Buttermere Village

[NY 170 176]

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Highlights

Several exposures, adjacent to Buttermere Village, reveal all the small-scale structures generally observed within the Skiddaw Group. At least three phases of deformation are recorded in the rocks here: F_0 folds, generated by slumping, are refolded by F_1 folds of the main D_1 late-Caledonian deformation; crenulation cleavage of D_2 age is also present.

Introduction

The easily accessible exposures around Buttermere Village illustrate well, many of the structural problems of the Skiddaw Slates. In the past, attempts have been made to explain most of the structures hereabouts in tectonic terms (Simpson, 1967; Moseley, 1972; Webb, 1972; Soper and Moseley, 1978). Although obvious sedimentary slumps, typical of many turbidite systems, have been recognized for many years (see Introduction, Chapter 1) the slates have seemed to have three distinctive phases of folding (all presumed to be tectonic), which have been previously labelled 'F_1', 'F_2', and 'F_3' (see (Table 3.1)). Folds identified as 'F_1' are small-scale, complex and have no associated cleavage. They have a variable trend, often N–S, and until recently they were believed to represent a pre-volcanic phase of minor folding (Jeans, 1972; Moseley, 1972; Webb, 1972). The F_2 folds are similar small-scale structures which resemble the F_1 structures, except that they have a generally NE to ENE trend and often have axial-planar cleavage. Most authors have attributed them to the main end-Silurian phase of the Caledonian Orogeny.

The F_3 folds are open recumbent structures with a subhorizontal crenulation cleavage which have also been thought to belong to the main Caledonian deformation.

Description

This site shows the muddy siltstones of the Buttermere Formation of the Skiddaw Group. At Buttermere Quarry [NY 1733 1727], the strata are inclined about 70°SE, with load casts near the top of the quarry showing the way-up. S_1 cleavage and bedding are parallel, but there are near horizontal F_2 crenulations.

On Long How [NY 1725 1730], outcrops of pelites with silty layers expose steeply plunging folds. These folds, once thought to be tectonic (Moseley, 1972) are now thought to be slumps refolded by the main D_1 movements.

Alongside Millbeck [NY 1700 1717], an F_1, vertically plunging fold is seen to be refolded by an F_2 recumbent fold (Moseley, 1972). Intrafolial folds are seen along one of the F_1 fold limbs.

The fourth locality [NY 1765 1703]; (Figure 3.4) is at Buttermere Church, where the gentle surface of a roche moutonée displays steeply plunging folds. The steep plunge is thought to represent a steeply dipping limb of a slump fold (F_0), whereas the folds themselves are largely the product of the D_1 late-Caledonian deformation. These tight folds are related to an S_1 cleavage. The vertical surface alongside the road reveals open recumbent folds (F_2) with a weak crenulation cleavage (Moseley, 1981).

Interpretation

Recent changes in interpretation by Webb and Cooper (1988; and see below — Hassness and Gasgale Crags) are that the F_1 and even some F_2 small-scale folds originated as slumps, those with the main Caledonoid north-easterly trend having been subsequently tightened and developing a cleavage during the main orogenic phase (now considered to be

Early Devonian). The difficulty in the field arises from the lack of unambiguous criteria for assessing the origin of the F_1 and F_2 folds. In this description, the F_1 folds, considered by Webb and Cooper (1988) to be of slump origin, are designated F_0, while the F_2 folds, which seem to be coeval with cleavage of late-Caledonian age, are designated F_1. Later folds associated with a flat crenulation cleavage are consequently designated F_2.

Although interference between F_0 and F_1 folds in these localities is limited, it is clear that three sets of structures are represented. The F_0 and F_1 folds are both tight and steeply plunging, but F_0 has S_1 cleavage superimposed. The steep plunge of F_1 can be attributed to a steep dip, produced by large-scale, slump folds (F_0). The interpretation of the F_0 minor structures and steep pre-F_1 dips as indications of sedimentary slump processes rests largely on the arguments of Webb and Cooper (see above). These authors show that the folds are related to major folds and olistostromes which have variable trend and vergence, but which predate the D_1 folds and cleavage.

The Buttermere outcrops show, particularly clearly, that the third set of structures are superimposed on the earlier two. The D_2 affects steeply dipping surfaces to give open and recumbent F_2 folds and a related flat S_2 crenulation, although attitudes depend on the dip of the affected surface.

The D_1 and D_2 structures are considered (Webb and Cooper, 1988) to be a product of the late-Caledonian deformation. It now appears that there are no significant tectonic folds that pre-date the Borrowdale Volcanic Group.

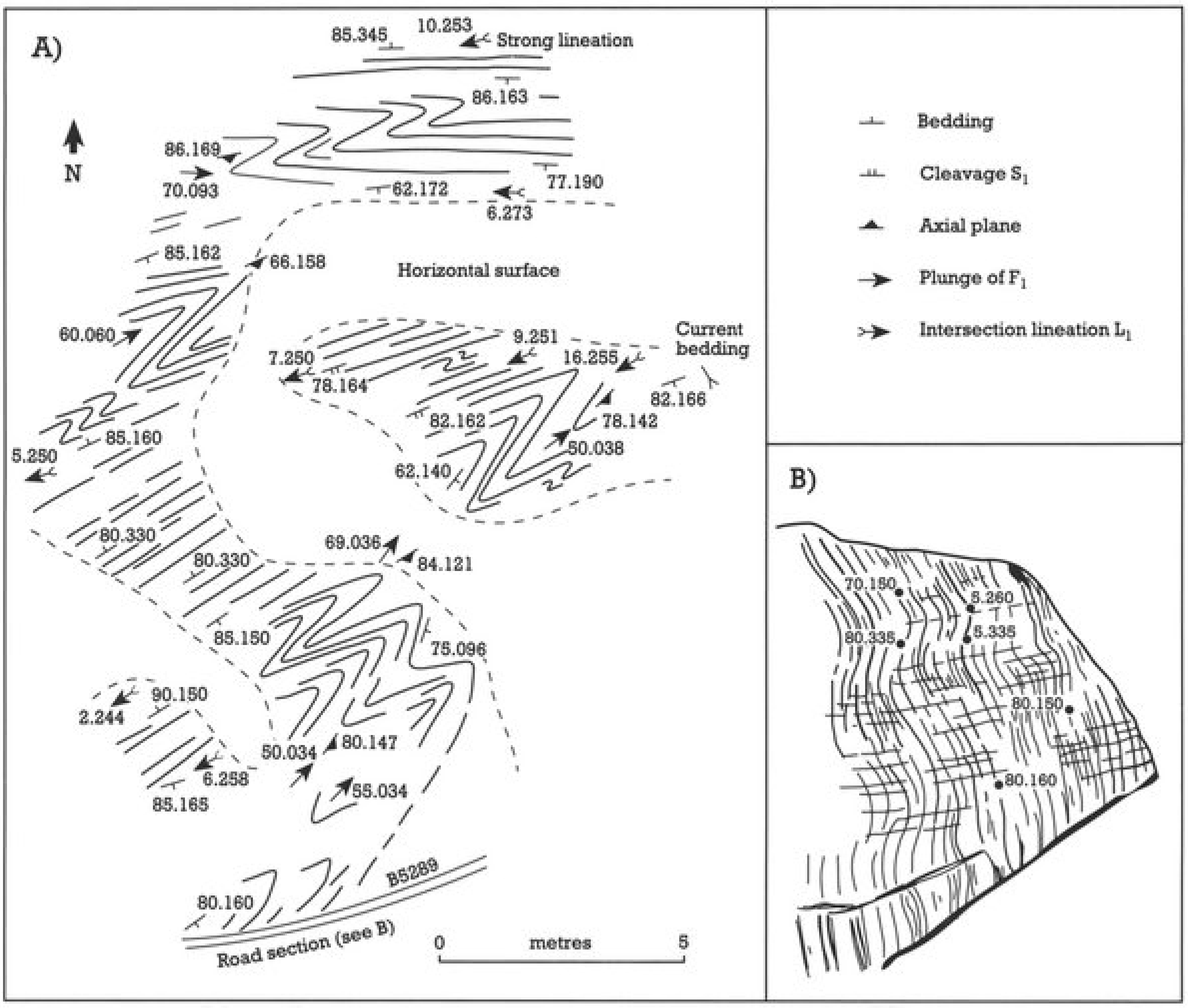
Conclusions

The Buttermere site is important in that, in adjacent outcrops, all three sets of structures that are common to much of the Skiddaw Group can be demonstrated. The first of these (isoclinal folds) were produced by slumping, that is, movement and deformation of masses of sediment either contemporaneous with, or relatively soon after, their deposition on a sloping sea-bed, which means that these folds are of Ordovician age. The second generation of folds (main phase, tight steeply plunging folds) were formed during the main Caledonian mountain-building 'storm', during the early Devonian, at about the time of the closure of the Iapetus Ocean through the convergence of the landmasses to its north and south. The third-generation (open recumbent) folds are taken to be late Caledonian. All three categories are important in the context of the Caledonian evolution of the Lake District.

References

Stratigraphy and timing of events	Description of deformation phase	Phase numbering and contributions by various workers					
		Simpson (1967)	Soper (1970) and others (see text)	Moseley (1972)	Roberts (1977)	Webb and Cooper (1988)	This volume
	FAULTING dominantly N and NW trends						
	N-S FLEXURES with weak fracture cleavage				D_4		D_3
	RECLINED FOLDS with flat crenulation cleavage		D_2		D_3		D_2
Late Early Devonian intrusion of Shap (394Ma) and Skiddaw (399Ma) Granites							
MAIN END-CALEDONIAN PHASE: (Pridoli) WINDERMERE GROUP (Mid-Caradoc)	UPRIGHT FOLDS Major and minor, with transecting cleavage, trending NE to E	F_3	D_1	Phase 3 Related to collision	D_2	D_3	D_1
VOLCANO-TECTONIC FLEXURING AND TILTING (Early Caradoc) BORROWDALE VOLCANIC GROUP (Llandeilo) VOLCANO-TECTONIC UPLIFT BEGINS?	Open E-W folding, block faulting; INITIATION OF ENE-TRENDING LAKE DISTRICT ANTICLINE?		E-W folds large scale, no cleavage	Phase 2 Related to subduction and closure	Not recognised in Skiddaw Group	D_2	Volcano-tectonic deformation (Branney and Soper, 1988)
(Llanvirn) (Arenig) SKIDDAW GROUP (Tremadoc) ?	N-TRENDING FOLDS no cleavage	F_1 and F_2 (descriptions as D_1 and D_2 this volume)	N-S folds minor, no cleavage	Phase 1 N-S folds, minor in largely unconsolidated sediments	D_1 N-S folds, recumbent and minor, in largely unconsolidated sediments	D_1 N-S folds (but variable), large and small scale submarine slides and slumps	D_0 Large and small scale slumps as Webb and Cooper (1988), early small scale slumps

(Table 3.1) Deformation sequences in the Lake District as interpreted by various authors; the last column shows the system adopted in the present volume.



(Figure 3.4) Skiddaw Group exposures, near Buttermere. (A) is a horizontal surface. (B) Vertical roadside section in (A) looking towards 060°. Three fold phases are represented in these exposures. The steep plunge of the folds represents the dip of a limb fold, initiated during F_0. The D_1 phase is represented by the tight ENE–WSW folds and related cleavage, and D2 by open recumbent folds and crenulation cleavage which can only be viewed on vertical surfaces, where the other two phases cannot be seen (after Moseley, 1981, and notes by D. Aldiss B.Sc. thesis, Birmingham University, 1974).