Yr Arddu and Llyn Gwynant

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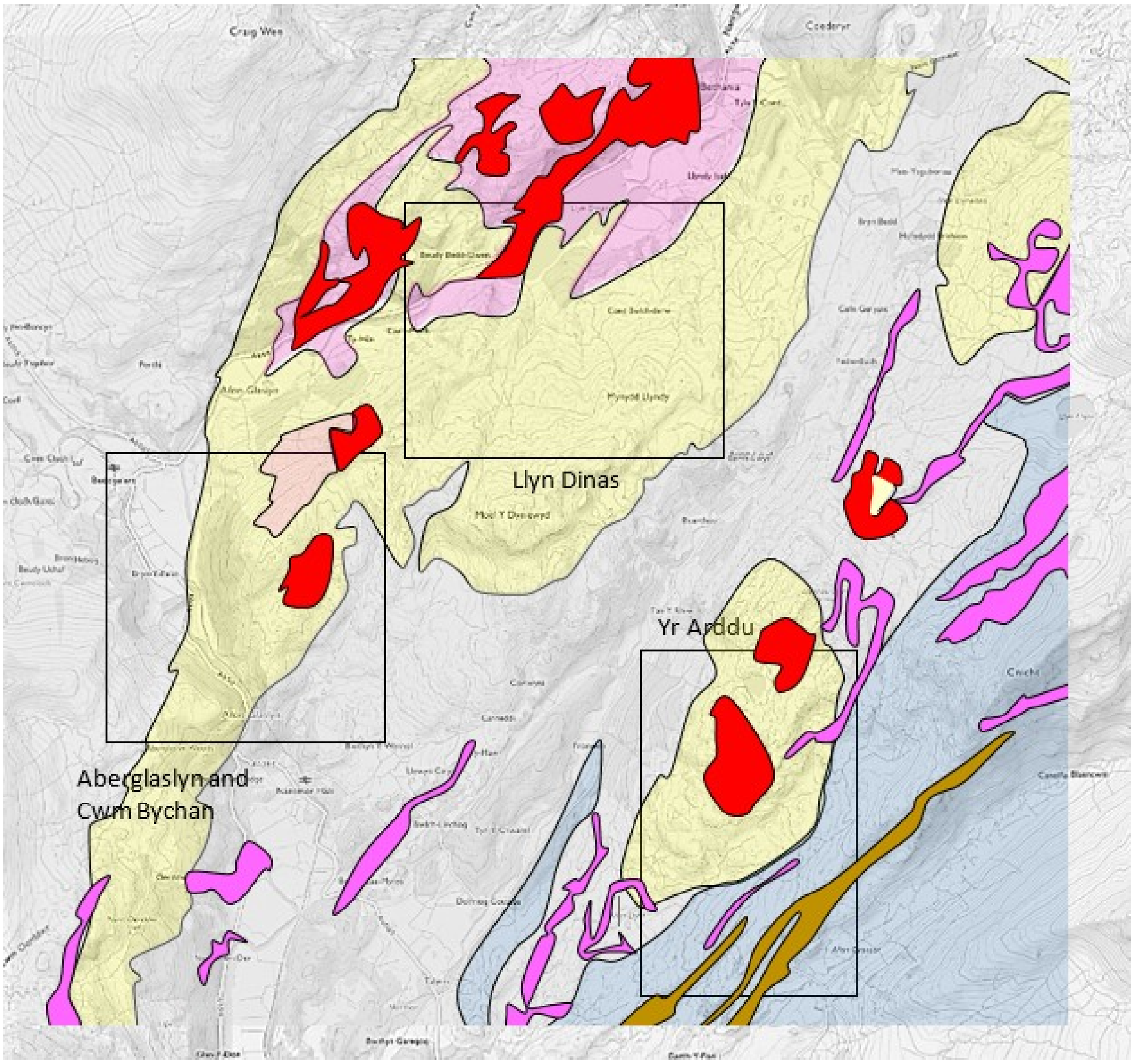


Figure 432: Field excursions.

In this chapter we continue our investigation of the Snowdon Volcanic Group by examining the Snowdon volcanic centre, which was one of the three active centres during the second phase of Ordovician volcanic activity in Snowdonia.

Deep crustal fractures are thought to be very important in controlling the distribution of volcanoes in North Wales. Both the Llwyd Mawr and Crafnant centres are associated with particular fracture zones (fig. 433). The Snowdon centre is unique in lying at the intersection of a series of deep fractures, which may explain the crustal instability in this location which led to the most prolific eruptions of any of the late Ordovician volcanic centres in Wales.

Following the discharge of the Pitts Head Tuffs from the Llwyd Mawr centre to the west, activity moved to the Beddgelert area as the Snowdon centre began to develop. Magma accumulated in a high level chamber beneath central Snowdonia, causing uplift of a horst of crustal rock bounded by several major northeast-southwest fractures (fig. 434). Volcanoes in the area of Yr Arddu erupted ignimbrite flows and coarser pyroclastic ashes of the Yr Arddu Tuff formation.

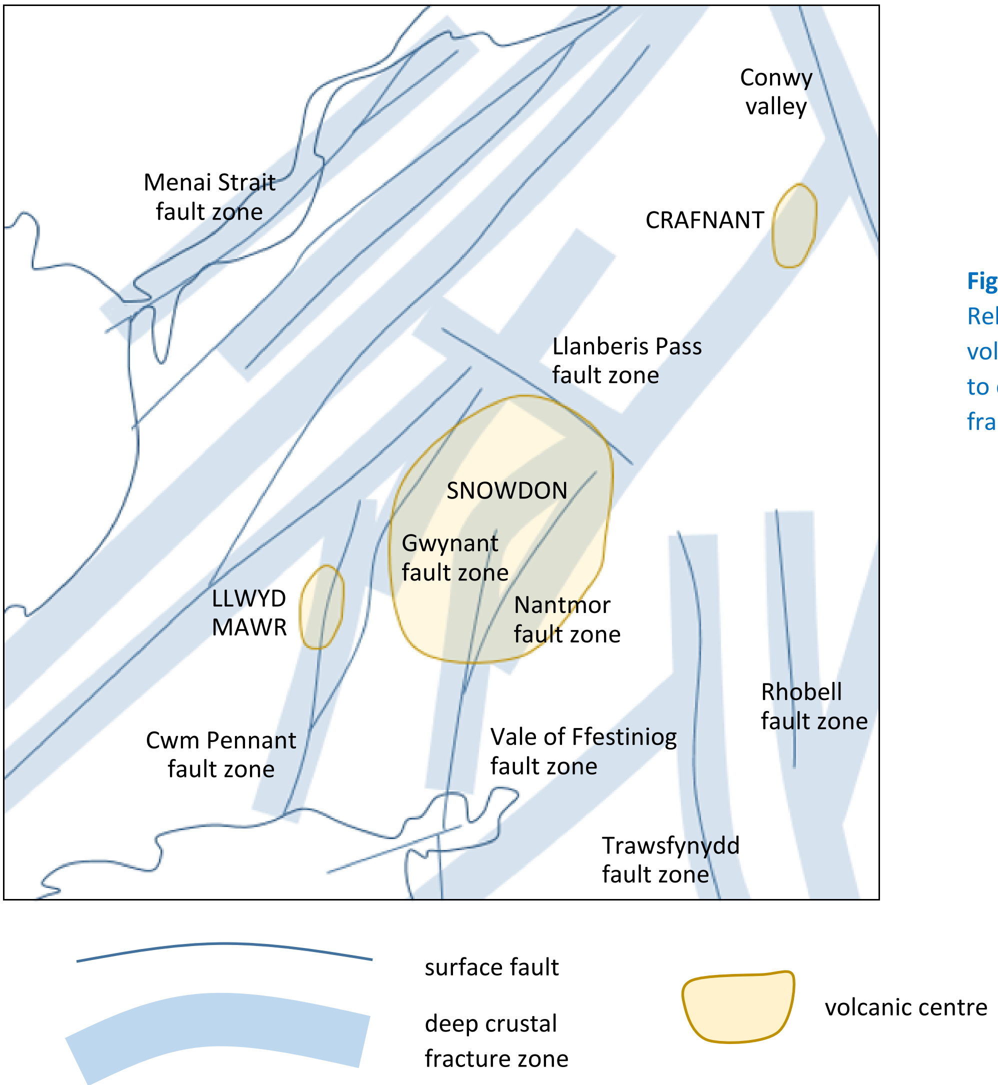


Figure 433: Relationship of volcanic centres to deep crustal fractures

As volcanic activity continued, the focus of the eruptions moved north-eastwards along the central fault zones to Snowdon and the Llanberis Pass. As magma continued to accumulate in the high level magma chamber, the overlying crust became structurally weakened. Collapse took place within a ring fracture to produce a caldera on the sea bed. Eruptions continued, creating a series of emergent volcanic islands around the caldera fracture. Enormous volumes of ashes were erupted, first as the felsic Lower Rhyolitic Tuff Formation, then the mafic Bedded Pyroclastic formation, and finally the felsic Upper Rhyolitic Tuff formation.

The collapsed caldera was oval in shape with a longer axis of about 12 kilometres, extending furthest in the direction of the northeast-southwest fracture zones. Much of the material erupted from volcanic islands accumulated on the sea bed in the central subsiding area of the caldera, but ash flows also travelled outwards across the sea floor to the areas of Cwm Idwal, Dolwyddelan and the Conwy valley. Subsidence was greatest in the northern area of the caldera, with the largest thickness of ashes accumulating around Snowdon and the Llanberis Pass.

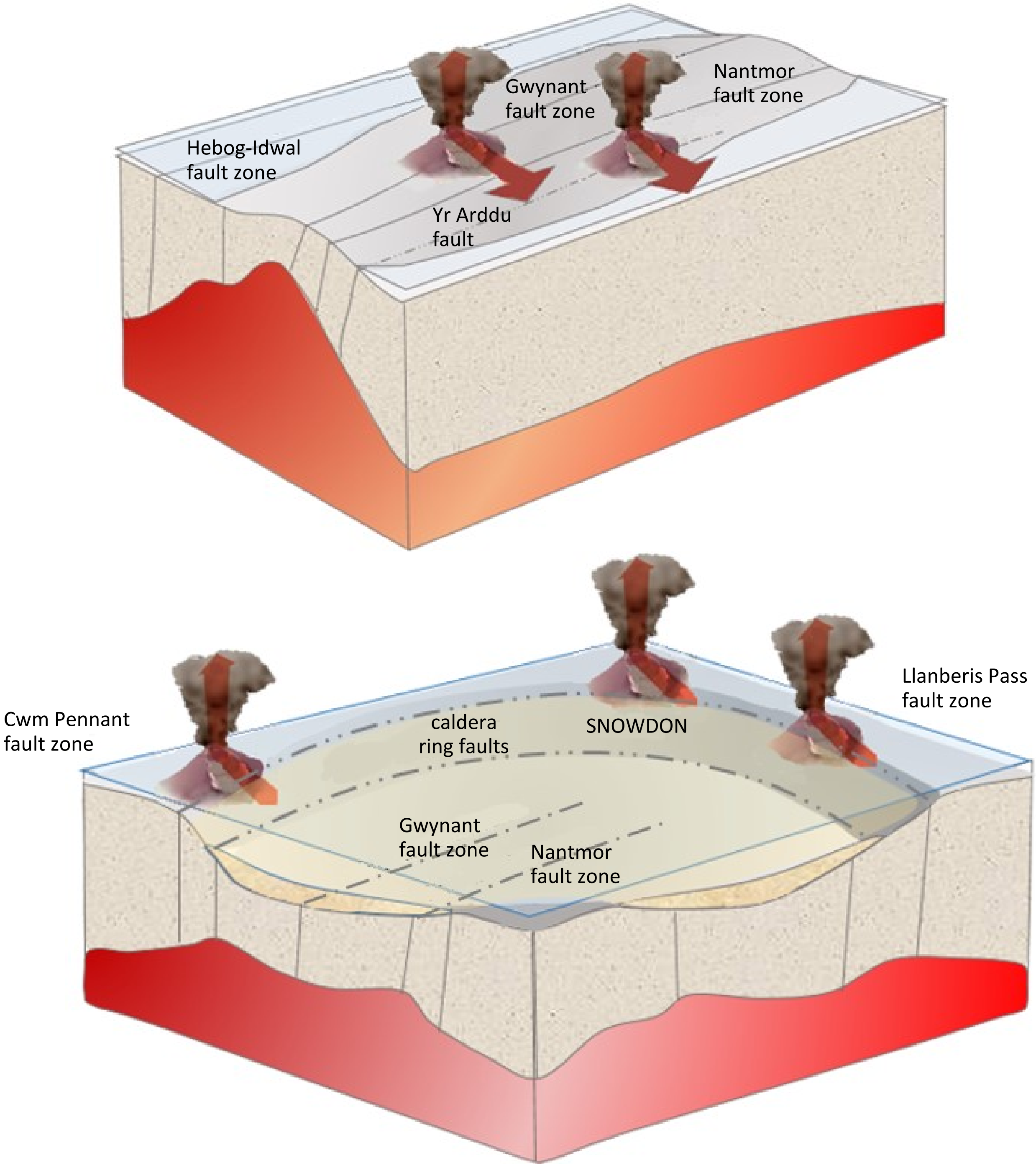


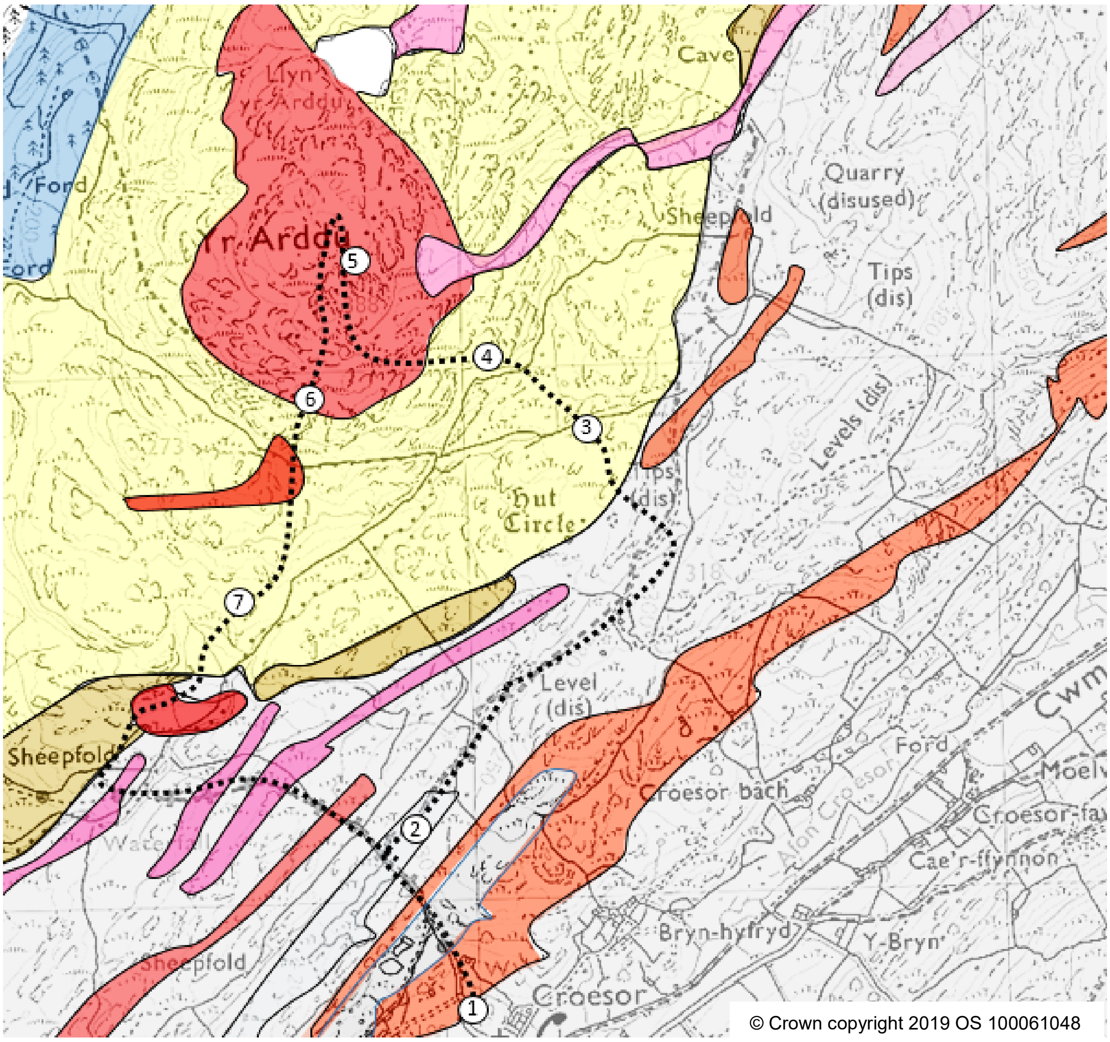
Figure 434: Evolution of the Snowdon volcanic centre. (above) Early uplift. (below) Late caldera collapse.

Many sill intrusions of both felsic and mafic composition reach the surface around the Snowdon volcanic centre, outcropping as arcs outside the caldera margin. These are cone-sheets, formed as different magmas were forcefully intruded upwards and outwards from the high level magma chamber. The magma in the chamber may have become gravity stratified, with silica content varying with depth, or the composition of the melt rising from deeper in the crust may have changed over time.

In the field excursions for this chapter we visit: the mountain of Yr Arddu, composed of ignimbrites and pyroclastic ashes of the Yr Arddu Tuff formation; the copper mines of Cwm Bychan, and the Aberglaslyn pass where the Lower Rhyolitic Tuff is exposed; and the Gwynant valley at Llyn Dinas where we see breccias which accumulated within the subsiding sea floor caldera.

Yr Arddu

4 miles: approximately 3 hours



Nant Ffrancon siltstone	Felsite
Lower Rhyolitic Tuff, felsic	Intrusive rhyolite
Cwm Eigiau sandstone	Microgabbro
Cwm Eigiau mudstone, siltstone	

Figure 435: Field excursion.

This excursion examines the sediments underlying the Snowdon volcanic centre, which have been intruded by cone sheets, then continues upwards through the ignimbrites and coarse pyroclastic ashes of the Yr Arddu Tuff formation. We arrive at the mountain summit of Yr Arddu where a volcanic vent is well exposed.

Yr Arddu lies on the line of a deep crustal fracture which has become a zone of subsidence. Volcanic ashes are preserved within a synclinal trough along the fracture, interspersed with sandstones and finer sediments of the Cwm Eigiau formation.

Start: A car park is provided in Croesor village [SH632447].

1: Take the road through the village past the chapel in the direction of Yr Arddu. Pass through a gate at the end of the road to join a footpath which climbs up the hill through woodland.

A rocky ridge to the right of the footpath is formed by a sill of porphyritic microgranite. This is a cone sheet which dips north-westwards towards the centre of the caldera. It is one of a group of cone sheet intrusions which outcrop along the Croesor valley, producing the impressive mountain peak of Cnicht at the head of the valley.

Figure 436:

(left) Ridge above Croesor village formed by a sill of microgranite.

(right) Detail of the porphyritic microgranite, with larger feldspar crystals in a fine quartz-feldspar matrix.

2: As the path reaches the top of the woodland, take the footpath branching to the right along a broad valley with the peak of Yr Arddu to the north.

Slates, siltstones and fine-grained sandstones outcrop alongside the path, and have been shown by fossil evidence to belong to the Caradoc stage of the upper Ordovician. The siltstones and sandstone have current bedding and parallel laminated bedding which are characteristic of a shallow near-shore environment. This suggests the uprise and emergence of the early volcanic ridge in central Snowdonia, as buoyant magma filled the underlying chamber.

Continue up the valley to the point where the waste tips of old slate workings in the Nant Ffrancon formation are seen. The slate produced would have been of poor quality, perhaps used only locally for roofing cottages and agricultural buildings.

3: Leave the footpath and cross the valley towards the mountain of Yr Arddu, passing outcrops of the Lower Rhyolitic Tuff above the stream.

Figure 437: (left) Ignimbrite sequence exposed in the cliffs above the stream. Columnar jointing is visible.
(right) Unwelded ash layer at the base of an ignimbrite flow.

The Lower Rhyolitic Tuff formation consists mainly of ignimbrite flows, laid down on the margin of the volcanic ridge either subaerially or in shallow water. Individual flows often begin with a thin, unwelded basal ash layer (fig.437). This grades up into a more massive welded flow, which may develop columnar jointing.

4: Head for the prominent grassy slope which climbs the side of Yr Arddu, following the line of a fault. By the dry stone wall at the base of the slope, examine outcrops of a very coarse pyroclastic deposit. This contains blocks and slabs of rhyolite in an ash matrix, and exhibits a crude flow structure. It is likely that this material is a mixture of ash and rubble which slid off the side of the volcano and accumulated in shallow water around the edge of the volcanic island.

Figure 438: Vent agglomerate, Yr Arddu.

Ascend the grassy slope, observing the pyroclastic rocks in the cliff face above the path. Ashes with different dominant particle sizes are seen, and may be the products of a mixture of explosive air fall eruptions vertically upwards from a vent, and horizontal outflows of ash.

Figure 439: Pyroclastic deposits, Yr Arddu.

At the head of the grassy slope, on a flatter area below the summit slopes of Yr Arddu, is another outcrop of very coarse rhyolite blocks within an ash matrix. This may again represent a debris flow from the edge of the volcanic cone.

5: Continue to the summit, crossing rocky terraces composed of flow banded rhyolite. We have now reached the main rhyolite dome of the Yr Arddu volcano. The banding picks out the flow paths of the very viscous magma ascending through the volcanic neck, which were contorted into tight folds in places as the magma was squeezed around obstructions in the vent.

Figure 440: (top) Outcrop of flow folded rhyolite below the summit of Yr Arddu. (bottom) Detail of flow folding.

We can now produce a model for volcanic activity at Yr Arddu. Earlier eruptions were explosive, producing a mixture of ignimbrite ash flows and air fall pyroclastics. As the activity came to a close, the magma became more viscose through loss of steam and other gases. The rhyolite continued to extrude, forming a dome with rapidly solidifying margins. Blocks and finer material slumped from the margins of the dome under gravity, forming the coarse debris flows seen earlier on the slopes of the mountain.

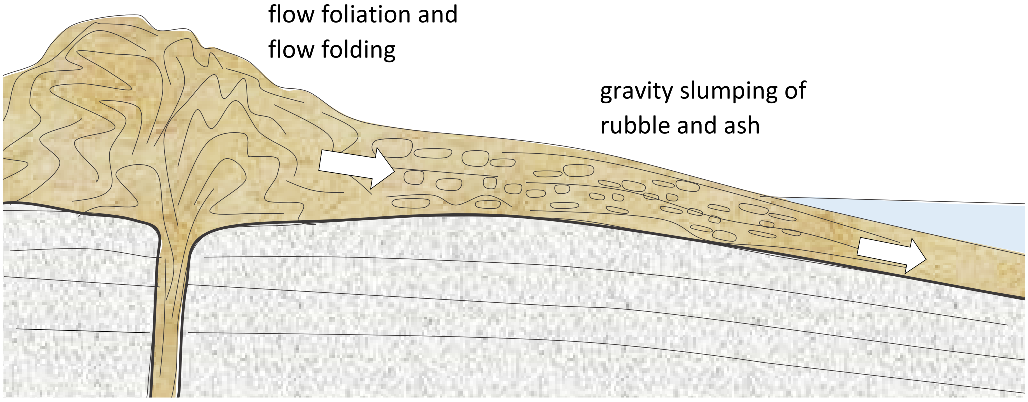


Figure 441: Rhyolite eruption.

From the summit of Yr Arddu, we get a panorama across the surrounding valleys and mountains. Yr Arddu lies on the axis of a syncline which preserves ashes of the Lower Rhyolitic Tuff formation, whilst older mudstones of the Nant Ffrancon formation are exposed in valleys to the south-east and north-west. It is possible that the syncline is related to the volcanic activity, and was initiated in the late stages of the Yr Arddu centre. The central area of the crustal ridge subsided as the underlying magma chamber emptied.

6: Descend from the summit to an area of flatter heathland to the south-west. Cross to the head of a fault gulley, then follow this downwards past impressive cliffs of welded ignimbrite with columnar jointing. At the base of a major flow, a prominent zone of large spherical silica nodules is seen (fig.442). The nodules are thought to have formed when superheated steam which was trapped by the upper welded layers of the ignimbrite deposit, dissolved silica and then redeposited it around centres of nucleation.

Figure 442: (left) Columnar jointing in welded ignimbrite flow. (right) Silica nodule layer near the base of an ignimbrite.

7: At the foot of the mountain, a large dry stone wall is reached. Follow this down the valley to re-join the Croesor track at a the bridge over the river. Return over the ridge of the felsic sill intrusion, then descend through the woodland to Croesor village.

Aberglaslyn and Cwm Bychan

5 miles: approximately 2½ hours

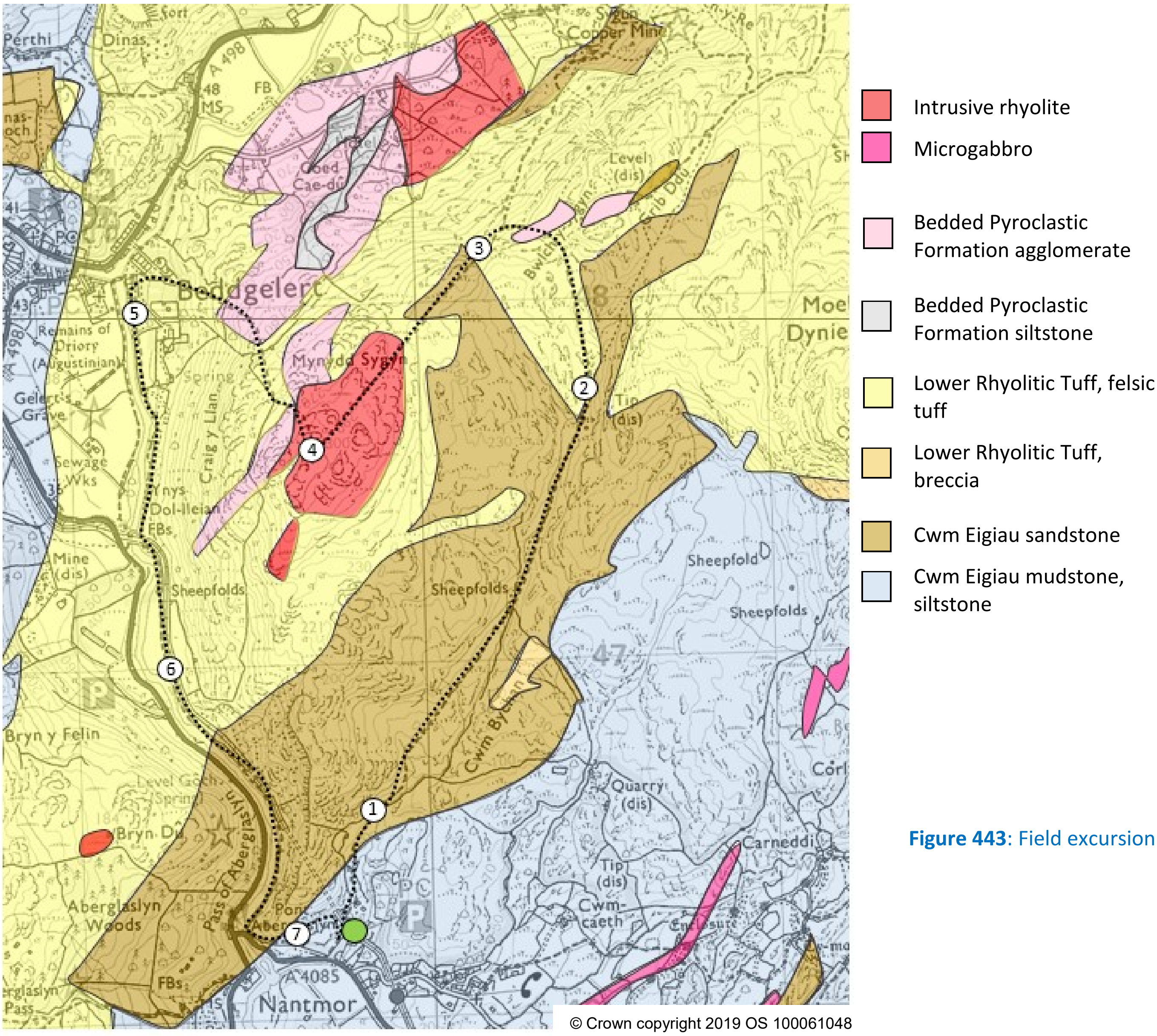


Figure 443: Field excursion.

In this excursion we walk up Cwm Bychan to the old copper mines, then continue to the summit of Mynydd Sygun where a rhyolite intrusion outcrops on the ring fracture of the Snowdon caldera. We then descend past outcrops of the Bedded Pyroclastic formation to the village of Beddgelert and return through the Aberglaslyn Pass, viewing the Lower Rhyolitic Tuff and Cwm Eigiau sandstones.

Start: Park in the car park at Nantmor [SH597462].

1: Follow the footpath up Cwm Bychan. In the upper section of the valley, a row of pylons still remain from the cableway which carried buckets of ore down from the mines.

Outcrops and loose boulders of Cwm Eigiau sandstone can be seen along the path. These sandstones are interbedded with the volcanic ashes of the Snowdon caldera, and represent shallow water deposits around the margins of a nearby volcanic island. The sediment has been derived by the reworking of submarine ash deposits by bottom currents. Large sand ripples formed, which moved across the sea bed to produce current bedding.

Figure 444: Remains of the cableway for copper ore, Cwm Bychan.

2: Continue to the termination of the cableway. Examine the horizontal wheel structure where buckets were loaded.

On the west side of the valley, rusty-weathering spoil tips extend from the entrances of adit tunnels. Climb up past the spoil tips to reach crags at the top of the hill where ore has been extracted

Figure 445: Cwm Bychan copper mine. Stope working accessed by adit tunnel, where the copper-bearing quartz lode has been excavated to the surface.

from opencast workings. With care, view the large slot, known as a ***stope***, left by the miners after removal of the steeply dipping quartz lode which contained the copper minerals (fig.445).

The quartz and associated heavy metal sulphides were deposited at the end of the Ordovician volcanic episode, as residual heat from the solidifying magma chamber beneath the caldera produced convection cells in the ground water circulating through the volcanic ashes and sediments. The hot saline waters were able to dissolve silica and metals, carrying them upwards through fractures until the temperature and pressure conditions allowed crystallisation to take place.

The mineral lodes in Cwm Bychan occur within the sandstone sediments. Individual thin veins of quartz may be found. However, it is more common for a mineralised fracture to contain a number of closely spaced quartz veins separated by thin sheets of country rock, or the mineralisation may occur within a fault breccia (fig.446).

Figure 446: Mineralised breccia, Cwm Bychan copper mine.

If you search of the waste tips around the mines you may find small specimens of the main minerals in the quartz lodes. Red rusty weathering is characteristic of pyrite. Copper is present along with iron in the sulphide mineral ***chalcopyrite*** which has a deep yellow colour. Grey crystals of the zinc sulphide ***sphalerite*** are common. The lead sulphide ***galena*** is present, but is rarer. Lead appears to be more common in mines towards the centre of the caldera structure, where the hydrothermal fluid temperatures were probably higher. Rarely, the tin oxide ***cassiterite*** has been found. Whilst it is thought that copper was leached from felsic volcanic ashes by the circulating groundwater, tin is more likely to have been contained in hydrothermal fluids released directly from the crystallising magma chamber.

3: Continue to Bwlch Sygun and follow the path to Mynydd Sygun.

The hill summit is formed by an intrusion of flow banded rhyolite which formed one of the vents around the ring fracture of the Snowdon caldera.

Figure 447: Intrusive rhyolite forming the summit of Mynydd Sygun.

4: Examine the intrusive rhyolite at the summit, then descend towards Beddgelert.

As we follow the steep path down from the rhyolite intrusion, we reach outcrops of the Bedded Pyroclastic formation in the cliffs above the path. As at Yr Arddu, strata of the Snowdon Volcanic Group are preserved in a synclinal fold along the caldera margin which may have resulted from subsidence in the late stage of the caldera eruptions as the underlying magma chamber emptied.

The outcrops of the Bedded Pyroclastic formation exhibit a variety of mafic rock types. We can identify a basalt agglomerate consisting of basalt blocks in a matrix of basaltic ash. This is overlain by a flow-banded and flow-folded basalt lava. In places, the lava is fractured into angular blocks, which represent auto-brecciation as the surface layers solidified and were dragged into the advancing lava flow.

Figure 448: Basaltic ashes of the Bedded Pyroclastic formation on the mountainside above Beddgelert.

5: From Beddgelert bridge, take the footpath which follows the eastern bank of the river towards the Aberglaslyn Pass and back to Cwm Bychan. Beyond the point where the Welsh Highland Railway crosses the river on a girder bridge, take the fisherman's path alongside the river.

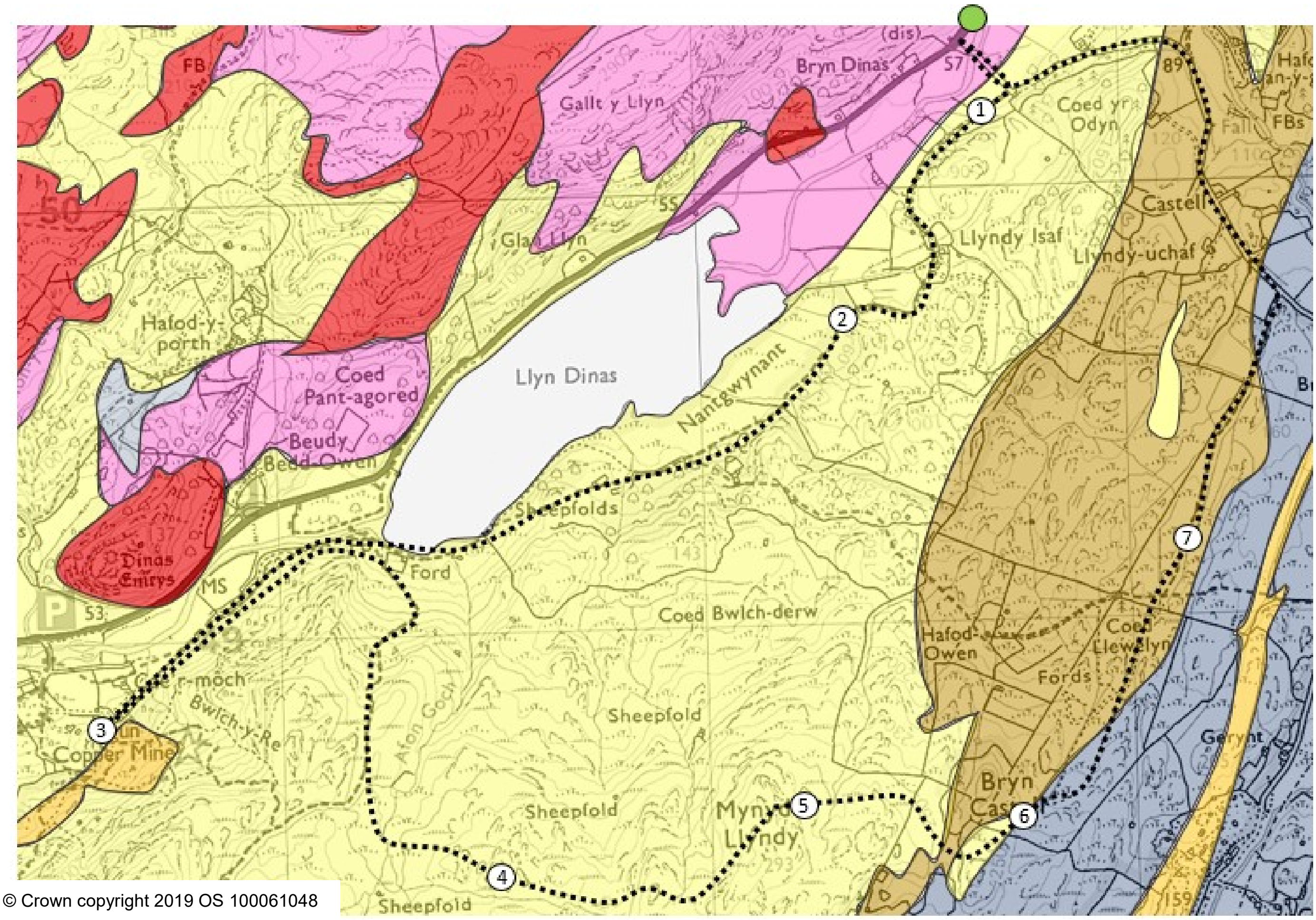
The path follows a series of steps, walkways and ledges around outcrops of Cwm Eigiau sandstone. The sandstones exhibit sedimentary structures consistent with the redistribution of volcanically derived sediments by bottom currents in the shallow water around a volcanic island. We see examples of sand and silt beds truncated by wave action, with further beds of a different grain size deposited above. Rippled bedding surfaces can be found. These features are characteristic of erosion and deposition around the mouths of estuaries.

Figure 449: Sediments of alternating sand and silt grade showing truncation by contemporaneous erosion.

Llyn Dinas

5 miles: approximately 2½ hours

mine museum: 1 hour



- Bedded Pyroclastic Formation agglomerate
- Bedded Pyroclastic Formation siltstone
- Lower Rhyolitic Tuff, felsic tuff
- Lower Rhyolitic Tuff, breccia
- Cwm Eigiau sandstone
- Cwm Eigiau mudstone, siltstone
- Intrusive rhyolite

Figure 450: Field excursion.

The main objective of this excursion is to examine the products of the Snowdon Volcanic Centre which accumulated within the subsiding caldera. In addition to layered ignimbrites, we find breccias produced by submarine slumping of volcanic material into deeper water within the ring of the caldera.

At Sygun, the disused copper mine has been opened as a visitor attraction and can be explored underground.

Start: Park in the lay-by alongside the A498 at Nant Gwynant [SH628507].

1: Follow the footpath past Llyndy Isaf farm to reach the southern shore of Llyn Dinas.

2: Continue along the path around the lake, examining outcrops of the Lower Rhyolitic Tuff formation.

The hillside to the south of the lake shows a series of terraces produced by individual massive ignimbrite flows. These rocks can be examined in outcrops near the path, and exhibit foliated and welded textures typical of the ignimbrites we have previously seen at the Llwyd Mawr centre. However, we also find a variety of unusual rock types which provide evidence of the tectonically unstable environment around the margins of the caldera.

Fragmental rocks, known as the Llyn Dinas breccias, contain pebbles and larger blocks of ignimbrite and sandstone in a fine ash matrix. Random orientations of ignimbrite foliation are found, indicating that the ashes had solidified before incorporation into the breccia. In places, large amounts of remobilised silica form veins through the rock, suggesting the presence of superheated steam permeating the deposits.

We may conjecture that ignimbrite eruptions from the series of vents around the caldera ring fracture built up volcanic islands of ignimbrite. Marine erosion remobilised some unwelded ash and redeposited it to form shallow water sandstones. At intervals, subsidence of the central area of the caldera occurred and was accompanied by violent earthquakes. Accumulations of rock on the flanks of the volcanic islands were broken up and subsided into the deeper water within the caldera. Materials accumulated as random debris on the sea bed, or were perhaps transported as volcanic mudflows which then settled with a crude stratification.

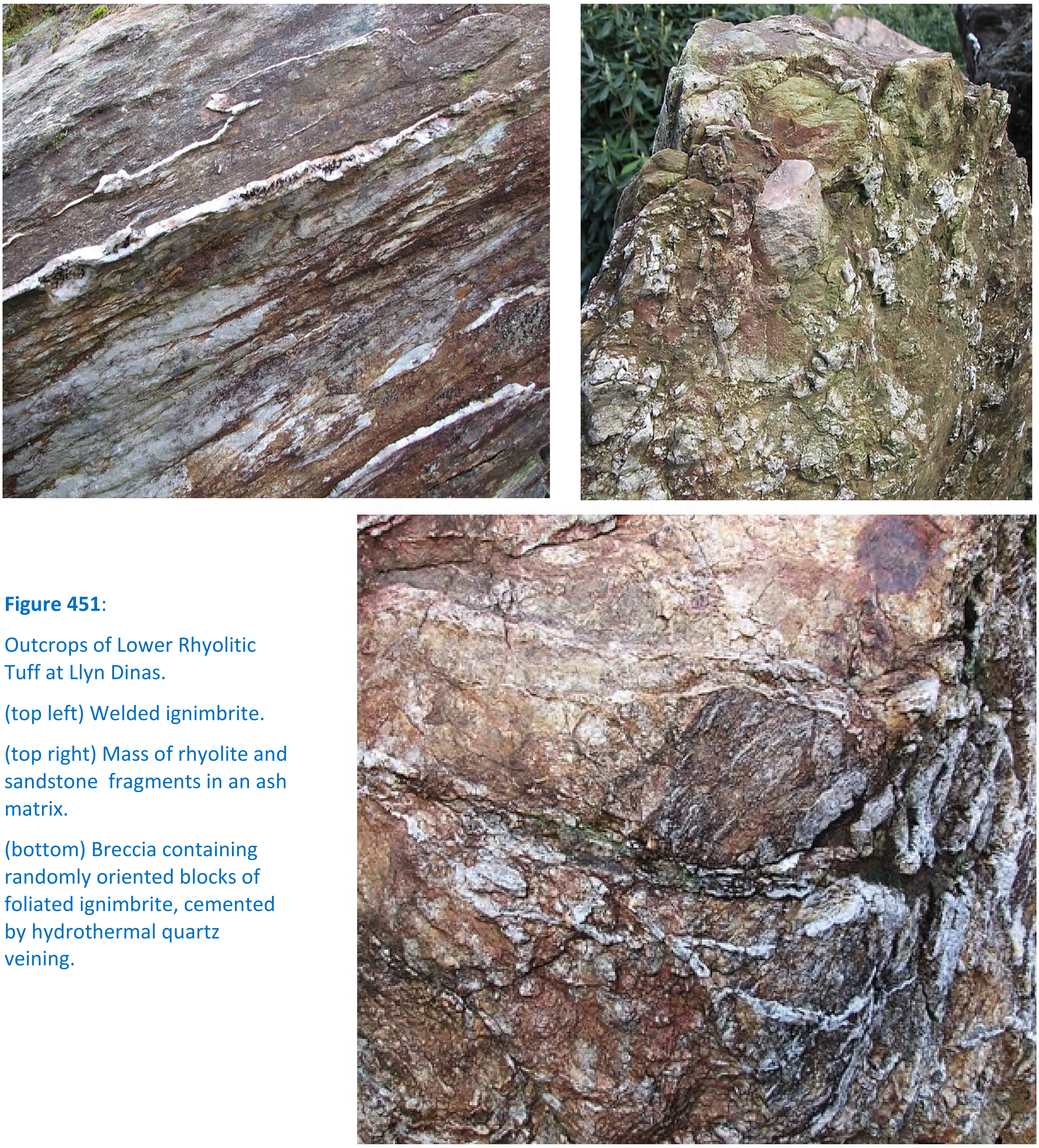


Figure 451:

Outcrops of Lower Rhyolitic Tuff at Llyn Dinas.

(top left) Welded ignimbrite.

(top right) Mass of rhyolite and sandstone fragments in an ash matrix.

(bottom) Breccia containing randomly oriented blocks of foliated ignimbrite, cemented by hydrothermal quartz veining.

3: Continue along the path to the Sygun copper mine. If time permits, you may wish to take a tour of the mine workings.

The mineral lode worked at Sygun is the same lode which we saw earlier in Cwm Bychan, and a series of small trial adits follow the vein across the mountainside between the two mines.

Although perhaps worked as far back as Roman times, the Sygun mine site was first developed on a major scale from the early 1800's. The lode was accessed by a deep adit at the base of the hillside and a higher adit, known as the Victoria level. Ore was extracted from ***stopes*** which extended upwards to connect the levels, and also below the level of the deep adit where the workings are now flooded. As the Sygun site developed, a further three adits were driven higher up the mountain to intersect the mineral lode. These workings formed a separate mine known as Llwyndu.

Over the period from 1850 to 1890, the mine had a mixed fortune and changed hands several times. However, a brief period of success occurred around 1898 with the introduction of the Elmore froth flotation process, discovered at Glasdir copper mine in Coed y Brenin. This considerably improved the percentage of copper recovered from the mined ore. The mine finally closed in 1903, mainly as a result of the increased availability of cheaper imported copper ore and metal.

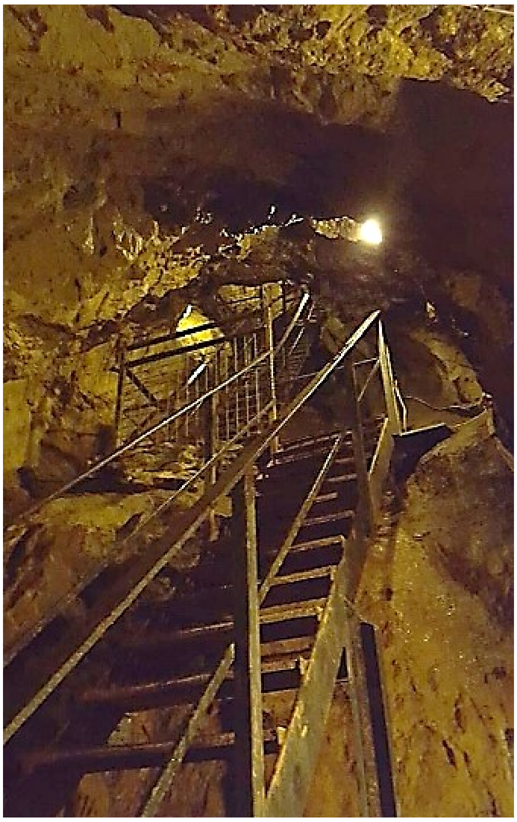


Figure 455: Sygun copper mine.

(left) Site of the Elmore froth flotation mill on the series of terraces above the visitor centre.

(right) Stairway between the deep adit and the Victoria level.

4: From the Sygun mine, return along the footpath to the start of the lake, then take the path which ascends across the mountainside to Mynydd Llyndy. Along this track we pass crags formed by ignimbrites of the Lower Rhyolitic Tuff. Individual flows can be identified, which typically have an unwelded ash base overlain by a welded massive interior. A layer of spheroidal silica nodules, similar in size to footballs, may be present where superheated steam trapped within the base of the flow has caused solution and re-precipitation of silica.

5: Descend from the summit of Mynydd Llyndy, towards the prominent rocky knoll of Bryn Castell.

6: Bryn Castell is a large glacially eroded crag of ignimbrite belonging to the Lower Rhyolitic Tuff. Examine the mass of ignimbrite between the cliff and the dry stone wall to the east. Bedding planes can be identified in the rock. We find that these are inconsistent with the regional dip of the rocks which is towards Llyn Dinas to the north-west. It appears that the rock mass is a huge block which broke away from the margin of the volcanic

Figure 456: Bryn Castell

island in a submarine landslip and subsided into the caldera basin. Indeed, it is possible that Bryn Castell itself is part of the same land-slipped mass.

On the hillside near the dry stone wall are found outcrops of a conglomerate, composed of rounded water-worn cobbles of various rock types including rhyolite and sandstone. It is likely that this material represents a beach deposit produced by storm waves along the coast of a volcanic island.

Figure 457: Conglomerate made up from water rounded cobbles of rhyolite and sandstone.

7: Follow the footpath north-eastwards to Coed Llewelyn, then back to the Nant Gwynant parking area.