Barlocco

[NX 5805 4880]–[NX 5890 4820]

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Highlights

The coastal section, which is easily accessible and continuously exposed, illustrates all the typical features of the Caledonian D_1 folding and cleavage in the Hawick Rocks, and the geometry of D_1 folds in the Central Belt of the Southern Uplands.

Introduction

This site is part of the shore exposures between Knockbrex and Kirkandrews (Figure 2.6)A, which are cited by Peach and Horne (1899, p. 215) and Craig and Walton (1959). The sites were important in the formation of the views of these authors on Southern Uplands structure. Craig and Walton (1959) used this section to illustrate their theory that the Southern Uplands structure comprised a number of large monoclines with alternating steep, relatively unfolded, limbs and flat zones in which a small thickness of rocks was repeated in recurrent symmetrical folds. The West Burrow Head site lies in part of one of these steep limbs, but the Barlocco site is part of a flat zone. Stringer and Treagus (1980, 1981) have contested this view, claiming that south-east verging fold pairs are evenly distributed in the Hawick Rocks and generally indicate a moderate sheet-dip to the north-west. Craig and Walton (1983) have defended their view.

The typical features of the D_1 deformation in the Hawick Rocks, seen in this site, are very similar to those in other adjacent Llandovery and the Wenlock formations. These features have also been described in papers by Stringer and Treagus (1980, 1981), where this section is mentioned in particular. Most of the characteristics of Southern Upland folding, described by Walton (1983), can be observed in this section. The typical features are: the wavelength, asymmetry, and plunge variations of the folds and the transection of these folds by the S_1 cleavage.

Description

The principal feature illustrated in this site is one common to much of the Southern Uplands, that of steeply dipping greywackes, younging to the north-west, but periodically interrupted by small-scale fold pairs. In this section, alternating greywackes (0.3 m to 3 m thick) dip steeply to the north-west or south-east. Sedimentary structures — grading, loading, and cross-stratification — are usually found to demonstrate the dominant northwest younging. About twenty major fold pairs are exposed, with an average wavelength of 42 m. Minor folds with wavelengths down to 5 m also occur, but shorter wavelengths are rare.

The folds are mostly tight to moderately tight (interlimb angle 20–70°) with axial surfaces which are subvertical. Hinge style varies according to lithology, thickness, and position in a fold stack; some in massive greywackes are concentric, but more typically alternating greywacke, siltstone, and mudstone multilayers show a style intermediate between chevron and 'similar' (that is, Class 1C, Ramsay, 1967).

The ratio of the width (measured horizontally) of the north-west-younging limbs to the south-east-younging limbs of these folds is, on average, 4:1, a reflection of the asymmetry of these south-east verging fold pairs (Figure 2.6)A. It is estimated that, if it could be assumed that faulting was unimportant in the section, the sheet dip is about 45° to the north-west.

It is clear, however, that the fold section is interrupted by a great number of fractures, some subvertical strike-parallel or dip-parallel, others dipping at low angles. Occasionally, it is possible to demonstrate apparent displacements of a few centimetres to a metre, but the absence of marker horizons makes matching across possible faults difficult and calculation of the precise movement sense problematical. One steep dip fault is particularly obvious in the section, from

the displacement of the folds on the upper foreshore relative to those on the lower foreshore.

Another feature of the site is the variation in plunge of the D_1 hinges, and the consequent variation in fold profile and the impersistence of individual hinges. Many hinges are sub-horizontal, but others plunge up to 30°, both to the north-east and south-west, and occasionally, across the foreshore, individual hinges can be seen to display this range within strike lengths of 10 m or more.

This site can also be used to examine the essential features of the S_1 cleavage in the Hawick Rocks. In sandstones, the cleavage is formed by parallel or anastomosing partings of 0.01–0.05 m. A weak, preferred, dimensional orientation of the quartz or feldspar is sometimes apparent, and dark seams, mica and opaque mineral concentrations, are the result of pressure solution. Even in the cleaved mudstones, the cleavage is domainal, with closely-spaced (0.1 mm and less) dark seams with strong mica orientation which separates paler microlithons with less-strongly oriented mica. In graded beds, cleavage shows gradations in intensity as well as refraction in dip. In profile view (Figure 2.6)B, the S_1 cleavage forms strongly convergent fans in folds of sandstone, centred on the axial surfaces. The cleavage in mudstone sometimes displays a finite neutral point in a hinge zone (Ramsay, 1967, p. 417).

In this site, one of the most interesting features is the transection of the folds, in plan view, by the S_1 cleavage. The section allows many individual hinges to be examined in three dimensions and it is revealed that the strike of the cleavage is clockwise to that of the axial surfaces. This angle, between the subvertical axial surfaces and sub-vertical cleavage in the mudstones, is commonly about 10°, but in all lithologies ranges up to 25°. Since, in profile view, the cleavage exhibits the conventional fanning and refracting relationships to the axial surfaces, the three-dimensional relationship of both individual cleavage planes and their intersection with bedding, as they cross fold hinges, must be quite complex — see (Figure 2.6)B and Stringer and Treagus 1980, for details. The principal difference from conventional cleavage and bedding relationships is that their intersection can be seen curving clockwise across fold hinges to become steeper on the limbs. Great care has to be taken in using the relationship between cleavage and bedding (in plan view) in the conventional way to interpret fold geometry.

Interpretation

The coastal section at Barlocco has been drawn upon by several workers in their interpretation of the Southern Uplands. In Peach and Horne (1899, p. 215) it is one of the few coastal sections remarked upon and then for the intensity of the folding exhibited. Craig and Walton (1959, 1983) and Walton (1961) used this coast as a model for their influential theory that the structure of the Southern Uplands comprises large-scale monoclines descending towards the north-west, made up of alternating steep belts of relatively unfolded rocks and flat belts (as at Barlocco) of strongly folded rocks.

Stringer and Treagus (1980, 1981) also refer extensively to this coastal section, but were unable to substantiate the monocline model (Stringer and Treagus, 1983). Instead, they maintain that the larger scale of D_1 folding in the Hawick Rocks is of 0.25–3.0 km wavelength, with long, north-westerly dipping limbs with a sheet dip of about 45° alternating with short limbs dipping steeply southeast (Figure 2.6)B. Smaller-scale folds corrugate the limbs of these structures, seen at Barlocco. The asymmetry of the larger folds and the smaller-scale folds on the long limb is typically to the south-east.

Rust (1965) and Weir (1968) have also described the folding and cleavage of the Hawick Rocks, in adjacent coastal sections. They produced more complex histories for the development of the deformation, described as D_1 by Stringer and Treagus (1980, 1981), which would seem to result from a difference in interpretation of the cleavage relationship to the folds. In particular, these workers would relate the transecting cleavage to an entirely superimposed deformation (but see Weir, 1979).

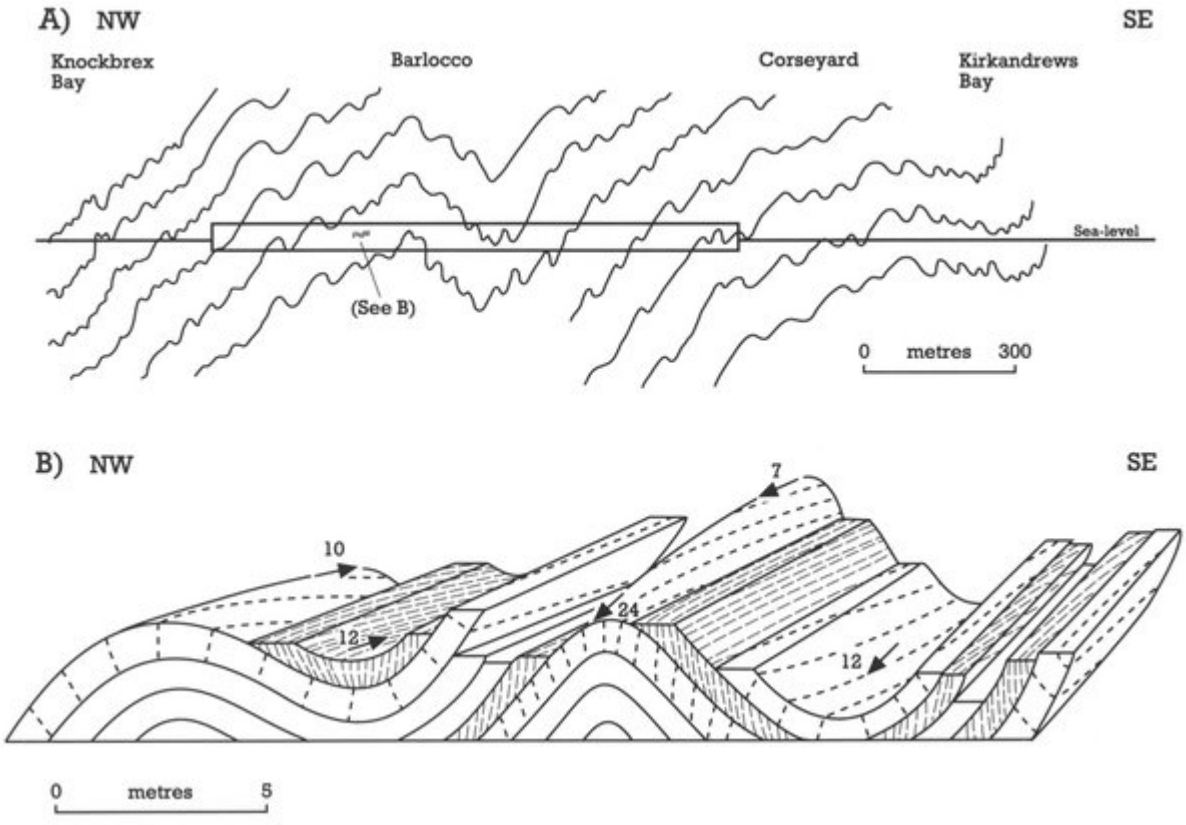
The history of the development of the folds and cleavage, such as that described from this site, and its relationship to external mechanisms is of great current interest. McKerrow *et al.* (1977) and Leggett *et al.* (1979) view the stratigraphical arrangement of the Southern Uplands in the context of an accretionary prism model and note that the north-west-verging monoclines of Walton (1961) are opposite to those seen in modern accretionary prisms. Stringer and Treagus (1981) suggested that the style of folding observed by them (steep south-east vergence) was consistent with the ocean-verging, initially recumbent attitude expected in accretionary complexes, subsequently rotated into their present attitude in

association with imbricate thrusting. Knipe and Needham (1986), working in an adjacent coast section, have identified disrupted rocks, thrusts and thrust-related folds which they show are similar to those described from modern accretionary prisms. Such features may well be present in the Barlocco site.

Conclusions

The Barlocco site has been selected as superbly exemplifying the principal features of the main Caledonian deformation (D_1) in the Southern Uplands. Rocks deposited in the seas of the early Silurian Period are here deformed by folds and cleavage planes (which in plan view are seen to cut across the folds). These features were produced by the intense compression of this area resulting from the convergence and final collision of the 'North American' and 'European' continents, which was responsible for the building of the Southern Uplands. This Caledonian mountain-building episode (orogeny) culminated around 400 million years before the present, at the end of the Silurian Period or early in the following Devonian. Although other locations might have been chosen, this site has the additional attractions of being historically important, easily accessible, and of being unaffected by subsequent phases of deformation.

References



(Figure 2.6) (A) Diagrammatic fold profile of the Knockbrex Bay–Kirkandrews Bay coast section, with box indicating the location of the Barlocco site. Approximate position of the folds illustrated in (B) is also shown. (B) Typical fold and cleavage geometry at the Barlocco site, based on field observations at [NX 5835 4865]. Cleavage is shown: open spaced in sandstones and narrow spaced in mudstone. Plunge of fold hinges and cleavage–bedding intersections are also shown (after Stringer and Treagus, 1980, figure 2).