Gasgale Crags and Whiteside

[NY 170 220]

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Highlights

Slump and gravity-slide structures, which formed through south-eastwards movement, towards the centre of the early Ordovician basin, are here refolded by late-Caledonian tectonic structures. The Gasgale Thrust probably post-dates formation of the Crummock Water Aureole, dated to *c.* 400 Ma, making it a late-Caledonian structure.

Introduction

Gasgale Crags and Whiteside afford excellent exposures which illustrate the characteristic structure of the Skiddaw Group (Early Ordovician) in the north-west of the Skiddaw Inlier. Some structures, previously interpreted as of tectonic origin, can be shown to be slump folds in the turbidites. Late-Caledonian folding, cleavage and thrusting are superimposed on these early structures.

The Skiddaw Inlier was originally surveyed by Ward (1876). The stratigraphy of the Gasgale–Whiteside area was first elucidated by Rose (1954), who recognized the Loweswater Flags overlain by the Mosser–Kirkstile Slates of Early Ordovician age. He also described the major tectonic style and the metamorphism of the Crummock Water Aureole. Jackson (1961, 1978) reviewed the stratigraphy of the Skiddaw Group, and recognized the Hope Beck Slates below the Loweswater Flags. An alternative stratigraphy was suggested by Simpson (1967); although his scheme has proved untenable, he was the first to identify polyphase deformation in the Skiddaw Group. His deformation sequence has since proved incorrect. Moseley (1972) gives details of the Whiteside site, in an overview of the polyphase deformation in the Skiddaw Group; Jeans (1974) also gives local details.

Description

The current interpretation of the stratigraphy and structure is that the bulk of Whiteside is composed of Loweswater Formation greywackes, about 900 m thick. These are overlain by the siltstones of the Kirkstile Formation, in excess of 1000 m thick, which is well exposed on Gasgale Crags (Figure 3.8). The Loweswater Formation is of Early Arenig age and the Kirkstile Formation for the most part of Late Arenig age.

The top of the Loweswater Formation and most of the Kirkstile Formation are affected by synsedimentary and early post-sedimentary slump folds. The sequence is refolded by F_1 and F2 tectonic folds (F_3–F_4 of Webb and Cooper, 1988). The tectonic folds (F_1), trend to the ENE and NE and have an associated cleavage (S_1); local developments of NW-trending cleavage (S_1?) and low-angled cleavage (S_2) and sideways-closing folds (F_2) also occur.

It will be seen (Table 3.1) that Webb and Cooper (1988, Table 1) propose a different 'D' (deformation) terminology from that used here. In this volume, D_1 (F_1, etc.) is assigned to the broadly contemporary Early Devonian deformation in the Caledonides, and D_0 (F_0) is used for gravity-driven deformation. The significance of the major lobate folds of the Darling Fell area, overturned to the south-east (designated F_1 by Webb and Cooper, 1988) has recently been reassessed. It is probable that they are in fact of F_1 and not F_0 origin, but they are broadly coaxial with the definite slump folds.

The Gasgale Crags are cut by a southerly directed thrust fault. The district is crossed by the elongate ENV-trending Crummock Water Aureole (Cooper *et al.,* 1988), the northern margin of which is exposed at the west end of Gasgale Gill.

Loweswater Formation

On Whiteside, the Loweswater Formation is exposed, dipping steeply southwards. Its basal contact with the Hope Beck Formation occurs on Dodd [NY 169 232] 1 km north of Whiteside. The bulk of Whiteside End is composed of medium- to thick-bedded greywacke beds, decreasing in thickness upwards [NY 1660 2169]. The formation is dominantly quartz-rich greywacke, and throughout exhibits well-developed sedimentary structures (Bouma, 1962) indicative of deposition from distal turbidity currents. Palaeocurrent indicators (flute and groove casts) show a southerly source (Jackson, 1961). The Loweswater Formation has an Early Arenig age, mainly within the *Didymograptus deflexus* and *D. nitidus* biozones.

Kirkstile Formation

The Kirkstile Formation, in excess of 1000 m thick, is dominantly siltstone with mudstone beds. Near its base, subordinate thin beds of quartz-rich greywacke (Bouma C units) also occur. The proposed type section for the base of the formation, and the rapid interbedded transition from the Loweswater Formation, is exposed on Whiteside End [NY 1660 2169]. The formation is poorly fossiliferous, of Late Arenig age, and yields evidence for the *Isograptus gibberulus* and *D. hirundo* biozones.

Slump folds

The upper part of the Loweswater Formation and much of the Kirkstile Formation are locally intensely folded by synsedimentary slump folds. These folds range in size from a few centimetres to ten metres or more and are typically recumbent to isoclinal. Typical slump folds, which occur west of Gasgale Gill [NY 1641 2095], are disharmonic and commonly bounded by bedding parallel shear planes. The slump and gravity-slide folds are mainly overturned to the south-east. These folds have the main cleavage superimposed across them, some are tightened and others refolded by the later tectonic folds; examples occur on Gasgale Crags [NY 179 221].

Tectonic folds and cleavages

On Whiteside End and Gasgale Crags, many examples of minor tectonic folds (F_1), with congruous axial-planar cleavages (S_1), occur. The axial planes and cleavages are mainly upright, northerly dipping (as at NY 1755 2211), but near the Gasgale Thrust they fan over to dip parallel to the fault, northwards at around 45°. Apart from the main cleavage (S_1), two other crenulation cleavages locally occur. One trends to the north or northwest and is mainly present as a lineation on bedding. The other is a late low-angle cleavage (S_2) with associated minor sideways-closing folds (F_2).

The Gasgale Thrust Fault

The Gasgale Thrust runs E-W along the foot of the main mass of Gasgale Crags. It dips northwards at 45–50° and thus has southerly-directed thrusting, and a throw of around 250 m. Here, the arenaceous lower part of the Kirkstile Formation is thrust over the less-competent siltstones higher in the formation; the lithological change picks out the fault. The Gasgale Thrust has a similar direction of throw and is subparallel to the Causey Pike Thrust which post-dates the Crummock Water Aureole (Cooper *et al.,* 1988). It is probable that both faults have a long history of movement, both pre- and post-aureole, with the final displacement occurring after the Early Devonian.

The Crummock Water Aureole margin

At the west end of Gasgale Gill [NY 1650 2111] the gradational northern margin of the Crummock Water Aureole is present (Cooper *et al.,* 1988). This elongate E-W-trending aureole, dated at around 400 Ma (Cooper *et al. ,*1988), was produced by an unexposed, probably granitic body, possibly along a shear zone. At the west of Gasgale Gill [NY 1641 2095] the slump-folded siltstone of the Kirkstile Formation is bleached and hornfelsed; the colour changed from dark to light grey and the rock has a hard flinty appearance. Weathered surfaces here show the slump folding far better than unmetamorphosed outcrops.

Interpretation

Early interpretations of the structures in the present locality and the site at Hassness as being tectonic in origin are summarized in the description of the latter. In the present site it is clear that there are at least two generations of structures, one attributed to a soft-sediment origin during the Ordovician and one to protracted late-Caledonian (early Devonian) deformation.

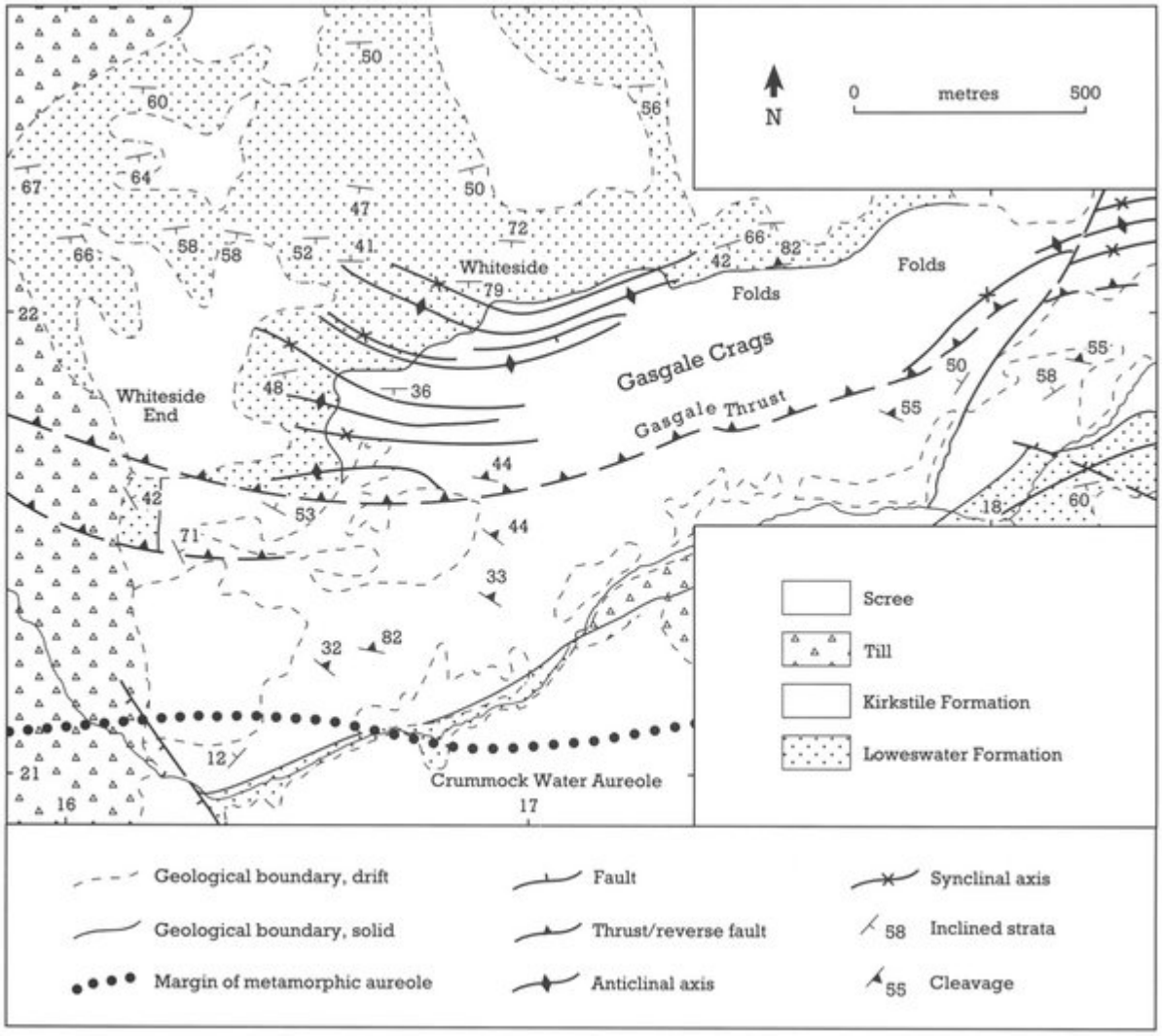
The Gasgale–Whiteside area typifies the normal stratigraphical, sedimentological, and structural character of the Skiddaw Group north of the Crummock Water Aureole–Causey Pike Fault Line. In the two areas either side of this, the Skiddaw Group shows different sedimentological and early fold histories, but similar tectonic fold histories. The Gasgale–Whiteside area shows southerly derived Arenig Series greywackes and siltstones. These distal turbidite facies are folded by slump folds (F_0), overturned in a south-easterly direction (Webb and Cooper, 1988, their F_1). This overturning is contrary to the source direction of sedimentation, and contrary to the westerly, overturned, gravity-slide structures developed further south (see Hassness). These early structures, along with later, open folding, pre-date the Borrowdale Volcanic Group (Llandeilo–Caradoc) and probably relate to strike-slip movements along the Crummock Water–Causey Pike Line. This line, which separates the opposed overturning directions of the slump folds of Hassness and Gasgale, may approximately mark the axis of a local depositional basin.

Caledonian structures are represented by the main ENE- to NE-trending folds and associated cleavage (F_1 and S_1), the thrusting along the Gasgale Fault and the late sideways-closing folds with low-angled cleavage (F_2 and S_2). The Crummock Water Aureole is also Caledonian; dated at *c.* 400 Ma, it post-dates the D_1 structures, but pre-dates the D_2 structures (Cooper *et al.,* 1988). It is post-dated and bounded by a southerly directed thrust at Causey Pike, with which the Gasgale Thrust might be synchronous. The latest movements on these thrusts therefore post-date D_1 but they may well have had a long history of movement, the early parts of which may have been related to the evolution of the sedimentary basin.

Conclusions

The Gasgale–Whiteside area demonstrates that some structures which have previously been interpreted as tectonic in origin were produced by slumping and the gravity-driven sliding sediments. The contrast of the westerly movements of the gravity folds at the Hassness site with the southeasterly movements at the present site, suggest that they lay on opposite sides of the local depositional basin in earliest Ordovician times. The site shows the local refolding of these slump folds by tectonic folds, with their associated cleavages (closely spaced fine parallel fractures), both refolding and cleavage being the product of the Early Devonian Caledonian Orogeny. The area also illustrates the relationships of these structures to the metamorphism at the margin of the Crummock Water Aureole and thrust movements on the Gasgale Fault. The aureole, the baked and chemically altered zone of rock caused by the emplacement of the igneous intrusion, was formed around 400 million years ago towards the end of the Caledonian mountain building episode. The Gasgale Fault is even later, having moved at the very end of the orogeny, although it may have its origins in the evolution of the sedimentary basin.

References



(Figure 3.8) Geological map of the Gasgale Crags and Whiteside area, based on Geological Survey map (NY 12 SE) surveyed by P. M. Allen, A. H. Cooper and B. C. Webb (see also Moseley, 1990, Figure 20).

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)	Open E-W folding, block faulting		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)
VOLCANO-TECTONIC UPLIFT BEGINS?	INITIATION OF ENE-TRENDING LAKE DISTRICT ANTICLINE?						
(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.