Shap Fell

[NY 554 057]–[NY 556 050]

F. Moseley

Highlights

The site provides an unrivalled continuous section through typical folds in the Upper Silurian rocks. It allows detailed observation of the style of these folds and, together with the Tebay site, demonstrates the geometry of the larger-wavelength folds in the Lake District.

Introduction

The Crookdale Crags section is situated alongside the A6, approximately 400 m south of Shap summit (Figure 3.16) and (Figure 3.17). It is entirely within the confines of the north-west limb of the Bannisdale Syncline, or Synclinorium, (a major F_1 fold). It exposes a sequence of the transition beds, which separate the Coniston Formation Grit from the Bannisdale Slate Formation (all Ludlow Series, Upper Silurian).

The general stratigraphy and structure of the Silurian rocks of Shap Fell and the surrounding country has long been known from the Old Series Geological Survey map. More recent descriptions of this and adjacent areas have been given by Moseley (1968), Soper and Moseley (1978), and Lawrence *et al.* (1986).

Together with the Jeffrey's Mount site, which lies on the south-east limb, the two sites provide cross-sections through the opposing limbs of the Bannisdale Syncline at very similar structural levels (Figure 3.16).

Description

The strata of this region are, in ascending stratigraphical order:

1. The Coniston Grit Formation, consisting of massively bedded greywacke with subsidiary, thin mudstone partings.
2. The transition beds, typified by the road section (Figure 3.17), consist of alternations of greywacke and mudstone. The former, in beds between 0.1 m and 2 m thick, display the same sedimentary features as the Coniston Grit Formation, whereas the latter range from less than 0.1 m thick to 7 m or more in thickness. There are also siltstones and fine greywackes.
3. The transition beds pass by gradation into the Bannisdale Slate Formation, with banded mud-stone the dominant lithology. The banding generally results from alternations of pale silty laminae and thicker, dark mudstone bands.

These formations are disposed on the major (F_1) Bannisdale Syncline, or Synclinorium. This is an asymmetrical fold, with a longer and steeper north-west limb and a half wavelength exceeding 8 km. Numerous minor parasitic folds, with half wavelengths ranging from 2 m to 200 m, are located on the limbs of this fold (Figure 3.18). Generally, the massive, competent Coniston Grit Formation, on the extreme flanks of the syncline, is uncomplicated by minor folding, but the overlying transitional beds and the Bannisdale Slate Formation exhibit numerous minor folds with differing arrangements in different parts of the syncline.

Cleavage (S_1) is strongly developed in the mudstones, less strongly in the siltstones and scarcely at all in the massive greywackes. It is noteworthy that the axial planes of the folds are oblique to cleavage, with trends of 055° and 060° respectively. There are also dextral and sinistral wrench faults which are complementary to the folds.

The A6 section illustrates the two styles typical of the north-west limb of the Bannisdale Syncline, that is, belts of sharp folds alternating with belts of uniform, steeply inclined strata (Figure 3.17). The section comprises 300 m of transitional beds and exposes nine folds, together with numerous associated structures such as cleavage with cleavage refraction, slickensiding, and disharmony.

Folds

The smaller folds within the fold belts are asymmetrical, with longer and more steeply inclined south-east dipping limbs (Figure 3.17). Fold plunge is constant, generally between 5° and 10°, to about 055°. Lineations related to the folding are found as slickensiding on the bedding planes. This is, apparently, bedding-plane slip formed during folding, but it is oblique to the direction of dip. However, if the folds are rotated so that the axes are horizontal, these slickensides become exactly downdip. Since the amount and direction of plunge is very similar to the dip of nearby Carboniferous rocks, the suggestion is that the fold plunge represents a post-Carboniferous tilt. Axial planes generally bisect the fold limbs, with beds having identical thicknesses on opposite limbs.

Varying competence of different lithologies during folding is revealed, particularly, by the differing behaviour of greywackes and mudstones where they are interbedded. The transitional beds between the Coniston Grit Formation and Bannisdale Slate Formation illustrate the effects best, with the sandstone bands showing near-concentric folding and the incompetent mudstones thickening out in axial regions with, concomitant development of strong cleavage (Figure 3.18). Measurements indicate (Moseley, 1968) the amount of axial thickening both in mudstones and in massive sandstones, which do in fact show this effect to a lesser extent. These measurements are given below as a ratio of the axial thickness (measured normal to the fold axis in the axial plane) to the limb thickness (measured normal to bedding):

1. Mudstone — 2.2:1 (mean of 13 mudstone bands, with an average limb thickness of 0.28 m);
2. Sandstone — 1.3:1 (mean of 18 greywacke bands, with an average limb thickness of 0.51 m).

Cleavage

Cleavage is strongly developed in the mudstones, less strongly in the siltstone and scarcely at all in the massive greywackes. It varies between genuine flow cleavage in some of the finer-grained mud-stones, to much more common fracture cleavage. Unlike Silurian outcrops to the south and southwest, no second phase of cleavage has been detected. There is, nonetheless, some complexity and no straightforward relation to folding. For example, cleavage has different orientations on opposite fold limbs and it is rarely parallel to the axial planes of the folds. Of particular significance, is the clockwise angle of about 5° generally found between the strike of the cleavage and of the axial planes (and between cleavage and axial trend, since these structures are high angle and the plunge is low). It is therefore apparent that cleavage–bedding intersections are not indicators of fold plunge hereabouts, and field measurements clearly show this to be the case, particularly on south-east-dipping fold limbs.

One further complication is to be found in refraction of cleavage, usually sharply bent at mudstone–siltstone junctions, frequently curved in sympathy with graded bedding, but often bending into the sinistral joint set. This latter phenomenon of cleavage refraction occurs with downward passage from mudstone to greywacke.

Interpretation

The rocks at Crookdale Crags were deformed (folded, cleaved, and faulted), during the main Caledonian deformation (D_1), as a result of continent–continent collision. Interbedded sequences of sandstones and mudstones exhibit the best examples of fold structure in the Lake District and the transition beds at Crookdale Crags provide an excellent example of one such sequence. The style of deformation in these Silurian rocks is comparable with, and of the same age as, that exhibited in analogous Skiddaw Group lithologies, with the notable absence of complexities due to superimposed folding.

It is important to note that the cleavage is not axial planar to the folds. Cleavage transects the axial planes of the folds by approximately 5–10° in a clockwise direction. This is a common, but important, feature observed regionally in late-Caledonian structures of the Lake District and also in Wales (Woodcock *et al.,* 1988) and the Southern Uplands (Stringer and Treagus, 1980). It has been attributed to sinistrally oblique transpression — see Chapter 1.

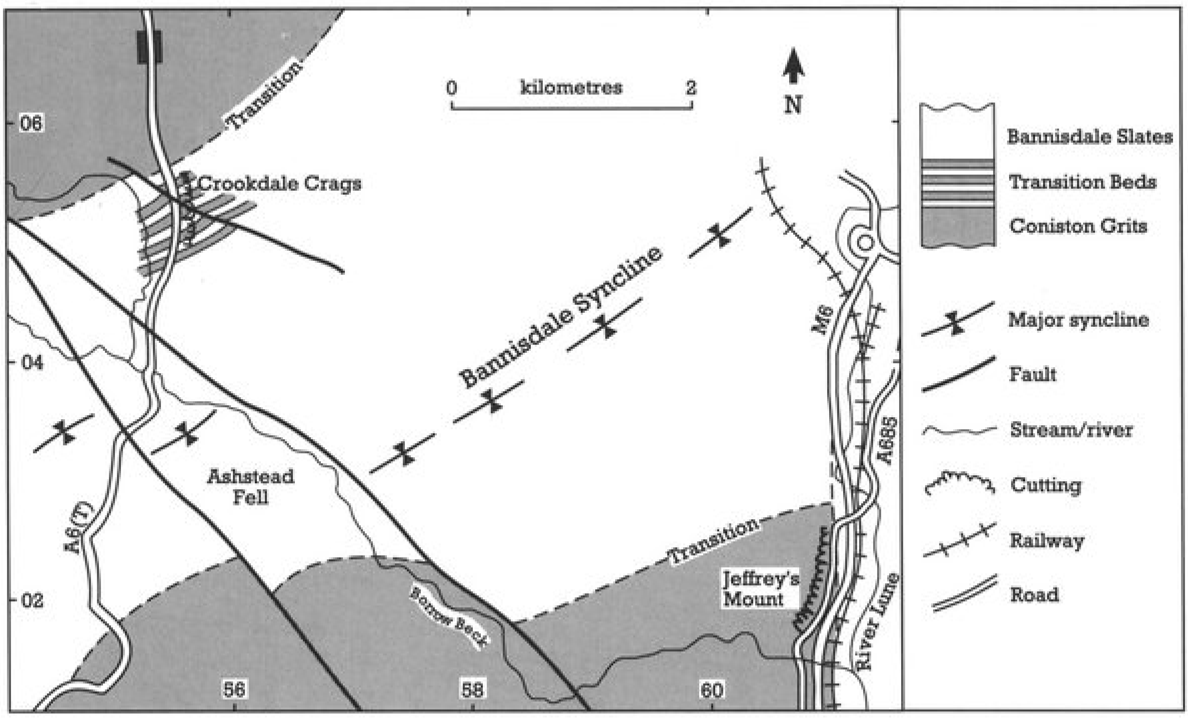
This section exemplifies the typical structure of the north-west limb of the Bannisdale Syncline with its alternating belts of sharp folds and belts of steeply uniformly inclined strata and north-west vergence of minor folds. Soper and Moseley (1978) used this vergence to delineate the axial trace of the fold and noted that these belts are comparable, in width, to the zones of intense and weak cleavage in the Borrowdale Volcanic Group and suggested that they might be analogous structures.

This section should be compared with the structure at the Jeffrey's Mount site on the southeast limb of the Bannisdale Syncline (Synclinorium) where the folding is less intense.

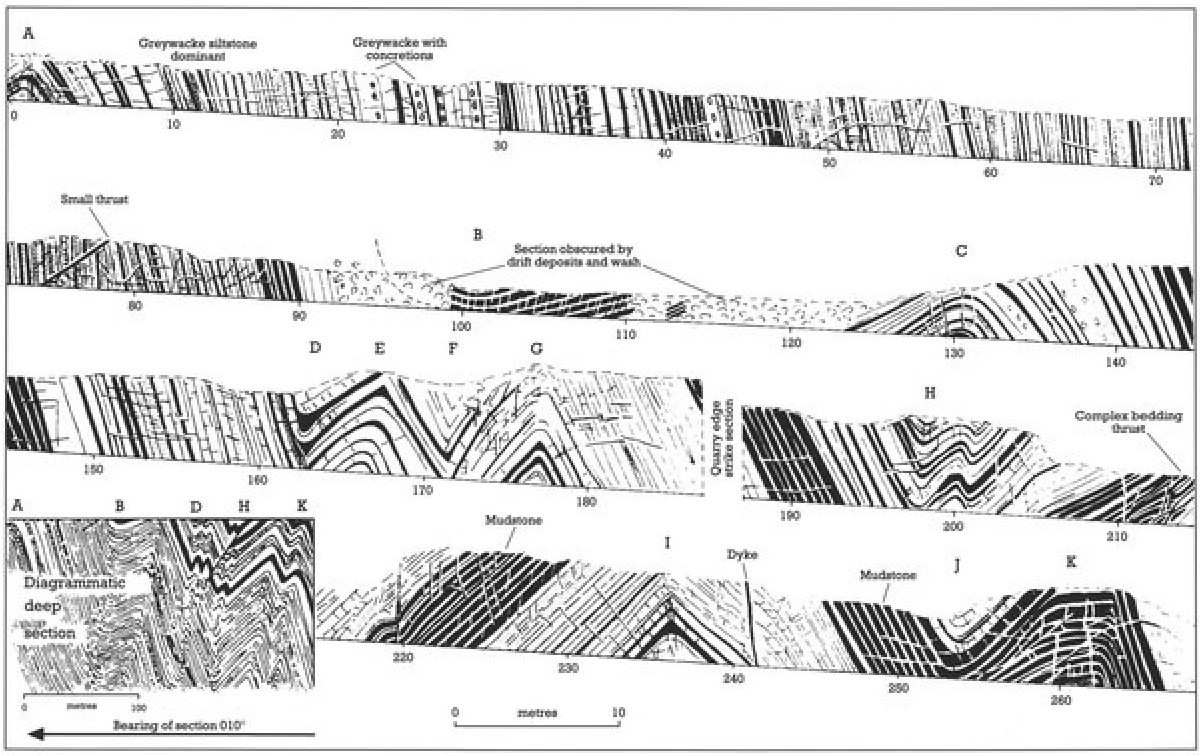
Conclusions

This site, probably the most visited in the Lake District, provides an opportunity to examine the style of Caledonian deformation that characterizes the rocks of the Windermere Group. It is particularly important for showing details of this style, especially that folds are inclined in a south-easterly direction on the northern limb of a major syncline. The cleavage (closely spaced, parallel fractures) is not precisely parallel in plan view to the axes of the folds; this is an unusual relationship, although typical in the Silurian of the Lake District. This has been explained as a result of the way in which the Iapetus Ocean closed and the continents to the north (Laurentia) and south (Avalonia) came together and collided. It is thought that, at the time of this coming together, the margins of the northern (North American') and southern ('European') continents were oblique to the direction of closure. Thus the intense, compressive stress imposed on the rocks by the collision has left graphic evidence, even demonstrating the orientation of the continental margins around 400 million years ago as Iapetus was closed.

[References](#)



(Figure 3.16) Geological map of the Bannisdale Syncline, showing positions of Crookdale Crags (see Fig. 3.17) and Jeffrey's Mount (after Moseley, 1986).



(Figure 3.17) Fold structure along A6 road-cuttings at Crookdale Crags, Shap (after Moseley, 1968).

(Figure 3.18) Shap Fell. D_1 folds developed in Silurian greywackes; cleavage can be seen in the interbedded muddy siltstone. View to east. (Photo: J. Treagus.)