Lligwy Bay

[SH 4930 8746]–[SH 4940 8803]

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Highlights

Lligwy Bay contains a rare example of (presumed) Devonian rocks deformed during the Caledonian Orogeny. As this is the only Devonian locality in North Wales, these rocks provide unique information with which to assess the duration of the orogeny in this region.

Introduction

The Devonian rocks in Lligwy Bay record polyphase deformation, involving folding, cleavage formation and thrusting. The two upper Old Red Sandstone Group formations, that is the Porth-y-mor Formation and the Traeth Lligwy Formation (Allen, 1965), lie in a broad synclinal structure. This open structure has a monoclinal fold on its northern limb; on the southern limb thrusting and tight, minor folds with axial-planar cleavage occur (Figure 4.19).

The locality was described by Greenly (1919) in his memoir of Anglesey. A sedimentological interpretation of the Old Red Sandstone by Allen (1965) included some brief comments on the structure. Bates (1974) made a reconnaissance survey of the site and confirmed the observations of Greenly (1919). A number of large-scale tectonic interpretations have used the available information on Lligwy Bay, including those of Nutt and Smith (1981) and Woodcock (1984a), and the site has also appeared in a field guide (Bates and Davies, 1981), but no detailed, modern structural interpretation has been published. No fossils have been recorded from the sequence and its Devonian assignment is based upon lithological and stratigraphical similarities with other localities in south and south-east Wales.

Description

The site consists of a varied sequence of Devonian sediments exposed in a series of low cliffs on the north side of Lligwy Bay as far north as Trwyn Porth-y-mor. The strike of bedding and cleavage is approximately E–W. The site is described from north to south and the structure is depicted on a cross-section (Figure 4.19).

On the small headland opposite Trwyn Porth-y-mor, beds dip at <25° toward the south, and the dominant cleavage (S_1) dips between 50–70° to the north (Figure 4.20). In common with the site as a whole, cleavage is better developed in finer-grained siltstones and calcrete layers, where cleavage surfaces may be spaced closer than 5 mm. In sandstones, the spacing may be up to 0.20 m. In conglomerate units the cleavage is not clearly discernible. A second, localized cleavage spaced at 0.03–0.05 m offsets S_1 surfaces and dips at shallow angles to the north.

Towards the south, bedding becomes steeper, dipping to the south. It is locally overturned around [SH 4940 8787]. Concurrent with this steepening of bedding, the principal cleavage becomes less steep, dipping at <30° to the north. To the south of this location, bedding returns to a shallow southerly dip, thus defining the monoclinal structure identified by Greenly (1919), and cleavage to a more steeply north-dipping attitude.

Bedding flattens out progressively to the south of the monocline, so that beds are undulating around horizontal at [SH 4942 8774]. A low-angle surface exposed in the wave-cut platform at this locality probably represents a small thrust. In addition, the undulating beds are affected by minor normal faults (displacements <0.5 m) which post-date the cleavage and have a variety of attitudes. Immediately to the west, [SH 4939 8774], a small anticlinal hinge is exposed to which the principal cleavage is axial planar (dipping 54°N). The axis of the fold plunges gently east. This structure is the 'sharply over-driven anticline' featured in Greenly (1919; Figure 282, p. 586). The lower limb of the anticline is faulted out and, to the east, the anticline is replaced by a low-angle discordance of bedding, similar to the thrust surfaces observed close by.

The fault surface has a parallel fabric which is similar in appearance, but oblique to the axial planar cleavage in the fold core; the contact between the two fabrics is not a distinct break.

From this point southwards, beds dip consistently north, first at shallow angles and then more steeply. A zone of thrusting at least 3 m wide and dipping at 40° to the north [SH 4933 8768] separates shallow north-dipping beds to the north from more steeply north-dipping beds to the south (Greenly, 1919; Figure 284, p. 586). In the footwall to the thrust, a tight synformal fold core can be observed at [SH 4932 8766]. Again the principal cleavage is axial planar to the fold, dipping at –50°N. The fold axis plunges gently east. To the south of this location, bedding dips at variable angles to the north.

Interpretation

On Anglesey, deformation of the Old Red Sandstone (which is presumed to be of late Silurian to early Devonian age) occurred before the deposition of the overlying Carboniferous Limestone succession (Allen, 1965). This, in conjunction with the site's location to the north of the Hercynian front, indicates that the deformation is not Hercynian (unless it is a freak local deformation) and therefore Caledonian, and that this phase was a post-Old Red Sandstone one. The deformed, presumed Devonian, succession at Lligwy Bay therefore provides crucial information for estimating the duration of the Caledonian Orogeny in North Wales.

A recent structural interpretation of the site is not available. However, its importance arises from the presence of deformation, rather than from its detailed interpretation. A number of important age relationships were established at Lligwy Bay by Greenly (1919), to which several additions can be made. These relationships indicate the polyphase nature of deformation. Greenly observed that cleavage was axial planar to the tight folds, but that it changed its orientation around the monocline, indicating that the monocline was a later structure. He also concluded that the thrusting post-dated the isoclinal folding because thrust surfaces are at a lower angle than, and they truncate, the cleavage. Although they may not be entirely synchronous, the spatial association between the tight folds and the thrusts does suggest that they are both a manifestation of the same deformation event. However, Greenly preferred to relate thrusting to monocline development which post-dates the main cleavage (and may be related to the sporadic second cleavage). Two observations which Greenly did not make are that the principal cleavage maintains a northward dip across the broad synclinal structure and that relationships between bedding and cleavage change on the northern limb. These two observations suggest that the syncline may partly pre-date the cleavage and is therefore the first recognizable structure.

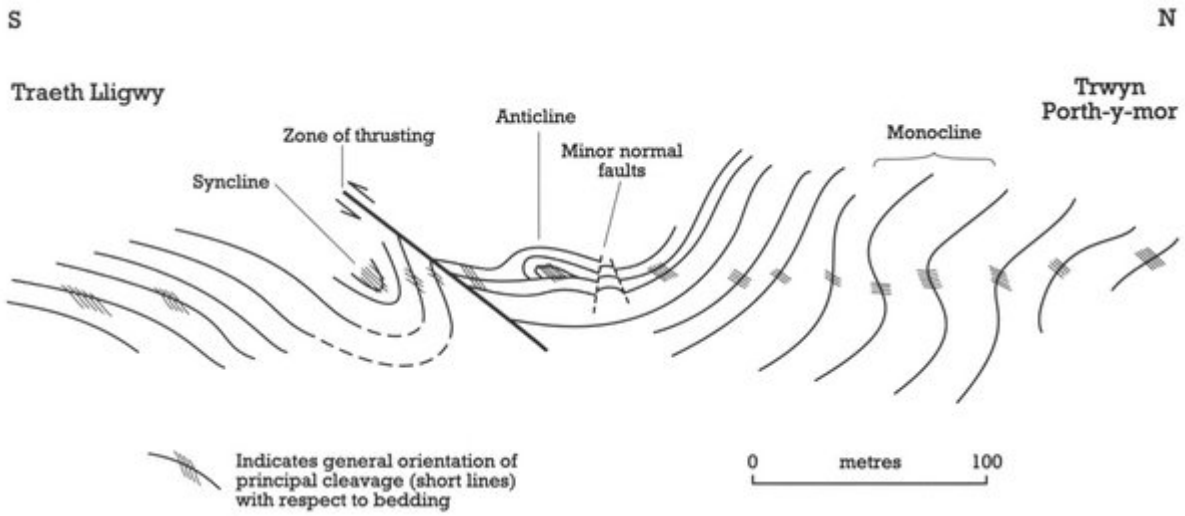
Deformation of the Old Red Sandstone at Lligwy Bay is, therefore, locally intense and polyphase, with possibly three phases of deformation and the development of thrusts. The deformation is, however, localized and, as Bates (1974) points out, is completely absent from the southern part of the inland outcrop. This variable intensity was interpreted by Bates as a reflection of basement control, deformation being most intense in the vicinity of major pre-existing faults.

The general consensus of opinion has been that the principal folds and cleavage in North Wales were produced in approximately end-Silurian times (for instance, Dewey, 1969; Coward and Siddans, 1979). A pre-Devonian age for the main deformation was based on the observation that the Devonian lies unconformably on older rocks in the Welsh Basin and elsewhere. On Anglesey, the Devonian lies unconformably on the Ordovician, the unconformity post-dating the Bodafon Thrust. This indicated to Bates (1974) that the Devonian was deposited after the main period of deformation, which was end-Silurian. However, other authors have maintained that the main deformation period extended into the early Devonian (for example, Shackleton, 1953; Jones, 1955; Woodcock, 1984a). The significance of the unconformity at the base of the Devonian is open to doubt, as it may be the result of pre-Silurian, rather than just pre-Devonian erosion (George, 1963). The evidence at Lligwy Bay is limited by the lack of a firm age for these rocks, but it supports the conclusion that the lower part of the Old Red Sandstone suffered Caledonian movements. These movements were at least as intense as those affecting the adjacent Ordovician, and they have the same sense of overturning, towards the south-east. Woodcock (1984a), after assessing the information available at Lligwy Bay, concluded that any deformation climax in late Silurian Wales probably extended at least through Pridoli time and into the early Devonian. Soper *et al.* (1987) and McKerrow (1988), assessing evidence from Wales and the Lake District, considered that the main end-Caledonian movements were probably Emsian in age, equivalent to the Acadian of the Canadian Appalachians.

Conclusions

Lligwy Bay contains sedimentary rocks, thought to have been deposited during the Devonian Period (approximately 410–360 million years before the present), which have suffered folding, thrusting (low-angle faulting) and cleavage (closely spaced, parallel fractures) all during the Caledonian mountain-building episode. The intensity of this deformation was at least as strong as that suffered by the Ordovician succession which underlies the Devonian rocks. The fact that Old Red Sandstone sedimentary rocks are deformed indicates that Caledonian deformation of some significance extended beyond the end of the Silurian and well into Devonian times.

References



(Figure 4.19) Sketch section illustrating the structure of the Devonian rocks on the north side of Lligwy Bay.

(Figure 4.20) Lligwy Bay, Anglesey. Strongly developed, spaced cleavage in ?Devonian siltstones dips to the north in the hinge of a south-facing monocline. (Photo: J. Treagus.)