Lead mining in Mid-Wales

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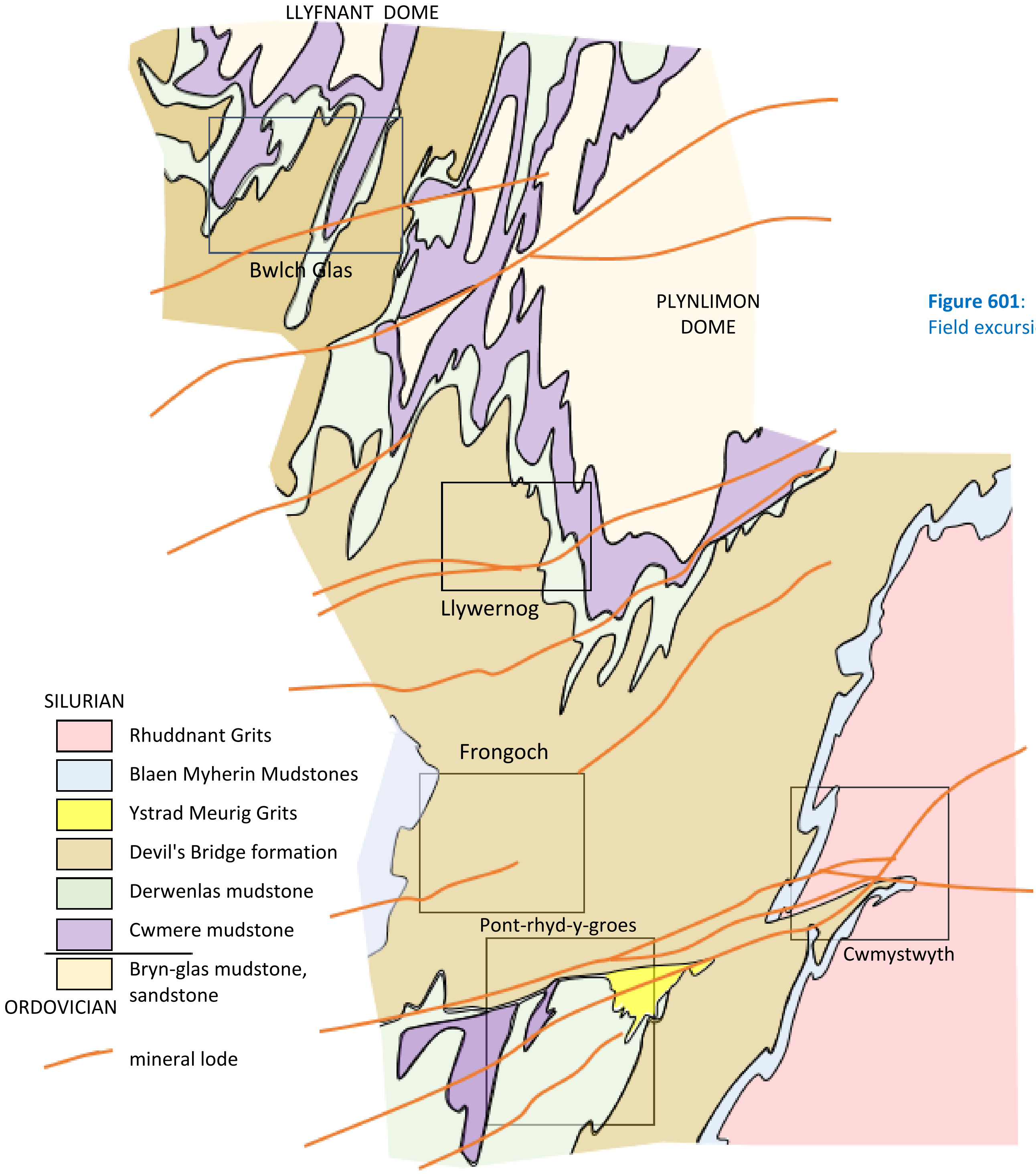


Figure 601: Field excursions.

In this chapter we examine the geological processes which produced important deposits of lead and other heavy metals in the North Cardiganshire mining field, and look at the geological settings of several of the major mines.

Safety note: Old mine tunnels and opencast workings in the area are often open and accessible, but it can be very dangerous to venture underground without an experienced guide with local knowledge. It is possible to fall down underground shafts and stopes which extend below the adit tunnels. Sections of tunnel may pass through unstable shale where the roof is supported by timbers which are now rotten and liable to give way. During mining operations it was often convenient to stack waste rock in mined-out stopes, rather than bring it to the surface; this material is unstable and can collapse without warning. A further danger is the build-up of carbon dioxide gas in poorly ventilated tunnels, produced by a chemical reaction between acid mine water and carbonate mineral veins.

To safely view the workings of a lead mine, we recommend a visit to the Llywernog mining museum at Ponterwyd (advertised as the Silver Mountain Experience). In addition to providing underground tours, the mine buildings and surface machinery on the site have been restored and provide an interesting insight into the operation of a nineteenth century lead mine.

The geology of the ore deposits in mid-Wales is complex. Radiometric dating of lead minerals has identified two separate phases of mineralisation: the first occurred just after the Acadian orogeny in the lower Devonian; and the second occurred many millions of years later at the time of Carboniferous limestone deposition in neighbouring areas such as the Great Orme in North Wales and the Vale of Neath in South Wales. In the first phase, lead and zinc were deposited and are accompanied by copper, silver, and minor quantities of other heavy metals in some mines. In the second phase, only zinc and lead were produced in significant quantities.

These two phases of mineralisation occurred by very different processes, but in both cases the deep crustal fractures of the type found in North Wales played an important role.

We begin by considering the mechanism for the earlier phase of lead mineralisation. Mines containing ore deposits of this age are found particularly around the southern margin of the Plynlimon dome. These include Goginan, which was one of the largest lead producers in the region, and the Llywernog and Castell mines. There is also a concentration of small mines along the western margin of the Plynlimon dome, including Bwlch Glas and Hafan. It appears that there is an important link between mineral lodes at these mines and areas where coarse grits were once deposited.

Coarse grits occur at several stratigraphic levels within the Plynlimon area. In previous excursions we have examined outcrops of the Ordovician Nant y Moch turbidite grit, and the Pencerrigtewion sandstone in the Drosgol formation which formed in shallower water during the ice age at the end of Ordovician times.

Continuing upwards through the Silurian succession around Plynlimon, we find two coarse turbidite grit sequences: the Ystrad Meurig and Rhuddnant grit formations. These are approximately the same age as the Aberystwyth grits to the west, but were laid down in a separate but parallel trough in the Welsh marine basin (fig.602).

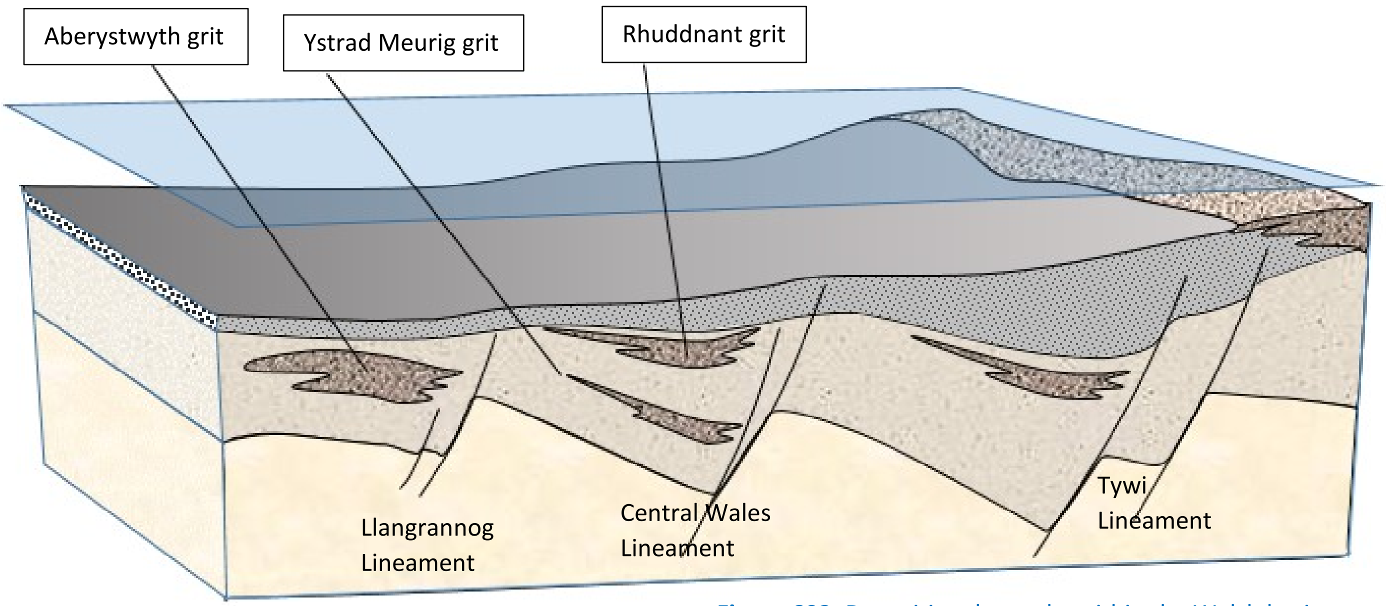


Figure 602: Depositional troughs within the Welsh basin.

The Rhobell-Corris deep crustal fracture zone of Snowdonia continues southwards along the coastal margins of Plynlimon as the **Llangrannog Lineament**. In an earlier excursion we visited the Llyfnant valley near Machynlleth, where the **Brwyno overthrust** forms part of this fault system. Inland of Plynlimon lies a similar deep fracture zone known as the Central Wales Lineament, with a third fracture zone called the Tywi Lineament closer to the Welsh border. During Silurian times, these fracture zones produced a series of half-graben basins which stepped downwards towards the deepest axial region of the basin.

The nature of the sediments which accumulated in the half-graben basins depended on a balance between subsidence and sedimentation rate. Where subsidence was rapid, a sea bed trough developed. If a large supply of coarse sand was available at the time, this could accumulate in the trough as a turbidite fan deposit. Examples are the Ystrad Meurig and Rhuddnant grits. At times of slow subsidence, a basin would fill and any further coarse sediment would continue westwards into the deeper regions of the trough, as in the case of shelf slope deposits in the Aberystwyth grits.

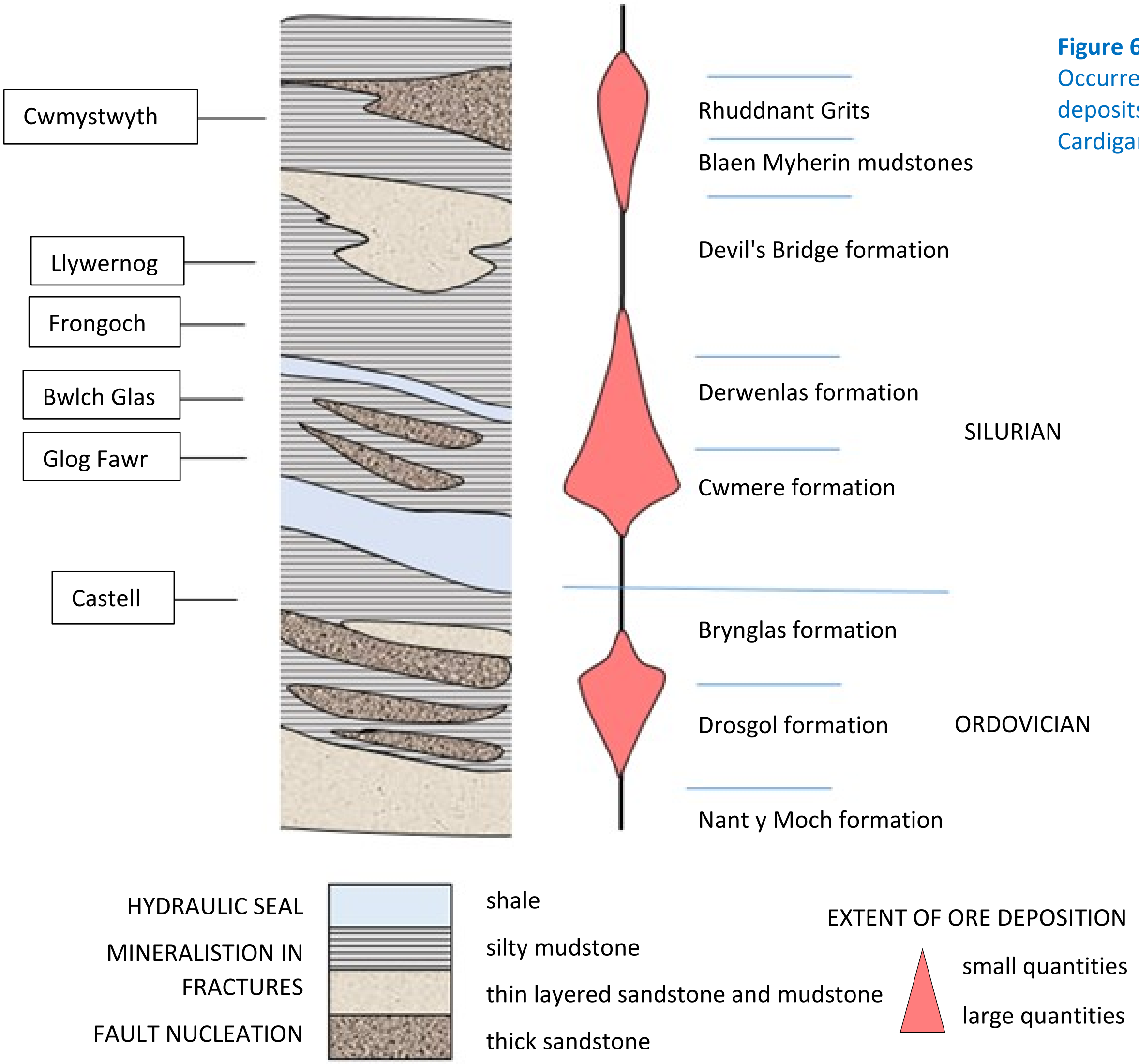


Figure 603: Occurrence of ore deposits in North Cardiganshire.

We can now turn our attention to the distribution of ore deposits within the Ordovician and Silurian strata. Rich deposits of lead occur at three stratigraphic levels (fig.603). These begin around the levels of the coarser sandstones and grits, and extend upwards into overlying mudstones before dying out. We need to find a geological explanation for this pattern. The mineralisation is linked to the Acadian earth movements in early Devonian times, when the Plynlimon dome was pushed upwards by movements along the bordering fracture zones. A series of north-south oriented minor folds were superimposed on the main structure at this time as thickening took place in the sedimentary succession. The lower strata of the Welsh basin, including Cambrian and Ordovician mudstones and Ordovician volcanic ashes, were depressed to depths of over 5 km where low grade regional metamorphism could begin. Recrystallization released hydrothermal fluids at high temperatures and pressures. These fluids had considerable solvent power, dissolving silica, iron and heavy metals as they passed upwards through the strata of the deep basin. However, the hydrothermal fluids were unable to escape to the surface due to high compressional forces which kept the rock impermeable.

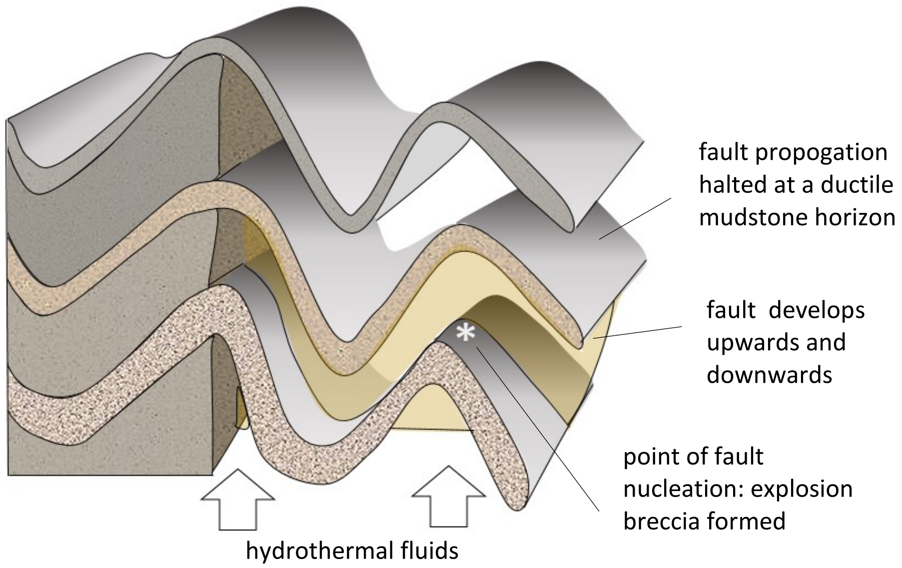


Figure 604: Fault initiation.

Upwelling hydrothermal fluids, travelling most easily through permeable sandstone, would be channelled towards anticline crests where the difference in pressure between the fluids and the overlying rocks would be greatest. Hydraulic fracturing occurred in the brittle sandstone when the fluid pressure exceeded the mechanical strength of the rock. Faulting could be explosive, with the sandstone shattering into breccia fragments as a cavity opened (fig.605). Faults developed outwards in a direction of least crustal stress, giving a ENE-WSW fracture orientation which crosscuts the north-south orientated minor folds. Once initiated, the fault could propagate both upwards and downwards through brittle rocks until halted at a ductile mudstone.

Once a fault had formed, hydrothermal fluid could flow rapidly into the fracture. Cooling and pressure release would allow minerals to crystallise from the fluid. These typically include both **gangue** minerals such as quartz, calcite and dolomite which are of no economic value, and sulphide ore minerals such as **galena** (lead),

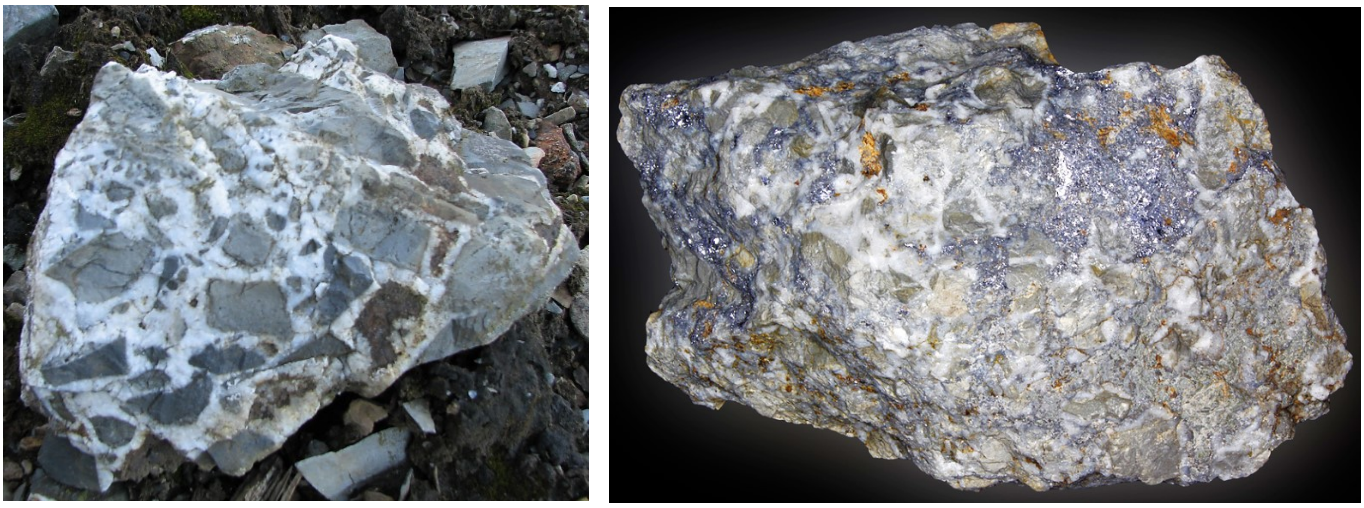


Figure 605: (left) Explosively produced fault breccia, cemented with quartz. Castell mine. (right) Fault breccia containing quartz with galena and pyrite, now weathered to rusty iron oxide. Bwlch Glas mine.

sphalerite (zinc), **chalcopyrite** (containing copper) and **tetrahedrite** (containing traces of silver).

As pressure builds up again in the fault, the seal in the overlying mudstone may break. The fault can again propagate to a higher level until inhibited by another ductile mudstone. This process may be repeated a number of times.

With each advance of the fault, a fresh flow of hydrothermal fluid would pass upwards through the fracture system, depositing minerals as the temperature and pressure were reduced. The cumulative volume of minerals deposited is greatest around the fault nucleation point, where the number of repeated inflows of fluid had been greatest. Each batch of hydrothermal fluid may have a slightly different chemical composition, leading to different minor minerals being deposited in addition to the dominant lead and zinc sulphides.

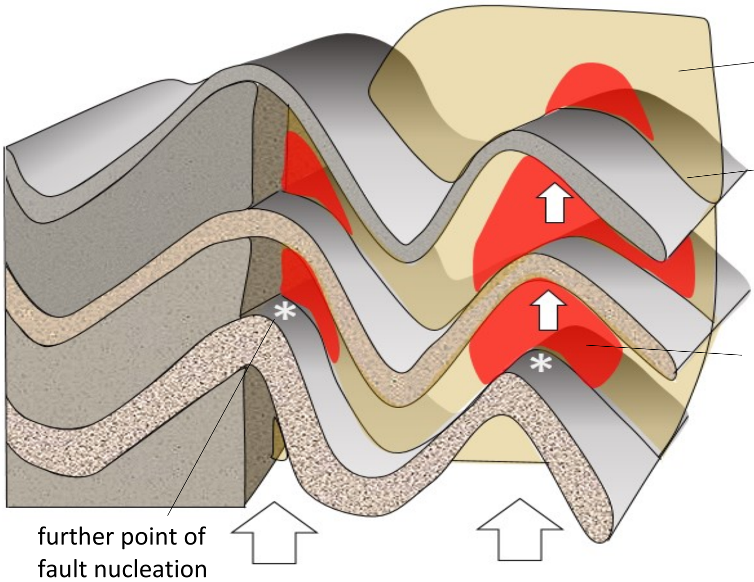


Figure 606: Mineral deposition.

We now move forward in geological time to the lower Carboniferous period. The Devonian mountain building episodes had ended, and the Welsh basin was now an area of crustal relaxation. Cavities opened in the rocks of the basin to a depth of more than 5km, providing pathways for water to circulate (fig.607).

The Plynlimon dome lies between deep crustal fractures, and was uplifted during the Acadian orogeny. This brought hot metamorphosed basement rocks closer to the surface, where they could provide a thermal driving mechanism for deeply penetrating convection cells. Recharge of pore water was readily available from the shallow seas above Wales.

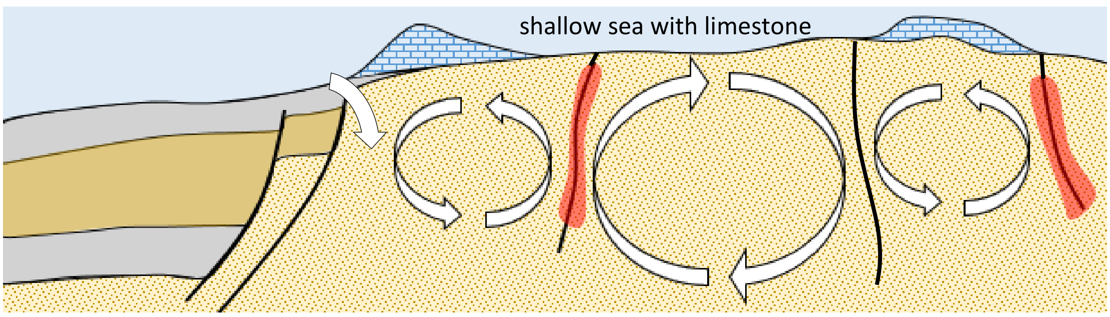
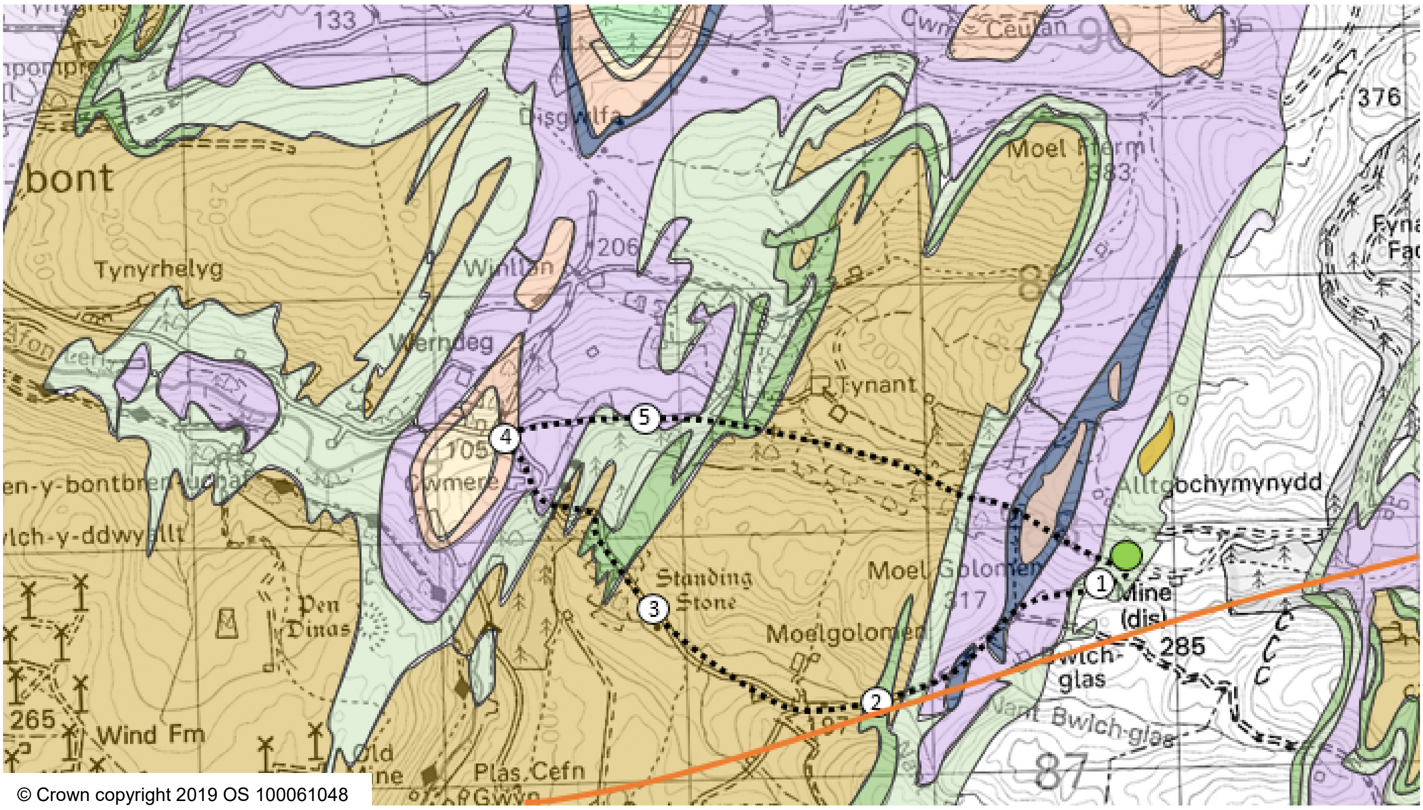


Figure 607: Mineral deposition by convection cells.

Heated saline convectional fluids had a high solvent power, and were able to pick up silica and heavy metals from deep rocks and carry these upwards to redeposit in faults and other fractures of the upper crust. The lodes associated with this second phase of mineralisation often have massive or layered crystal development suggesting crystallisation from an unimpeded flow of mineralising fluid (fig.617).

Bwlch Glas

4 miles: approximately 1½ hours



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SILURIAN

- Borth mudstone
- Devil's Bridge mudstone
- Rhayader mudstone
- Derwenlas mudstone
- Cwmere mudstone
- Llandovery Mottled Mudstone

ORDOVICIAN

- Bryn-glas slumped mudstone, siltstone, sandstone
- Bryn-glas mudstone, sandstone
- Pencerrigtewion slumped mudstone, siltstone, sandstone

mineral lode

Figure 608: Field excursion.

Start: Follow the minor road up the valley from Talybont to reach Bwlch Glas mine. Park on the roadside below the concrete foundations of the processing mill [SN710878].

1: Examine the Bwlch-glas mine site.

The mine lies on the eastern flank of an anticline in Derwenlas and Cwmere mudstones, and worked two parallel lodes along the Hafan fault which follows the line of the upper valley towards the Hafan mine at Carn Owen.

The first workings began near the summit of the hill where the quartz lodes were exposed at the surface. In the 1880's, an adit was driven from the hillside to intersect the lodes at depth and facilitate drainage. Soon after 1900 the deeper adit was cut, which we now see at the roadside.

Concrete walls and foundations now indicate the relatively modern nature of the working in comparison to other mines in mid-Wales. The site is intersected by the track bed of the old Hafan Tramway, which was operated by steam power and transported passengers and ore.

In an area of the mine accessible only to cavers is an underground headframe in the deep adit for access to lower levels. The cages which carried miners and trucks of ore are still in place.

Figure 609:
Bwlch Glas mine:

(above) Concrete foundations of the processing mill.

(below) Underground headframe above the deep shaft.

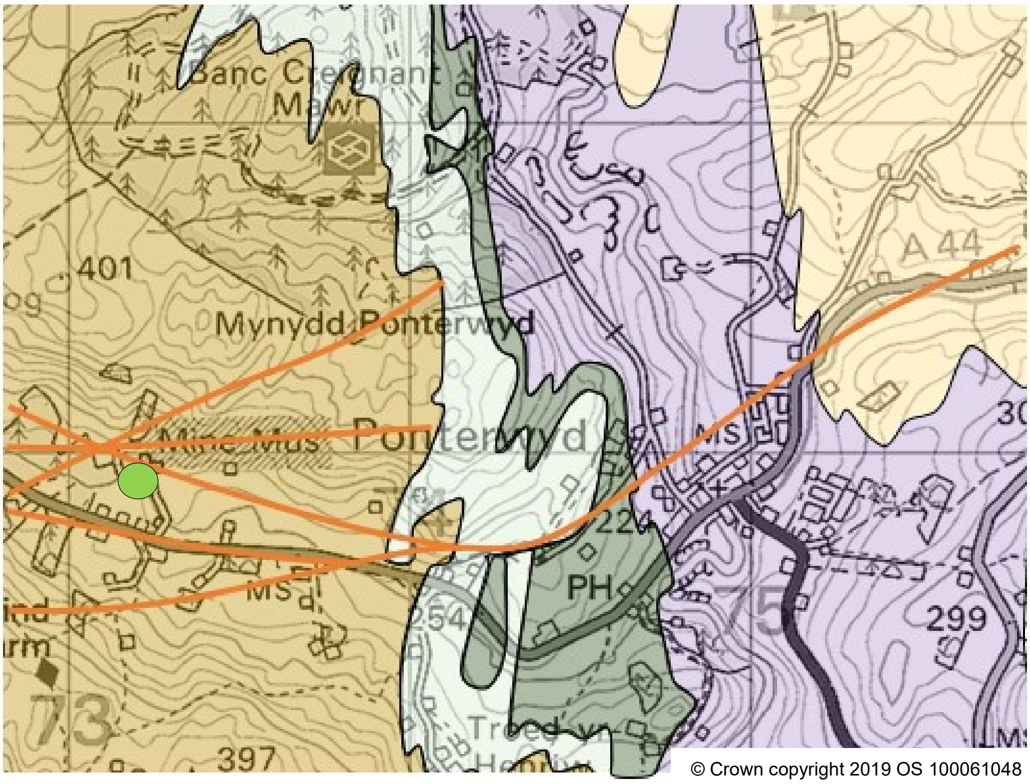
2: Take the track over the hill to Moelcolomen. A number of small exposures on the hillside illustrate the steeply dipping nature of the strata.

3: Continue over outcrops of Devil's Bridge sandstones and mudstones in the core of the syncline. It is likely that mineralising fluids rose along the Hafan fault and were deflected upwards through the permeable sandstone beds towards the anticline at the Bwlch Glas mine where minerals were deposited.

4: Descend along the road to Cwmere village, then return to Bwlch Glas mine.

Figure 610: Thinly bedded Devil's Bridge sandstones and mudstones west of Bwlch Glas mine.

Ponterwyd: Llywernog (Silver Mountain) Mining Museum



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- Devil's Bridge mudstone, sandstone
- Rhayader mudstone
- Derwenlas mudstone
- Cwmere mudstone
- Llandovery Mottled Mudstone
- Bryn-glas slumped mudstone, siltstone, sandstone
- mineral lode

Figure 611: Field excursion.

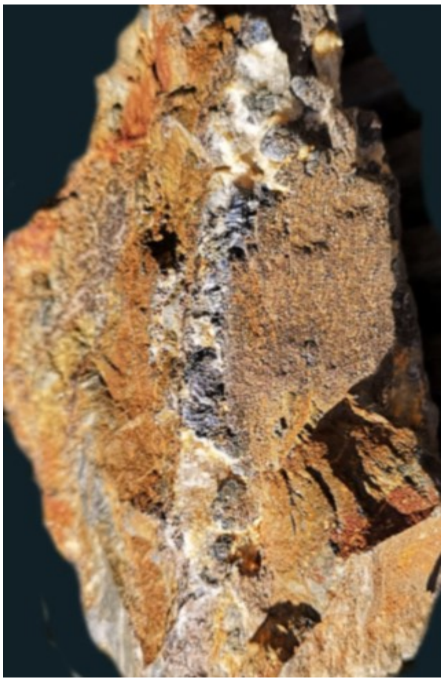

Figure 612: (above left) Stope within the Llewernog mine. (right) Quartz vein containing galena.

The Llywernog mine lies at the intersection of a number of mineral loads developed along fractures in thinly bedded Devil's Bridge sandstones and mudstones. The fractures are branches of the Castell fault system, which was reactivated on a number of occasions. It is likely that the lodes belong to the earlier period of mineralisation following the Acadian orogeny in Devonian times. The intersection of the fractures would have provided a steeply rising channel carrying the maximum quantities of mineralising fluids, and formed a focus for ore deposition.

Start: The mine is located alongside the Aberystwyth to Ponterwyd main road, and has a visitor car park [SN732809].

Llywernog Mine was originally worked in the 1740's. In common with most mines in the Welsh mountains, Llywernog relied on water power for hauling ore to the surface, and for operating machinery for crushing and separating the ore. Large waterwheels, some manufactured by local iron foundries in Aberystwyth, have been restored to working order.

Follow the waymarked trail to visit the headgear at the mine shaft, and the crusher building containing a Cornish roll crusher. Alongside the lower waterwheel is an outcrop of the Devil's Bridge sandstones and mudstones.

Underground tours of the stope workings are available.

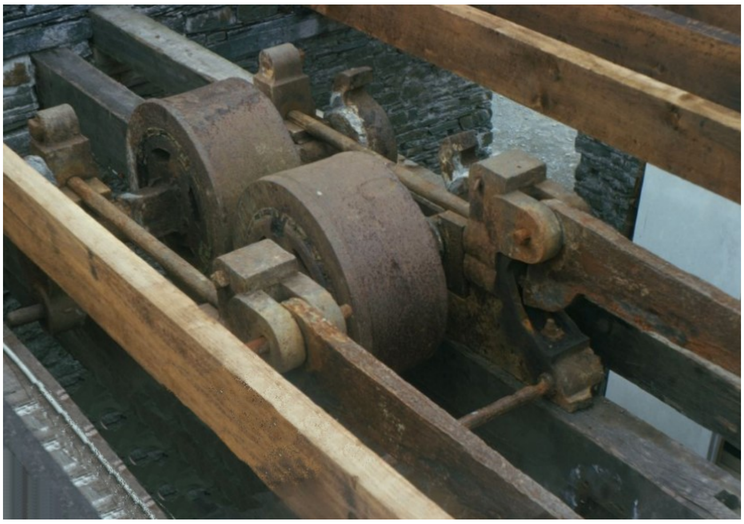

Figure 613: Llywernog mine museum:

(above left) Restored water wheel, which originally powered crushing machinery.

(above right) Headframe above the main shaft.

(below right) Cornish roll crusher during restoration. Ore would be tipped through a hopper into the rotating heavy rollers. A large counterweight kept the rollers in contact, but allowed them to move apart when necessary to prevent a blockage.

Frongoch

2 miles: approximately 1½ hours

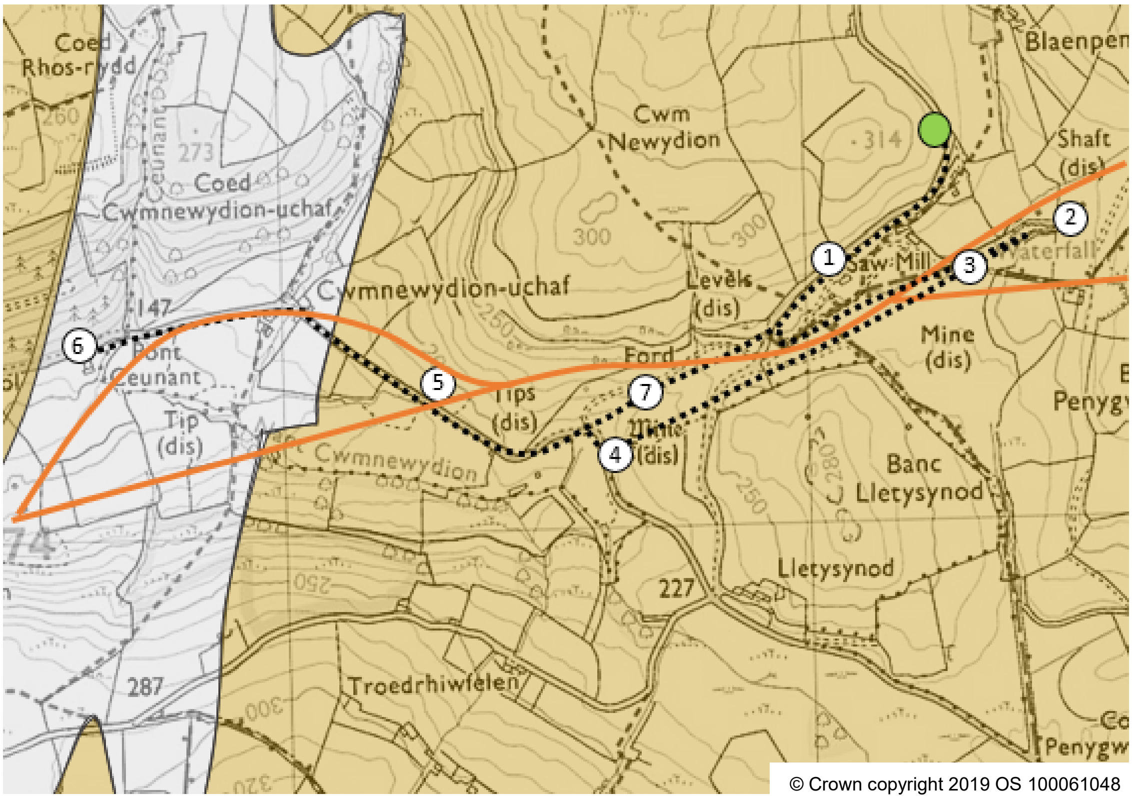

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Figure 614: Field excursion.

Blaen Myherin mudstone

Devil's Bridge mudstone, sandstone

mineral lode

Frongoch, along with Cwmystwyth and the group of mines around Pont-rhyd-y-groes, lies some distance to the south of the Plynlimon dome. The ore deposits at these southerly mines were formed mainly during the Carboniferous period. The younger mineral lodes tend to be more massive than the thin quartz-hosted veins of the mines closer to Plynlimon, making the southern area historically the largest producer of lead and zinc in mid-Wales. The ore lodes are associated with fault zones whose orientations are close to east-west.

Mining for lead began at Frongoch in the mid 1700's, with large scale mining commencing in the mid-1800's. Steam power was used for pumping and raising ore from the deep levels of the mine.

In 1899 a Belgian mining company took over and invested heavily in new equipment. The winding shaft, tramway for transport of ore to the mill and the processing machinery were all powered by electricity. A generating station was built a mile to the west at Pont Ceunant to provide the power.

Immediately to the west of Frongoch lies the Wemyss mine, working a continuation of the same mineral lode. In the 1800's, Wemyss was purchased by Frongoch, so that the Wemyss mine adit on the hillside to the west could be used to drain the Frongoch workings. A tunnel was driven to connect the mines underground for this purpose.

Frongoch became an important producer of zinc in its later years as demand for this metal increased. Underground mining ended before the First World War, but the mine waste tips were later reprocessed to recover their remaining metal content.

Start: Park near the timber yard which now occupies part of the Frongoch mine site [SN722745].

1: View the remains of the engine houses. This is the most complete set of 19th century steam engine houses at any of the Welsh mine sites. Beam engines operated pump rods in three deep shafts situated in front of the engine houses. This

Figure 615: Frongoch engine houses.

allowed mining along the mineral vein to extend downwards to over 600 feet, with water pumped from the lower levels to discharge along the drainage adit.

2: Walk up the valley past the timber yard to reach the Frongoch opencast. The mineral lode was exposed at the surface at this point, continuing westwards underground for about a mile.

Figure 616: Frongoch opencast.

The Frongoch lode lies within mudstones and sandstones of the Devil's Bridge formation. The width of the opencast suggests that the mineral lode was very wide at this point, reaching up to 30 feet. However, it is likely that multiple vertical veins of quartz and heavy metal sulphides were separated by sheets of country rock, as each successive inflow of hydrothermal fluid followed a slightly different path within the zone of fractured rock.

3: Continue to the flat area in front of the engine houses to reach Vaughan's shaft. This area was originally covered by waste tips, but has been landscaped in recent years as part of a scheme to reduce heavy metal contamination of neighbouring rivers.

Vaughan's shaft lies at the start of an incline which carried ore to the mill. Trucks of ore were carried along by chains, powered by an electric winding engine. Follow the incline down hill, crossing the minor road at a point where the railway track originally passed under a bridge.

4: Examine the mill site. The foundations seen today supported a timber dressing mill on a series of levels. Rock crushing machinery was located at the highest level. The fine crushed ore was fed under gravity to water separation tanks on the lower levels. Heavy metal concentrates were recovered for smelting, whilst waste quartz was deposited on waste tips which are seen below the road.

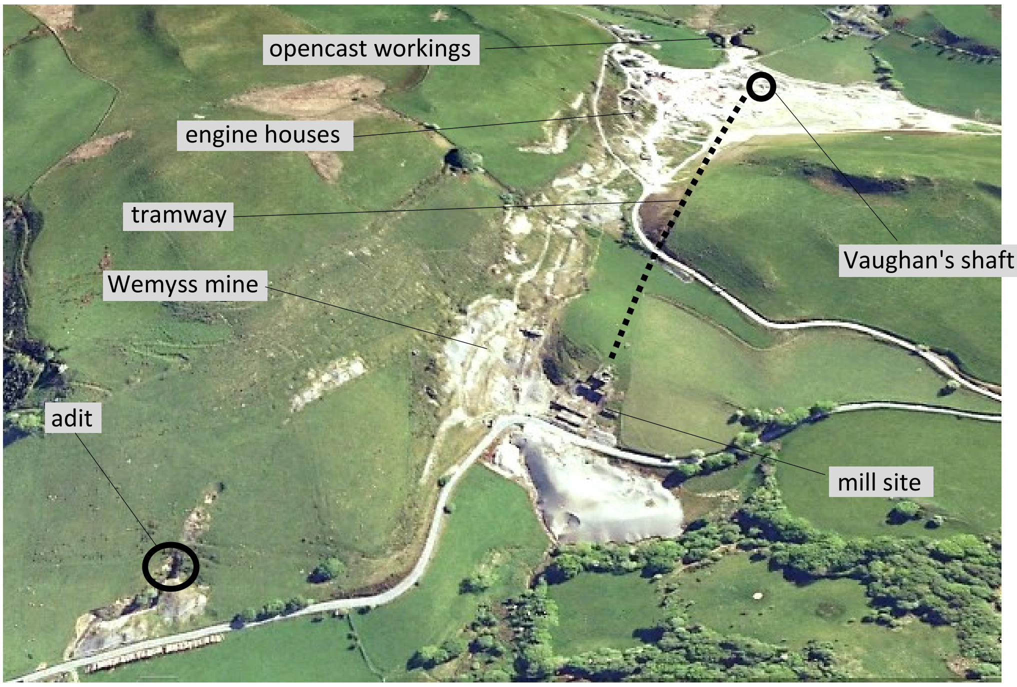


Figure 617: The area around Frongoch mine.

5: Walk westwards along the road to reach a stream flowing out of a small gorge. Follow the stream to reach the Wemyss drainage adit.

6: Continue down the road to the Pont Ceunant generating station. A short distance before the station building is reached, a valley descends the hillside from the north. A reservoir was constructed at the head of this valley to provide water power for the Pont Ceunant turbine. A pipeline descended to the generating station at this point.

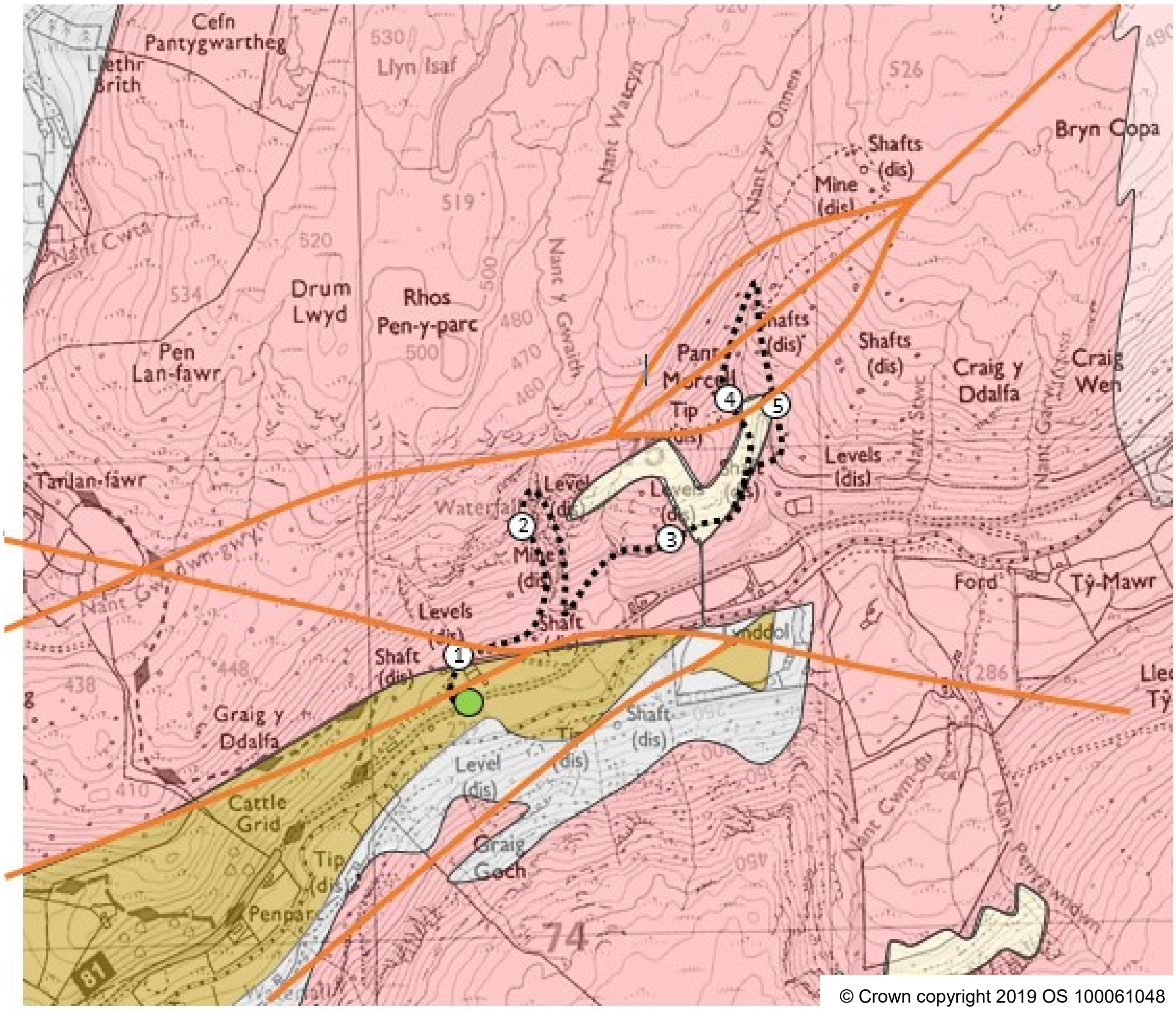
The remains of the generating station lie between the road and the river. The building had an L-shape, with the main wing near the river housing the turbine and electric generator. The annexe nearer the road housed a back-up steam engine and coal-fired boiler for use during dry periods when the water supply was insufficient.

7: Return along the road to the mill site. Take the track which ascends the valley along the western side of the mill. You will pass the remains of the Wemyss mine before reaching the Frongoch engine houses. Return along the minor road to the parking place.

Figure 618: (left) Foundations of the Frongoch processing mill. (right) Pont Ceunant generating station.

Cwmystwyth

2 miles: approximately 2 hours



Rhuddnant Grits sandstone, mudstone

Llyn Teifi sandstone, mudstone

Llyn Teifi mudstone

Blaen Myherin mudstone

Devil's Bridge mudstone, sandstone

mineral lode

Figure 619: Field excursion.

Cwmystwyth mine in the upper Ystwyth valley is perhaps the most impressive lead mine site in Mid-Wales, with visitors able to explore an area of huge waste tips, tramroads, remains of mine buildings and the entrances to numerous adit levels.

The productive ore lodes at Cwmystwyth lie within the Rhuddnant Grits formation, which were deposited by turbidity currents flowing along the Welsh basin, confined within a narrow half-graben (see fig.602 above). The coarsest and thickest bedded grit within this formation, known as the Llyn Teifi Member, is exposed in the rock outcrops on the valley side above the mine.

Structurally, the mine lies at a point where a series of faults intersect close to the major east-west Cwmystwyth fracture zone. The faults formed in a series of earth movements during the Acadian orogeny in the early Devonian, with the later faults cutting and displacing sections of the earlier fractures. Each of the faults has been mineralised to some extent, mainly by hydrothermal

Figure 620: Second phase minerals deposited at Cwmystwyth mine: (left) Quartz and galena vein. Courtesy of Ceredigion Museum, Aberystwyth. (right) Sphalerite.

convection during the lower Carboniferous period of mineralisation.

There is an astonishingly long history of mining at Cwmystwyth. The site was worked as far back as Roman times for lead. In the Middle Ages, mining was continued by monks from the nearby Strata Florida Abbey. Much of the early work took place in opencast workings at Graig Fawr in the west and Copr Hill in the east. The workings were accessed by numerous short shallow adits.

Large scale mechanised operations began in the mid-1700's under the control of the mine engineer Thomas Bonsall, who was responsible for driving the Lefel Fawr adit to access the main ore reserves beneath Graig Fawr. Ore extraction continued successfully through the 1800's, with the Cwmystwyth lodes worked as four separate and unconnected mines along the valley which were often under different ownership.

In 1900, the Cwmystwyth Mining Company took over the complete site, and major modernisation was carried out by the manager Henry Gammon. A large processing mill was constructed, powered by a hydro electric turbine. As at Frongoch, increased demand for zinc focussed production on the large reserves of zinc blende which had remained unworked in the mine. Tramways and inclines were built to connect adits around the hillside to the new mill.

Production continued on a declining scale until 1950, when the mine finally closed.

Start: Park alongside the road below the mill site [SN802745].

1: View the remains of the mill area. The extensive concrete foundations supported a large timber and corrugated iron mill building which housed rock crushers and water separation tanks.

Figure 621: Cwmystwyth mine.

2: Climb up behind the mill on the western side of the ravine leading to the opencast workings. The Llyn Teifi turbidite grit can be examined in the outcrops in the ravine. Individual beds may be up to 6 feet in thickness. Between the turbidite deposits may be found thin hemipelagic muds laid down by quiet sedimentation within the marine basin between turbidite events.

Figure 622:

Ravine below the Cwmystwyth opencast workings, with outcrops of Llyn Teifi turbidite grit.

3: Return to the lower level of the mill, then follow the tramway eastwards. Cross the stream which descends from the ravine, and continue to the entrance of the Level Fawr adit.

The workings within the mine may be explored by groups under the guidance of experienced leaders.

Level Fawr leads into an area of extensive stopes on Michell's lode, Comet lode and Kingside lode. The cross-section of the workings (fig.623) indicates the way in which movement on the fault occupied by Mitchell's lode has caused offset of the Comet and Kingside lodes.

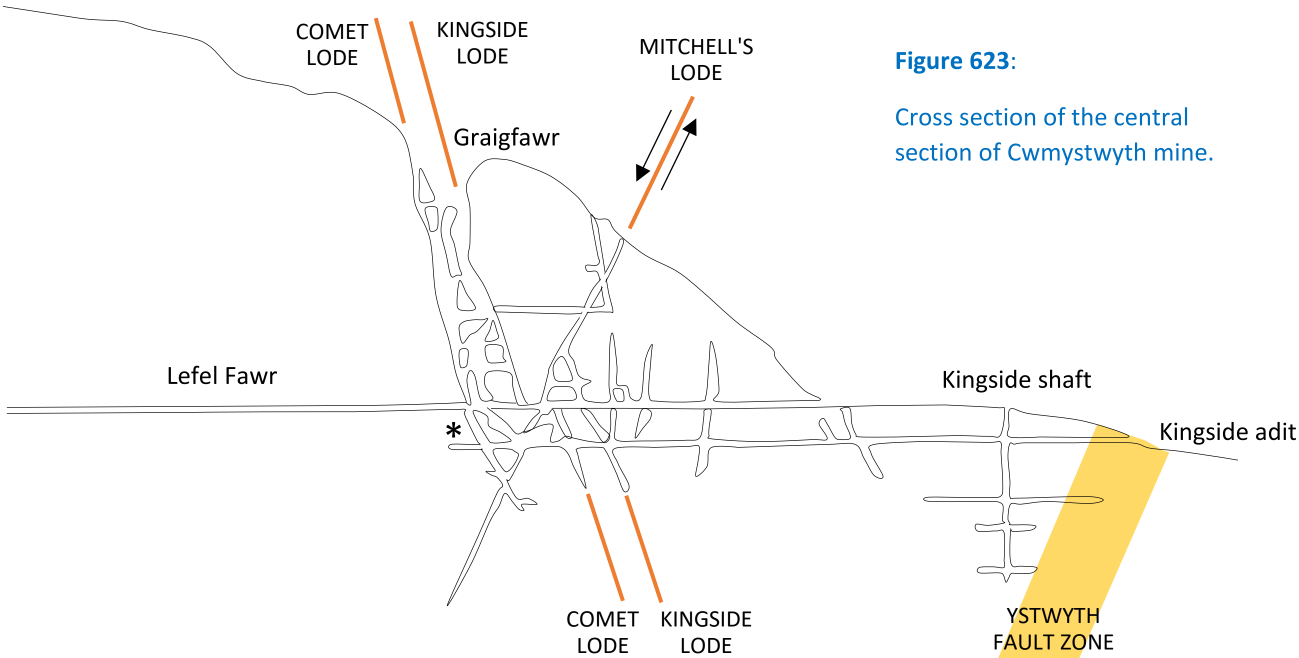


Figure 623:

Cross section of the central section of Cwmystwyth mine.

Figure 624: (left) Entrance to Lefel Fawr. (right) Near-vertical shaft connecting Level Fawr to the Kingside level at the location marked '*' in fig. 623 above. To the left is the railway track for raising skips of ore. To the right are a series of timber platforms for the ladderway used by miners.

Ore has been extracted from stopes which extend upwards and downwards from Lefel Fawr. An interesting feature of the mine is a near-vertical shaft equipped with a railway track which was used for hauling skips of ore up from the lower workings. This ore was then taken out of the mine in trucks and along the tramway to the mill for processing.

4: Continue up the valley, following the old tramway and incline to reach the valley below Copr Hill. Mining has taken place in this valley from earliest times, and numerous adits may be found. There are connections underground to the Lefel Fawr workings.

Many mineral lodes cross the valley. An interesting discovery made by archaeologists is that early miners located the lodes by a method known as 'hushing'. A small reservoir was constructed near the top of the valley. When full of water, the dam was breached and a wave of water was released. This washed away the soil, revealing the bedrock and mineral veins.

Return along the tramways and inclines to the mill, then to the parking place.

Figure 625: (left) Valley leading to Copr Hill. (right) Pengeulen adit, which is one of the numerous adits, shafts and opecast workings in this old area of mining.

Pont-rhyd-y-groes

5 miles: approximately 2½ hours

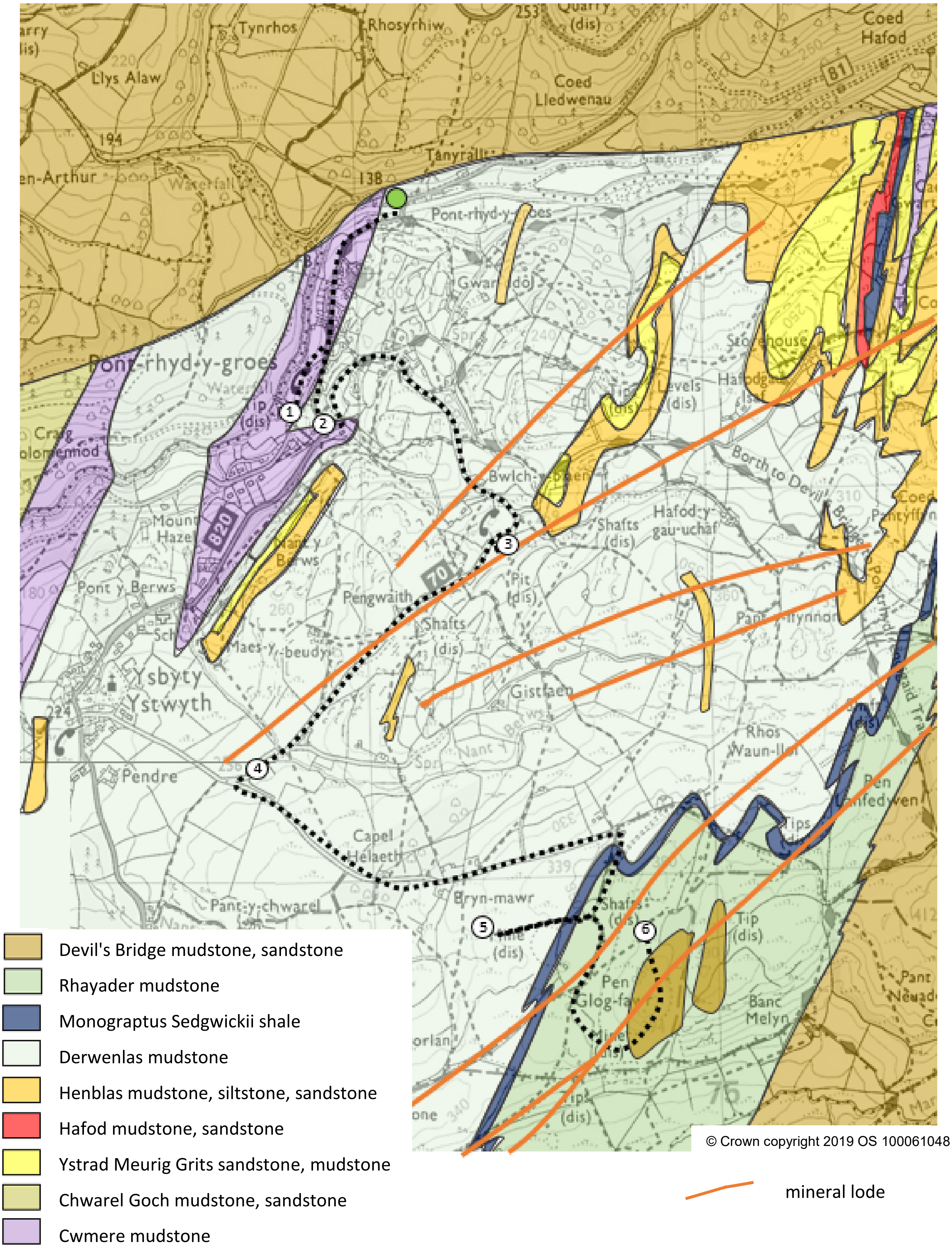


Figure 626: Field excursion.

One of the greatest engineering achievements in mining in Mid-Wales was the construction of the Lefel Fawr at Pont-rhyd-y-groes. This tunnel of about 2 miles in length was constructed to drain a series of mines in the hills above the Ystwyth valley. We begin at the mouth of Lefel Fawr, then visit the Logaulas and Glog mines which were linked underground by the Lefel Fawr.

The excursion can be carried out entirely on foot, leaving a car in Pont-rhyd-y-groes [SN739725]. Alternatively, you may drive between the mine sites, parking by the roadside at each locality.

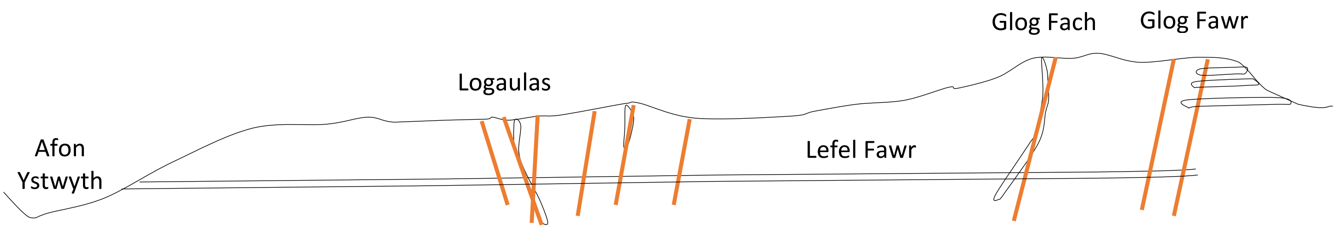


Figure 627: Section along the Lefl Fawr and associated mines.

1: From the centre of the village, take a road which descends past a small industrial estate towards the river. The road reaches the recently restored waterwheel which is powered by the stream flowing from the Lefel Fawr drainage adit.

2: Return to the main road and continue to the old mine office building which has now been restored as a private house. The mouth of the Lefel Fawr and the outlet stream may be seen below the road embankment, with gardens in front of the house occupying the mine yard where workshops and an ore processing mill were located.

Figure 628: Pontrhydygroes.
(left) Water wheel powered by the outlet stream from the Lefel Fawr.
(right) Lefel Fawr adit.

On the bend of the main road above the Lefel Fawr adit, turn left up a steep minor road. Continue to the head of the valley. As the road emerges onto flatter ground above the deep Ystwyth valley, the site of Logaulas mine is reached. To the left of the road are waste tips and a small reservoir for water power.

3: Leave the road and cross the field to reach a shaft and opencast workings. The quartz lode at this point was passing through mudstones of the Derwenlas formation. The mine was developed during the early 1800's, and extended to a depth of over 600 feet. Waterwheels pumped water up from the lowest levels to discharge through the Lefel Fawr, and ore was also hauled up to Lefel Fawr and taken out by tram for processing at Pont-rhyd-y-groes. In addition to the common lead sulphide ore **galena**, the mine also yielded the lead carbonate mineral **cerussite**.

Figure 629: Logaulas mine site. (left) Remains of opencast workings and a shaft. (right) A very well constructed shaft on the hillside to the south of the opencast workings. This shaft was probably equipped with ladders and provided access for the miners.

4: Continue along the minor road, taking a left turn at the road junction above Ysbyty Ystwyth. Continue to a gate which marks the entrance to the Glog mines. Glog Fach worked the plateau area to the north, whilst Glog Fawr worked the hill summits which overlook the Marchnant valley to the south. The mines operated from the early 1800's until final closure in 1920, with the peak of production in the later half of the 19th century.

The Glog mines lie within the Devil's Bridge formation, with thick sandstones making up much of the succession. The hardness of the rock is said to have made mining difficult.

A number of shafts and opencast workings are found around the large area of waste tips and on the adjacent hillsides. The mines connected underground to the Lefel Fawr which provided drainage. Due to the transport distance involved, much of the ore was hauled directly to the surface for processing, rather than being carried by tram through the Lefel Fawr to Pont-rhyd-y-groes.

Figure 630: Folded and faulted sandstones of the Devil's Bridge formation.

5: Cross the waste tip to examine the remains of the crusher building and the adjacent shaft.

6: Climb up the hillside to the east of the waste tips. View a series of shafts and trench workings along the mineral lode. Beyond lies a reservoir constructed for water power, although a steam engine was also employed at the mine to operate the mill machinery.

Return along the minor roads to Pont-rhyd-y-groes.

Figure 631:

Glog mines.

(right) View across the Glog Fach mine site.

(below left) Crusher building at Glog Fach.

(below right) Opencast working in Devil's Bridge sandstone.