity during the Ordovician period.

Towards the end of Cambrian times, uplift began in the north of the Welsh basin. Earth movements and volcanic activity were associated with the breaking away of the Avalonian microcontinent from Gondwana, and the beginning of subduction of oceanic crust as Avalonia moved out into the Iapetus ocean. In previous chapters we examined folds and faults in Cambrian strata, and the basalt lavas and intrusive rocks of the Rhobell Volcanic episode, which were formed at this time.

After the Rhobell volcanic episode, the uplifted landmasses of north Wales underwent erosion and began to subside below sea level. An early embayment of the sea was the Dolgellau basin, into which sediments of the Allt Lwyd formation were deposited (fig. 307).

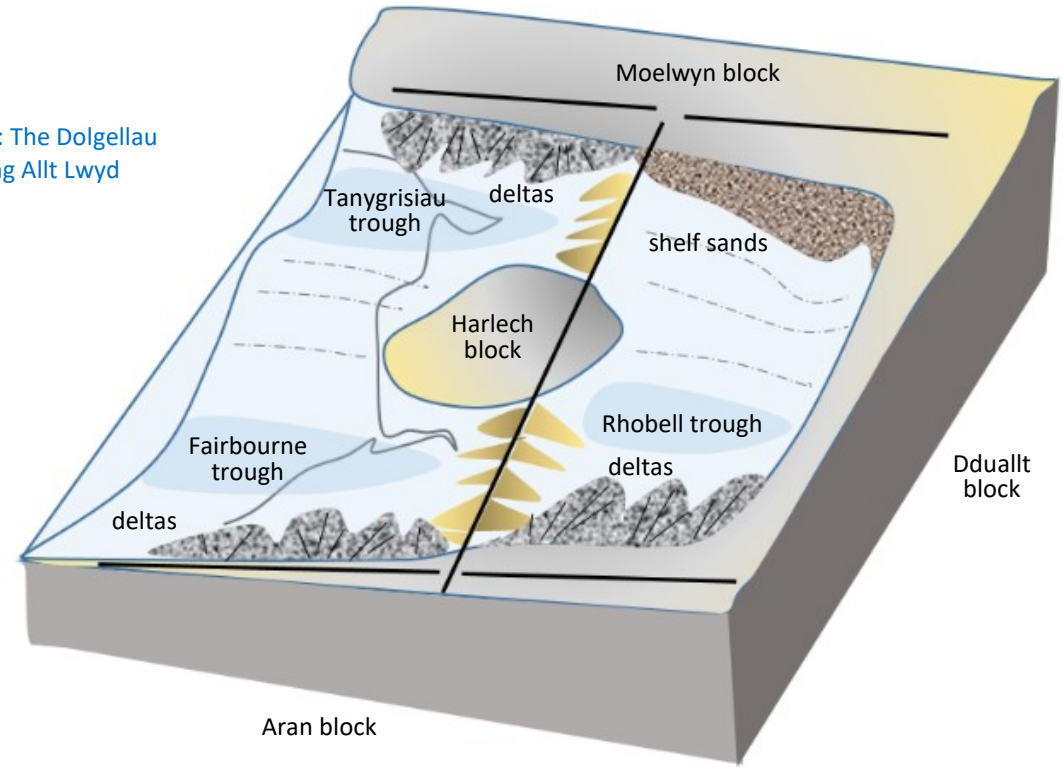


Figure 307: The Dolgellau basin during Allt Lwyd times.

Subsidence of the Dolgellau basin was largely controlled by movements along two major sets of faults: a north-south set which included the Rhobell-Corris fracture zone, and a northeast-southwest set which included the Bala-Mawddach fracture and a similar fracture zone around the Moelwyn mountains to the north of the Harlech Dome.

The structure of the basin was quite complex with the remnants of an uplifted area in the central Harlech Dome, perhaps underlain by buoyant hot magma which remained in the lower crust after the Rhobell volcanic event. The basin was separated into two parts by the Rhobell fracture zone, with deep troughs developed around the present locations of Fairbourne, Tanygrisiau and Rhobell fawr. Coarse deltaic sandstones and conglomerates were discharged into these troughs, whilst finer sands and muds were deposited in the shallower shelf area at the northeast of the basin.

Volcanic activity soon recommenced in the Welsh basin and continued intermittently for much of Ordovician times. In our study of Cader Idris, we found a clear division of lavas and ashes into high silica rhyolites and low silica basalts, with few rocks of intermediate silica content present. This pattern is continued into the Aran mountains, but basaltic rocks become less frequent as we move northwards around the margin of the Harlech Dome. At Arenig, the volcanic succession is almost entirely composed of high silica rhyolitic ashes. An explanation for this pattern can be found by considering the subduction processes taking place beneath the Welsh basin (fig.308).

Subduction of oceanic crust took place in a southeasterly direction from a sea floor trench in the area of the present day Isle of Man and north of the Lake District. Magma diapirs were generated in the mantle wedge above the subducting plate, and would have risen to create

convection cells beneath the lithosphere. As a consequence, the overlying crust was subjected to extensional forces which allowed the opening of northeast-southwest fractures such as the Bala-Mawddach fracture zone. This in turn allowed basaltic magma to rise rapidly to the surface where submarine lava flows or ashes were erupted. By contrast, north-south oriented fractures such as the Rhobell-Corris fracture zone were held closed by compressive forces. Magma was still able to rise through the fractured rock, but did so by a slower process of assimilation and melting. Much of the new material incorporated into the melt would be sandstone and shale with a high silica content, gradually changing the melt to a rhyolitic composition. Rhyolite magma is more viscous than basalt magma, so builds steep volcanic cones from which ashes are explosively erupted. Rhyolitic volcanoes often developed as islands in the Welsh basin.

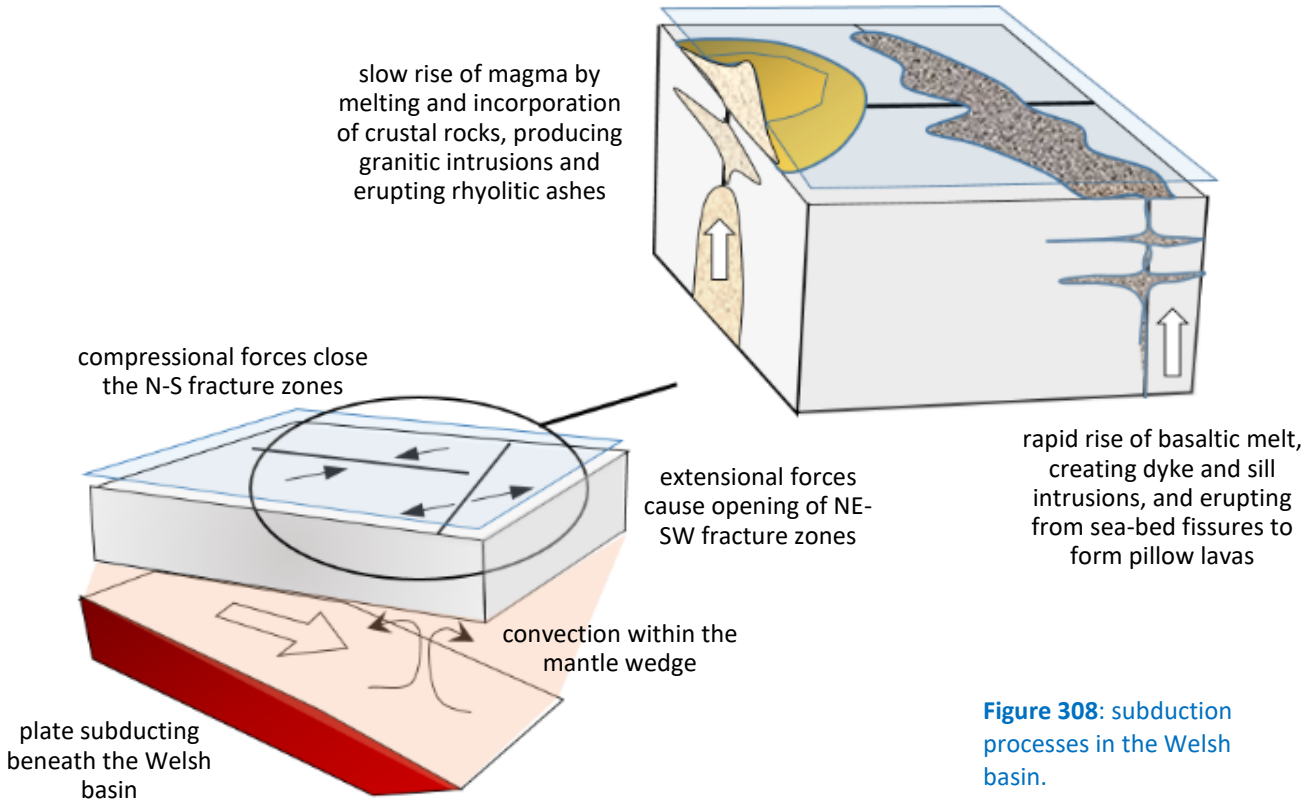


Figure 308: subduction processes in the Welsh basin.

In this chapter we will examine the Aran volcanic group as we move inland from Cader Idris towards the Aran mountains. The same general succession of volcanic lavas, ashes, and interbedded sediments is seen. However, as mentioned above, there are some differences related to location within the marine basin and the role of the fracture zones in controlling the eruption of magma.

The Aran volcanic group begins with the sedimentary Allt Lŵyd formation. This consists mainly of sandstones around Cader Idris, but in the Aran mountains we also find a coarse conglomerate known as the **Aran boulder bed** which was produced as a pebble beach deposit along the shoreline. The overlying Offrwm formation of felsic ashes were then erupted extensively across the area.

In the Aran mountains, the sequence of mudstones, ashes and agglomerates of the Cregennen formation merges laterally into the Melau formation of mafic ashes and thin basalt and rhyolite lava flows (fig.309). We then move upwards into the Brithion formation of felsic ash-flows which were associated with a localised rhyolitic dome.

The next volcanic phases at Cader Idris, the Llyn y Gafr and Pen y gadair basaltic formations, merge laterally into the Benglog basaltic formation in the Aran mountains.

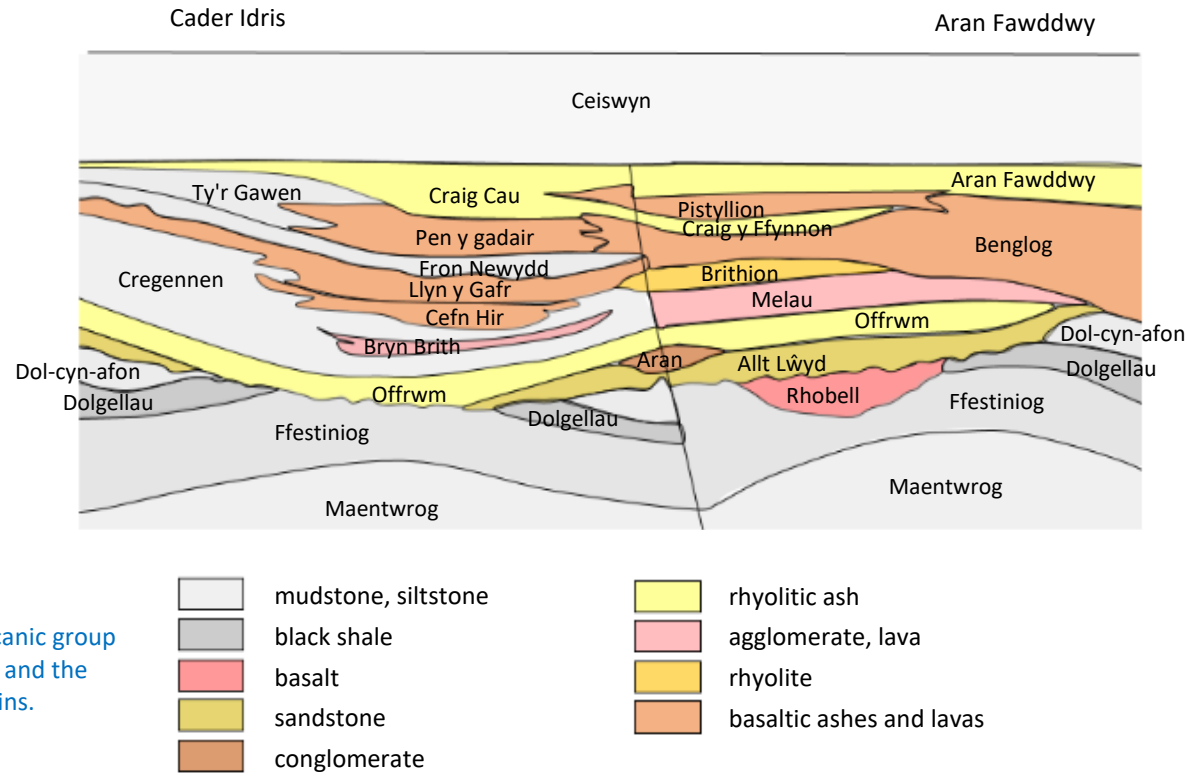


Figure 309: The Aran volcanic group at Cader Idris and the Aran mountains.

We find rhyolitic lavas and ashes at various levels through the Aran succession. The Brithion formation is unusual in being a single localised rhyolite dome in the centre of the Aran mountains from which lava flowed for a relatively short distance.

Towards the end of the Aran volcanic episode, much greater volumes of rhyolitic ash were erupted, depositing ignimbrites over a wide area. At Cader Idris these produce the Craig Cau formation, whilst in the Aran mountains we find two ignimbrite sequences, the Craig y Ffynnon and Aran Fawddwy formations.

Rhyolitic magma rose to a high level magma chamber before erupting through a volcanic vent. If we look for the location of a volcano, the most likely candidate is a large rhyolite intrusion at Foel Ddu in the central Aran mountains near the intersection of the Rhobell and Bala fracture zones (fig.310).

The Foel Ddu intrusion has a diameter of about 2 kilometres, and ascends vertically through upper Cambrian Ffestiniog sediments. The central portions of the intrusion show steeply inclined flow foliation, produced as the magma moved towards the surface. It is possible that initially a large rhyolite dome formed at the surface then exploded to release clouds of rhyolite ash, in a similar way to the recent eruptions of Mount St Helens. Ignimbrite flows spread outwards to reach as far as Cader Idris in the west and Arenig in the north.

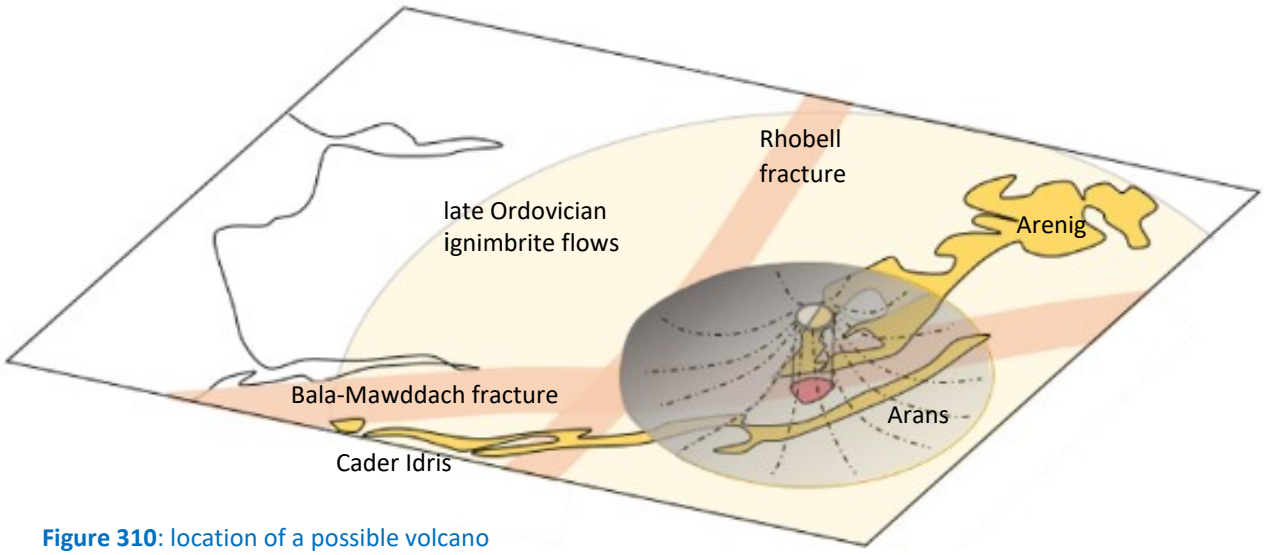
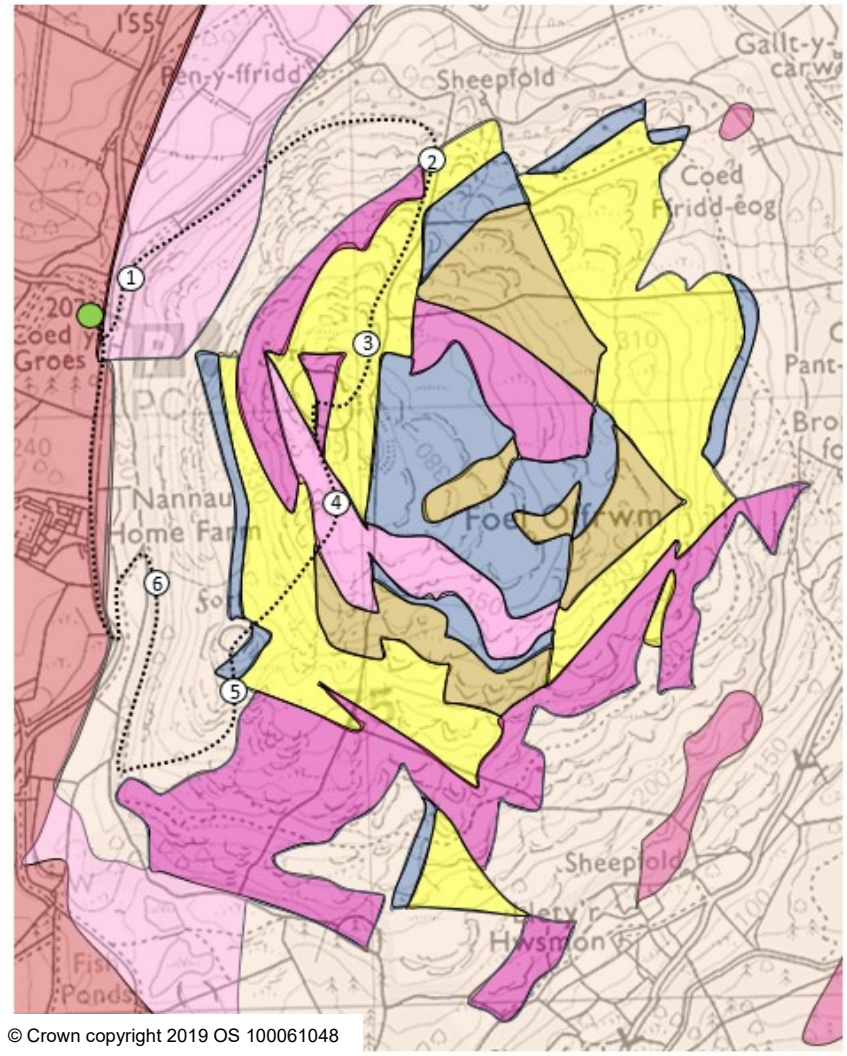


Figure 310: location of a possible volcano centred on the Foel Ddu rhyolite intrusion.

Moel Offrwm

2 miles: approximately 1½ hours



Aran basalt
Aran siltstone tuff
Aran agglomerate tuff
Offrwm felsic tuff
Allt Llwyd sandstone
Rhobell basalt

Microgabbro
Diorite and gabbro

Figure 311:
Field excursion.

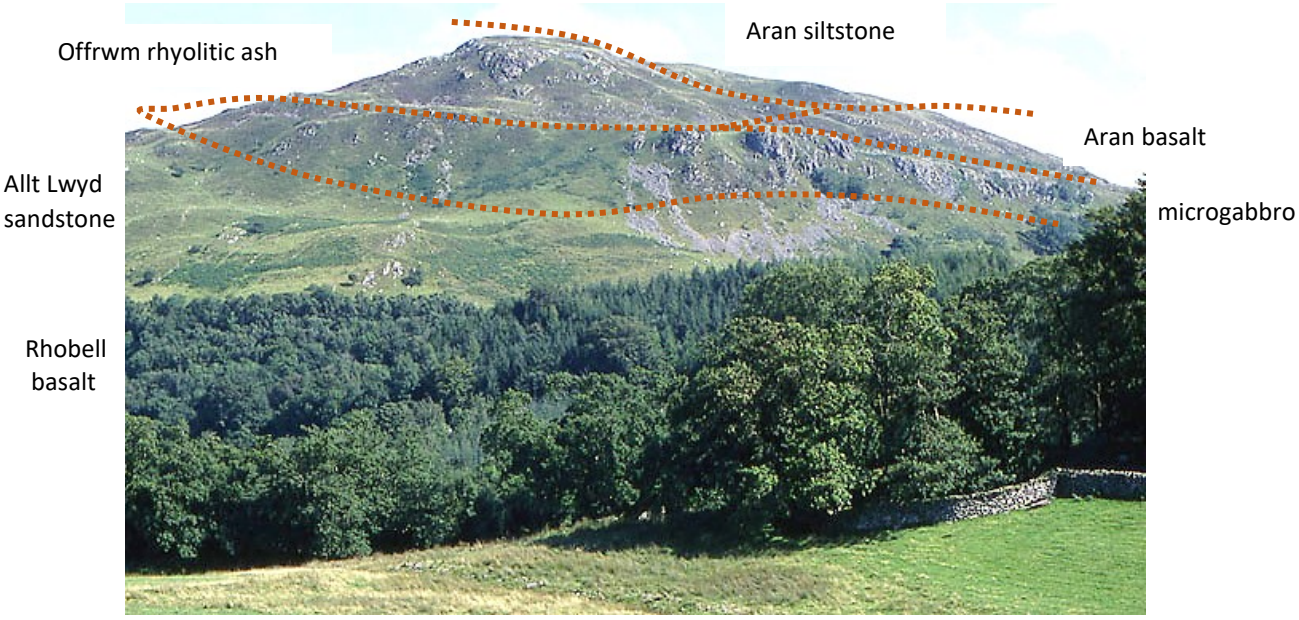


Figure 312: Moel Offrwm, viewed from the north-west.

In this excursion, we examine outcrops on the isolated peak of Moel Offrwm, which lies near the intersection of the Rhobell-Corris and Bala-Mawddach fracture zones on the south-east of the Harlech Dome. The area is heavily fragmented by faults and we find a variety of blocks of differing geological formations have been moved into contact with one another.

Start: Park in the car park at the start of the Precipice Walk [SH746212].

1: Cross the road to join the footpath which curves to the north around the base of Foel Offrwm.

Ordovician rocks rest unconformably on Rhobell lavas. Small outcrops of these basalts alongside the path are partly altered to sericite and calcite by low grade metamorphism, but the remnants of large amphibole phenocrysts can be found.

2: Continue around the hillside above the wood. When a dry stone wall is reached, leave the track and follow the wall up towards the summit of the hill.

The first outcrops seen are sandstones and mudstones of the Allt Lŵyd formation. These sediments were deposited in shallow water near the early Ordovician coastline.

Figure 313: Offrwm ignimbrite.

3: Examine outcrops of the Offrwm formation which overlie the sandstones. The Offrwm formation consists of rhyolitic ashes which show evidence of deposition from gravity flows to form ignimbrites. Towards the centres of the thicker ash deposits, welding has produced a fiamme texture. The ignimbrites appear to rest conformably on Allt Lwyd mudstone. A thin band of ashy mudstone overlies the ignimbrite.

The Offrwm formation extends westwards to Cader Idris, but is thickest around Moel Offrwm and in the Aran mountains. The location of the eruptive centre is not known, but this may have been at or near the Foel Ddu rhyolite intrusion.

Continuing up the hillside, we pass crags formed by a large micrograbbro sill intrusion (fig.314). This may represent a high level offshoot from a fissure carrying basaltic magma to the sea floor during eruption of the Benglog formation.

The outcrops on the eastern flanks of Moel Offrwm are a faulted block of agglomerates containing fragments of rhyolite in a basaltic ash matrix. These are likely to be underwater slump deposits of the Melau formation, the lateral equivalents of similar agglomerates at Cregennen in the Cader Idris area. They formed in shallow water close to the shore of a volcanic island.

Figure 314: Microgabbro sill.

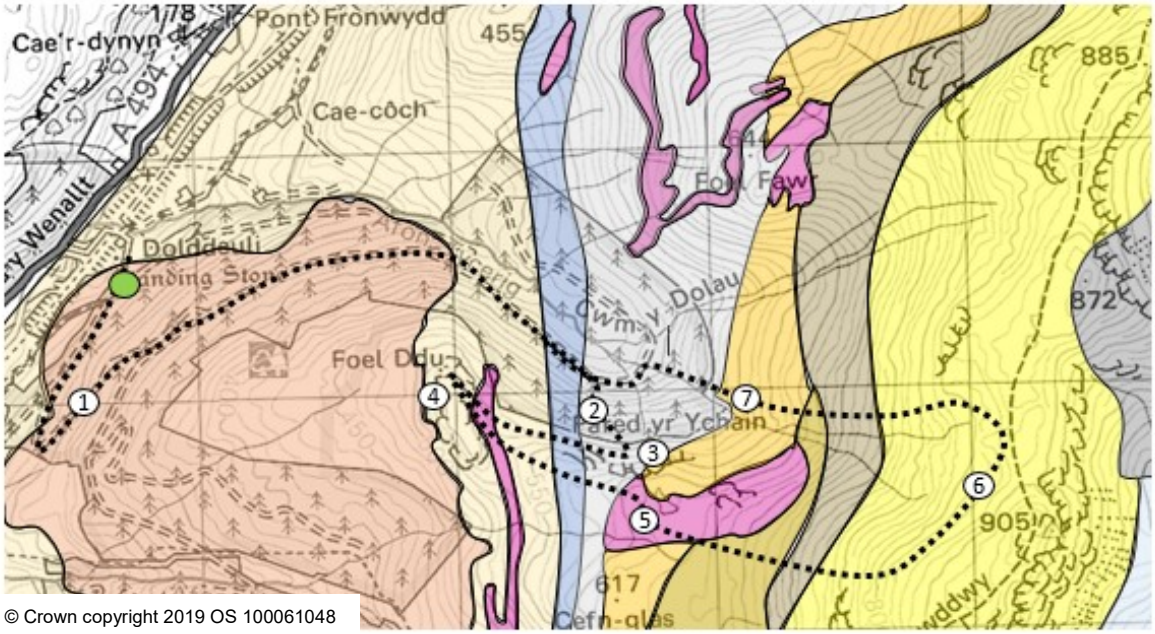
4: After reaching the summit of Moel Offrwm, descend across the hillside in a southerly direction towards the lower Iron Age hill fort. Outcrops of rubbly basalts of the Benglog formation are crossed. These are likely to have been erupted from fissures on the nearby seabed.

5: At the hill fort, the outcrop of Allt Lŵyd quartzose grit is reached. Pebble bands occur at points within the sequence, suggesting deposition close to a local shoreline.

6: Return down the hillslope and around the track to Nannau Home Farm.

Pared yr Ychain

6 miles: approximately 3 hours



- Nant Ffrancon siltstone
- Ceiswyn mudstone, siltstone
- Craig Cau felsic tuff
- Pistyllion tuff, lava
- Brithion felsic tuff
- Aran conglomerate
- Intrusive rhyolite
- Microgabbro

Figure 315: Field excursion.

The objective of this excursion is firstly to examine the large rhyolite intrusion at Foel Ddu. We then ascend through the Aran Volcanic Group to reach outcrops of Craig Cau ignimbrites which form the crest of the Aran mountain escarpment.

Start: Turn off the main Dolgellau to Bala road east of the village of Rhydymain, and park at the start of the forest road at Dolddeuli [SH827236].

1: Walk up the forestry road to Cwm y Dolau. A series of road cuttings expose outcrops of the Foel Ddu rhyolite intrusion. At the more central locations within the intrusion, flow foliation is visible, both in hand specimens and in the rock face. Foliation occurs as a series of folds. When the regional dip is restored, the fold axes are steeply dipping or vertical.

Figure 316: Foel Ddu rhyolite intrusion: (left) Flow foliation in the central area of the intrusion. (right) Sheet intrusions of rhyolite at the margin of the igneous body.

Close to the edge of the intrusion, a series of sheets of rhyolite of varying thickness overlie one another, and would have had a horizontal orientation originally. At this depth, the intrusion is passing through Ffestiniog beds of the upper Cambrian, so the sheets represent multiple sill intrusions, probably following bedding planes within finer mudstones which would provide an easy flow path.

2: Leave the forestry road where it begins to curve around the head of Cwm y Dolau. Ascend through the forest to the base of Pared yr Ychain.

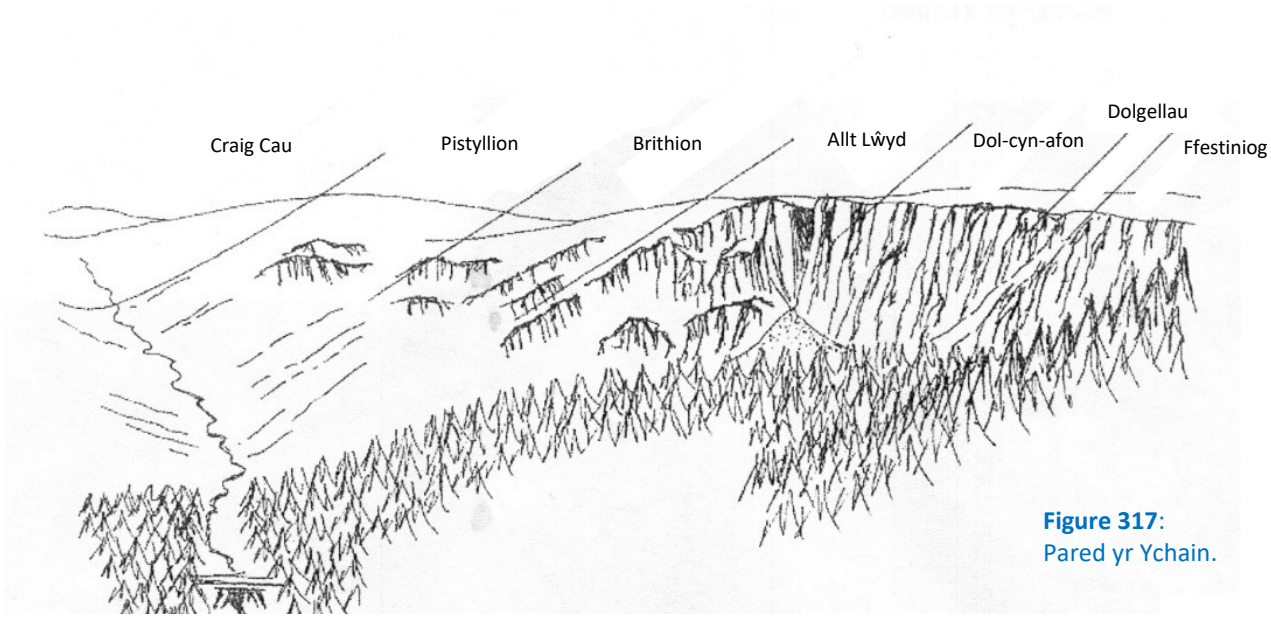


Figure 317: Pared yr Ychain.

3: Observe the sequence of Upper Cambrian and basal Ordovician strata in the cliff face of Pared yr Ychain.

Outcrops of Upper Cambrian Ffestiniog, Dolgellau and Dol-cyn-afon sediments form the western end of the Pared yr Ychain cliff face. The Ordovician Aran Volcanic Group continues the sequence eastwards towards the Aran mountain ridge.

The Aran Volcanic Group begins with the Allt Lŵyd formation. The boundary at this point appears to be a fault, whilst elsewhere it is an unconformity representing a break in sedimentation during which was the Rhobell volcanic episode. The Allt Lŵyd rocks are conglomerates, with a muddy matrix exhibiting spectacular slump folding which occurred by downslope movement while the material was still unlithified. The rock fragments within the conglomerate are mainly porphyritic felsite, a fine grained intrusive rhyolite containing larger feldspar crystals.

Figure 318: (left) Slump folds in Allt Lŵyd basal conglomerate, Pared yr Ychain. (right) Aran boulder bed.

4: Climb up alongside the cliff of Pared yr Ychain to reach the hillside of Cefn Glas. As the outcrop of the Allt Lŵyd formation is followed upwards in the sequence, the proportion and size of the clasts increases. The coarsest conglomerates, termed the **Aran boulder bed** represent a poorly sorted underwater flow of angular volcanic debris which slumped from the shoreline. The exact source of the clasts is uncertain but it is likely that a rhyolitic volcano was active to the south of the Aran mountains around the time of the Rhobell volcanic episode. Traces of this volcanic centre are now hidden by the covering of younger Ordovician and Silurian sediments.

5: Continue around the head of Pared yr Ychain to a small lake, then on towards Aran Fawddwy. We pass outcrops of ashes of the Melau formation (fig.319).

Figure 319: Ashes of the Melau formation, Aran Fawddwy.

Figure 320: Ignimbrite at Aran Fawddwy, with foliated ash grading downwards into welded ignimbrite.

6: At the head of the valley we reach the outcrops of massive ignimbrites of the Craig Cau formation which produce the summit ridge of the Aran mountains. The ashes are welded within thicker flows, with a foliated texture towards the margins of the flow.

7: Return down the valley of the Afon Tycerig, observing basalt lavas of the Pistyllion formation in the stream bed and basaltic ashes in outcrops on the stream bank.

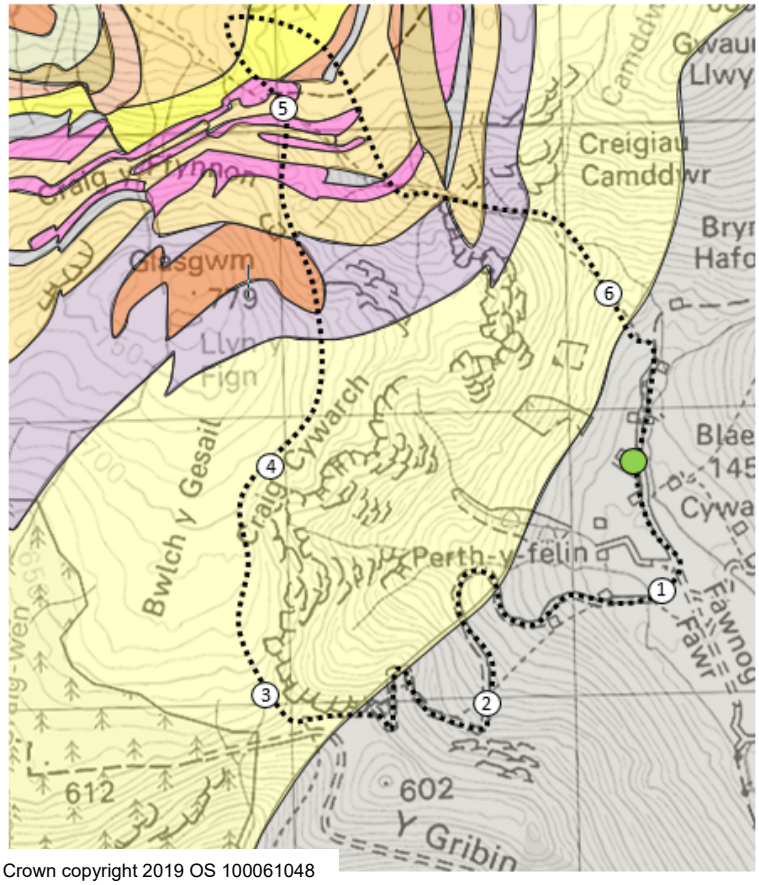
Figure 321: Outcrops of Pistyllion formation basalt lavas in the bed of the Afon Tycerig.

The lavas are massive and vesicular in their upper parts, with no evidence of pillow structures. The ashes are roughly stratified, with fine and coarser pyroclastic fragments present. It is possible that the lava was extruded from fissures along a coastline, and flowed in large volumes into shallow water. Ashes would be associated with explosive eruptions, perhaps as water entered the fissure system and was turned to high pressure steam.

Re-join the forestry road in Cwm y Dolau and return to the parking point at Dolddeuli.

Cwm Cywarch

4 miles: approximately 2½ hours



- Intrusive rhyolite
- Microgabbro
- Ceiswyn mudstone, siltstone
- Craig Cau felsic tuff
- Pistyllion tuff, lava
- Craig-y-ffynnon felsic tuff
- Benglog siltstone
- Benglog tuff, lava
- Ty'r Gawen mudstone
- Cregennen mafic tuff
- Brithion felsic tuff
- Brithion rhyolite
- Aran conglomerate
- Allt Lwyd sandstone
- Dol-cyn-afon mudstone, siltstone

Figure 322: Field excursion.

Figure 323: Craig Cywarch.

The purpose of this excursion is to examine outcrops on the southern dip slope of the Aran mountains. We ascend the glacially steepened valley side of Cwm Cywarch, moving downwards through the geological succession from the Ceiswyn mudstones which were deposited in the Welsh basin after the long period of eruptions of the Aran Volcanic Group ended (fig.324).

Start: A car park is provided in Blaencywarch village [SH852188].

1: Take the track which rises up the valley side from Fawnog Fawr. The path winds upwards past old farm settlements towards the cliffs of Y Gribin.

2: Observe the Ceiswyn mudstones exposed in outcrops at Y Gribin.

Figure 324: Ceiswyn mudstones.

The Ceiswyn mudstones lie conformably on the volcanic strata, suggesting an abrupt end to volcanic activity but continued quiet sedimentation in the Welsh basin. Most of the Ceiswyn rocks are composed of fine mud, with very little coarser silt or sand present. The Aran area may therefore have lain within the deeper axial part of the basin, well away from eroding shorelines. Sedimentary structures suggest a source area to the north, with bottom currents carrying mud southwards along the axis of the trough.

An interesting feature observed during mapping of the Ceiswyn mudstones in the Aran area is that some gentle folding occurs, but the folded strata lie on slide planes above flat underlying mudstone strata. Soft mud units may have broken away and slid down the gentle submarine slope produced by continuing subsidence and deepening in the central area of the basin.

Further to the east, in the area of Bala, the Ceiswyn mudstone sequence becomes thinner, perhaps towards shallower water. Some limestone beds are present and may be evidence of warmer water conditions as the Avalonian microcontinent moved northwards across the Iapetus ocean away from the southern pole and towards the tropics.

3: At the top of the path, continue northwards around the cliffs of Craig Cywarch.

4: Observe outcrops of ignimbrites.

The outcrops along the summit crest of the Aran mountains are rhyolitic ignimbrite ashes belonging to the Craig Cau formation. These beds are a continuation of similar ignimbrites on Cader Idris, and may have shared the same eruptive source; this may have been the nearby Foel Ddu volcanic centre, a possible eruptive centre further north in the Arenig area which we will visit in the next chapter, or a centre further south which is now concealed beneath younger Ordovician and Silurian sediments. All the suggested sources of the ignimbrite eruptions lie within the Rhobell-Corris deep crustal fracture zone.

The ashes were emplaced as hot ash-flow tuffs during explosive volcanic eruptions. There is evidence of welding of the hot glass shards as the ash flow settled. It appears that at least two major eruptions occurred, each producing great thicknesses of ash. Rough bedding suggests multiple ash flows were released during each eruption. In places, the fabric of the welded material is folded, suggesting that the ignimbrites slumped down a slope whilst still not fully lithified.

Figure 325: Ignimbrite outcropping above Cwm Cywarch.

In places there are thin mudstone bands present within the ignimbrite sequence, suggesting eruption took place into water, with bottom currents able to pick up and redistribute the finest ash particles.

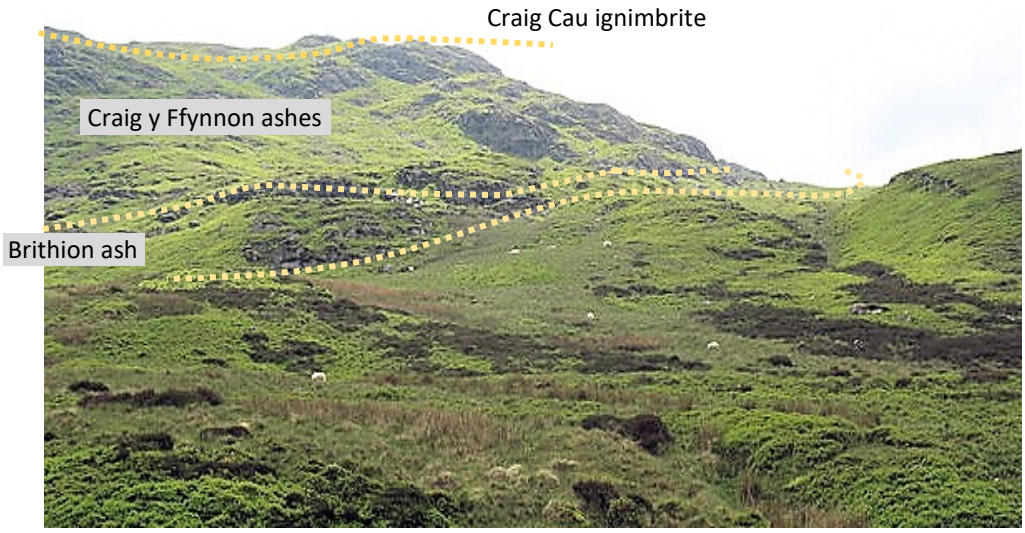


Figure 326: View of the low gap in the Aran ridge above Creigiau Camddwr. Outcrops of Craig y Ffynnon ashes are interspersed with microgabbro sills on the upper hillside to the left of the stream.

5: Descend across Craig y Ffynnon to the river valley west of Creigiau Camddwr (fig.326).

This is the type locality of the Craig y Ffynnon formation, which consists of a rhyolite lava flow overlain by rhyolitic ash flows. Near the base, the ash contains fragments of pumice and is not welded, but welding appears in the upper layers of ash.

The Craig y Ffynnon formation occurs over a relatively small area within the Aran mountains so is likely to have had a local source, perhaps in early volcanic activity at the nearby Foel Ddu centre.

Figure 327: Rhyolitic ash of the Craig y Ffynnon formation.

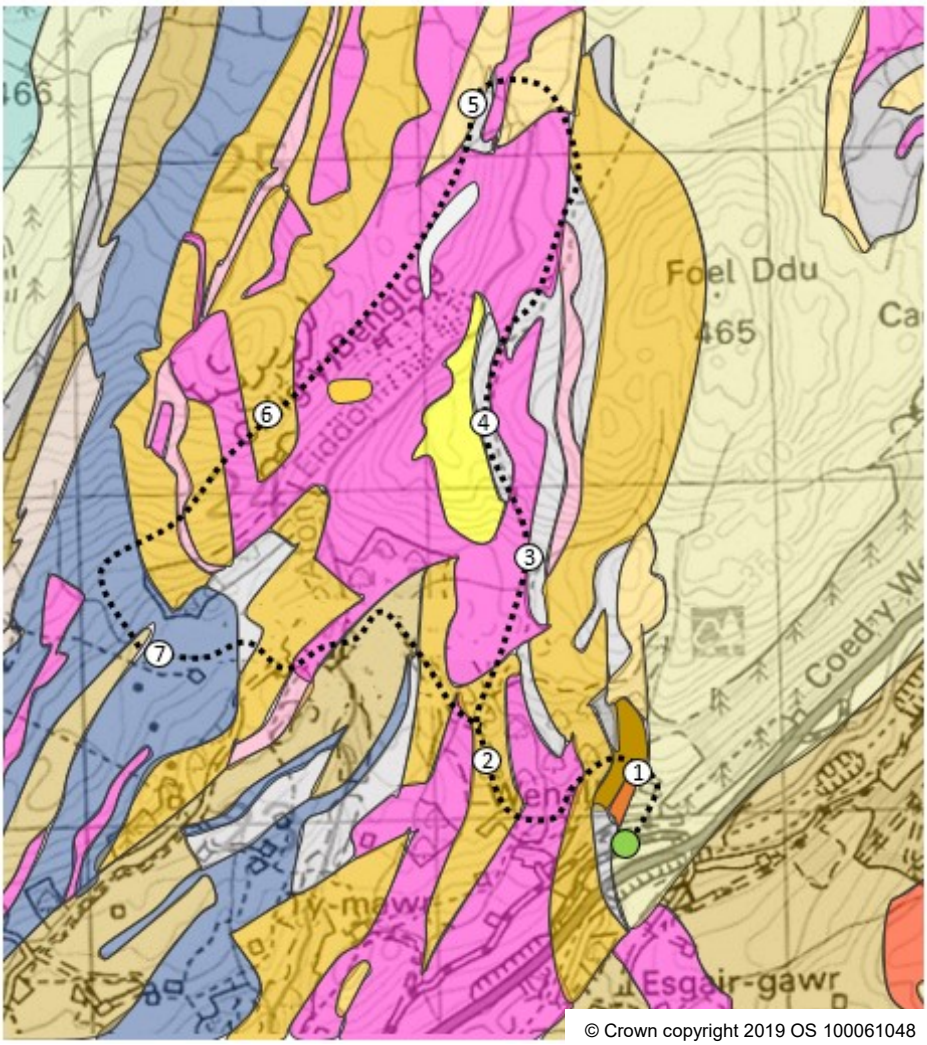
Microgabbro sills are found within the Craig y Ffynnon formation, following the bedding planes between finer ashes.

6: Follow the stream up towards a lower gap in the Aran ridge. At this point, basaltic ashes of the Pistyllion formation are exposed in crags. These rocks are the eruptive equivalents of the microgabbro sills seen earlier, which would have been emplaced at a shallow depth beneath the seabed. Both the sills and ashes seem to be associated with fissure eruptions along the Bala-Mawddach fracture zone during a period of north-south crustal extension.

Continue down the path below Creigiau Camddwr to reach Cwm Cywarch village.

Craig y Benglog

4 miles: approximately 2 hours



Intrusive rhyolite
Microgabbro
Aran Fawddwy siltstone
Aran Fawddwy tuffite
Aran Fawddwy felsic tuff
Aran mudstone, siltstone
Benglog tuffaceous-siltstone, tuff
Melau mafic tuffite
Melau mafic tuff
Craig-y-ffynnon felsic tuff
Benglog basalt
Benglog mafic tuff
Aran siltstone, tuffaceous-siltstone
Allt Lwyd sandstone
Allt Lwyd mudstone, siltstone
Dol-cyn-afon mudstone, siltstone
Dolgellau mudstone, siltstone
Ffestiniog siltstone, mudstone

Figure 328: Field excursion.

The main purpose of this excursion is to examine the basaltic lavas and ashes of the Benglog formation in their type area around Craig y Benglog. These rocks are a lateral equivalent of the Llyn y Gafr and Pen y Gader basaltic frmations of Cader Idris.

Start: Park in the lay-by on the main road below Coed y Wenallt [SH814228].

1: Ascend through the woodland to Wenallt farm. The track passes outcrops of sandstone and siltstone within the Allt Lŵyd Formation.

2: Continue up the track, past woodland on your left, to reach a point where the cliffs of Craig y Benglog are first seen.

3: Cross a stile over a dry stone wall. The stream crossing the road follows an outcrop of a softer-weathering basalt. In the exposure to the south of the road the basalt shows columnar jointing.

Figure 329: Basalt lavas of the Benglog formation.

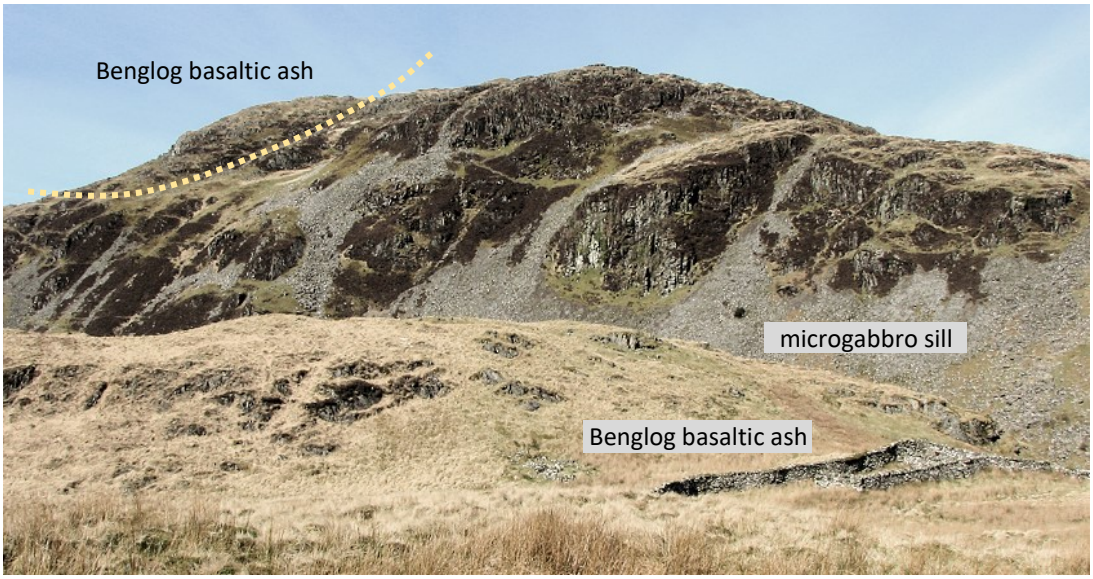


Figure 330: Craig y Benglog.

4: Follow the track upwards along a small valley as it ascends towards the northern end of Craig y Benglog. To the left is a low ridge of basaltic ashes of the Benglog formation (fig.329). Beyond the valley of the Afon Eiddon lies the main cliff face of Craig y Benglog, composed of a thick sill intrusion of columnar microgabbro. The southern crest of Craig y Benglog again exposes basaltic ashes of the Benglog formation.

Cross to the outcrops on the low hill to examine the Benglog ashes. These contain plagioclase crystal fragments and small lapilli of basalt in a fine matrix. This suggests explosive eruption of magma which had begun to crystallise in the fissure system within the crust.

Both the basalts and ashes of the Benglog formation have been found to contain plagioclase feldspar with a high sodium content, along with the presence of the hydrothermally formed minerals **chlorite** and **epidote**. This is an alteration feature caused by chemical reaction with sea water, and gives further evidence of eruption onto the sea bed. Rocks with sodium enrichment Basalts showing this form of alteration are known as **spilites**.

5: Continue along the track, past the dry-stone walls of sheep pens, to the Afon Eiddon. Cross the stream and ascend the end of Craig y Benglog to the summit plateau. Small outcrops of Aran Fawddwy rhyolitic ashes are passed before reaching the micrograbbro sill intrusion.

6: Continue south-westward across the summit plateau (fig.331) over micrograbbro until outcrops of Benglog basaltic ashes are seen. The ashes are well bedded, with thin bands of mudstone between the coarser volcanic material, suggesting reworking by bottom currents after eruption.

7: Return down the track through the Benglog nature reserve to rejoin the farm road at Wenallt. Descend through the woodland to the parking area.

Figure 331: The summit plateau of Craig y Benglog.