Cwm Idwal

[SH 638 588]–[SH 649 607]

W.R. Fitches

Highlights

The Idwal Syncline is the best known and most studied major Caledonian fold in Wales. Cwm Idwal is excavated along the axis of the syncline; it provides outstanding exposures of the fold in plan and profile.

Introduction

Cwm Idwal (Figure 4.5), a glacial cirque, is cut along the hinge zone of the Idwal Syncline, which is a major end-Caledonian fold. The rocks deformed by the structure are products of Ordovician (Caradoc Series) volcanism and sedimentation and belong to the upper part of the Cwm Eigiau Formation, the Lower Rhyolitic Tuff Formation, and the lower part of the Bedded Pyroclastic Formation ((Figure 4.6); Howells *et al.,* 1981). The various rocks and processes which produced them are outlined in field guides to Cwm Idwal (Roberts, 1979; Howells *et al.,* 1981) and the site is encompassed by the BGS 1:25 000 Geological Special Sheet for Central Snowdonia.

Description

The Idwal Syncline is a component of the Snowdonia Synclinorium — see Roberts, 1979; (Figure 4.1) and (Figure 4.2). Its profile is exposed in the back wall of the cirque, where it is seen to be an open to close structure with a NE–SW (Caledonoid) axial plane inclined very steeply to the north-west, while the hinge line is nearly horizontal. Bedding planes in the limbs dip at about 50° toward the trough of the fold. The axial trace continues to the north-east to Llyn Idwal, then turns N–S to pass through the Idwal Cottage Youth Hostel area before ascending the slopes of the Carneddau. In the Idwal Cottage area, the fold tightens and becomes more asymmetrical as the western limb steepens more than the eastern limb, and the southerly plunge becomes moderate to steep. The tightening and increase in plunge intensify toward the closure of the fold in the Carneddau, probably because there the layered rocks were compressed against the Pen-yr-Ole-Wen rhyolite plug (on the north side of Nant Francon) (Wilkinson, 1988, p. 80).

The site exhibits a variety of small-scale structures, several of which have been recently investigated by Wilkinson (1988) during his analysis of strains in Snowdonia. In particular, he used the siliceous concretions in the Pitts Head Tuff and the accretionary lapilli in the Lower Rhyolitic Tuff to measure the amounts of shortening and extension which took place during deformation of the· rocks.

The site encompasses an area of several square kilometres so, for descriptive convenience, six separate localities (A–F), containing structures representative of those found in various parts of the site, are described in the following sections (Figure 4.6).

Locality A: South-east limb of Idwal Syncline: Idwal Slabs [SH 645 589]

The rocks comprising the Idwal Slabs and adjacent crags are massive-bedded, acid ash-flow tuffs, volcanic breccias, tuffs, and interbedded sandstones and mudstones of the lower part of the Lower Rhyolitic Tuff (Howells *et al.,* 1981, p. 61). Layering dips to the north-west at moderate angles in the south-east limb of the Idwal Syncline, and this has been exploited by erosion to form the surfaces of the Slabs. Cleavage is poorly developed in the massive, rigid rocks, but can be discerned as a result of the weathering out of phyllosilicates and fine volcanic fragments, which are weakly aligned following the tectonic fabric. In places, some of the larger volcanic fragments, up to 0.15 m across, have a preferred alignment in cleavage, although the majority of clasts are aligned in bedding.

The rocks are cut by numerous veins of quartz, accompanied locally by chlorite, which range in thickness from less than one millimetre to about 0.25 m. Several veins are parallel, or nearly parallel, to layering and some of these comprise quartz fibres elongated normal to vein walls. These bedding-parallel veins are commonly slickensided, the striations plunging down the dip of the vein. A second type of quartz vein, accompanying the other type, or occurring independently, is horizontal or inclined gently to the south-east. Several large examples of this second type crop out high up on the Idwal Slabs. Quartz fibres in these flat-lying veins are also elongated normal to the vein walls and are parallel with the striations on the bedding-parallel veins. The flat-lying veins are seen locally to cut those of the other type. Rarely, the flat-lying veins are gently folded in the cleavage.

Locality B: Crags immediately south-west of Idwal Slabs [SH 644 589]

The crags adjacent to the footpath and above the Idwal Slabs are formed of beds of upper Lower Rhyolitic Tuff Formation, comprising well-bedded sandstones, siltstones, tuffs, and tuffites (Howells *et al.,* 1981, p. 61). Here, cleavage is more strongly developed than in the Idwal Slabs, because of the better alignment of feldspars and volcanic fragments in the tectonic fabric. Large volcanic clasts and brown-weathering carbonate concretions, between 0.10 m and 1.5 m across, mostly remain aligned parallel with bedding, but some smaller ones have been apparently rotated towards the cleavage.

Locality C: Syncline core [SH 642 591]

The well-bedded rocks at (B) dip at progressively shallower angles to the north-west into the hinge of the Idwal Syncline, forming a line of low crags which descend from locality B towards the southern end of Llyn Idwal. Clean, fresh exposures of the rocks are found in the beds of streams descending to the lake and cutting through the crags.

Cleavage is well-developed in these rocks of the fold hinge, and is formed by the strong preferred alignment of quartz grains, quartz pressure-fringes on feldspars, and phyllosilicates. The rocks also contain scattered, dark-grey accretionary lapilli, pea-sized clots of volcanic ash which were originally nearly spherical, but are now deformed into triaxial ellipsoids, flattened parallel to the cleavage and extended vertically. Volcanic clasts and carbonate concretions also commonly show strong alignment in the cleavage; contrasting with most other localities where the majority remain elongated parallel to the bedding.

Locality D: North-west limb of syncline [around SH 646 601]

The Pitts Head Tuff and the sandstones, siltstones, and acid tuffs above, belonging to the Cwm Eigiau Formation, are well exposed in the north-west limb of the Idwal Syncline, in a broad strike-parallel ridge which extends from the northern end of Llyn Idwal toward the Idwal Cottage Youth Hostel. Bedding dips steeply to the south-east at angles of up to 80°, and cleavage dips at about 70°NW. Cross-bedding in the sandstones shows that the beds are the right way-up and that the structure is upward-facing.

Siliceous concretions (lithophysae) are common in the upper part of the Pitts Head Tuff. These are pea- to tennis ball-sized, white-weathering masses of silica, or very fine quartz, which were precipitated from solutions migrating through the volcanic pile soon after its accumulation. The originally nearly spherical concretions have been slightly flattened in cleavage and extended vertically during deformation.

In places along the ridge, the Pitts Head Tuff shows well-developed columnar jointing formed during cooling and contraction of the volcanic pile. The columns were originally set perpendicular to layering, but have been realigned by compression in the Idwal Syncline and now lie at angles of about 60° to layering and plunge at moderate angles to the north-west. These deformed columns afford the opportunity for the measurement of strain in the Idwal Syncline. As at the Idwal Slabs (above), this ridge contains numerous examples of quartz veins. Some are parallel with bedding, while others with a flat-lying attitude, form ladder arrays nearly parallel with bedding.

Locality E: Honestone Quarry [SH 648 602]

The long, ravine-like quarry immediately above the Youth Hostel cuts along the strike of interbedded, light-coloured, fine-grained tuffs and dark mudstones of the Eigiau Formation. Bedding dips very steeply to the south-east, in the north-west limb of the Idwal Syncline, and according to cross-bedding in some tuffs, youngs to the south-east. Cleavage is nearly vertical and is unusually strong due to the high degree of phyllosilicate alignment, which is sufficiently intense to give some of the deformed mudstones a phyllitic fabric, characterized by shiny surfaces.

Locality F: A5 road-cutting and adjacent crags [SH 649 606]

A series of crags some 15 m north-east of the road exposes well-bedded volcanogenic sandstones which lie immediately above the Pitts Head Tuff. The sandstones, dipping about 70°SE, contain 0.1–0.5 m-thick layers, crowded with 10–40 mm brachiopod shells preserved in brown-weathering carbonate. These shells have been strongly deformed in the steeply dipping cleavage. On steep surfaces striking at right-angles to the cleavage, the originally gently curved shells are seen to be almost isoclinally folded.

In the cutting on the north-east side of the road, the upper parts of the Pitts Head Tuff show the very strong planar alignment of *fiamme* (pumice fragments) and other volcanic ejecta caused by compaction and welding during accumulation of the hot ash pile; this fabric is mostly parallel with bedding in the overlying sedimentary rocks. Unlike those sedimentary rocks, the welded tuffs are often uncleaved, due to their greater rigidity during deformation. However, cleavage is developed in places, usually in narrow, 0.5 m-wide zones. Locally in the tuffs, particularly rigid layers have been boudinaged, individual boudins becoming separated by 0.1–0.2 m-long quartz lenses.

In the cutting on the south-west side of the road, there are several quartz veins, mostly less than 1 m in length, which dip moderately to steeply to the south-east. These veins are arranged *en échelon* in two tension gash arrays, the larger of which is over 10 m in length. The sense of shear indicated by these arrays is top side to the southeast.

The Idwal Syncline as exposed in Cwm Idwal is a major fold with a steep NE–SW axial plane and nearly horizontal plunge. The south-east limb is represented at the Idwal Slabs (Locality A), the north-west limb at Locality D, and the core at Locality C. Toward the north-east the fold tightens, the axial plane swings to a more nearly N–S strike and the plunge becomes steep to the south, probably because the rocks were deformed against the rigid Pen-yr-Ole-Wen Rhyolite (Wilkinson, 1988). The fold is typical of those produced by the main deformation phase. It offers particularly fine, three-dimensional exposures to study the full geometry of such a major fold.

The exposures, the variety of lithologies and the presence of deformed strain markers provide an unrivalled opportunity to examine the relationships of cleavage to a main-phase fold. Cleavage is more or less axial planar to the syncline in Cwm Idwal, striking NE–SW and dipping very steeply to the north-west. Wilkinson (1988) reports that it transects the northern end of the structure in a clockwise sense in the flanks of the Carneddau, north of the site.

The character of the cleavage within the site is variable, probably because of the variations in lithology. Cleavage is commonly absent or barely discernible in the strongly welded parts of the Pitts Head Tuff (for example, Locality F). The ash-flow tuffs, breccias and coarse volcanogenic sandstones usually take a feeble cleavage; a spaced type with little grain alignment. In parts of the volcanic rocks, however, the cleavage becomes penetrative, as the volcanic clasts, quartz pressure fringes on feldspars, and new phyllosilicates take on a strong preferred alignment. The strongest cleavage within the site is found in the Honestone Quarry (for example, Locality E) where phyllosilicates in the original mudstones and fine-grained volcanic and volcaniclastic rocks are aligned sufficiently uniformly to give an almost phyllitic cleavage.

There are various strain markers within the site: originally nearly spherical accretionary lapilli (for example, Locality C) and siliceous concretions (for example, Locality D), brachiopod shells (for example, Locality F), and columnar joints which were originally elongated normal to layering in the Pius Head Tuff (for example, Locality D). Wilkinson (1988) has used the accretionary lapilli and concretions to show that strains in Cwm Idwal are nearly plane strain: the flattening in cleavage is almost compensated for by vertical extension while there was little change in dimensions horizontally in the cleavage.

There are a number of small-scale structures exposed at the site, related to the development of the main-phase fold. These have not been studied previously but offer considerable research potential. Veins are common but appear to have attracted no comment in published literature. Of particular interest are the veins aligned parallel with bedding and those which are flat lying (for example, Localities A and D). These two types of vein are considered here to be products of flexural slip which accompanied the development of the Idwal Syncline. The bedding-parallel veins represent slip surfaces along bedding, while the others are more or less contemporaneous tension gash arrays. The slip-senses, deduced from rare *en bayonet* bedding-parallel veins, the *en échelon* arrangement of the other veins (Figure 4.7)B, and the down-dip striations on bedding-parallel veins, are consistent with displacement resulting from accommodation during folding (Figure 4.7)B.

Interpretation

The folding of some tension-gash veinlets (Locality A) is interpreted as the effect of flexural slip during initial buckling, as illustrated in (Figure 4.7)B. The observation that these veinlets are themselves folded, indicates that cleavage develop' ment outlasted parts of the flexural slip history of the fold. The boudins (Locality F) are interpreted as examples of inverse boudins (cf. Ramsay, 1983, Figure 3B); quartz veins which had been formed at the necks of early, square-ended boudins acted as more rigid layers during later, more ductile stages of extension, so that the sites of necking moved into the boudins which had been formed early in the progressive deformation.

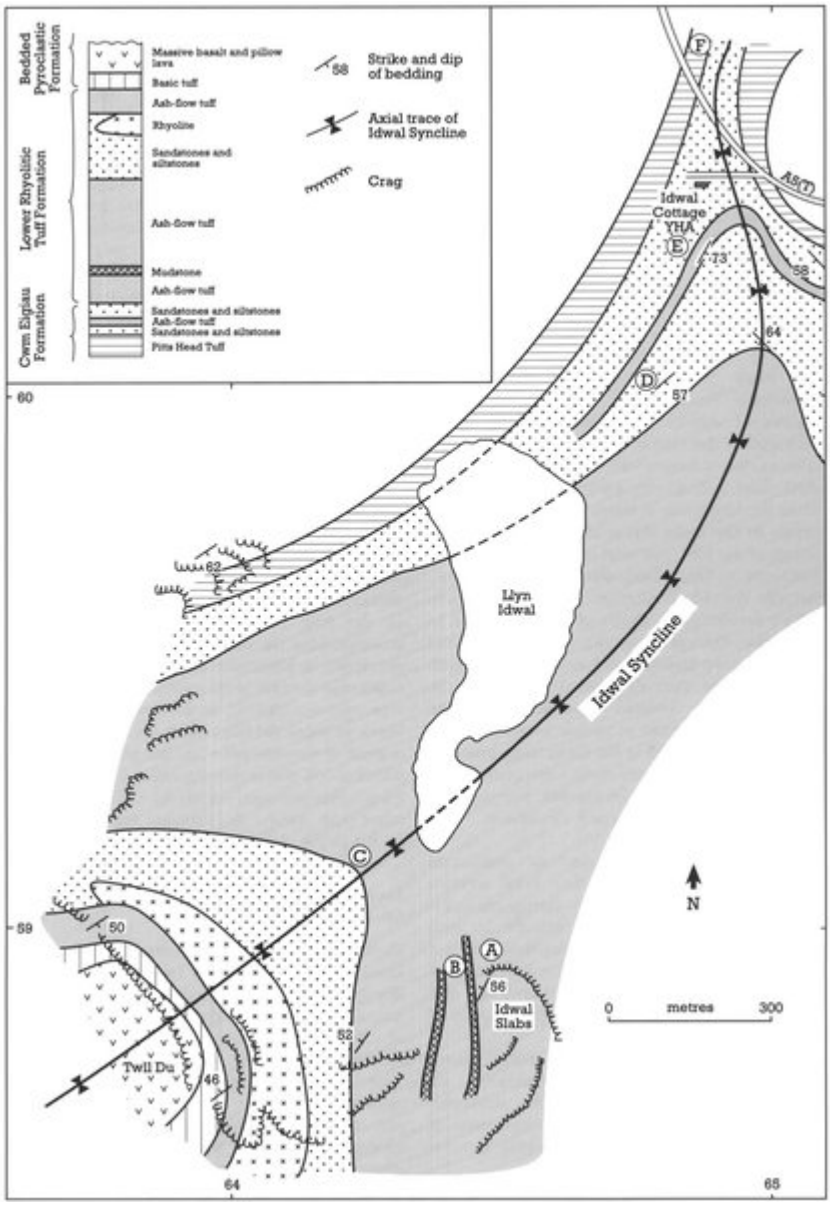
The Idwal Syncline is one of the best-known Caledonian structures in Britain thanks to the superb exposures provided in the floor and walls of Cwm Idwal. The scale of the features, and the high level of exposure here, present an outstanding opportunity for detailed structural studies including three-dimensional strain variations within a major Caledonian fold, developed in the main phase during the late Silurian–early Devonian. The fold has the NE–SW trend characteristic both of Snowdonia and of the British Caledonian fold belt. The Idwal Syncline characterizes the gentler style of deformation and lower levels of strain typical of central Snowdonia, contrasting with the high strains of the Slate Belt. There is marked variation in cleavage development within the site from very weak in parts of the Pitts Head Tuff to strong and phyllitic in the mudstones of the Honestone Quarry. Other minor structures such as volcanic lapilli and deformed fossils are valuable as strain markers and have been used in recent regional studies. The locality provides the best exposed structure of its kind in central Snowdonia, with great potential for future studies.

Conclusions

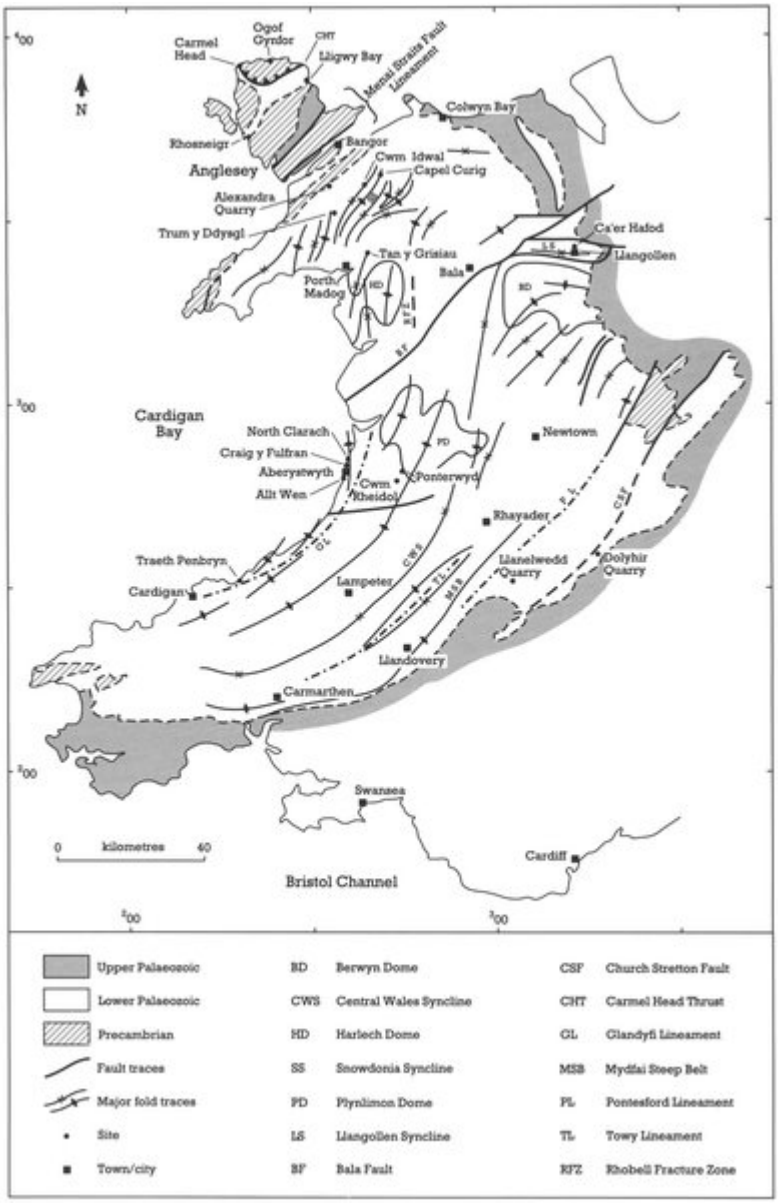
The scale and three-dimensional nature of the rock exposures at Cwm Idwal provide unrivalled opportunities for detailed studies of a major fold formed during the Caledonian mountain-building period. Small-scale structures associated with the fold, including cleavage (fine, closely-spaced, parallel fractures), deformed fossils, concretions, and mineral veins are exposed at many localities, and these enable detailed studies of the nature and intensity of strain and its variation throughout the folds to be carried out. This site affords opportunities to study, in three dimensions, a major structure that may be assigned to the main phase of Caledonian deformation around 400 million years before the present during the late Silurian or early Devonian.

References

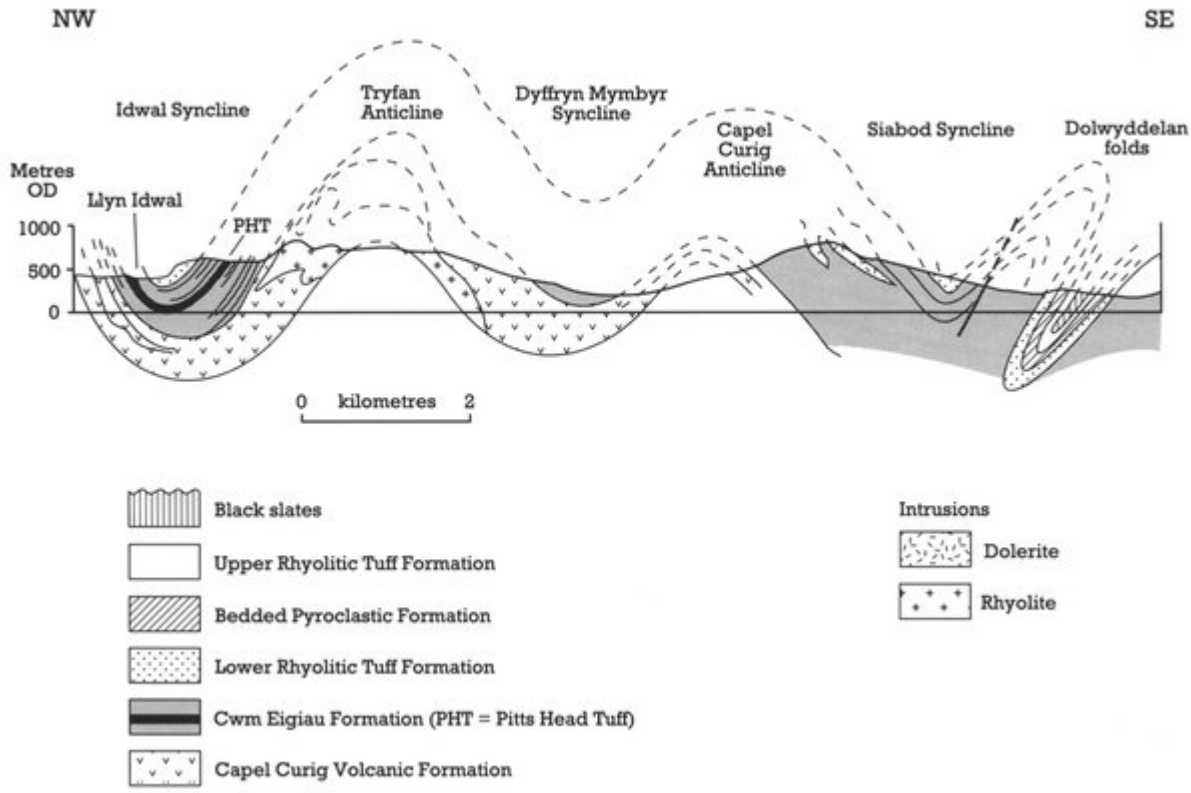
(Figure 4.5) Cwm Idwal, Gwynedd. The right- and left-sloping slabs above the central scree form the syncline hinge of one of the major Caledonian fold structures in Snowdonia, in Ordovician sediments and volcanics. View to south-west, cliff is approximately 300 m high. (Photo: S. Campbell.)



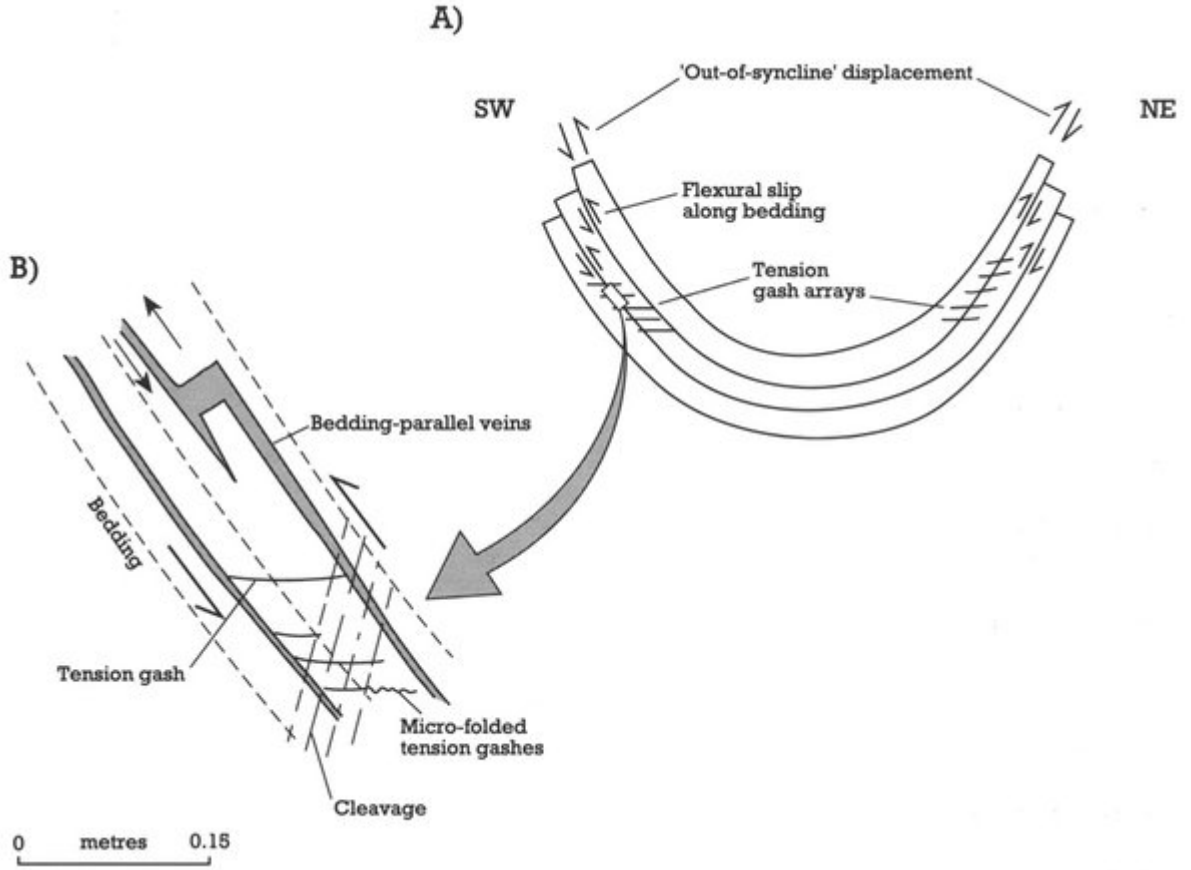
(Figure 4.6) Cwm Idwal. Geological map showing the positions of Localities A–F described in the text.



(Figure 4.1) Map showing the traces of the principal folds and faults of Caledonian age in Wales. The localities described in the text are also shown.



(Figure 4.2) Section through the major folds of Snowdonia (after Wilkinson, 1988).



(Figure 4.7) Cwm Idwal. (A) 'Out-of-syncline' flexural slip and tension gash arrays in the 1dwal Syncline. (B) Combination of en bayonet bedding-parallel veins and tension gashes, south-east limit of Idwal Syncline (Locality A).