Moel Hebog to Moel yr Ogof

[SH 568 464]–[SH 557 483]

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Introduction

The Moel Hebog to Moel yr Ogof GCR site is one of two GCR sites that lie at or near the margin of one of the major eruptive caldera centres defined in the Caradoc rocks of North Wales. The Snowdon Centre, belonging to the 2nd Eruptive Cycle of Howells *et al.* (1991), is interpreted as a marine island caldera complex whose margins may be recognized by one or more of the following features:

1. Localized shallowing and emergence within a regionally subsiding marine environment.

2. Ponding of ash-flow tuff deposits.

3. Large-scale disruption of the volcanosedimentary sequences.

4. The emplacement of a series of rhyolitic domes and sills and basaltic magmas.

The complex geology displayed on Moel Hebog and Moel yr Ogof (Figure 6.38) shows many of the above features, including excellently exposed examples of subaerially emplaced acid ash-flow tuffs, primary and reworked intra-caldera tuffs, basic pillow lavas and spectacular large-scale disruption and slumping of blocks off the rim of the caldera.

The exposed strata comprise the Snowdon Volcanic Group which is divided into four formations. Only the three lowest formations are exposed at the Moel Hebog to Moel yr Ogof GCR site; the upper formation is seen at the Snowdon Massif GCR site. The lowest part of the succession crops out on the eastern side of Moel Hebog and includes marine sandstones of the Cwm Eigiau Formation overlain by acid ash-flow tuffs of the Pitts Head Tuff Formation, representing the outflow facies from the adjacent Llywd Mawr Centre (see the Craig y Garn GCR site report). These are in turn overlain by ash-flow tuffs representing the intracaldera facies of the Lower Rhyolitic Tuff Formation. The Bedded Pyroclastic Formation crops out at Moel yr Ogof and is interpreted as the site of an eruptive basic vent subsequently capped and intruded by rhyolite domes and sills.

The site area was originally described by Williams (1927) and Shackleton (1959), both of whom regarded the tuffs as extrusive rhyolites. They were subsequently shown to be welded ash-flow tuffs by Rast *et al.* (1958) and were remapped in detail at the 1:10 000 scale by the British Geological Survey between 1984 and 1985. Detailed descriptions are provided by Reedman *et* al. (1987) and Howells *et al.* (1991) and the site is included on the 1:50 000 scale Geological Sheet 119 (Snowdon) (1997).

Description

Sedimentary rocks of the Cwm Eigiau Formation underlying the Pitts Head Tuff Formation crop out along the south-eastern part of the site, east of South Buttress (around [SH 5695 4671]) and along the main summit path from Beddgelert (at [SH 5694 4729]) (Figure 6.38). Described and logged in detail by Orton (1988), thcy comprise a lower succession of interlayered siltstones and mudstones passing up into medium- to coarse-grained tabular sheets of pebbly sandstones with trough cross-bedding. Thin interlayers of white-weathering vitric tuff or tuffaceous sedimentary rock are developed sporadically. Debris flows and rapid variations in grain size characterize the uppermost units although bedding features are generally destroyed within 0.5 m of the overlying tuff.

The 2nd Eruptive Cycle of Caradoc volcanicity in Snowdonia, represented on Moel Hebog by the Pitts Head Tuff Formation, commenced with the eruption of ash-flow tuffs from the Llywd Mawr Centre. The intracaldera facies is described in the Craig y Garn GCR site report and is lithologically identical to the outflow facies on Moel Hebog, which is represented by two distinct layers of ash-flow tuff.

The lower tuff, up to 90 m thick, forms the lower parts of the crags immediately east of the summit of Moel Hebog (Figure 6.39), and is composed of welded and non-welded crystal-rich tuff. The basal contact appears conformable on the underlying sandstones. Locally, a distinctive unit, approximately 1 m thick, of thinly bedded non-welded vitroclastic tuff with polygonal jointing, intervenes between the main tuff and the underlying sandstones. The base of the main tuff unit is non-welded but grades rapidly up into strongly jointed welded tuff with chloritic fiamme and distinctive zones of siliceous nodules (Figure 6.40). These nodular zones are 1–3 m thick and individual nodules up to 40 cm in diameter are not uncommon; microscopically they comprise a quartz mosaic. Planar concordant siliceous segregations accentuate the strong parataxitic fabric in the remainder of the overlying tuff. The top of the tuff is irregular and eroded but locally a fine-grained top is preserved. The tuffs are devitrified and recrystallized and in thin section comprise aggregates of sericite, quartz, feldspar and chlorite. Shards are well defined and euhedral phenocrysts of albite-oligoclase feldspar and perlitic fracturing may be seen in the basal welding zone.

A prominent feature of this tuff unit is the development of areas of autobrecciation. Brecciated tuffs, composed of rotated angular clasts of welded tuff, occur as thin discontinuous zones or along joints but elsewhere may occupy the entire thickness of the tuff. Reedman *et al*. (1987) noted that the crystal-rich or weakly welded basal portions of the tuff thin when traced laterally to areas of pervasive brecciation, and develop lobate protrusions into the underlying sediment or in places are completely absent. These changes are matched by a reduction in the development of siliceous nodules close to the zones of brecciation. Where the breccia occupies the complete tuff it is markedly discordant with the underlying sediment. Locally, the upper parts of the brecciated tuff are disrupted and may occur as detached rafts and fragments within ash-flow tuff deposits of the overlying Lower Rhyolitic Tuff Formation (Figure 6.39). A subsidiary site located *c.* 800 m north of Moel Hebog, around Y Braich [SH 5660 4785], displays more complex relationships between the Pitts Head and Lower Rhyolitic tuffs with large overturned rafts forming a volcanic megabreccia.

The upper tuff, up to 70 m thick, occupies the middle part of the Ladder Buttress [SH 567 467] and differs from the lower flow in the absence of a basal nodular zone. It wedges out to the NE and is not present north of the summit of Moel Hebog. Geochemically, the upper tuff is distinguished by its lower TiO_2 content and enrichment in Nb relative to the lower tuff and the intracaldera tuffs on Llywd Mawr (Howells *et al.,* 1991).

The upper parts of the crags immediately east of the summit area are formed of primary and reworked ash-flow tuffs of the Lower Rhyolitic Tuff Formation. These tuffs rest unconformably on the underlying upper or lower units of the Pitts Head tuff. The lower, basal unit comprises up to *c.* 20 m of massive, brown-weathering primary welded lapilli-tuff with a well-developed eutaxitic foliation and is overlain by massive non-welded tuff and reworked tuffaceous sedimentary rocks. The reworked tuffs comprise planar-bedded tuffaceous siltstones and sandstones with 20–50 cm-thick tuff layers and contain numerous zones of hummocky cross-stratification and coarse-grained debris-flow conglomerates (Fritz *et al.,* 1990). The upper tuff is well bedded and displays trough cross-bedding. It is interlayered with tuffaceous sandstones and rare current-rippled vitric tuffs. Locally, the base is marked by a 1 m-thick clast-supported breccia containing pumice blocks and bombs and thin layers of parallel laminated tuff. Loading and irregular basal contacts to individual beds indicate deposition onto a semi-lithified substrate.

The later stages in the evolution of the main caldera phase at the Snowdon Centre were marked by an episode of basaltic volcanic activity. The deposits from this activity, known as the Bedded Pyroclastic Formation (Howells *et al.,* 1983), are widely dispersed across Snowdonia. In the north-western part of the GCR site the formation is superbly exposed in the crags surrounding the southern, eastern and northern flanks of Moel yr Ogof [SH 5583 4767], which are located within the core of the Moel Hebog Syncline. Well-featured ground rising up from Bwlch Meillionen (Figure 6.41) shows up to 230 m of extrusive basalts, variably pillowed with associated pillow breccias and hyaloclastites.

The lower beds within Bwlch Meillionen comprise a crudely bedded basaltic breccia with bombs and blocks of basalt, up to 50 cm in diameter, and lapilli in a matrix of basaltic tuff. These are interlayered with basic tuffs and thin rhyolitic vitric tuffs. Above, and to the north, the main crags show blocky basaltic lavas with pillow forms up to 1 m across. The pillowed basalt lavas can be traced laterally into pillow breccia deposits, hyaloclastites and well-bedded basaltic tuffs. With a decreasing frequency of basalt lava flows, the succession grades up into reworked basaltic tuffaceous and volcaniclastic sandstones with two prominent basalt lava flows. The tuffaceous rocks are generally well bedded, 1–10 cm thick with parallel- and cross-lamination. Transgressive basaltic sills and dykes occur within the succession and are particularly numerous to the north of Moel yr Ogof. These sills and dykes can be traced downward into a basalt/dolerite dyke feeder system exposed immediately to the west of the GCR site and down through the sedimentary rocks below the Pitts Head Tuff Formation to a massive dolerite sill.

Immediately south and west of the summit of Moel Hebog and on Moel yr Ogof, flow-banded and flow-folded autobrecciated rhyolite sills and domes cap the succession. These acid intrusive rocks form part of the second phase of rhyolite intrusions in Snowdonia (Campbell *et al.,* 1987) post-dating caldera subsidence, and were associated with resurgent activity broadly contemporaneous with the Bedded Pyroclastic Formation.

Interpretation

The bleached weathered appearance of the Pitts Head Tuff Formation makes it one of the most distinctive tuff sequences in Snowdonia. On Moel Hebog the formation is represented by two primary rhyolitic ash-flow tuffs. Lithological and geochemical similarities with the 700 m-thick intracaldera tuff sequence on Llywd Mawr support the interpretation that the Pitts Head tuffs are the outflow facies from the Llywd Mawr Centre, although detailed correlations with the tuff sequence on Craig y Garn remain uncertain. Evidence from the south side of Moel Hebog and to the north indicates a considerable time gap between the upper and lower tuffs and therefore they must represent two distinct eruptive events. Facies and bedform analyses of the underlying sedimentary rocks have been interpreted by Orton (1988) to indicate alluvial plain and fan environments dominated by braided stream deposits derived from the W or SW.

These studies, combined with post-emplacement textures, thus support a subaerial emplacement for both tuffs. The non-welded, locally bedded base and the conspicuous zones of nodules marking the transition from non-welded to welded tuff probably resulted from the entrapment of volatiles near the zone of intense welding and growth during compactional welding and cooling, an interpretation supported by textural relationships. Above, the intense silicified planar parataxitic fabrics, with collapsed pumice clasts replaced by silica, indicate post-emplacement welding and compaction. In contrast, sections in the Pitts Head tuff farther north towards Snowdon show no siliceous nodule development and welding fabrics extend to the base of the flows. These changes correspond with a progressive north-eastward change to a submarine environment.

The evidence for post-emplacement brecciation and ductile flow of the Pitts Head tuff in a still plastic state and its presence as isolated rafts and blocks within tuffs of the Lower Rhyolitic Tuff Formation are distinctive and important features of the geology along the east side of Moel Hebog. These features have been interpreted as indicating instability and slope generation, probably by contemporary fault movements, post-Pitts Head tuff emplacement and during Lower Rhyolitic Tuff Formation times (Reedman *et al.,* 1987; Howells *et al.,* 1991). When this evidence is combined with the restriction of the upper Pitts Head tuff to the southern part of Moel Hebog and localization of acid and basic intrusive activity, it supports a model of fault-controlled topography along a caldera margin with the mass movement of welded tuff to form megabreccia deposits within a subsiding caldera.

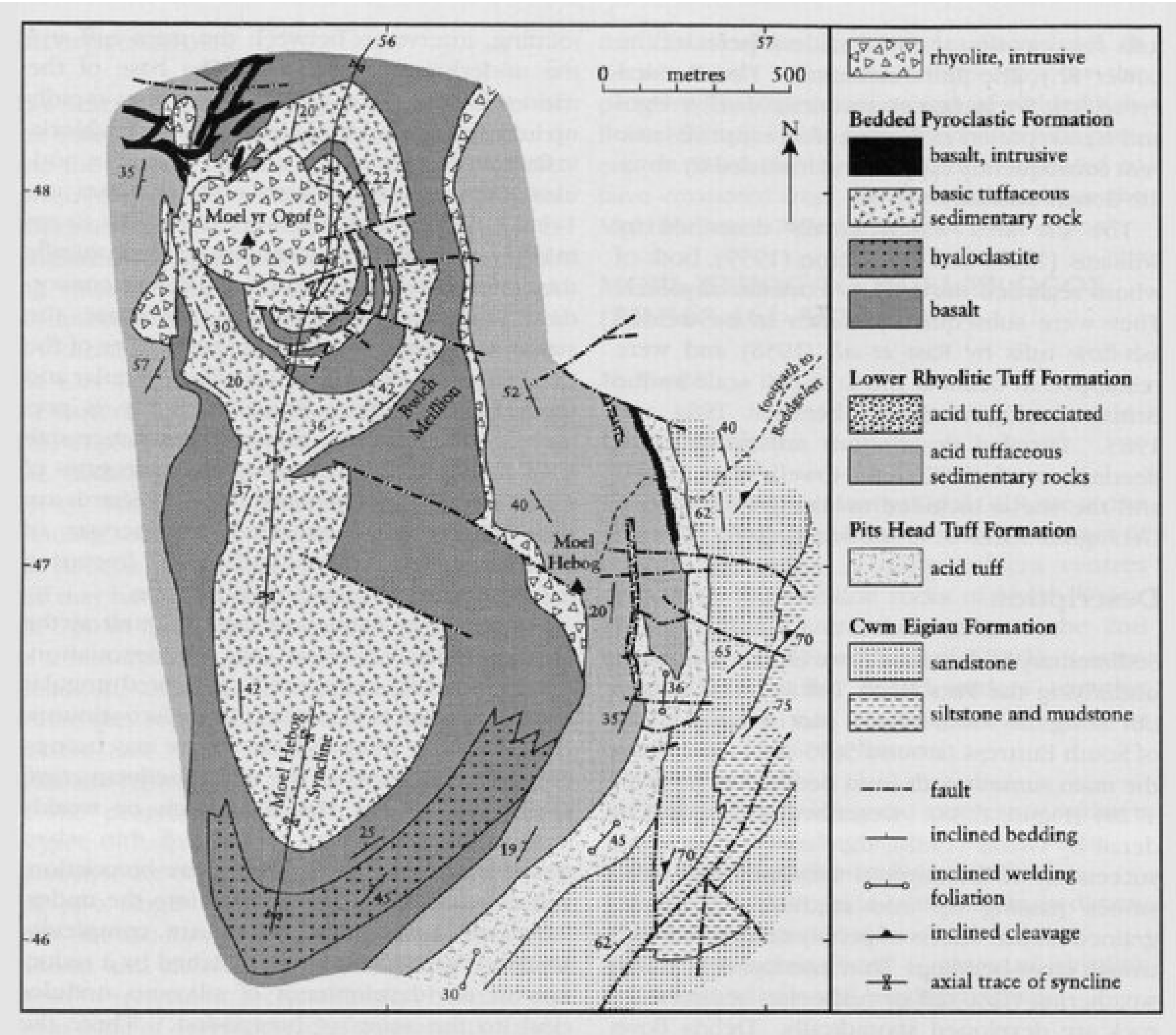
The developing caldera was then infilled by the Lower Rhyolitic Tuff Formation with the widespread ponding and reworking of ash-flow tuffs and related mass-flow deposits within a shallow-marine environment. The basal welded unit is a primary ash-flow tuff possibly erupted from a vent to the east around Beddgelert. The presence of welding at the upper contact suggests that the upper part of this flow was eroded prior to the deposition of the overlying reworked tuff and breccia deposits.

The complex lateral facies relationships within the Bedded Pyroclastic Formation on Moel yr Ogof, with basaltic dykes and sills feeding up into basaltic pillow piles and lavas, suggest the formation of a basic vent and renewed activity along the caldera structure. The formation of pillows is inferred to reflect continued subsidence within the caldera and the continuation of marine conditions.

Conclusions

The Moel Hebog to Moel yr Ogof GCR site is a key site for the interpretation of the textures and emplacement mechanisms of acid ash-flow tuffs related to the 2nd Eruptive Cycle of Caradoc volcanic activity in Snowdonia, and in the identification of faulting and renewed volcanism along the caldera margin of an ancient submarine volcano. The Pitts Head tuffs represent the outflow from the caldera of the Llwyd Mawr Centre (see the Craig y Garn GCR site report). Their sub-aerial emplacement within an alluvial fan grading offshore into a shallow shelf provides an important contrast with marine conditions farther north. Subsequent fault-related activity along the south-western caldera margin of the Snowdon Centre and continued subsidence during the main phase of volcanic activity is graphically displayed in the brecciation, sliding and widespread disruption of previously emplaced ash-flow tuffs. Renewed basaltic activity and the intrusion of rhyolite domes serve to emphasize the importance of the caldera margin fracture in the channelling of magma to shallow crustal levels during later phases of resurgent activity.

References



(Figure 6.38) Map of the Moel Hebog and Moel yr Ogof area (after BGS 1:10 000 Sheet SH54NE).

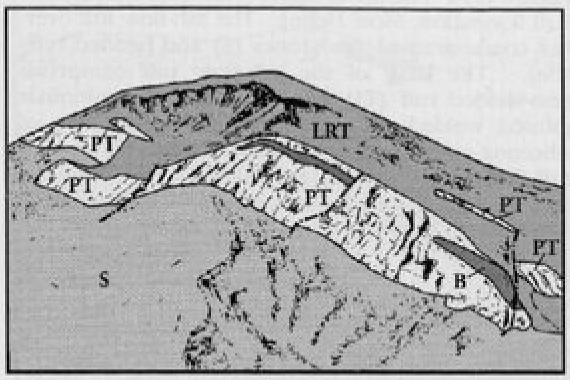


Figure 6.39 Moel Hebog, viewed from the NE, showing primary and reworked tuffs of the Lower Rhyolitic Tuff Formation (LRT) overlying and enclosing disrupted rafts and blocks of the Pitts Head Tuff Formation (PT) near the southern margin of the Lower Rhyolitic Tuff Formation caldera. The Pitts Head Tuff Formation is underlain by sediments (S) and intruded by basalt (B). Reproduced from Howells *et al.* (1991).

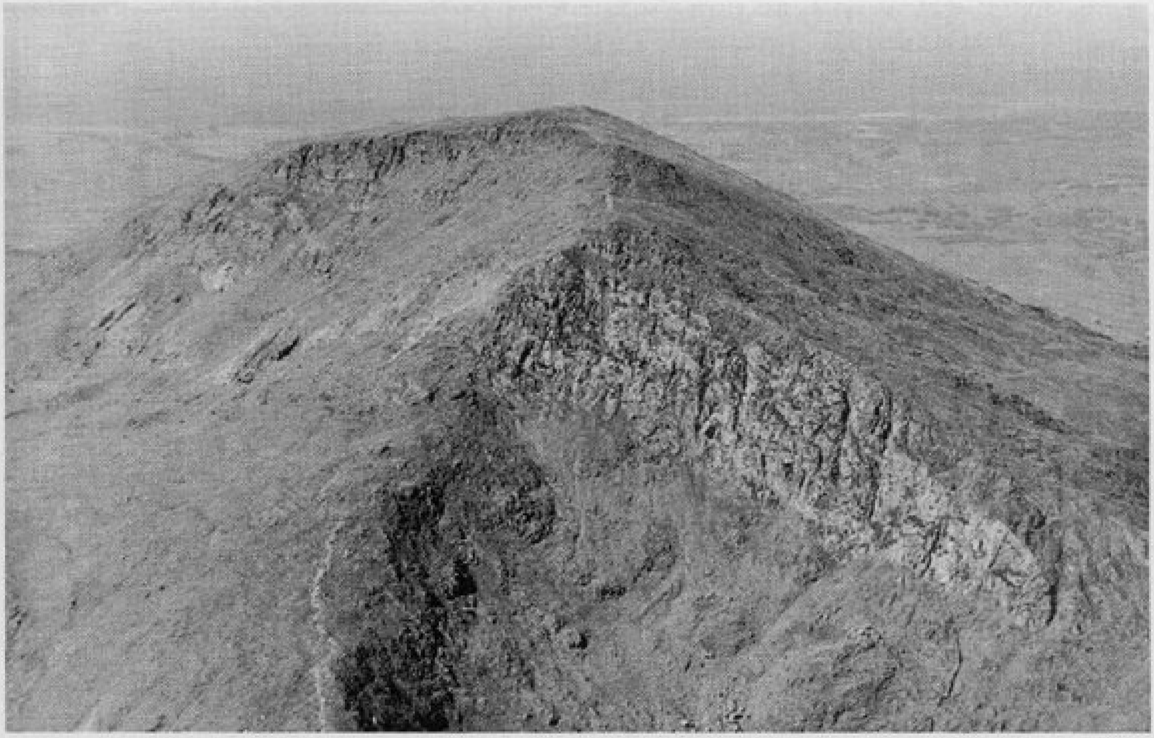


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Figure 6.40 The lower outflow tuff of the Pitts Head Tuff Formation, Moel Hebog. The ash-flow tuff overlies coarse-grained sandstones (S) and bedded tuffs (Be). The base of the ash-flow tuff comprises non-welded tuff (T1) and is overlain by columnar jointed welded tuff (T2). A prominent zone of siliceous nodules (N) is overlain by densely welded tuff (T3) with a conspicuous, silicified, welding foliation (SH 5684 4694). Reproduced from Howells *et al.* (1991). (Photo: BGS no. A14658.)

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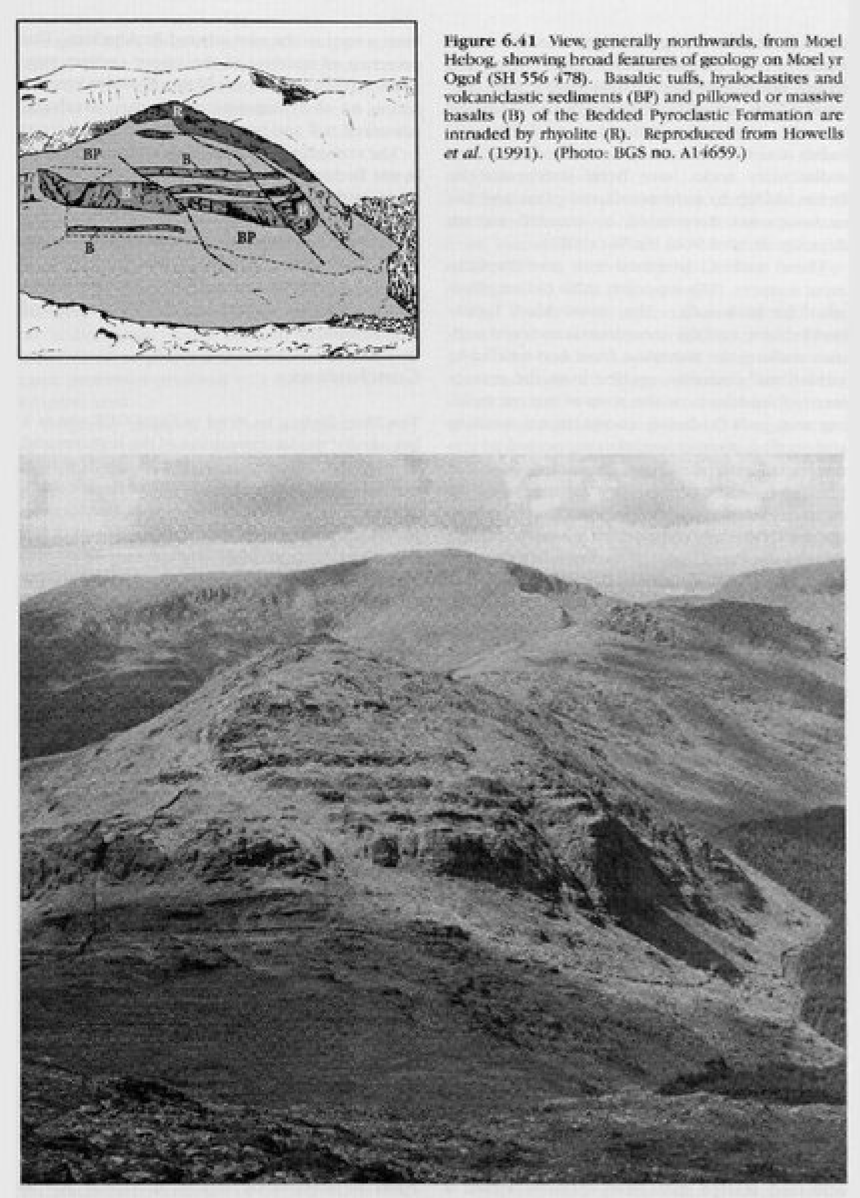

(Figure 6.41) View, generally northwards, from Moel Hebog, showing broad features of geology on Moel yr Ogof [SH 556 478]. Basaltic tuffs, hyaloclastites and volcaniclastic sediments (BP) and pillowed or massive basalts (B) of the Bedded Pyroclastic Formation are intruded by rhyolite (R). Reproduced from Howells et al. (1991). (Photo: BGS no. A14659.)