British Geological Survey

NATURAL ENVIRONMENT RESEARCH COUNCIL

Geological notes for the Silurian strata and their Quaternary cover on 1:10k sheets SD48NW, SD58NE (Old Hutton) and SD58NW

GLNB Programme

Internal Report IR/06/129

BRITISH GEOLOGICAL SURVEY

GLNB PROGRAMME

INTERNAL REPORT IR/06/129

Geological notes for the Silurian strata and their Quaternary cover on 1:10k sheets SD48NW, SD58NE (Old Hutton) and SD58NW

P Stone

Keywords

Silurian, Windermere Supergroup, Kendal Group, Bannisdale Formation, Kirkby Moor Formation

Bibliographical reference

STONE, P. 2006. Geological notes for the Silurian strata and their Quaternary cover on 1:10k sheets SD48NW, SD58NE (Old Hutton) and SD58NW. *British Geological Survey Internal Report*, IR/06/129. 16pp.

Keyworth, Nottingham British Geological Survey 2006

BRITISH GEOLOGICAL SURVEY

The full range of Survey publications is available from the BGS Sales Desks at Nottingham, Edinburgh and London; see contact details below or shop online at www.geologyshop.com

The London Information Office also maintains a reference collection of BGS publications including maps for consultation.

The Survey publishes an annual catalogue of its maps and other publications; this catalogue is available from any of the BGS Sales Desks.

The British Geological Survey carries out the geological survey of Great Britain and Northern Ireland (the latter as an agency service for the government of Northern Ireland), and of the surrounding continental shelf, as well as its basic research projects. It also undertakes programmes of British technical aid in geology in developing countries as arranged by the Department for International Development and other agencies.

The British Geological Survey is a component body of the Natural Environment Research Council.

British Geological Survey offices

Keyworth, Nottingham NG12 5GG

☎ 0115-936 3241 Fax 0115-936 3488
e-mail: sales@bgs.ac.uk
www.bgs.ac.uk
Shop online at: www.geologyshop.com

Murchison House, West Mains Road, Edinburgh EH9 3LA

☎ 0131-667 1000 Fax 0131-668 2683
e-mail: scotsales@bgs.ac.uk

London Information Office at the Natural History Museum (Earth Galleries), Exhibition Road, South Kensington, London SW7 2DE

☎ 020-7589 4090 Fax 020-7584 8270
☎ 020-7942 5344/45 email: bgslondon@bgs.ac.uk

Forde House, Park Five Business Centre, Harrier Way, Sowton, Exeter, Devon EX2 7HU

☎ 01392-445271 Fax 01392-445371

Geological Survey of Northern Ireland, Colby House, Stranmillis Court, Belfast BT9 5BF

☎ 028-9038 8462 Fax 028-9038 8461

Maclean Building, Crowmarsh Gifford, Wallingford, Oxfordshire OX10 8BB

☎ 01491-838800 Fax 01491-692345

Columbus House, Greenmeadow Springs, Tongwynlais, Cardiff, CF15 7NE

☎ 029–2052 1962 Fax 029–2052 1963

Parent Body

Natural Environment Research Council, Polaris House, North Star Avenue, Swindon, Wiltshire SN2 1EU

☎ 01793-411500 Fax 01793-411501
www.nerc.ac.uk

Foreword

This report is the published product of a field study by Dr P Stone carried out between 2003 and 2005. The report describes the geology of 1:10 000-scale Bedrock and Superficial Deposits Geology Series sheets SD 58 NE (Old Hutton) and parts of SD 48 NW and SD 58 NW, which constitute part of the England and Wales 1:50 000 series sheet 49, Kirkby Lonsdale. This report should be read in conjunction with the 1:10 000-scale maps. The work was completed as part of the British Geological Survey's Northern England – Alston Block Project led by Dr D Millward, who has also edited this report.

Acknowledgements

Drs N. H. Woodcock and N. J. Soper are thanked for their contributions to discussion of the Windermere Supergroup's stratigraphy and structure.

Contents

FIGURES

PLATES

Summary

The area described in this report forms part of the north-western sector of the Kirkby Lonsdale 1:50 000 sheet, England and Wales 49; it lies in the south-east of the English Lake District. Geologically, the area forms part of the south-eastern extremity of both the Lake District Lower Palaeozoic inlier as a whole, and of the main outcrop of the Windermere Supergroup. Two outcrops of Silurian rock are described, separated by Carboniferous strata belonging to the Dinantian, platform limestone succession of South Cumbria. The main geological boundaries are major faults trending broadly north to north-north-west, but in the north of the SD48NW sheet, the Carboniferous rocks are unconformable on those of Silurian age. The Silurian strata form parts of the Bannisdale and Kirkby Moor formations; these comprise the Kendal Group, the uppermost unit of the Windermere Supergroup. The Bannisdale Formation is made up of beds of fine-grained turbidite sandstone grading up to siltstone, and between about 50 cm and 1 m thick; these are interbedded with thinner units of banded siltstone and mudstone. An unusual thinly-bedded lithofacies is described from the top of the formation. The Kirkby Moor Formation is characterised by medium- to thickly bedded, generally fine-grained micaceous sandstone grading up into thin layers of mudstone or siltstone. Beds commonly range up to about 75 cm thick, more rarely to more than 1.5 m. A distinctive reddened, finer grained lithofacies appears within the Kirkby Moor Formation, and has been defined as The Helm Member at The Helm, to the south-east of Kendal. Folding and cleavage development affecting the Windermere Supergroup strata are described and assigned to the Acadian Orogeny, of Emsian (latest Early Devonian) age.

1 Introduction

The area described in this report forms part of the north-western sector of the Kirkby Lonsdale 1:50 000 sheet, England and Wales 49 (Figure 1). It lies to the south of the English Lake District and supports a sparse, hill-farming population. In the west, craggy hillsides rise to about 220m above sea level. To the east, drumlins become the dominant landscape feature with rolling hills rising to about 270 m above sea level. Geologically, the area forms part of the south-eastern extremity of both the Lake District Lower Palaeozoic inlier as a whole, and of the main outcrop of the Windermere Supergroup. Two outcrops of Silurian rock are described, separated by Carboniferous strata belonging to the Dinantian, platform limestone succession of South Cumbria. The main geological boundaries are major faults trending broadly north to north-north-west, but in the north of the SD48NW sheet, the Carboniferous rocks are unconformable on those of Silurian age. The Silurian strata form parts of the Bannisdale and Kirkby Moor formations; these comprise the Kendal Group, the uppermost unit of the Windermere Supergroup.

Early work in the area, notably by Sedgwick, has been discussed and listed by Oldroyd (2002). The results of the primary Geological Survey mapping were reported in the original Kirkby Lonsdale memoir (Aveline et al., 1872). More recent academic study of the area has developed the biostratigraphy (Shaw, 1968, 1971) and lithostratigraphy (King, 1992, 1994), the latter supported by sedimentology and facies analysis. There is one curious omission from the primary survey database in that no field slips or clean copy maps exist for about 8 km^2 in the south-east quadrant of SD58NE. It is not clear whether the original maps were completed but have since been lost, or whether the area was never mapped during the primary survey. In either case, the work reported here may be claimed as a belated contribution towards the completion of the primary geological survey of England.

2 Bannisdale Formation, Kendal Group

The Silurian strata on 1:10 000 sheet SD48NW are all assigned to the Bannisdale Formation. Beds of fine-grained sandstone grading up to siltstone, and between about 50 cm and 1 m thick, form the bulk of the sequence but are interbedded with thinner units of banded siltstone and mudstone. The proportion of the latter may be underestimated since it is the thicker beds that provide much of the obvious, craggy exposure. The banded siltstone intervals may be calcareous and are commonly picked out by bedding-parallel zones of weathered-out hollows. Overall, siltstone-grade rock dominates, and whilst sporadic, thicker and coarser sandstone beds do occur, they are not mappable over any great distance. This is the Bannisdale “mixed” facies described by Soper (1993) from adjacent ground to the west. Mudstone forms a thin top layer to most of the graded beds but is only rarely developed to a thickness of more than a few centimetres; bioturbation is rare and usually bed-parallel where seen. Internally, the beds are variously parallel or ripple cross-laminated. Their bases are generally sharp and may be loaded or carry current-induced grooves. Deposition was from repeated, low-density turbidity flows into relatively deep water (King, 1994).

The Bannisdale Formation was formally defined by Kneller et al. (1994), following a long history of traditional usage as the Bannisdale Slates. In total it is over 4 000 m thick but both the top and base are widely transitional, may be diachronous, and are not necessarily taken at a

uniform level across the whole of the southern Lake District outcrop (Rickards and Woodcock, 2005; Woodcock and Rickards, 2006). Neither the top nor the base of the formation crops out on SD48NW.

The formation is only sparsely fossiliferous (graptolitic) in the central and western part of its outcrop, but to the east, in the Middleton and Howgill Fells, graptolite faunas have been recovered from several stratigraphical levels. All are referable to the uppermost Ludlow, *leintwardinensis* Biozone (*sensu* Rickards and Woodcock, 2005; Woodcock and Rickards, 2006).

3 The Bannisdale Formation lithofacies exposed at Hill's Quarry

About 250 m thick.

Type section: the disused Hill's Quarry [SD 5963 8802] adjacent to the Old Scotch Road, SD58NE (Old Hutton).

Hill's Quarry worked a thinly bedded lithofacies at the very top of the Bannisdale Formation (Plate 1) which has a limited outcrop spanning the boundary of 1:10 000 sheets SD58NE and SD59NW (see Woodcock and Rickards (2006) for a description of the latter). The rocks are graded siltstone and mudstone but bedding surfaces are generally ill-defined and the overall appearance is of an irregularly banded, fairly uniform, dark and fine-grained sequence interrupted sporadically by coarser, siltstone to fine sandstone beds ranging up to about 30 cm thick. These interbeds are commonly cross-laminated, and weather to a pale brown colour that is usually a consequence of a carbonate-rich matrix. The mudstone – siltstone sequences are pervasively bioturbated, and it is this feature that contrasts with the broadly similar, but largely unbioturbated strata of the Bannisdale Formation (*sensu stricto*). The bioturbation seen at Hill's Quarry is both penetrative and bed-parallel, and was used by Shaw (1968, 1971) to characterise part of his Underbarrow Flags; subsequently formalised as the Underbarrow Flag Formation by Lawrence et al. (1986) and the Underbarrow Formation by King (1994).

The Underbarrow Formation has proved a difficult concept in subsequent work. Shaw's original definition was largely in biostratigraphical terms and different outcrops of his Underbarrow Flags prove to have different lithofacies characteristics with diachronous relationships. The current tendency is to subsume most of the "Underbarrows" into the uppermost Bannisdale Formation (Rickards and Woodcock, 2005; Woodcock and Rickards, 2006) and that is the policy adopted in this account. There may well be some merit in separating out the resulting, distinctive bioturbated top of the Bannisdale Formation as the Hill's Quarry Member, but a formal definition is not possible on the basis of the information currently available.

Around Hill's Quarry the Bannisdale Formation strata occupy the core of an open anticline plunging gently eastwards, in which direction the putative Hill's Quarry Member is overlain by the medium- to thickly bedded sandstones of the Kirkby Moor Formation. The contact is transitional, and lies within an area of poor exposure mostly on the adjacent SD 68 NW 1:10,000 sheet, but is there regarded as closely mappable (Woodcock and Rickards, 2006). To the west, the anticlinal, Hill's Quarry outcrop of the uppermost Bannisdale Formation is cut out by a substantial fault trending NNE–SSW. It throws down to the east so that the Bannisdale

Formation rocks are juxtaposed against strata of the Kirkby Moor Formation. As a result, the base of the putative Hill's Quarry Member is not seen, and therefore it cannot be adequately defined from this area alone.

4 Kirkby Moor Formation, Kendal Group

Most of the Lower Palaeozoic strata at outcrop across 1:10,000 sheets SD 58 NE and NW are assigned to the Kirkby Moor Formation. This unit was formally adopted by Kneller et al. (1994) following descriptions by Lawrence et al. (1986), but was recognised in all earlier stratigraphical schemes as the Kirkby Moor Flags. Traditionally, the type area has been taken at "Kirkby Moor" but this is a poorly-defined area, perhaps intended to be near Kirkby Lonsdale and not to be confused with the "Kirkby Moor" in Furness [SD 260 845] where the sequence exposed ranges no higher than the Bannisdale Formation. However, this distinction is not clear from the early literature, as also noted by Oldroyd (2002, footnote to p 181). Good sections are seen in the vicinity of Benson Knott [SD 548 941] to the east of Kendal, which is referred to as a type area by Furness et al. (1967). Alternative good sections are identified by Lawrence et al. (1986) at Black Crag [SD 4647 9933] to the west of Kendal (cited as the type section by Kneller et al. (1994)), and are listed by Woodcock and Rickards (2006) from the area to the east of that described in this report. Within the area described here, good, representative exposure of the Kirkby Moor Formation can be seen across the craggy hillsides eastwards from Crosslands Farm, [SD 573 865] to [SD 589 870]. In total the formation may exceed 1000 m in thickness but only the lower half, approximately, is seen in the area described here.

The formation is characterised by medium- to thickly bedded, generally fine-grained micaceous sandstone grading up into thin layers of mudstone or siltstone at the top of the beds. These commonly range up to about 75 cm thick and more rarely to more than 1.5 m, although many of the thicker beds may be amalgamated (Plate 2). The base of the formation, above the Hill's Quarry lithofacies of the Bannisdale Formation, is marked by a relatively abrupt appearance of thick, fine-grained sandstone beds; elsewhere, a more gradual transition over about 50 m has been reported (Lawrence et al., 1986; Woodcock and Rickards, 2006). The thickness of individual beds seems to be variable on a "pinch and swell" pattern. Convolute lamination and disruption of bedding by de-watering are common and characteristic features, whilst hummocky cross-stratification is widespread. Some beds have strongly loaded bases; others have wave-rippled tops. The fine-grained tops to the beds may be bioturbated, but bioturbation is by no means as pervasive as in parts of the underlying, uppermost Bannisdale Formation. Trace fossils occur both as bed-parallel trails and as penetrative burrows, of which U-shaped examples were noted in several places.

Lenticular accumulations of shell debris are widespread, though never common. Most occur at the bases of beds as a lag deposit (Plate 3). Good examples within the area described in this report were observed at Crow Hill [SD 5400 8680] and immediately east of the M6 bridge over the minor road between Bracken Halls and Crosslands [SD 5590 8626]. At both of these localities small snails are the dominant component of the fauna, but Shaw (1971) describes a more extensive regional assemblage that includes brachiopods, ostracods and trilobites. A biostratigraphic position high in the Ludlow (or perhaps into the Přídolí) is indicated.

The Kirkby Moor Formation has all the characteristics of deposition in a shallow marine environment (King, 1994). The bed thickness and internal structures suggest deposition from relatively high-energy turbidite flows sourced from an abundant sediment supply. The typical

bed-form has, in upward sequence, a locally erosive base, a shelly lag accumulation, hummocky cross-stratification, large-scale convolution, ripple cross-lamination, and bioturbation. Overall, this would seem to indicate a brief erosive phase with subsequent deposition from the waning flow before a quiescent interval preceded the next flow. The presence of hummocky cross-stratification is indicative of deposition from storm-generated waves in relatively shallow water. The large-scale and widespread convolution, caused largely by de-watering, suggests rapid deposition.

5 The Helm Member, Kirkby Moor Formation

Up to c. 300 m thick.

Type section: disused quarry on the north-west side of The Helm [SD 5306 8909]. Type area: The Helm [SD 532 890].

At The Helm [SD 532 890], about 2 km to the south-east of Kendal, a distinctive reddened, finer grained lithofacies appears within the Kirkby Moor Formation, and has been defined as The Helm Member by King (1994). The strata had been previously assigned by Shaw (1971) to his *Scout Hill Flags*, now redundant. King also noted one other occurrence of The Helm Member, further south in a small, disused quarry [SD 5912 8333] to the north of Old Town. Although this locality lies on the SD 58 SE sheet the site was visited, but only to establish that the old quarry had been infilled and was now overgrown. The very limited exposure that survives shows rock that is not emphatically similar to The Helm Member, although it is finer grained and more thinly bedded than the characteristic sandstones of the Kirkby Moor Formation, and is patchily reddened. It is possible that this Old Town example is of a similar lithofacies to The Helm Member (*sensu stricto*) but is a thinner unit, and may be interbedded in the Kirkby Moor Formation at a different stratigraphical level.

The Helm Member in its type area (Plate 4) comprises finely bedded to laminated siltstone and mudstone, with the individual sediment layers ranging from 2 mm up to about 10 mm. The bedding is irregular and some of the siltstone layers appear as lenticular, cross-laminated ripples. Fine-grained sandstone interbeds range up to about 50 cm thick and increase in abundance towards the base of the sequence, where they carry tabular cross-bedding. Bioturbation is widespread in the mudstone and siltstone, though it is by no means pervasive. It usually shows as irregular, branching trails on bedding surfaces whilst some surfaces are pitted, perhaps indicating emergent burrows, although there is no corresponding vertical expression. Small mud flakes are imbricately entrained in some of the thicker siltstone and fine-grained sandstone beds. Rare, small accumulations of mostly fragmentary shell material were reported by Shaw (1968) and King (1994) from some of the sandstone beds, but were not noted during the re-survey reported here. The alternating silt and mud laminae, with variable ripple cross-lamination, that form the bulk of The Helm Member suggest deposition in a shallow-water environment subject to irregular wave action. King (1994) suggested that the member originated as tidal mudflats in estuaries or lagoons, or behind barrier islands or sand bars.

The Helm Member in its type area is entirely contained within a NE–SW fault plexus that merges at its south-west end with a major NNW–SSE fault throwing down Carboniferous strata to the west. The dip is consistently to the NE at around $20\text{-}30^{0}$. The base of the member is transitional and taken where laminated siltstone and mudstone become dominant over more thickly bedded sandstone; evidence for this is provided by archival data and the transitional base

is not currently exposed. The top of the member is taken where unreddened, fine-grained sandstone beds appear [e.g. SD 5346 8963] and then dominate the sequence after a short transitional interval of a few tens of metres. The dip and outcrop size indicate a thickness for the member of up to at least 250 m, assuming there is no structural repetition. This is greater than the approximately 150 m estimated by King (1994) in her original definition. King places The Helm Member high in the Kirkby Moor Formation, but its precise position is uncertain. The fauna described by Shaw (1968, 1971) is indicative of a Přídolí age.

6 Carboniferous rocks

The contacts between the Silurian strata and younger, Carboniferous rocks are mostly faulted, but in several places an unconformable relationship is preserved. In the north of SD48NW, beneath Whitbarrow Scar [SD 4360 8980] limestone (a dark grey packstone, locally dolomitised) of the Martin Limestone Formation rests unconformably on the folded sandstones and siltstones of the Bannisdale Formation. Further east, spanning the north-east and north-west corners respectively of SD58NW and NE, an outlier of the Martin Limestone Formation occurs in the Strickley area [SD 5485 8962], but is largely unexposed.

7 Structure

All of the folding and cleavage development affecting the Windermere Supergroup is now regarded as Emsian (latest Early Devonian) in age, produced during the Acadian Orogeny. A recent review of the pertinent regional evidence is provided by Soper and Woodcock (2003).

Across the western outcrop of Silurian rock, on the SD48NW sheet, Bannisdale Formation strata are folded about upright, relatively open folds with hinges plunging around 20^0 to the ENE (Figure 2). The folds are symmetrical but south-dipping limbs appear to be longer than the north-dipping limbs. The effect of this is to bring in higher levels of the formation southwards. In regional terms, the area lies on the south-east limb of the large-scale Lowick Anticline. A strong, upright slaty cleavage is developed approximately parallel to the axial planes of the folds. In adjacent parts of the Windermere Supergroup outcrop it can be demonstrated that the cleavage is clockwise transecting by a few degrees (e.g. Soper, 1993) but that phenomenon cannot be shown from the SD48NW data.

Further east, across the northern part of SD58, bedding strike in the Kirkby Moor Formation is approximately east-west, and the strata are locally folded about hinges that plunge only a few degrees eastward (Figure 2). The folds are slightly asymmetrical, with the north-dipping limbs usually steeper than the gently-inclined, south-dipping limbs, to produce north-verging fold pairs. These may culminate in a broad, large-scale anticlinal hinge zone trending about ESE through Esset Hill [SD 5815 8843], but limited exposure to the north of this line prevents a conclusive assessment. The Hill's Quarry outcrop of Bannisdale Formation strata lies in the hinge of an open anticline that also plunges a few degrees to the east.

Across the northern half of SD58 cleavage is only sporadically developed as a slaty fabric in the finer-grained rocks, and a more irregular and spaced, pressure solution fabric in the sandstones. It is generally steeply inclined but its strike suggests a clockwise transection of up to 20^0 (Figure 2). This is similar to the situation described from the adjacent ground to the east by Woodcock

and Rickards (2006), but is in marked contrast to the approximately axial planar relationship seen in the Bannisdale Formation outcrop on SD48NW. However, the wide variation in cleavage attitude seen across the northern half of SD58 makes it unlikely that the degree of transection is uniform.

Major faults crossing the area are orientated around NNE–SSW in the east but tend more towards NNW–SSE in the west; they form part of a widespread, regional pattern. The two fault trends merge at the western margin of the Silurian outcrop. In the extreme north-west of SD58NE near Saint Sunday's Bridge [SD 5510 8994], and across into the adjacent north-east corner of SD58NW around Strickley [SD 5485 8962], an outlier of Carboniferous strata is contained between two faults, the eastern trending NNW and the western trending just east of north; these faults merge northwards and the southern margin of the outlier is an unconformity. A little further west on SD58NW, the NNE-trending fault slice containing The Helm Member runs into the NNW-trending fault, with major downthrow to the west, that juxtaposes Silurian and Carboniferous strata. A similar picture emerges from the Bannisdale Formation outcrop on SD48NW. There, the major fault throwing Carboniferous strata down against the Silurian rocks runs about NNW–SSE, but the Silurian outcrop is cut by faults trending just east of north, which appear to partition fold development into discrete fault blocks. These latter faults were clearly active during the Acadian deformation, but faults affecting the Carboniferous were either reactivated or instigated later, probably as an end-Carboniferous extensional effect contemporaneous with Variscan deformation farther south.

8 Quaternary geology

There is a marked difference in the landscapes of the two areas of Silurian rocks described in this report, due mainly to the contrasting effects of glaciation. In the west, across the Bannisdale Formation on SD48NW, the principal effect was erosion; superficial deposits are thin or absent across the higher ground, and the hillsides feature numerous rocky crags and knolls. In the east, across the Kirkby Moor Formation on SD58NE, the principal effect was deposition; a thick blanket of glacial till covers much of the area, drumlins are a prominent feature, and the topography is smooth and rounded. In the west, small crag and tail features, ice-moulded rock knolls and rare striae all support a flow of ice from north to south. The drumlins in the east have a general NE–SW orientation becoming more north-south in the south-east, suggesting some divergence of ice flow around the higher ground extending northwards from Kitridding Hill [SD 582 843]. Till sections of at least 2 m are widespread in the eastern area and reveal a coarse rubbly mixture of mostly sub-angular, local sandstone blocks closely packed in a brown, sandy-clay matrix. Perched, erratic boulders of the distinctive Shap Granite were observed at several localities on SD58 NW & NE, for example at the south-west end of The Helm [SD 5290 8863], but none were noted *in situ* in till exposures.

The major river valleys drain southwards into the estuary of the River Kent, and thence into Morcambe Bay. The River Winster flows southwards in a broad valley that bisects sheet SD48NW. Most of the Silurian strata described in this report lie to the west of the river, with the east side dominated by the mesa-like Carboniferous limestone massif of Whitbarrow. In the southern part of SD48NW the valley floor sediment is regarded as lacustrine, a continuation of the moraine-dammed lake deposits seen to the south. Northwards these merge with normal alluvial spreads but the dividing line drawn is somewhat arbitrary. Moundy moraine shown at the southern margin of the sheet is equivocal in itself, but continues the more distinctive spreads mapped further south.

The eastern area of Silurian strata described here is divided by the valley occupied by Peasey Beck, which coincides approximately with the sheet boundary between SD58NW and NE. The valley floor alluvium locally merges at its margins with alluvial fan gravels brought down from tributary streams. Moundy, valley-side features with the appearance of kame terraces are made up of coarsely cross-bedded sand and gravel, for example around Gatebeck [SD 549 859] and have been interpreted as glaciofluvial outwash deposits.

9 Archived material

Photographs:

- Uppermost Bannisdale Formation strata exposed in Hill's Quarry. P616301 (Plate 1), P616302, P616309.
- Typical outcrop of Kirkby Moor Formation sandstone. P616306 (Plate 2), P616307.
- Wall constructed from slabs of Kirkby Moor Formation sandstone. P616308.
- Shell lag accumulation in the Kirkby Moor Formation. P616303 (Plate 3).
- The Helm Member in its type area at The Helm. P616304 (Plate 4).
- Kendal from The Helm; Kendal castle occupies a prominent drumlin in the centre of the picture. P616305.

Specimens:

- LX 990. A typical example of bioturbated siltstone from the uppermost Bannisdale Formation at Hill's Quarry. SD 5963 8803.
- LX 991. Typical examples of reddened, laminated micaceous siltstone from the Helm Member of the Kirkby Moor Formation in its type area at The Helm, near Kendal. SD 5306 8907. a – with bed-parallel bioturbation and possible burrow pits superimposed on a rippled surface; b – with current-imbricated mud flakes.
- LX 992. Shelly lag accumulation forming a lens within the Kirkby Moor Formation, from a road cutting adjacent to an underpass beneath the M6. SD 5591 8626.
- LX 993 (in 3 pieces). Shelly lag accumulation (mostly snails and brachiopods) forming a lens within the Kirkby Moor Formation at Crow Hill, SD 5400 8681.

References

Most of the references listed below are held in the Library of the British Geological Survey at Keyworth, Nottingham. Copies of the references may be purchased from the Library subject to the current copyright legislation.

AVELINE, W. T., HUGHES, T. M. and, TIDDEMAN, R. H. 1872. The geology of the neighbourhood of Kirkby Lonsdale and Kendal. *Memoir of the Geological Survey, England and Wales*, Sheet 98SE.

FURNESS, R. R., LLEWELLYN, P. G., NORMAN, T. N. and RICKARDS, R. B. 1967. A review of Wenlock and Ludlow stratigraphy and sedimentation in N.W. England. *Geological Magazine*, **104**, 132-147.

KING, L. M. 1992. *A basin study of the early Palaeozoic Windermere Group, NW England*. Unpublished PhD thesis, University of Cambridge.

KING, L. M. 1994. Turbidite to storm transition in a migrating foreland basin: the Kendal Group (Upper Silurian), northwest England. *Geological Magazine*, **131**, 255-267.

KNELLER, B. C., SCOTT, R. W., SOPER, N. J., JOHNSON, E. W. and ALLEN, P. M. 1994. Lithostratigraphy of the Windermere Supergroup, Northern England. *Geological Journal*, **29**, 219-240.

LAWRENCE, D. J. D., WEBB, B. C., YOUNG, B. and WHITE, D. E. 1986. The geology of the late Ordovician and Silurian rocks (Windermere Group) in the area around Kentmere and Crook. *Report of the British Geological Survey*, **18/5**, 32 pp.

OLDROYD, D. R. 2002. *Earth, water, ice and fire: two hundred years of geological research in the English Lake District*. Geological Society, London, Memoirs, **25**, 328 pp.

RICKARDS, R. B. and WOODCOCK, N. H. 2005. Stratigraphical revision of the Windermere Supergroup (Late Ordovician – Silurian) in the southern Howgill Fells, NW England. *Proceedings of the Yorkshire Geological Society*, **55**, 263-285.

SHAW, R. W. L. 1968. *The faunal stratigraphy of the Kirkby Moor Flags of the type area near Kendal, Westmorland*. Unpublished PhD thesis, University of Newcastle-upon-Tyne.

SHAW, R. W. L. 1971. The faunal stratigraphy of the Kirkby Moor Flags of the type area near Kendal, Westmorland. *Geological Journal*, **7**, 359-380.

SOPER, N. J. 1993. The Silurian rocks of 1:25 000 Sheet SD38, Low Furness, Cumbria. *British Geological Survey Technical Report*, WA/93/16.

SOPER, N. J. and WOODCOCK, N. H. 2003. The lost Lower Old Red Sandstone of England and Wales: a recoerd of post-Iapetan flexure or Early Devonian transtension? *Geological Magazine*, **140**, 627-647.

WOODCOCK, N. H. and RICKARDS, R. B. 2006. Geological notes and local details for 1:10 000 sheet SD68NW (Middleton) and part of sheet SD68NE (Gawthrop). *British Geological Survey Technical Report*, WA/06/101.

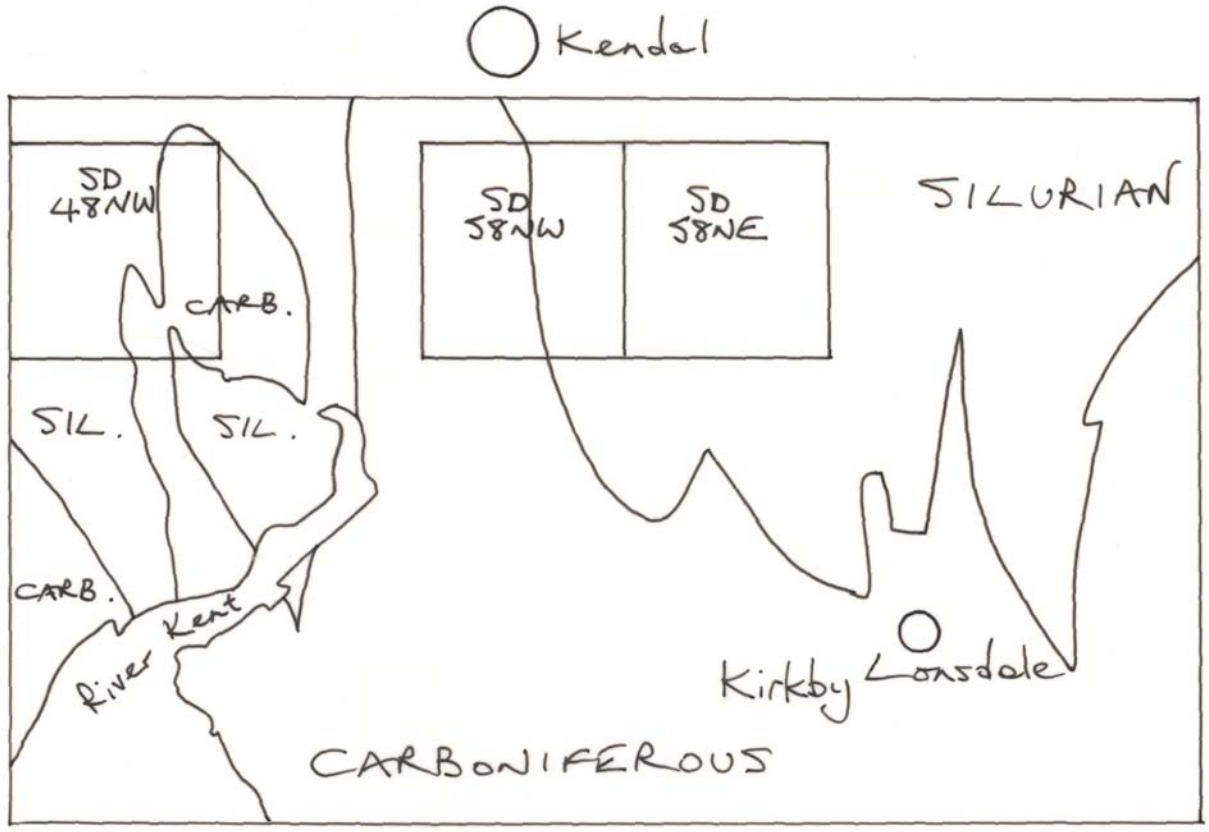

Figure 1 Outline geology of the Kirkby Lonsdale 1:50 000 Sheet (E&W49) showing the locations of the areas described in this report.

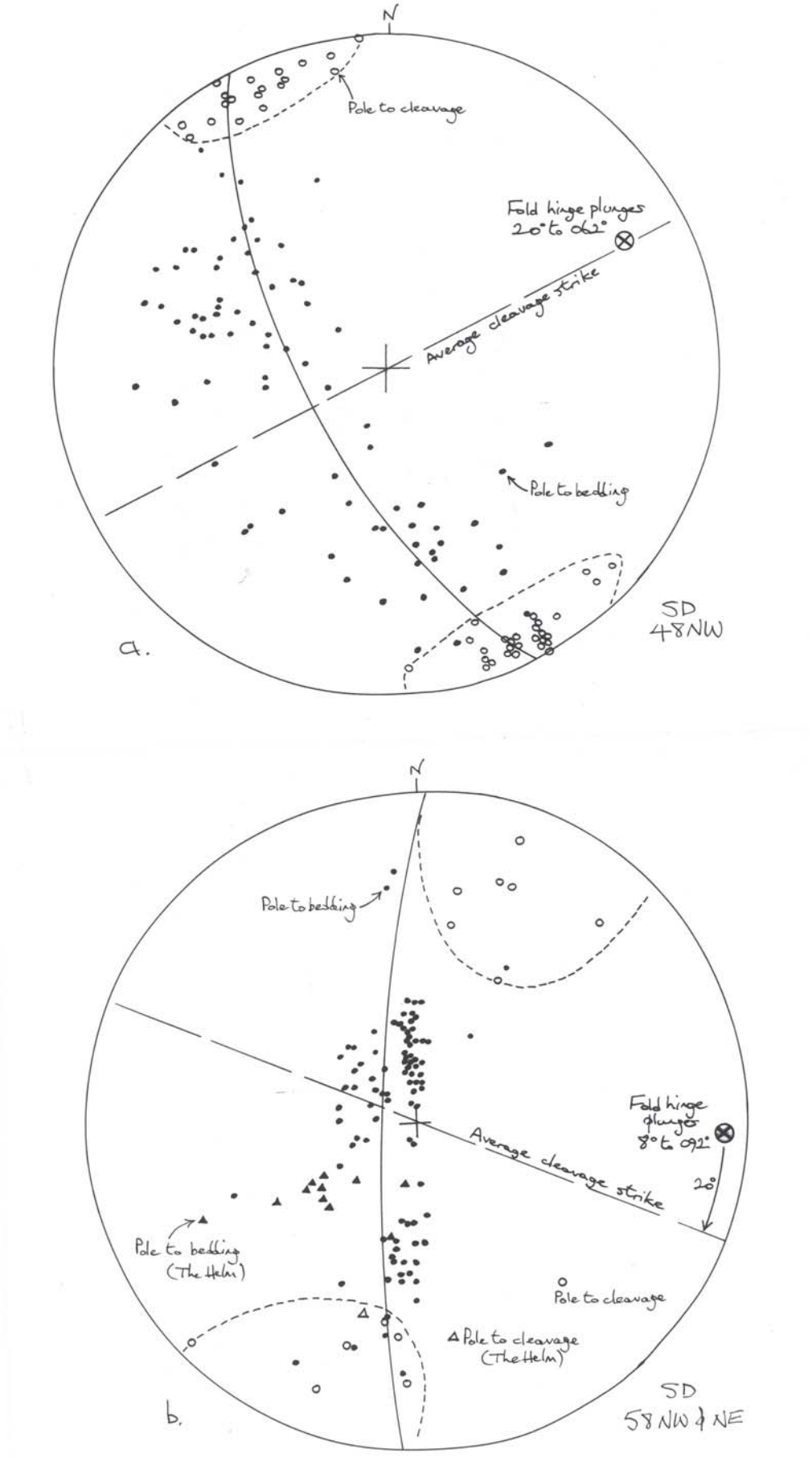

Figure 2: Equal-area stereogram plot of poles to bedding and cleavage on SD58NW and NE. a. Bannisdale Formation on SD48NW. b Kirkby Moor Formation

Plate 1: The uppermost Bannisdale Formation as exposed in Hill's Quarry [SD 5963 8802]. P616301.

Plate 2: Typical appearance of the Kirkby Moor Formation in a small, quarried exposure [SD 5893 8725] with the Howgill Fells in the background. P616306.

Plate 3: Shell lag accumulations in the Kirkby Moor Formation [SD 5590 8626]. P616303.

Plate 4: Reddened, laminated siltstone of The Helm Member in its type area at The Helm [SD 5300 8866]. P616304.