Isle of Whithorn Bay

[NX 4766 3650]–[NX 4760 3616]

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Highlights

A feature of the Caledonian D_1 deformation in the Hawick Rocks of the Southern Uplands is a narrow zone of steeply plunging folds. The Isle of Whithorn Bay is the best locality for the examination of this fold zone.

Introduction

This site occurs within the Hawick Rocks, of probable Llandovery age, in the Central Belt of the Southern Uplands — see 'Introduction', Chapter 1, and (Figure 2.9). The regional attitude of these rocks, as described by Craig and Walton (1959), is of steep north-west-dipping and north-west-younging bedded sediments, interrupted by southeast-verging D_1 folds on a variety of scales (Rust, 1965; Stringer and Treagus, 1981). These folds usually display a range in plunge up to 30° to the north-east, or the south-west (see Barlocco and Cruggleton Bay: (Figure 2.10)).

At Whithorn Bay the plunge variations are on a larger scale and only become apparent from careful examination of successive outcrops. These folds, which are part of a 1500 m wide belt (Figure 2.1) across the Whithorn Peninsula, may be related to one or more strike-parallel thrusts. This site also reveals from examination of way-up criteria, the presence of an isoclinal fold which pre-dates D_1. Such folds have been described from several localities in the Hawick Rocks; they have been interpreted as the products of soft-sediment deformation, developed early in the history of the accretionary prism.

Stringer and Treagus (1980) described this zone, near the south-west margin of the Central Belt (labelled B on (Figure 2.1)), which exhibits the steeply plunging and locally downward-facing D_1 folds, seen at this site. Rust (1965) interpreted the steep-plunging folds of the Whithorn area as a response to a third episode of shortening, which affected already vertically dipping rocks. Stringer and Treagus (1980) interpreted these folds as an exceptional development of the ubiquitous D_1 folds, with the associated S_1 cleavage.

Description

The foreshore on the western side of the bay (see (Figure 2.9)) contains six major D_1 hinges in the typical alternations of greywacke, siltstone, and mudstone. The rocks broadly trend NE–SW, with subvertical dips and younging to the north-west. The short limbs have a similar dip, but more north-westerly strike and young to the south-east. Thus the fold hinges are themselves subvertical and occasionally can be directly observed. In detail, some fold hinges plunge steeply north-east (some as shallow as 40°) and can be traced along their axial surfaces to plunge steeply south-west. Some hinges plunge as shallowly as 20°, giving a total range of plunge of 120° about the vertical. Unlike the John's Road site, it is not possible to demonstrate that individual hinges curve through this range. The variation in plunge is illustrated by Stringer and Treagus (1980, Figure 6c and p. 324).

Throughout the site, it is usually possible to demonstrate the direction of younging from sedimentary structures. At the northern end about [NX 4770 3645], 1 m-thick greywackes display unusually clear examples of graded bedding, with gritty, loaded and flute-casted bottoms, and cross-laminated silts and cleaved mudstones at the tops. Such indications, elsewhere at the site, show that the majority of the folds face sideways, or upwards, to the south-west. The folds that plunge to the north-east can, similarly, be shown to be downward-facing to the south-west. However, a reversal of younging of the rock sequence, at [NX 4762 3622], which cannot be accounted for by the D_1 folds, implies the presence of a major isoclinal fold that pre-dates D_1. Similar pre-D_1 folds at Cairnhead [NX 4867 3838], considered to be of soft-sediment origin, have been described by Stringer and Treagus (1981, p. 141) and Rust (1965). That the folds are D_1,

is clearly demonstrated from the relationship between the folds and the cleavage, the latter is everywhere developed in the finer-grained lithologies. It is approximately axial planar, showing the usual refraction through the various lithologies. The cleavage also exhibits the transecting relationship to the fold hinges, shown throughout the Hawick Rocks (Stringer and Treagus, 1980; (Figure 2.11)).

Interpretation

The principal interest of this site is that the steeply plunging folds, which it so clearly exhibits, are part of a zone of such structures that runs for some 20 km along the southern margin of the Central Belt (labelled B on (Figure 2.1)). At Whithorn the zone is 1000 m wide, whereas to the north-east, on the other side of Wigtown Bay, it appears to be represented by two narrower components (Stringer and Treagus, 1980, Figure 1). No descriptions exist of such structures in the poorly exposed inland areas, but the site at Agate Point and John's Road on the north-east coast may be part of the same, or a parallel, zone 200 km along strike.

The origin of the folds has been attributed to a post-D_1 deformation by Rust (1965). This was contested by Stringer and Treagus (1980) who pointed out that:

1. these folds were part of a range of D_1 fold plunge in the area;
2. that the folds exhibit, apart from their plunge, all the usual features of D_1 folds in their wavelength, vergence and general style; and that
3. the regionally developed cleavage has the same relationships to these folds as it does to the regional D_1 folds, namely subaxial planar or slightly transecting, and refracting through the various lithologies.

Kemp (1987) described some steeply plunging folds in the Southern Belt in strongly sheared rocks, to the south-east of the zone described here. He showed that the folds have a consistent sinistral vergence and post-date early folds (and presumably cleavage). Clearly, the post-D_1 folds have a different origin, more clearly related to shearing than those discussed here.

The origin of these folds is still unexplained and will undoubtedly be the subject of further research, particularly in view of the unusual deformation characteristics that would be expected as a result of the position of these rocks in a possible accretionary prism. Stringer and Treagus (1980) suggested, firstly, that they might be related to unusual strain gradients which might be associated with the thrusting that is an essential feature of the accretionary process. Folds that curve into the extension direction are usually related to strong extensive strains (Roberts and Sanderson, 1974) often in shear zones (Cobbold and Quinquis, 1980). However, no exceptional strain parameters have been reported from these rocks, indeed the fabric suggests oblate strain. Stringer and Treagus (1980), secondly, suggested that D_1 folds may have been rotated in packets between shear planes as part of the thrust related (D_1 and later?) deformation. The boundary between the Hawick Rocks and Wenlock strata, immediately to the south-east of the zone (see West Burrow Head), may be the location of one such thrust. The site certainly contains planes or zones along which there is local disruption, intensification of cleavage and veining. These zones could mark the boundaries of anastomosing minor thrust packets, although there is apparently no great discontinuity of fold structure, or lithological type across them. The age, the sense of shear, and the relation to external stresses of the zone of steeply plunging folds is an obvious target for future work.

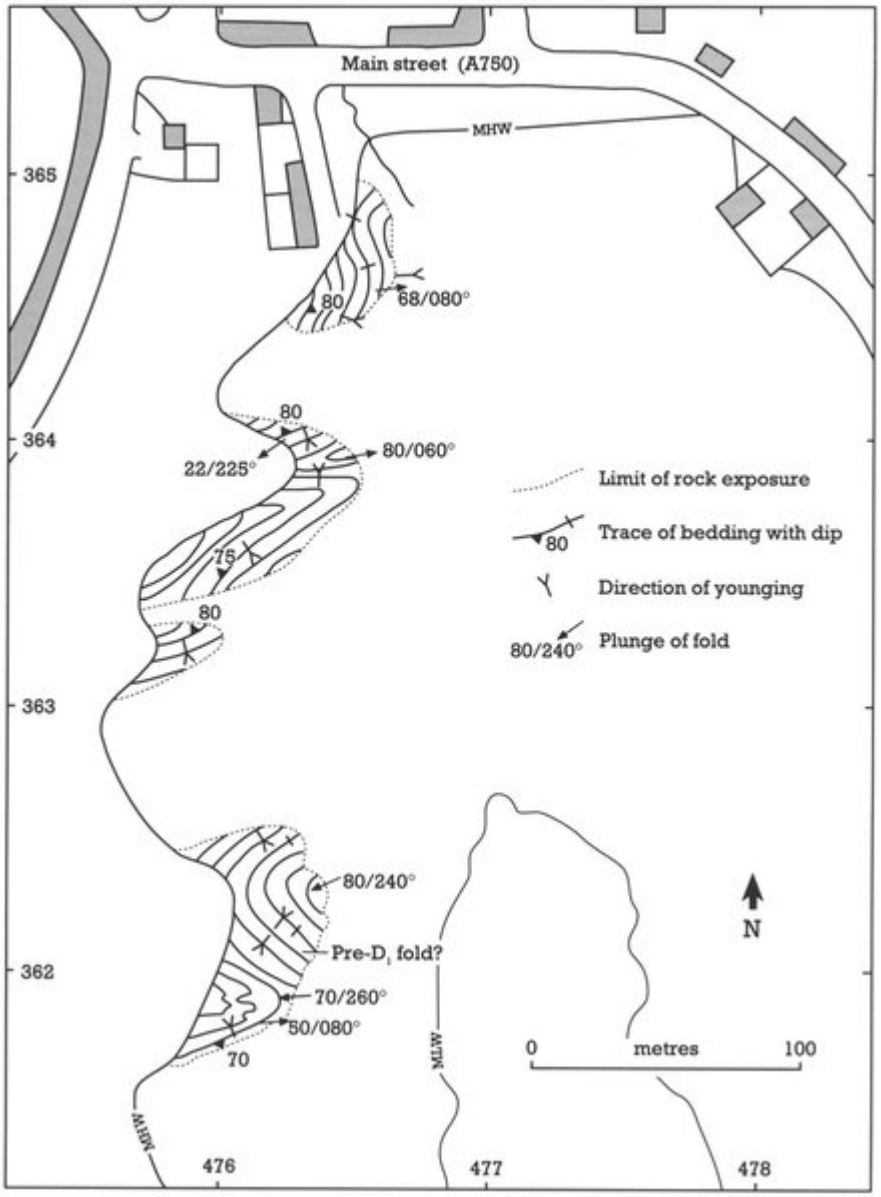
A second feature of interest here is the apparent presence of a pre-D_1 isoclinal fold. Such folds, unrelated to cleavage, or minor structures, have been attributed (Stringer and Treagus, 1980, 1981) to soft-sediment deformation. Again, this feature, as well as those of similar origin described by Knipe and Needham (1986) and Kemp (1987), need to be further studied. Soft-sediment structures need to be more closely related to those in accretionary prisms. Their geometry and origin in the Southern Uplands or in modern prisms cannot yet be related with confidence.

Conclusions

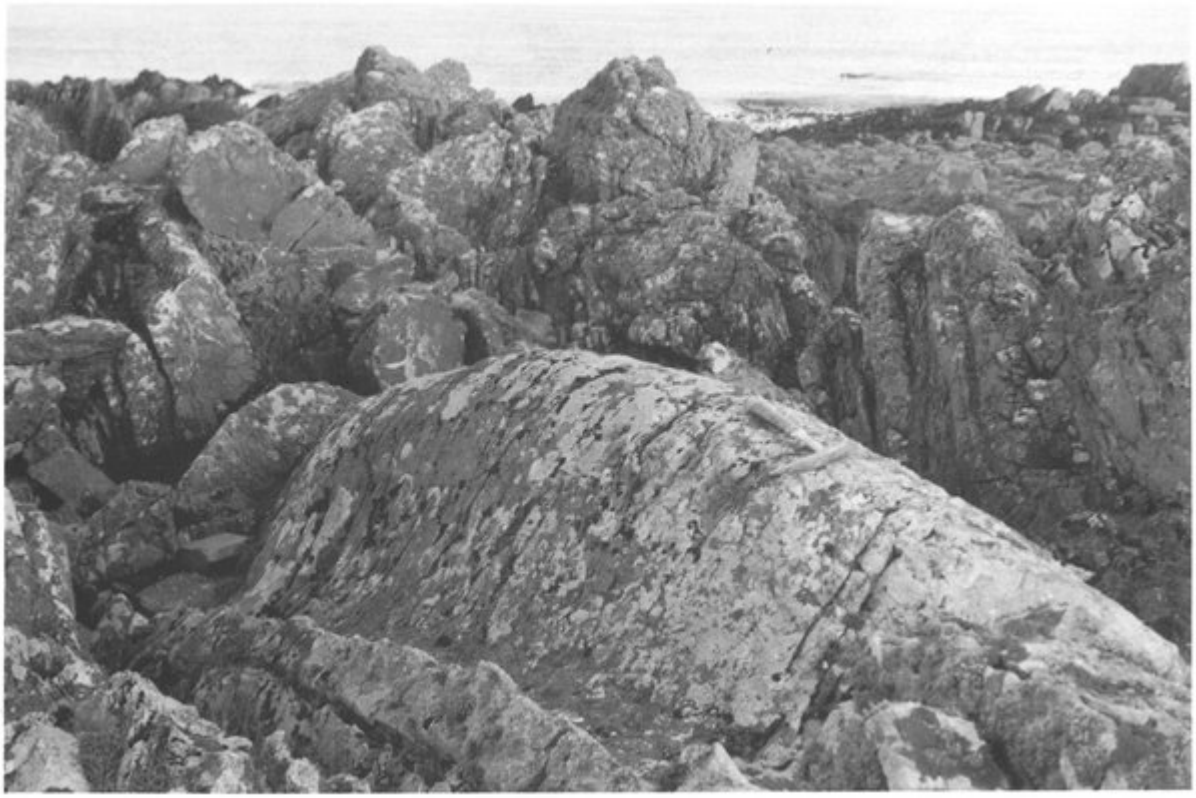
The site has been included in the Geological Conservation Review as the most convincing and accessible location for the study of steeply-plunging folds in the Southern Uplands. These folds, which vary considerably in their orientation

(plunge), through a total range of 120° about the vertical, are highly unusual features of slate belts and must be an important, but as yet poorly understood, feature of the accretionary development of the north-western margin of the Iapetus Ocean. In the Hawick Rocks of this area they are characteristic. These folds were the product of extreme compression during the Caledonian mountain building episode at the end of the Silurian Period or early in the Devonian. They affect older folds here, thought to have formed by the slumping of unconsolidated sediments on a sloping early Silurian sea-bed, perhaps initiated by disturbances in the early stages of accretion. Thus the locality displays graphically sedimentary and tectonic deformation over a period of around 40 million years.

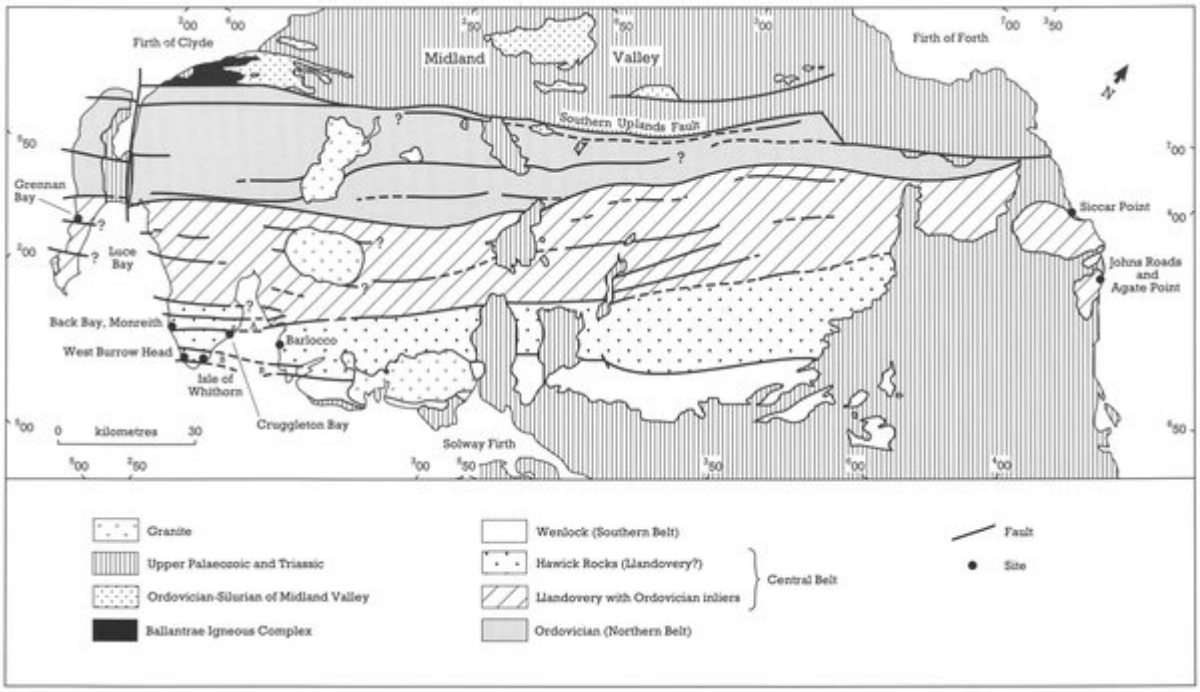
References



(Figure 2.9) Sketch of the Isle of Whithorn Bay site.



(Figure 2.10) Typical fold plunge variation in Hawick Rock greywackes. This pericline, viewed from the north-west, is at Shaddock Point [NX 478 393], near the Isle of Whithorn site. (Photo: P. Stringer.)



(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 2.11) Typical cleavage refraction from mud/siltstone to sandstone seen in Hawick Rocks in profile view; in plan view cleavage transects the fold hinges. Locality: Port Allen [NX 478 411], near Isle of Whithorn. (Photo: P. Stringer.)