Cwm Idwal

[SH 646 606]–[SH 640 583]

M. Smith

Introduction

Cwm Idwal is a National Nature Reserve of outstanding geological, geomorphological and botanical interest that is easily accessible from the A5 trunk road near Llyn Ogwen. The geology is varied and complex and includes features of volcanological, sedimentological, and structural importance that are clearly displayed in the eastern and southern cliffs above Llyn Idwal and in the lower ground NW of Ogwen Cottage (Figure 6.48).

The GCR site encompasses a heterogeneous sequence of rock types ranging from rhyolitic ash-flow tuffs, basic tuffs and lavas, to intrusive rhyolites, all interlayered with volcaniclastic marine sedimentary rocks (Figure 6.49). It includes representatives of the two main eruptive cycles related to major caldera activity within central Snowdonia during Caradoc times. Outflow tuffs from both the 1st Eruptive Cycle, related to the Llwyd Mawr Centre, and the 2nd Eruptive Cycle, related to the Snowdon Centre are present. Of particular interest are the sections through the Lower Rhyolitic Tuff Formation (LRTF), of the 2nd Eruptive Cycle, which record the deposition of caldera-sourced pyroclastic breccias and welded tuffs, passing up into reworked tuffs and turbidites. The shelly faunas contained within the sedimentary rocks indicate an age range of Soudleyan to Longvillian (mid-Caradoc).

The primary survey of the area was completed in 1852 (Ramsay, 1881) and later the area was partly described by Williams (1930). Detailed remapping by the Geological Survey at the 1:10 560 scale was completed in 1977 and incorporated into the 1:25 000 scale geological Sheet SH65/66 (Passes of Nant Ffrancon and Llanberis) (1985). General descriptions of Cwm Idwal were given by Roberts (1979) and Howells *et al.* (1981), with detailed descriptions of parts of the succession in Reedman *et al.* (1987), Fritz *et al.* (1990), Howells *et al.* (1991) and Kokelaar *et al.* (1994). Geochemical data were presented by Howells *et al.* (1991).

In ascending order the succession includes the Cwm Eigiau Formation, the Pitts Head Tuff Formation, the Lower Rhyolitic Tuff Formation (LRTF) and the Bedded Pyroclastic Formation (BPF). The strata are deformed in a classic open symmetrical synclinal fold termed the Idwal Syncline (Fitches, 1992). This NE-trending structure, and the complementary Tryfan Anticline to the east, are major fold structures formed during Caledonian orogenesis.

Description

In the site area, strata occurring immediately below the Snowdon Volcanic Group (the Cwm Eigiau Formation), and three formations belonging to the Snowdon Volcanic Group are magnificently exposed.

The lower strata of the Cwm Eigiau Formation, which crop out in the western part of the site (Figure 6.49) and form the crags west of Llyn Idwal, can be traced both south-westwards to Y Garn and northwards into the Braich to du GCR site. They overlie the Capel Curig Volcanic Formation conformably and comprise steeply dipping very fine-grained structureless sandstones interlayered with siltstones and thin mudstones. Beds containing disarticulated brachiopod shells are common and are well exposed around [SH 6487 6041], NW of Ogwen Cottage. By comparison with the Berwyn district, these faunal associations have been assigned to the *Dinorthis–Macrocoelia* community (Pickerill and Brenchley, 1979) and provide important information on the palaeoenvironment prior to the main volcanic events. A prominent knoll at the north-western end of Llyn Idwal [SH 6430 5981] shows excellent exposures of cross-bedded sandstones overlain by contorted, wavy siltstones and fine-grained sandstones. The overlying welded tuff also contains a raft of contorted sandstone. Similar features, with lobate and flame structures, are also preserved in quarry sections west and NW of Ogwen Cottage, (for example at [SH 6492 6082]), and together these features indicate syn-emplacement deformation of semi-lithified sediments immediately beneath the Pitts Head tuffs.

The overlying acidic ash-flow tuff is the most northerly representative of the Pitts Head Tuff Formation in Snowdonia and is the distal outflow facies from a major caldera centre located some 25 km SW at Llywd Mawr (see the Craig y Garn GCR site report). The tuff varies from 30–50 m in thickness and is well exposed in numerous sections and cuttings immediately south and north of the A5 road, (for example at [SH 649 606]), and in the lower western crags rising up across the ridge of Castell y Geifr to Y Garn. The base is generally concordant on the underlying sandstones.

Three main sub-units are recognized in the Pitts Head Tuff at this locality: a basal non-welded zone 1–2 m thick and rich in feldspar crystals with a vitrodastic texture; this grades up into 25–45 m of white, siliceous, welded tuff with a prominent eutaxitic foliation; and an upper fine-grained tuff. Distinctive ragged, flattened and streaky fiamme, up to 5 cm in length, are pres ent throughout the central part of the tuff. Some 5 m above the base, cooling and contraction joints are well developed and fiamme increase markedly in size. The welding foliation is accentuated by siliceous segregations locally reaching 30 cm in length, although these are less well developed compared with the southern outcrops around Moel Hebog. Zones of siliceous nodules 1–3 cm in diameter occur irregularly through the tuff and rheomorphic flow textures, indicated by the variable orientation of the fiamme with respect to the margins of the flow, are common. Locally, (for example at [SH 6476 6024]), strong linear fabrics may be observed, and are interpreted as having formed by extreme extension in the flowing and compacting tuff (Howells *et al.,* 1991). The upper sub-unit comprises cleaved vitric dust-rich tuff, which is variably welded and locally reworked.

The Pitts Head tuffs, in turn, are sharply overlain by up to 200 m of sandstones representing a continuation of the Cwm Eigiau Formation with fining-upward sequences and rare thin mudstones. These strata form the striated and ice-sculpted ridges, crags, and waterfalls immediately east of Llyn Ogwen and have been described in detail by Orton (1988) in Cwm Bochlwyd, immediately east of the GCR site. Sedimentary features are common, including trough cross-bedding, swaley cross-stratification, and low-angle cross-lamination to horizontal lamination. Upwards, the sandstones become planar bedded with thin layers of tuff-turbidite and are characterized by careous-weathering lenses of winnowed, disarticulated brachiopod shells, coquina-filled scours and rare, low to moderately dipping cross-beds with shells dispersed along the foresets.

The acidic ash-flow tuffs, intrusive rhyolites, breccias and interbedded sedimentary rocks which comprise the overlying Lower Rhyolitic Tuff Formation (LRTF) dominate the well-known cliff sections and prominent Idwal Slabs around the eastern and southern parts of the site (Figure 6.50).

The LRTF is a heterogeneous unit up to 110 m thick, which rests with marked disconformity on the underlying sedimentary rocks. This discordance increases to the south to an unconformity (Howells *et al.,* 1986). In the west, the LRTF cuts down through easterly-dipping sandstones, locally cutting out thin tuffaceous units, and comprises welded primary ash-flow tuffs with no intercalated sediments. In contrast, on the eastern limb of the Idwal Syncline the basal relationships are complicated by intrusive basalts, lavas and the development of a pyroclastic breccia facies at the base of the LRTF.

The basal sections of the LRTF are best seen at the foot of a wall immediately SW of two streams that drain into Llyn Idwal at [SH 6470 5894]. Here, the basal beds include vesicular, massive basaltic pillow lavas, heterolithic basaltic debris-flow deposits and thin turbiditic tuffs. The debris-flow deposits contain subrounded basalt blocks up to 1 m in diameter, in a fine-grained matrix of basic tuff with dispersed feldspar crystals. The overlying pyroclastic breccia, up to 12 m thick, comprises a coarse lithic breccia occurring as layers or lenses which thin and pass laterally into the host matrix-supported ash-flow tuff. Individual blocks, 0.1–0.7 m in length, range in composition from basalt, acid tuff and rhyolite to rare sandstone and siltstone. A crude stratification can be discerned by variations in grain and clast size, and lithology.

The main part of the LRTF is a thick sequence of stratified welded lapilli ash-flow tuffs with beds up to 1.5 m thick and a prominent eutaxitic foliation. Thin breccia layers similar to the basal breccia have been recorded up to 42 m above the base (Kokelaar *et al.,* 1994). In thin section, the fiamme are chloritic and are set in a matrix of undeformed devitrified shards and fine-grained dust. Several units are indicated on the 1:25 000 scale map and are separated by laterally impersistent layers of siltstone. The highest beds are composed of well-bedded and upwardly graded reworked tuffs. A dark porcellaneous laminated fine-grained tuff marks the top of the sequence.

The overlying sedimentary rocks, up to 100 m in thickness, have been described in detail by Fritz *et al.* (1990). The lowest bed is a 2 m-thick laminated pyritic mudstone, passing up into tuffaceous siltstones with hummocky and swaley cross-stratification and abundant large carbonate concretions. Above, are up to 75 m of brown-weathering, greenish coarse-grained volcaniclastic sandstones with interbeds of pale tuffaceous siltstone and rare impersistent ash-flow tuffs. Individual bed thicknesses range between 10–50 cm and show a progressive upward decrease in the volcaniclastic component. The sandstones, up to 7 cm thick, are massive and planar bedded with flat, locally scoured bases and reworked hummocky tops. Sedimentary features include cross-lamination, ripples, grading, washouts, intraformational unconformities, and slump folds with contorted bedding indicating deformation of semi-lithified sediment (for example at [SH 6402 5904].

The upper parts of the backwall of Cwm Idwal are dominated by a thick columnar-jointed rhyolitic lava flow, which can be traced across the core of the synclinal structure. The rhyolite lava is dark blue-grey, flinty and finely banded with locally developed perlitic fracturing. The upper surface, exposed along the footpath between Cneifion Duon and Y Garn, is brecciated, and in places, hollows and depressions are infilled with coarse volcanic detritus. The zones of brecciation contain classic jig-saw breccia fabrics and can be traced laterally into flow-banded rhyolite indicating in-situ autobrecciation. The rhyolite lava is in places separated from the overlying BPF by up to 35 m of planar and cross-laminated rhyolitic tuffaceous sandstone representing the top of the LRTF.

The Bedded Pyroclastic Formation (BPF) crops out to the SW of Twll Du (or Devil's Kitchen) and around Llyn y Cwn, immediately south of the GCR site. Up to 24 m of flaggy-bedded, greenish basic tuffaceous sedimentary rocks and coarse-grained tuffaceous sediments including block- and lapilli-rich beds are exposed. Sedimentary structures, including cross-lamination and wave-rippled surfaces, are common. Elsewhere, these beds grade into volcaniclastic sedimentary rocks with a sparse, are shelly fauna, interpreted as indicating a probable upper Longvillian age (Howells *et al.,* 1991). The latter are overlain by up to 70 m of auto-brecciated non-vesicular basaltic lavas with sparse plagioclase phenocrysts and variably developed pillow forms. Where well developed, the pillows reach 1.5 m in diameter. At the very top of the section the basalt lavas are overlain by basic tuffaceous sedimentary rocks displaying cross-lamination.

Interpretation

The geology of Cwm Idwal and the surrounding area provides an unrivalled opportunity in Snowdonia to assess the changes in sedimentation in the marine environment caused by the introduction of large volumes of hot ash-flow deposits proximal to a large caldera structure. The lower sedimentary rocks and contained faunal assemblages of the Cwm Eigiau Formation suggest a shallow-marine environment with water depths of less than *c.* 25 m. The interlayered sandstones and siltstones are interpreted as shelf-ridge sands with interbar silts and muds, within which the more massive and thicker sandstones may represent discrete storm events (Howells *et al.,* 1991).

Into this environment the Pitts Head tuffs were deposited as hot gas-charged pyroclastic flows. The submarine emplacement and post-emplacement features of the Pitts Head tuffs in Cwm Idwal contrast with the subaerial environment at the Moel Hebog to Moel yr Ogof GCR site and imply a north-easterly dipping palaeoslope (Reedman *et al.,* 1987). The lack of disruption along the basal contact and the internal fabrics suggest that the tuff appears to have ingested little water, and retained sufficient heat to weld on emplacement. The overlying, less dense gas-rich cloud above the tuff is thought to have travelled across the water surface, eventually settled, and is represented by the upper vitric dust tuff (Howells *et al.,* 1991). Estimates of water depth, often problematical in shallow-marine settings, is considered to be less than 20 m, and therefore it would seem unlikely that the tuffs would have been completely submerged.

The overlying sandstones, with their abundant sedimentary features and transported faunal debris, represent the continuation of marine conditions with high-energy regimes on a mid-to outer storm-dominated shelf (Orton, 1988). With time, deeper water conditions prevailed; the upper turbiditic sandstones and siltstones, with a lack of coarse-grained detritus, record subsidence prior to the next period of volcanic activity.

The following cycle of volcanic activity recorded by the LRTF commenced with localized basic magmatism and the formation of a distinctive suite of pyroclastic breccia deposits. These breccias, identical to intracaldera lag breccias south of Snowdon, are only found in the Cwm Idwal area up to 4 km north of the margin of the LRT caldera (Figure 6.51). From

their lithology and nature, they are interpreted to be co-ignimbritic lag breccias (Howells *et al.,* 1986). The overlying main part of the LRTF shows a marked absence of any compositional or fabric variations both between or within individual beds, suggesting repeated pulses of ash-flows from a single eruptive phase (Howells *et al.,* 1986). This is supported by their trace element geochemistry, which shows consistent relative abundances of the elements Zr, Nb, Th and TiO_2. Vertical variations in trace element profiles suggest a break near the top of the main body of pyroclastic breccias.

The primary tuffs were overlain by remobilized pyroclastic debris and sediments, interpreted to represent deposition on a pyroclastic apron that formed along the northern margin of the caldera (Orton, 1988; Fritz *et al.,* 1990). A rapidly shallowing sequence from deep, non-volcanically influenced sedimentation represented by the black mudstones to above storm-wave base with water depths of *c.* 100 m is indicated by the hummocky and cross-stratified sandstones. The increase in grain size and extensive reworking of the overlying sandstones may represent turbidity-current deposition and progra-dation of the apron, fed by sediment from the caldera margin, to within and above storm-wave base (Fritz *et al.,* 1990). Howells *et al.* (1991) noted that the overall volume of reworked material exposed around the northern edge of the caldera is small compared to the infill. This suggests that the edifice of the Snowdon caldera had a limited subaerial expression and ponding of eruptive products occurred within a shallow-marine depression.

A thick rhyolite flow was intruded into the upper part of the LRTF; the presence of an auto-brecciated carapace indicates that this was probably locally extrusive onto the sea floor. The overlying tuffs and their rhyolitic clasts, which mark the top of the LRTF, are geochemically distinct from the underlying tuff sequence but closely match the composition of the rhyolite. This supports their emplacement as a distinct magmatic event within the evolution of the Snowdon caldera.

Following resurgence and reworking of the main caldera-related tuffs, the Snowdon eruptive centre was dominated by basaltic volcanic activity. This activity is represented at Cwm Idwal by the Bedded Pyroclastic Formation which erupted into a shallow-marine environment, as is indicated by the presence of basaltic pillow lavas and reworking of the upper basic tuffs and lavas.

Conclusions

The Cwm Idwal GCR site provides magnificent exposures of volcanic products from both the 1st and 2nd eruptive cycles which occurred in Snowdonia in Caradoc times. The heterogeneous sequence at Cwm Idwal records the dramatic influence of major caldera-related explosive volcanism on the sedimentation patterns in a marine environment. Combined volcanological and sedimentological studies reveal significant changes in sediment supply and modification of the tectonic environment in response to volcanic activity. In addition the Cwm Idwal site provides excellent examples of emplacement features of welded ash-flow tuffs in a shallow-marine setting and emphasizes the importance of reworking and the widespread redistribution of volcanic material in such an environment.

References

Figure 6.48 The Idwal Syncline viewed along the axis, across Llyn Ogwen towards Cwm Idwal and the Devil's Kitchen. (Photo: BGS no. L2390)

structure. Numerous studies have revealed the complex inter-relationships, through time, between alternating acid and basic magmatism, changing styles of volcanic activity and the background sedimentation. These relationships, most clearly expressed within the later stages of basaltic activity, represented by the Bedded Pyroclastic Formation, provide valuable insights into the ancient environments of Snowdonia during Caradoc times.

CWM IDWAL (SH 646 606–640 583)

M. Smith

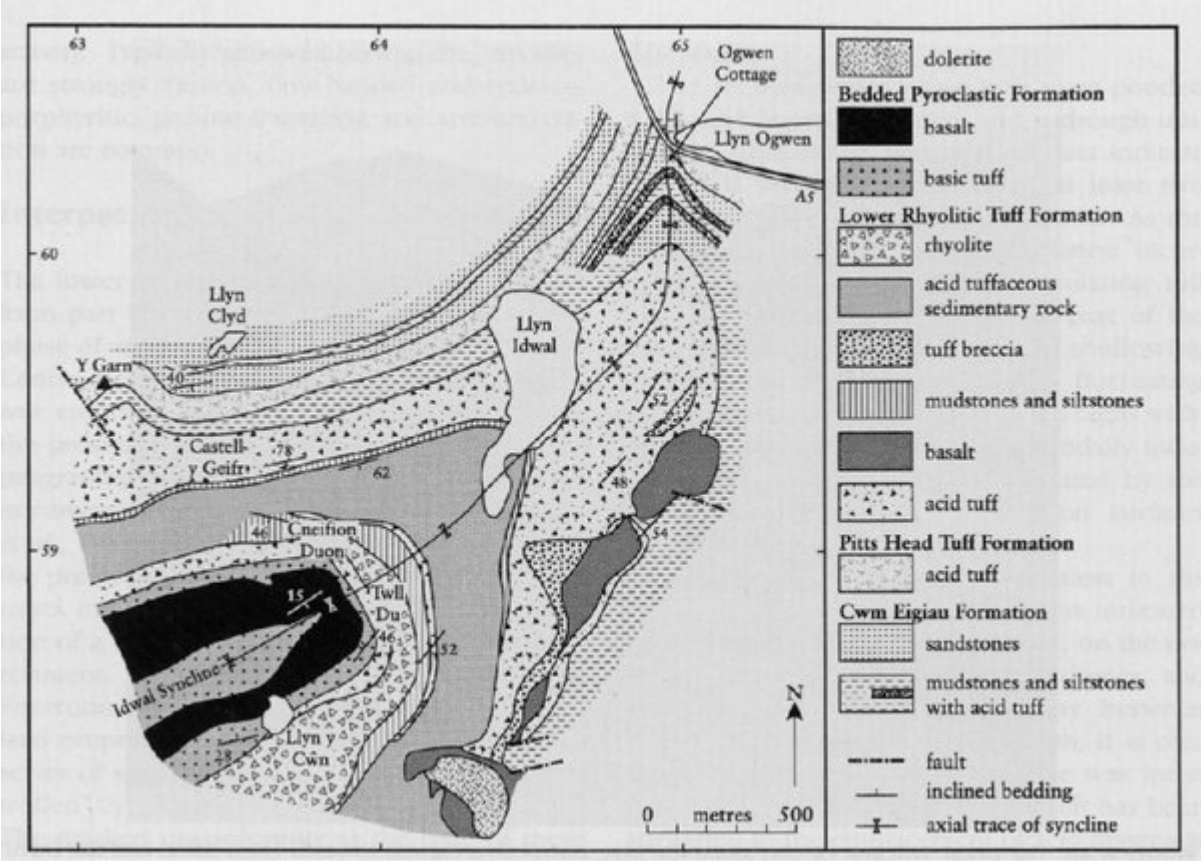
Introduction

Cwm Idwal is a National Nature Reserve of outstanding geological, geomorphological and botanical interest that is easily accessible from the A5 trunk road near Llyn Ogwen. The geology is varied and complex and includes features of volcanological, sedimentological, and structural importance that are clearly displayed in the eastern and southern cliffs above Llyn Idwal and in the lower ground NW of Ogwen Cottage (Figure 6.48).

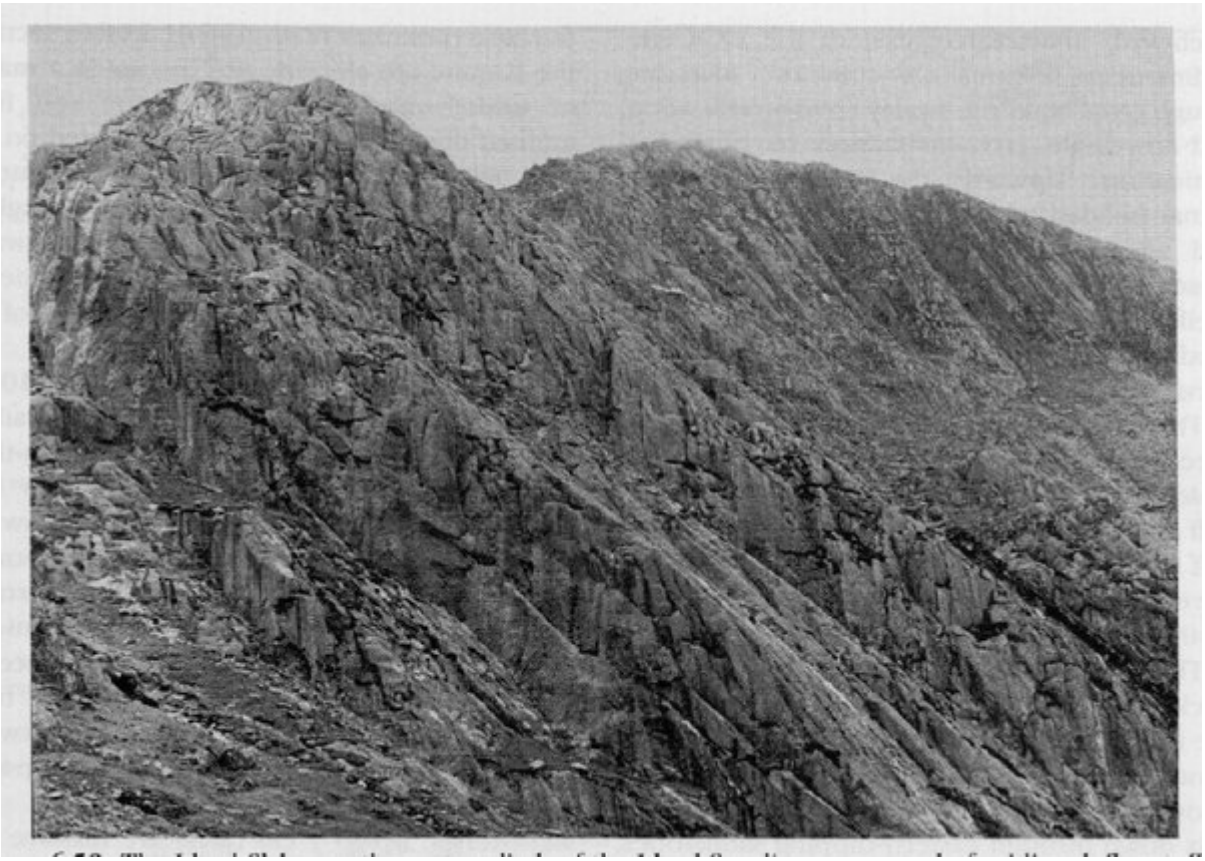
The GCR site encompasses a heterogeneous sequence of rock types ranging from rhyolitic ash-flow tuffs, basic tuffs and lavas, to intrusive rhyolites, all interlayered with volcaniclastic marine sedimentary rocks (Figure 6.49). It includes representatives of the two main eruptive cycles related to major caldera activity within central Snowdonia during Caradoc times. Outflow tuffs from both the 1st Eruptive Cycle, related to the Llwyd Mawr Centre, and the 2nd Eruptive Cycle, related to the Snowdon Centre are present. Of particular interest are the sections through the Lower Rhyolitic Tuff Formation (LRTF), of the 2nd Eruptive Cycle, which record the deposition of caldera-sourced pyroclastic breccias and welded tuffs, passing up into reworked tuffs and turbidites. The shelly faunas contained within the sedimentary rocks indicate an age range of Soudleyan to Longvillian (mid-Caradoc).

The primary survey of the area was completed in 1852 (Ramsay, 1881) and later the area was partly described by Williams (1930). Detailed remapping by the Geological Survey at the

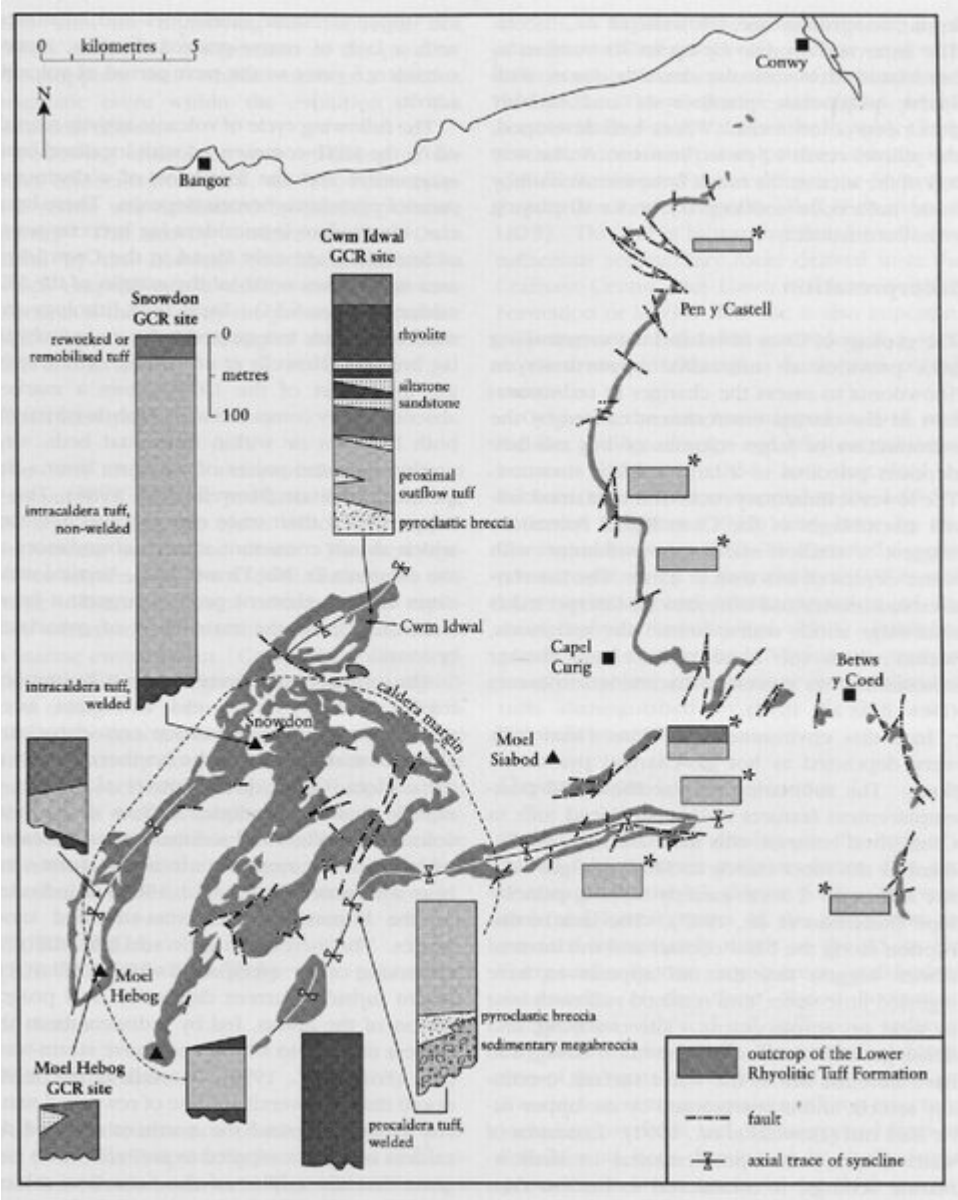
(Figure 6.48) The Idwal Syncline viewed along the axis, across Llyn Ogwen towards Cwm Idwal and the Devil's Kitchen. (Photo: BGS no. L2390)



(Figure 6.49) Map of the Cwm Idwal GCR site, after BGS 1:25 000 Sheet 65/66 (1985).



(Figure 6.50) The Idwal Slabs, on the eastern limb of the Idwal Syncline, composed of acidic ash-flow tuffs of the Lower Rhyolitic Tuff Formation. (Photo: BGS no. L2636.)



(Figure 6.51) Outcrop and measured sections of the Lower Rhyolitic Tuff Formation. Asterisks indicate distal outflow tuff sections. After Howells et al. (1991).