River Caldew

[NY 331 325]–[NY 325 328]

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Highlights

The River Caldew section exhibits one of the finest sets of fold structures in the country. They are displayed with a clarity rare in the Ordovician Skiddaw Group, partly as a result of hornfelsing; they provide a critical locality for the understanding of the early deformation history of the group.

Introduction

At least two phases of deformation are represented here; the first producing originally sideways-closing N–S folds, but now characterized by a steep plunge, thought to be of slump origin, and the second the main end-Caledonian structures.

The section extends for almost 500 m upstream of a small dam [NY 331 325] on the River Caldew and also includes the lowest seventy metres of Grainsgill Beck up to the contact of the hornfelsed Skiddaw Slate Group with the greisen at the margin of the Skiddaw Granite. Although now hornfelsed, by the intrusion of the Skiddaw Granite, the rocks of the area have been identified as the Mosser–Kirkstile Slates (now Kirkstile Formation) (Arenig Series) (Jackson, 1961), equivalent to the Slates and Sandstone Group (Eastwood *et* al., 1968). Roberts (1973, 1977a) favoured Jackson's usage, with a subdivision into a lower slate and sandstone division and an upper slates division. It is the lower division that is present in the River Caldew section, essentially a grey striped siltstone sequence with some thin mudstone layers and a few thin sandstone bands. The site displays a complex set of folds which have been significant in determining the structural evolution of the Skiddaw Group. The structures in the Skiddaw Group of the Northern Fells indicate four phases of deformation (Roberts, 1977a).

Some aspects of the site are referred to in the Memoir of the Geological Survey (Eastwood *et al.,* 1968); various opinions of the structures are mentioned in a report of a Geologists' Association field meeting (Mitchell *et al.,* 1972); but the definitive paper on the section is that of Roberts (1971), which formed part of a fuller study of the Skiddaw Group of the Northern Fells (Roberts, 1973, 1977a).

Description

A map of the section is presented herein (Figure 3.9) and it shows the overall structure, together with offset diagrams of key localities with accompanying stereographic projections.

The style of folds in the section is complex, with frequently more than one style being present in a single fold. Folds show concentric, similar, chevron, and conjugate fold elements, although close to tight similar folds are the most dominant style (Figure 3.10). Interference patterns caused by refolding can also be detected, a good hook-type being visible at the junction of Grainsgill Beck (see (Figure 3.9); Locality A). One common feature of many structures is disharmony of fold wavelength in the core of the folds, together with discordant structures. There is no obvious consistent orientation of the structures, although a generalized NE–SW trend can be detected. What is obvious, however, is the steep plunge of the folds over the entire section, with only a few exceptions. Roberts (1971) removed a regional dip from these structures and showed that originally many had a N–S recumbent attitude. Good representatives of the overall nature of the structure are seen at several localities: a prominent set of folds near the road approximately 200 m west of the dam ((Figure 3.9), Locality B); exposures each side of a small waterfall 30 m west of the small tributary ((Figure 3.9), Locality C); and those 50 m upstream of the confluence of Grainsgill Beck ((Figure 3.9), Locality D).

One important aspect of these folds, however, is that despite their tight nature, often angular hinges, and the presence of such structures as conjugate fold pairs, many folds show evidence of disruption, convolute folds, and some disharmony not consistent with tectonic structures. It is the interrelationship of structures which appear to be tectonic, with others that are more consistent with soft-sediment deformation, that makes this particular site of special interest. The absence of any tectonic fabric, such as cleavage, due to the effects of metamorphism, adds to the problems of establishing the true nature of the deformation history.

Interpretation

The majority of structures in the River Caldew Section can be precluded from late-Caledonian deformation events, on account of their steep plunge and variable orientation, which is totally inconsistent with any known main-phase structures in the Lake District. Consequently, it is generally accepted that many of the folds in this section are the product of an earlier deformation phase of the Skiddaw Group.

The suggestion of Brown *et al.* (1964), that the tight folds in the hornfels were formed as a result of the forcible injection of the granite, is also rejected, on the grounds that these folds are earlier than the main late-Caledonian (D_1) deformation, whereas the granite was probably intruded either synchronous with, or slightly later than D_1, but certainly earlier than D_2 (Soper and Roberts, 1971).

Roberts (1971) preferred to attribute these structures to pre-Windermere Group deformation, on account of their original N–S trend which was consistent with that reported for the 'pre-Bala' (pre-Caradoc) folds in the Borrowdale volcanics (Mitchell, 1929). However, as outlined in the introduction to this chapter, detailed study has shown that north-trending pre-Caradoc folds do not exist within the Borrowdale Volcanic Group (Soper and Numan, 1974). Moreover, Branney and Soper, 1988 have demonstrated that deformation in the Borrowdale Volcanic Group and at the Borrowdale–Windermere Group unconformity originated from volcanotectonic, rather than compressive, processes. A resurvey of the west section of the Skiddaw Group has demonstrated that the north-trending folds are most probably gravity or slump structures (Webb and Cooper, 1988) (F_0 of this volume).

A close re-examination of the folds in this section reveals much disharmonic folding, disruption in the fold hinge, apparent shears sealed prior to metamorphism, and some irregular convolute folds not dissimilar to features produced as a result of slump folding of unconsolidated sediments. This, together with the original recumbent attitude, would point to gravity sliding of unconsolidated material as a more likely mechanism for the formation of the folds in the Caldew Valley, as suggested by Roberts (1977a). It is not at all easy to put an indisputable age to the formation of the folds, but regional evidence would point to instability during the onset of Llanvirn or Llandeilo Series volcanism as being the most likely cause. Since Llanvirn volcanic rocks occur to the north of Carrock Fell, this is the favoured time for fold formation; the proximity of those rocks may be the reason why folds are so prolific in the Caldew Valley but are much less common elsewhere in the Lake District.

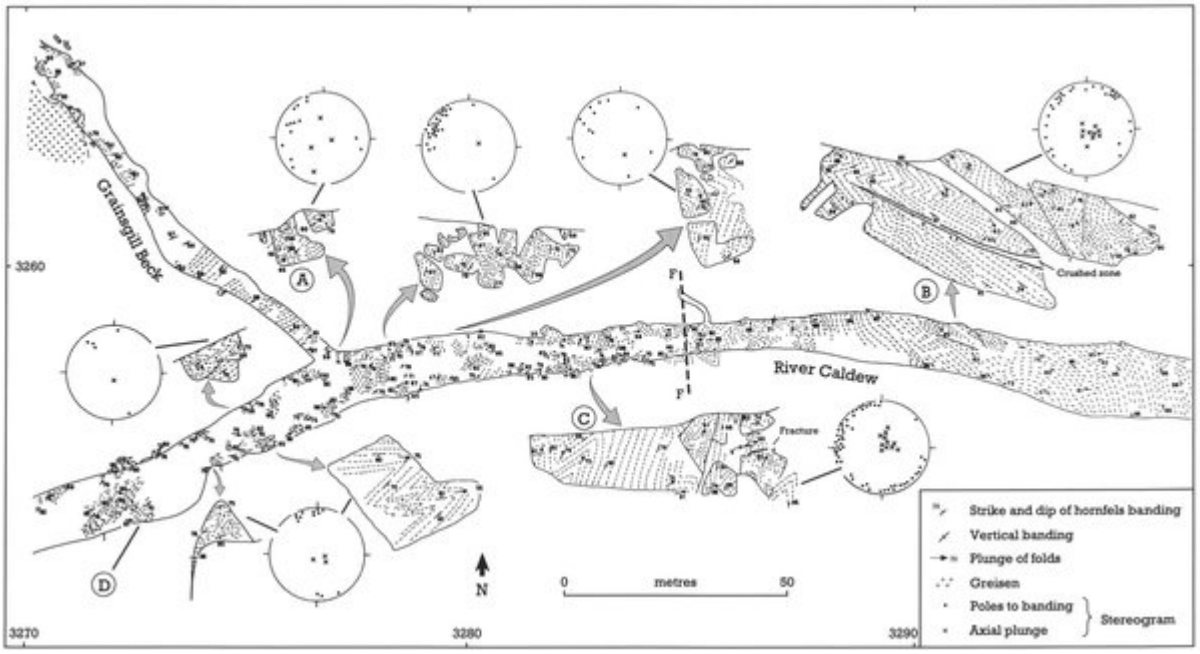
Perhaps it would be unwise to categorically state that all the folds in the River Caldew section are the result of gravity sliding, since it is highly likely that these structures were subsequently deformed by main-phase Caledonian deformation. This could account for the refolds and also for those structures with a gentle plunge to the east or west. The tight nature of some folds with angular hinges is also likely to be the result of the recumbent folds having been flattened by the main Early Devonian tectonic event. However, in view of the complexity of gravity folding, which itself could produce refold patterns, it would be a difficult task to distinguish individual structures which could conclusively be attributed to main-phase Caledonian deformation.

Conclusions

The exposures of baked (hornfelsed) Skiddaw slates in the River Caldew section display a complex set of folds which can best be interpreted as the original product of the sliding of unconsolidated sediments under gravity. This first deformation event (D_0) is likely to have occurred during the onset of volcanism in Llanvirn times, that is, during the early part of the Ordovician Period. The original flat-lying N–S folds were subsequently refolded to some extent during the main

phase of Caledonian tectonic movements (D_1), in the Devonian. During these movements, folds were tilted steeply to the north, thus accounting for the steep attitude (plunge) that the fold hinges now display. Earlier suggestions that the original N–S folds were the result of Late Ordovician (Caradoc) tectonic deformation are now completely rejected. The site has been of interest for a long time, and, although the interpretations of the structures have changed, the remarkable clarity with which the folds are displayed makes it one of the most significant sites in the Lake District for understanding the development of the Caledonides in that area.

References



(Figure 3.9) Structural map of the River Caldew section, showing the main folds in the hornfelsed slates of the Skiddaw Group. Inset diagrams are enlargements (x4) of selected localities, each with an accompanying equal-area projection of the structural elements of that locality (after Roberts, 1971). Localities A–D referred to in text.

(Figure 3.10) River Caldew. Steep NE-plunging folds in hornfelsed slates of the Skiddaw Group produced largely by gravity-driven slumping. They show the truncations and variable, disharmonic style typical of this process. Bedding

planes are chalked (compass top right for scale). (Photo: D. Roberts.)