Back Bay, Monreith

[NX 3678 3947]–[NX 3694 3930]

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Highlights

Back Bay, Monreith has the most dramatically exposed cliff section of large-scale folding in the Southern Uplands (Figure 2.13). Two large-scale, D_1 fold pairs are completely exposed in the 30 m-high cliffs, with an excellent example of D_2 structures superimposed. The geometry of these features is characteristic of the deformation style in the Central Belt of the south-west Southern Uplands.

Introduction

The rocks of this site display a typical range of lithologies in the Hawick Rocks, including some massive greywackes, as well as thinner-bedded greywackes, siltstones, and mudstones. The principal feature of the site is the refolding of the north-westerly fold pairs by a D_2 fold pair with a flat-lying south-easterly dipping axial surface and crenulation cleavage. The style of this D_2 deformation is typical of its local development throughout the Central Belt, but here is part of a 2.3 km-wide zone that crosses the Whithorn Peninsula and can be traced to the north-east coast of Wigtown Bay (Figure 2.1). The D_2 deformation is locally associated here with minor north-west directed thrusting, but regionally appears to result from subvertical shortening of the D_1 fold stack.

The site is part of the Whithorn area described by Rust (1965) in which he recognized four phases of deformation related to folds and cleavage. The F_1 folds of Rust are the D_1 folds of the West Burrow Head site 10 km to the south, and of the present description. Superimposed on this phase Rust recognized two sets of folds, his F_2 and F_4 phases, and the Back Bay locality is quoted (Rust, 1965, p. 14 and Plate 2) as an example of the F4 folding with accompanying cleavage. The distinction of F_2 and F_4 appears to be partly on the flatter dips of the axial surfaces of the latter and also on the superimposition of F_4 on the locally developed, steeply plunging F_3 folds.

Stringer and Treagus (1980, 1981), recognized one dominant phase of deformation, D_1, with its associated (but non-axial planar) cleavage. This is locally affected by a D_2 deformation (incorporating Rust's F_2 and F_4) particularly in one 2 km-wide, NE-trending belt (labelled A on (Figure 2.1)), on which the Back Bay site lies in a median position.

Description

The north-western half of the section (Figure 2.14) is dominated by a spectacular profile of a large open D_2 fold (minimum amplitude 5 m) superimposed upon a tight upright D_1 anticline at [NX 3682 3942] and a syncline at [NX 3685 3940] of *c.* 30 m amplitude (Rust, 1965, Figure 1 and Plate 2). The folds plunge gently to the north-east. At the north-west end of the section, steep NW-dipping strata and S_1 cleavage are deformed by smaller-scale, D_2 'step' folds with axial surfaces and sporadic, D_2 crenulation cleavage inclined gently to the south-east (Stringer and Treagus, 1981, figure 3A). Minor thrust faults, with small northwesterly displacements and a zone of quartz veins, are associated with the D_2 folds.

The south-eastern half of the section (Figure 2.14) comprises a D_1 anticline at [NX 3691 3937] and syncline at [NX 3693 3936], see (Figure 2.13) forming an asymmetrical D_1 fold pair (Folds 3 and 4 in Stringer and Treagus, 1981, figure 3A) which verges to the south-east. The folds are tight (interlimb angle 20–35°); overturned strata in the common short limb (15 m wide, measured horizontally) dip steeply to the north-west, and strata in the long limbs (50 m wide) dip moderately to steeply to the north-west. The D_1 fold pair (wavelength *c.* 75 m, amplitude *c.* 30 m) is probably intermediate in scale to larger scale, 0.25–3.0 km, D_1 folds. Gentle curvature of the north-westerly-dipping axial surfaces indicates large-scale D_2 folding. The D_1 cleavage in mudstone and sandstone beds strikes close to 070° and 090° respectively, markedly oblique to the north-easterly strike of the D_1 fold axial surfaces.

The site generally offers the opportunity to examine all aspects of the D_1 and D_2 deformations, including the relative thickening of fold hinges compared with limbs, boudinage of limbs, the variable development of the S_2 cleavage, and the associated quartz veining and thrusting.

Interpretation

The interest of the site lies in the scale and geometry of both D_1 and D_2 folds, and the fact that it affords the rare opportunity to observe one phase superimposed on the other.

The D_1 folds give a glimpse of the amplitude and wavelength of this phase of folding, although the first-order D_1 folds in the Central Belt are thought by Stringer and Treagus (1983) to be of the order of 0.25–3.0 km. The section (see (Figure 2.14)) also reveals the south-east vergence of these second-order folds, as seen by the relative thickness of the north-west- and south-east-younging limbs respectively. In fact, the north-west-younging limb, between the north-west and south-east fold pairs, is uncharacteristically gently dipping, pre sumably as a consequence of D_2 deformation. A 30° sheet-dip to the north-west would probably represent the pre-D_2 value, seen here interrupted by major folding. In the accretionary model, these folds would be interpreted as having a primary attitude with gentle landward-dipping (NW) axial planes and south-east vergence. Their rotation to their approximate present attitude would have taken place during thrusting, possibly exemplified at the West Burrow Head site. Finally, the transecting cleavage would have been impressed on the folds during the late Silurian closure of the Iapetus and before dykes were emplaced, the latter dated by Rock *et al.* (1986) at 418–395 Ma.

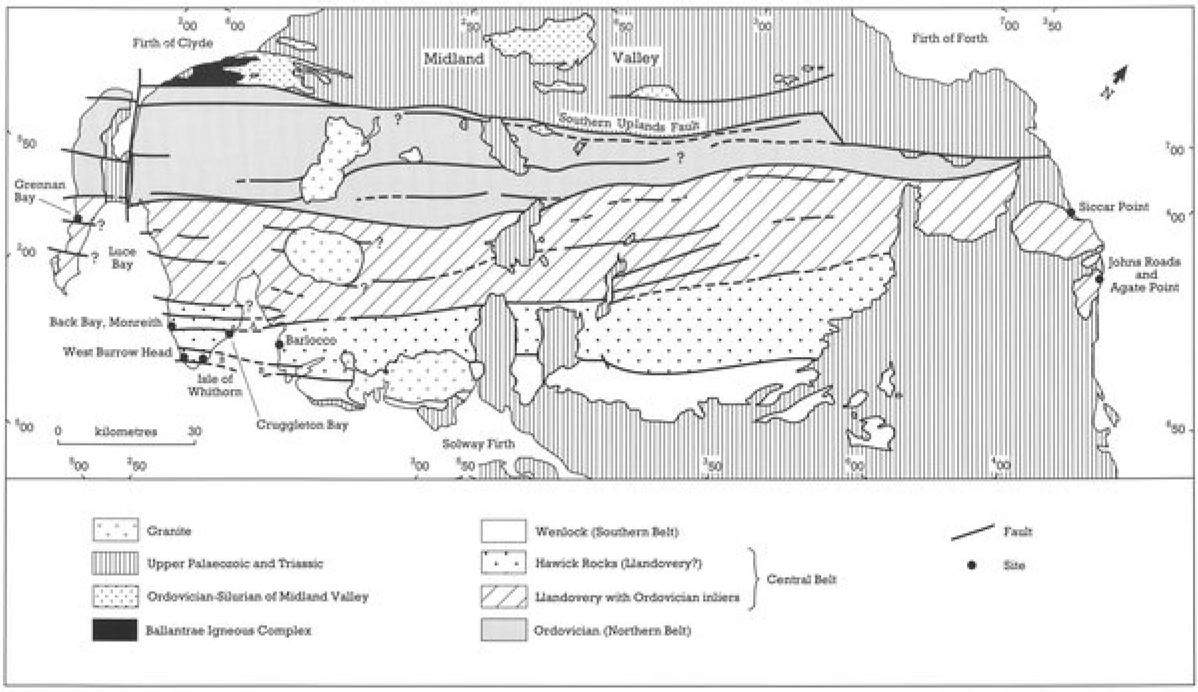
The D_2 folding shows the typical (but often steeper) dip to the south-east of the axial surfaces of the folds and their consequent south-easterly vergence. Like Rust (1965), but for different reasons, Knipe and Needham (1986), elsewhere, distinguished two generations of folds with this geometry. The earlier, with steeper axial surfaces, they ascribe to pre-accretion rotation and associate with continuing oceanward rotation from D_1 (Knipe and Needham, 1986, Figure 11). The second set, with flatter, south-easterly-dipping axial surfaces like those at Back Bay, they attribute to post-accretion rotation and note the association with minor thrusting directed to the north-west. They associate this structure with shortening in the collision related to the closure of the Iapetus. Stringer and Treagus (1980, 1981) were unable to distinguish these two sets of post-D_1 structures, either on the basis of interference of one set with another or from differences in morphology or mineral growth related to the respective crenu-lation cleavages. The present description shows that all structures here called D_2 must post-date the S_1 cleavage and must reflect very late (post-395 Ma) post-collision adjustments, possibly related to the adjacent granite bodies of this age. The Back Bay site would be an obvious locality for further work to unravel this contentious post-D_1 deformation history.

Conclusions

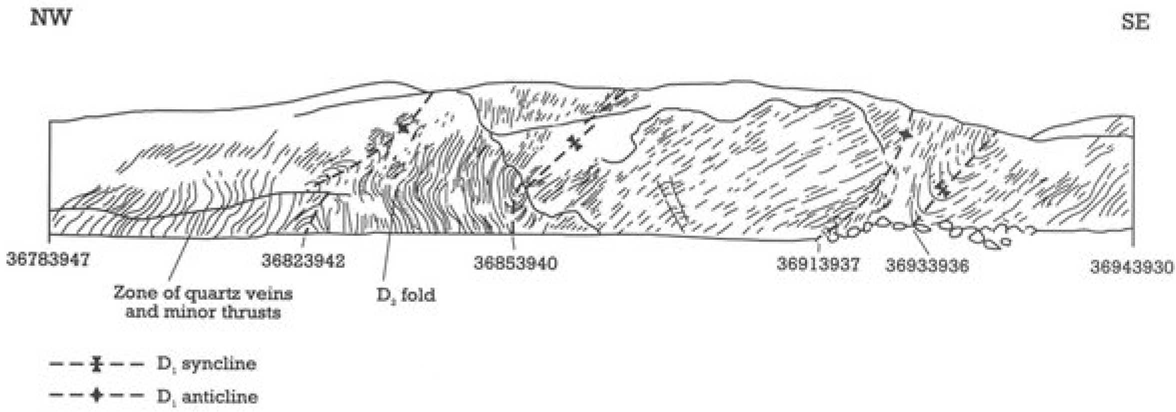
This site is important as the best-known locality where the Caledonian D_2 folds of the Southern Uplands can be clearly seen to be superimposed D_1 folds, formed earlier in that mountain-building phase. Large, upright asymmetrical folds with amplitudes up to 30 m, associated with steeply inclined cleavage (fine, closely spaced, parallel fractures), are refolded by a second generation of smaller folds orientated almost at right-angles to the first. The first generation (D_1) of folds is thought to result from the subduction of oceanic crust during the closure of the Iapetus Ocean, whereas the cleavage probably relates to eventual continental collision in the end-Caledonian mountain-building episode. The second generation of folds (D_2) is possibly related to uplift. As well as providing an unequalled view of the style and scale of D_1 folds, this locality must rank as one of the most dramatic large-scale exposures of major refolded folds anywhere in the British Isles.

References

(Figure 2.13) Type-D_1 syncline in massive Silurian greywackes, Back Bay, Monreith. View to the north-east, with figure for scale. (Photo: J. Treagus.)



(Figure 2.1) Geological map of the Southern Uplands, showing the distribution of the three main belts, some of the steep faults that bound these belts, and subsidiary tracts. The positions of the sites discussed are also shown. A and B, in the south-west, show the zones of D_2 folding and steep D_1 plunge respectively, as discussed in the text.



(Figure 2.14) Sketch of the Back Bay site, drawn from photographs. Horizontal scale is not linear; total length is approximately 200 m.