Allt Wen

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Highlights

The Allt Wen site shows some of the wide variety of small-scale structures that characterize the northern part of the early Silurian Aberystwyth Grits Formation outcrop. Of particular interest here are folds which have unusually complex morphologies, the obliquity between the cleavage and some of the folds, and various brittle structures and veins.

Introduction

The 250 m-long coastal section comprises sandstones and shales of the Aberystwyth Grits Formation, a sequence of Llandovery-aged turbidites showing repeated Bouma B to E units (Wood and Smith, 1958; Cave and Haim, 1986). According to Price (1962) the section lies in the core of a major, Caledonian periclinal anticline; several folds with a 10–20 m wavelength, which are parasitic to this major fold, are exposed on the wave-cut platform. Thrusts, folds, and other structures within the site are illustrated and discussed by Craig (1985), Cave and Haim (1986), and Fitches *et al.* (1986) in the context of the timing of deformation with respect to the main Caledonian tectonism in the Welsh Basin.

Description

At the junction between the wave-cut platform and the coastal cliffs, are numerous small-scale structures of particular interest. Their positions are indicated on (Figure 4.13)A.

Folds

Periclinal anticline–syncline pair (Locality 1)

These folds have a wavelength of 2.5 m. The anticlinal axial plane is oriented 011/64°E, and its hinge plunges 10/020° in the north and 23/186° in the south. The structure is complicated in various ways:

1. The anticline comprises two *en échelon* anticlines, the one offset north and west of the other, without an intervening syncline;
2. In the syncline east of the anticline, a sandstone has been partly duplicated by a fault lying close to bedding;
3. A feeble cleavage in the anticlinal crest is oriented 036/64°E, and further down the axial plane appears to flatten. The cleavage is not axial planar to the folds but transects them in a clockwise sense.
4. The west limb of the anticline is disrupted by an intermittently exposed composite structure that comprises a recumbent fold, ductile shear zone, and fault.

The recumbent fold is almost co-axial with the anticline, plunging 04/014°, but its axial plane is nearly horizontal (130/04°S). The recumbent fold was produced by ductile displacement along a westward-directed thrust which is marked in places by a 0.01–0.02 m-thick breccia. Cleavage is also deflected by this structure, implying that the fold–fault combination is late in the tectonic sequence.

Tight transected fold (Locality 2)

The crest of a tight, almost isoclinal fold, easily recognized by its 'gothic-arch' form, is exposed in the cliff-face. Its axial plane is N–S and upright, its plunge is nearly horizontal. The fold is upward-facing according to younging evidence in the west limb. However, the cleavage in that limb dips away from, and makes a large angle with, the axial plane so that the

west limb of the fold is downward-facing with respect to cleavage; this unusual, non-axial planar relationship characterizes folds transected by cleavage.

Complex syncline (Locality 3)

The geometry of this fold has not been fully elucidated and it requires detailed grid-mapping. The northern part of the structure appears to be simple; its axial plane is N–S, upright, and the plunge is nearly horizontal. The southern part, however, closes on a highly curvilinear hinge which, from north to south, steepens from horizontal to vertical and beyond; this southern closure has the shape of the prow of an Indian canoe, which results in bedding being overturned. The southernmost end of this complex fold is hidden by shingle, but on the nearby wave-cut platform a series of small folds trend toward the syncline and are likely to have been responsible for refolding it.

Southern anticline (Locality 4)

This large, *c.* 10 m wavelength fold is an open to close, round-hinged structure with an upright, NNE–SSW axial plane and southerly plunging hinge line (*c.* 10/205°). Of particular interest is the crestal region in which the bedding planes are exposed. On the bedding there is a series of low-amplitude (*c.* 0.02 m), short-wavelength (*c.* 0.05 m) cuspate anticlines and rounded synclines (see Cave and Haim, 1986, Plate 17), which resemble the cusp-and-lobe fold mullions described by Sokoutis (1987) and Ramsay and Huber (1987).

On several bedding planes there are bedding-parallel ferroan dolomite, quartz, and chlorite veinlets up to 0.05 m thick. These veins are striated by slickensides which plunge approximately normal to the anticline hinge. In the cliff behind the fold crest several more of these veins are exposed, spaced at intervals of 0.05 to 0.50 m.

Faults

Particularly noteworthy is a series of small faults considered by Fitches *et al.* (1986) to be contemporary with the striated veins described above. Several examples are exposed along the section and three are described below.

Thrust fault (Locality 5)

A thrust fault with a minimum displacement of 8 m to the south or south-east causes a repeat of the turbidite beds at this locality (Figure 4.13)B. The fault, in places marked by a centimetre-thick breccia layer and by fine quartz–carbonate veinlets, lies nearly parallel to the bedding in most places. In the central part of the exposure, however, the fault climbs a footwall ramp which is gently inclined and dips northward.

Thrust-hanging wall anticline

This structure, illustrated here in (Figure 4.13)C, lies in the western limb of the complex syncline described above. The thrust climbs a long, very gently inclined footwall ramp, which dips northward, and carries a hanging-wall anticline, in the southern limb of which the bedding is steep to overturned.

Opposing minor thrusts (Locality 6)

A thrust plane, which is mostly parallel with bedding, cuts up two opposite-dipping ramps to produce an inverted triangular fault block or 'pop-up' structure.

Interpretation

This site illustrates a variety of small-scale folds, relationships between cleavage and fold, faults and veins. The folds have the complicated non-cylindrical, sometimes *en échelon,* morphologies to be found at several localities along the coast near Aberystwyth; they contrast with the relatively simple morphologies of the small folds occurring in most parts of the Welsh Basin. They have not yet been studied in detail and the causes of the complexities are uncertain. One possibility is that they result from accommodation space problems in the inner arcs of major folds, or alternatively, some

of them at least were formed before the host strata were fully lithified. The site requires mapping and analysing in detail and the resulting information needs to be combined with that obtained at North Clarach and other coastal localities before a sound interpretation is possible.

The site's examples of folds transected by cleavage are important in arguments concerning the origin of this relationship. Craig (1985, 1987) accounted for the transection along the Cardigan Bay coastline, which includes Allt Wen, in terms of strike-slip deformation during the regional compression, along a major NNE–SSW zone, the Llangranog–Glandyfi Lineament.

The thrust faults, striated veins and some small folds have been interpreted by Fitches *et al.* (1986) as products of deformation before or during the earliest stages of the regional deformation. The bedding-parallel veins are regarded as products of hydraulic jacking. That is, high fluid pressures caused by impeded upward migration of fluids during burial of the sediment pile led to cavities being opened along bedding and minerals being deposited. It is suggested that the thrusts and displacements on the bedding-parallel veins are the result of gravity gliding, at some depth in the sediment pile, which took place before the onset of folding and cleavage development, but after lithification. Davies and Cave (1976) considered structures of this type to have developed before lithification because of their apparent association with dewatering structures in the sediments.

Allt Wen is an important site illustrating the complex morphologies of the small-scale folds that characterize the Aberystwyth part of the Welsh Basin. The origin of these folds is not yet understood and is the subject of ongoing research. The site also provides examples of rare cases of small folds transected by cleavage which is a topic under close scrutiny, not only in the Welsh Basin (Woodcock *et al. ,* 1988), but in other parts of the British and North American Caledonides (Soper *et al.,* 1987); explanations of the phenomenon will lead to a clearer understanding of the plate tectonic evolution of the basin.

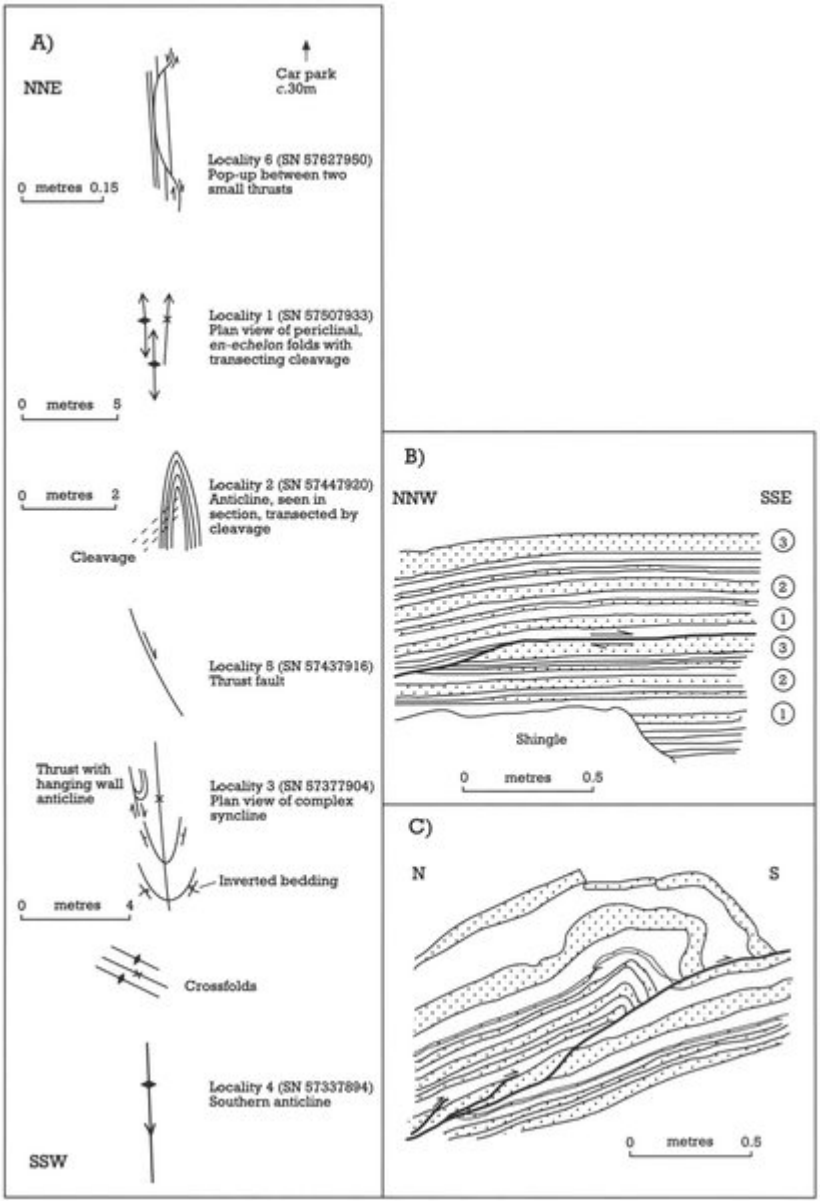
Several of the small-scale structures at Alit Wen have been illustrated and discussed in recent publications dealing with the timing of the structures, with respect to lithification and the regional deformation. These topics remain controversial and the site is likely to receive further attention by researchers.

Conclusions

The site at Allt Wen includes a whole suite of structures, folds, cleavage (very fine, closely spaced, parallel fractures), and faults, which affect the early Silurian-aged Aberystwyth Grits. These structures are the result of extreme compression during the Caledonian mountain-building episode, around 400 million years before the present. The complexities of the thrusts (low-angle faults), folds, and cleavage here have yet to be studied and explained fully. For instance, the cleavage slightly cuts across the planes that bisect fold limb-pairs (the axial planes). This is an uncommon relationship in fold belts but, by analogy with other Caledonian terranes in Britain, may be related to the oblique approach of the colliding continents as the Iapetus Ocean closed.

Some structures here are thought to have been generated before the main (Devonian) deformation phase of the orogeny, and to have been formed as contortions in the perhaps still wet sediment pile, or perhaps as the sediments moved downslope under the influence of gravity. Upon this folding would have been superimposed the regional tectonic pattern of folding and cleavage. This remains a site with much potential for future study.

References



(Figure 4.13) Allt Wen. (A) shows the relative positions of Localities 1–6 and sketches of the structures described in the text. Total length of the section is approximately 250 m. (B) Thrust seen at Locality 5 (after Cave and Haim, 1986, plate 23; Fitches et al., 1986, figure 4C). (C) Thrust and hanging-wall anticline seen at Locality 3 (after Fitches et al., 1986, figure 4D).