Natural Environment Research Council

British Geological Survey

Onshore Geology Series

TECHNICAL REPORT WA/89/28

Geology of the Quernmore area

1:10 000 sheet **SD55NW**

Part of 1:50 000 Sheet 59 (Lancaster)

R A HUGHES

Geographical index
Lancaster, Bowland Fells, Quernmore

Subject index
Geology, Craven Basin, Carboniferous, Namurian, Arnsbergian, Kinderscoutian

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1. INTRODUCTION

This report describes the surface geology of the 1:10 000 Series sheet SD 55 NW, part of the 1:50 000 Series sheet 59 (Lancaster). Detailed descriptions of the geological sequence encountered in the Wyresdale Tunnel, which crosses beneath the eastern part of this area, can be found in Johnson (1981) and Wilson *et al.* (1989).

The area was first mapped at the 1:10 560 scale by J.R. Dakyns and R.H. Tiddeman in 1875-76 and published at the 1:10 560 scale in 1880 as parts of the Lancashire County Series sheets 30, 31, 34 and 35. In 1884 the geological information was published at the 1:63 360 scale as part of the Old Series sheet number 59 (Lancaster). During the present survey, the area to the south-east of the Quernmore to Garstang road (approximately three quarters of the sheet) was mapped by Dr A.A. Wilson in 1984, as part of the BGS work commissioned by the North-west Water Authority in response to the Abbeystead Explosion Public Enquiry. Several, significant and previously unknown marine band localities were discovered by Dr Wilson during this survey. The remainder of the sheet was surveyed by Dr R.A. Hughes in 1988. A limited amount of field work was carried out by Dr A Brandon in 1990 and parts of the geological mapped revised.

The area is one of hilly pastureland, marginal to the high, heather covered moorland of the Bowland Fells to the north-east. The rugged escarpment of Clougha extends into the north-east corner of the sheet, the highest point [5492 5939] being 421 m above Ordnance Datum. In the west, the north-east trending valley of the River Conder is the major topographical feature, and drains to the south. The lowest point is at the western end of the Conder valley [579 500], where elevation is less than 45 m above Ordnance Datum. To the east of the Conder valley the main lines of drainage flow from north to south along a series of glacial meltwater channels. The only centre of habitation is the ribbon development of Quernmore [59 51].

The north-eastern part of the area was mapped by Moseley (1954). A detailed geological log of the Wyresdale Tunnel, constructed to link the drainage systems of the Rivers Lune and Wyre, was made by E.W. Johnson, N. Aitkenhead, J.I. Chisholm, R.S. Arthurton, and D.J.C. Mundy of the BGS, during construction. The results were published in a sedimentological synthesis by Johnson (1981), who described the succession in terms of a prograding delta-front sequence. Following the Wyresdale Tunnel explosion in May 1984, the BGS surveyed the area in an attempt to identify the source and the trap of the methane which exploded. A description of the geology as found during this survey is given in Wilson, Brandon, and Johnson (1989). All fossils recorded in this report were identified by Dr N.J.Riley.

Subsequent to the preparation of the original draft report the stratigraphy and geological map of the area has been revised, particularly with regards to the Roeburndale Formation. This report therefore includes parts revised by Dr A Brandon in consultation with Dr A A Wilson.

2. GEOLOGICAL SUCCESSION

DRIFT

QUATERNARY

- Landslip
- Peat
- Head
- Alluvial fan deposits
- River terrace deposits
- Alluvium
- Glaciofluvial sand and gravel
- Glacial sand and gravel
- Moraine
- Till

SOLID

MILLSTONE GRIT

- Millstone Grit Group, undivided
  - Ellel Crag Sandstone
  - Dolphinholme Mudstone
  - Wellington Crag Sandstone
- Crossdale Mudstone Formation
- Silver Hills Sandstone Formation
- Claughton Formation
  - Heversham House Sandstone
- Caton Shale Formation
- Ward's Stone Sandstone Formation
- Roeburndale Formation
  - Close Hill Siltstone Member
  - Rowton Brook Sandstone
  - Hall Gill Sandstone

3. MILLSTONE GRIT GROUP

3.1 ROEBURNDALE FORMATION

This formation is of delta slope facies and consists predominantly of grey, finely sandy micaceous shaly siltstones with interbeds of fine- to medium-grained, sandstones, which are probably mostly of turbidite origin. Three marine bands are known from the general area (Wilson *et al.*, 1989) but only one is known to be exposed within the area of the sheet.

3.1.1 *the sequence north-west of the Quernmore Fault*:

These rocks are not exposed on the present sheet, where possibly up to 100 m of strata are present, but to the north they are known to consist of interbedded sandstones and siltstones. Two topographical features traced onto the present sheet from the north are interpreted to be caused by sandstones. The rocks above this sandstone are known from a borehole [5021 5989] (SD 55NW /9) near to Langthwaite Farm. The borehole revealed dark grey, sandy siltstones to a depth of 15.10 m, below 1.62 m of till and topsoil. Spores recovered from a depth of 10.6 m in this borehole indicate a late P_2-E_2b age (Biostratigraphy Research Group Report PD 88/347). Evidence from the sheet to the north suggests that these rocks may be in the lowest part of the Roeburndale Formation. The Cravenoceras cowlingense Marine Band probably occurs just above this sequence but does not crop out within the area of the sheet.

3.1.2 *Hall Gill Sandstone*:

With the exception of the ground to the north-west of the Quernmore Fault, the oldest rocks present on the sheet belong to the Hall Gill Sandstone. The upper part of the sandstone is exposed in the core of the Grizedale Anticline in the south-east of the sheet, but the base does not crop out. The sandstone was once quarried in the area close to the axis of the anticline, and several small exposures are present in small, now disused quarries. The most informative of these exposures [5489 5602] is some 100 m to the west of Abbeystead Lane, where 0.9 m of brown, flaggy, fine- to medium-grained

sandstone is exposed. Other, smaller exposures nearby show similar lithologies. In the tunnel the Hall Gill Sandstone was encountered at 1500 m inbye from the Abbeystead Portal.

3.1.3 *strata between the Hall Gill Sandstone and the Rowton Brook Sandstone*: This part of the succession is well known from the Wyresdale Tunnel to the east of the present area.

In the tunnel, this part of the succession consists of siltstones, silty sandstones and mudstones. Spectacular slump folds, sedimentary boudinage, and microfaulting were seen in the tunnel, notably at 700 and 975 m inbye of Rowton Portal.

Sandstones are present at the surface in two sections in the south of the area. In Sparrow Gill [532 560] are exposures of flaggy, thinly bedded, fine-grained sandstones, dipping at up to 13 degrees to the east. The most complete exposure, on the east bank of Sparrow Gill [5326 5591], shows 4 m of these sandstones. In Smithy Beck [535 567] fine-grained sandstones up to 2.5 m thick are present in a thickness of 8.8 m of interbedded sandstones, siltstones, and mudstones. Other small exposures of this part of the sequence occur in the headwaters of Damas Gill [53 58], north of Hare Appletree Farm. Several discontinuous exposures here show the sequence to consist of interbedded, thin, fine-grained sandstones, siltstones and sideritic mudstones.

3.1.4 *Rowton Brook Sandstone*:
The Rowton Brook Sandstone, up to 50 m thick, is named after Rowton Brook, a westerly flowing tributary of the River Conder [53 59]. Several exposures are present to the east of Rooten Brook Farm [529 593]. The most complete section is on the south bank of Rowton Brook [5347 5916] where up to 7 m of thinly bedded, fine- to medium-grained sandstones overlie 1.5 m of slumped siltstones. The same sandstone has also been worked in the vicinity of Withered Hills [53 58]. North of the Abbeystead to Quernmore road are two, small, long disused quarries [531 585] in which are exposed up to 1.5 m of

thin-bedded, fine-grained sandstones. At one of these quarries [5312 5844] excellent flute casts can be seen at the base of the sandstone (Wilson *et al.*, 1989, plate 4a).

The Rowton Brook Sandstone also occurs in the extreme south-eastern corner of the sheet. Here, on the southern limb of the Grizedale anticline, the sandstone is concealed beneath thick drift deposits.

The likely correlative of the Rowton Brook Sandstone in the tunnel is between 315 m and 490 m inbye from the Rowton Portal, and consists of four discrete sandstones with siltstone interbeds. The sandstones have erosive bases and contain intraformational faults.

3.1.5 *strata between the Rowton Brook Sandstone and the Close Hill Siltstone Member*:
Scattered and generally poor exposures show that this part of the sequence, possibly 40m thick, consists dominantly of mudstones, with silty mudstones and thin, fine-grained sandstones. Evidence of syn-sedimentary deformation is common. The Eumorphoceras ferrimontanum Marine Band is inferred to lie within this sequence of strata but is not exposed. At least two mappable sandstones are present and are thought to overlie the marine band.

About 0.8 m of fine-grained sandstone exposed [5279 5920] adjacent to Rooten Brook Farm is part of a thicker sandstone unit which forms a strong topographical feature along strike to the south, and on which are abundant fine- to medium-grained sandstone blocks. These rocks are mapped as a discrete sandstone unit which is believed to occur above the E. ferrimontanum Marine Band.

3.1.6 *Close Hill Siltstone Member*:
The siltstones from 40 m above the Rowton Brook Sandstone form several scars along a 1 km length of Rowton Brook and are characterised by layers with sporadic but distinctive, huge silty limestone nodules up to 0.8 m thick and 1.5 m wide.

The largest scar [5407 5909] in 22 m of silty mudstone, including 5 m striped with siltstone bands, shows a listric fault which flattens out westwards from 45 to 0 degrees. The beds below the fault are nearly horizontal whilst those above the fault dip at 45 degrees parallel to the fault plane, a configuration different from the back-tilted strata more usually associated with syn-depositional listric faulting. Slumped beds are also seen just below the Rowton Brook Sandstone. Silty mudstones with *Sanguinolites* sp. and cf. *Curvirimula* sp. were noted in a Rowton Brook tributary [5328 5894].

3.1.7 *strata between the Close Hill Siltstone Member and the base of the Ward's Stone Sandstone*:
Exposures [5241 5917] just south of Low Pleasant show approximately 2 m of slumped, fine-grained sandstones overlying 0.55 m of contorted mudstones with enclosed sandstone balls, overlying 1 m of fine-grained sandstones. Along strike from these sandstones in Rowton Brook [5249 5941] upstream from Brackenbrae are exposed 4 m of fine-grained sandstones. These sandstones form a topographical feature immediately east of Clougha Cottage [522 589].

Further exposures [5235 5933] through rocks of this interval south-east of Brackenbrae show approximately 10 m of sideritic mudstones. An exposure [5241 5930] some 60 m upstream from here shows 4 m of sideritic mudstones, isoclinally folded by syn-sedimentary slumping, overlying 1.5 m of silty mudstone with sandstone lenses, and at least 1.2 m of fine-grained sandstones (Wilson, *et al.*, 1989, plate 4b). South of Rigg Plantation [525 597] a number of closely spaced bell pits show where coal trials were attempted. Small exposures in the area and the borehole SD 55 NW/4 show the rocks to be mudstones and silty mudstones.

The *Eumorphoceras yatesae Marine Band* is known on this sheet from one very small and deeply weathered exposure [5313 5943] north-east of Rooten Brook Farm, discovered by Dr A.A. Wilson. This section was previously assigned to the Eumorphoceras ferrimontanum Marine Band (Wilson *et al.*, 1989). The fauna

obtained from the dark grey mudstones here consists of *Obliquipecten* sp., *Posidonia corrugata*, Orthocone fragments, and crinoid ossicles, and is not diagnostic of the marine band.

3.1.8 *the area enclosed by the Longmoor, Greenalls Farm and Mount Vernon faults*:

Four isolated outcrops of easterly dipping sandstone occur in this area. East of Greenalls Farm one of these sandstones is exposed in an old quarry [5182 5801] where 2.9 m of cross-laminated, medium-grained sandstones overlie 3.0 m of coarse-grained sandstones containing pebbles up to 5 mm across. South-east of Black House are isolated exposures [520 570] of massive, medium-grained sandstones. The fine-grained sandstones exposed to the south [523 577] of Lower Browtop are the youngest in this fault-bounded area. The stratigraphical level represented by these fault-bounded exposures is unclear. Some, or all of the sandstones, could even be Ward's Stone Sandstone emplaced by growth faulting down the palaeoslope. This mechanism may also account for the steeply inclined, fault-bounded, medium-grained sandstone, estimated to be at least 40m thick, south of Fell End Farm [532 595].

3.2 WARD'S STONE SANDSTONE FORMATION

The Ward's Stone Sandstone forms the high escarpment of Clougha in the north-east corner of the sheet and crops out on both limbs of the Quernmore Syncline to the north of the Mount Vernon Fault. The thickness of the sandstone probably varies from 35 m in the Quernmore Syncline to 92 m on Clougha.

The lower part of the sandstone consists of thickly bedded, medium- to coarse-grained and commonly pebbly sandstones, with low angle, tabular cross-bedding and parallel- laminations. A topographical feature some 25 m above the base of the unit on the Clougha scarp face is produced by a 2 m thickness of siltstone and micaceous, ripple laminated, fine-grained silty sandstone. Exposures of the lower part of the Ward's Stone Sandstone are abundant and continuous along the length of the Clougha scarp face and on the dip-slope.

The upper part of the Ward's Stone Sandstone, referred to as the Pott Yeats Sandstone in Wilson *et al.* (1989) but not differentiated here, consists of more thinly bedded, fine- to medium-grained sandstones with ganisters. These beds are not present on Clougha, but appear to constitute most if not all of the thickness of the Ward's Stone Sandstone in the Quernmore Syncline. The only exposures on the western limb of the syncline are in and around the disused quarry on Little Fell [508 599], where a thickness of approximately 60 m is present. In the quarry are exposed thickly bedded, fine- to medium-grained sandstones, with thinner, coarse-grained sandstones. External moulds of large plant fragments are abundant on many bedding planes, and although no conspicuous rootlet layers are present, many sandstone beds are fine-grained and highly siliceous. The rocks exposed in and around the quarry are highly silicified because of their proximity to faults.

A thin coal seam probably in the upper part of the formation has been worked in the Mount Vernon area [5057 5880]. Clare and Hudson (1981, p.14) report it to have been worked as recently as 1926 or 1930 and they reproduce a 1970's survey of one of the adits. (See also Section 6.)

Exposure of the Ward's Stone Sandstone on the eastern limb of the syncline is very poor, and limited to three localities. 1.1 m of fine-grained ganister sandstone is exposed in a small, disused quarry [5205 5939] north of Quernmore Post Office. At the northern end of Rigg Plantation [525 599] are small exposures of siliceous, fine- to medium-grained sandstones. At the bottom of the steep bank to the south-west of Titterington Cottage [514 582] are many loose blocks, not far removed from outcrop, of fine- to medium-grained sandstone.

3.3 CATON SHALE FORMATION

These are highly fossiliferous, grey, shaly mudstones (claystones), deposited in a marine environment, with a calculated thickness of 60 m. They are not exposed in the present area, but overlie the Ward's Stone Sandstone and its correlatives throughout the Lancaster Fells area.

3.4 CLAUGHTON FORMATION

In the Lancaster Fells area this delta slope facies generally consists of grey, finely sandy, micaceous, shaly siltstones with subordinate and very variable, fine- to medium-grained sandstones (e.g. Brandon, in prep.). The formation is poorly exposed locally and appears to comprise mostly sandstones, the Heversham House Sandstone, overlain by mudstones with siderite mudstone nodules.

3.4.1 *Heversham House Sandstone*:

This sandstone crops out in three fault-bounded areas in the south-west of the sheet, where its thickness is calculated to be 75 m. The uppermost 60 m are exposed in a gorge at Clough Wood, Heversham House [5200 5541], and consist of thick bedded, parallel-bedded, fine- to medium-grained sandstones. Two small, disused quarries here are separated by a rocky terrace made up of dip-slopes in the higher beds of the sandstone, with a seatearth sandstone at the very top. Outcrops of the sandstone [5170 5598] to the north of Black Wood show trough cross-bedding in fine-grained sandstones. Exposures [5124 5641] in an old quarry east of Higher Knowe Hill show 0.2 m of thinly bedded sandstones which are also thought to belong to the Heversham House Sandstone.

3.4.2 *strata between the Heversham House Sandstone and the Silver Hills Sandstone Formation*:

Strata in the uppermost 20 m of the formation are not exposed on this sheet, but on the sheet to the south, on Sheet SD 55 SW, they consist of unfossiliferous mudstones with siderite mudstone nodules.

3.5 SILVER HILLS SANDSTONE FORMATION

This sandstone is not exposed on the present sheet, but to the south, on Sheet SD 55 SW, it consists of up to 12 m of fine-grained sandstone with two allochthonous coals. In was called the Starbank Wood Sandstone in an previous report (Wilson *et al.*, 1989).

3.6 CROSSDALE MUDSTONE

Approximately 165 m of grey mudstones overlie the Silver Hills Sandstone Formation. Exposures of three distinct *Isohomoceras subglobosum* marine bands and the *Homoceras beyrichianum* Marine Band were discovered by Dr.A.A.Wilson in the present area. The most complete section through the *I. subglobosum* marine bands is in a section in Cocker Clough Wood [507 599]: all three bands are present here (Biostratigraphy Group reports PD 84/266 and 85/185). The section upstream from a point [5091 5583] 20 m east of a small landslip on the south bank (as measured by Dr N.J.Riley) consists of:

Mudstone, top not seen, fissile, deeply weathered, with scattered ironstone nodules	c. 4.00
Mudstone, sub-fissile	2.00
Mudstone, fissile, containing *I. subglobosum*, *Caneyella* cf. *semisulcata*, cf. *Dunbarella carbonaria*, and *Selenimyalina* sp. (juv)	0.30
Mudstone, platy, calcareous, with bivalves and thin-shelled goniatites	1.20
Gap	0.50
Mudstone, deeply weathered, fissile	1.00
Siderite mudstone	0.03
Mudstone, fissile, barren	0.60
Gap	1.00
Limestone bullion band with *I. subglobosum*	0.15
Mudstone, fissile	0.30
Gap	3.50
Mudstone, deeply weathered, fissile	1.30
Siderite mudstone, nodular band with *Isohomoceras* sp.	0.13
Mudstone, fissile, deeply weathered, occasional bivalves	0.40

Between the middle and highest *I. subglobosum* bands, the stream is crossed by a small fault. About 120 m west of the fault [5079 5591], the highest *I. subglobosum* Marine Band has yielded *I. subglobosum* and indeterminate dimorphoceratids (Biostratigraphy Group Report PD 85/158).

One of the *I. subglobosum* bands is also exposed in Damas Gill [5190 5596], in less than 1 m of deeply weathered mudstone. The fauna recovered includes *I.* cf. *subglobosum*, cf. *Actinopteria* sp., *Myalina* sp., and *Selenimyalina* sp. (Biostratigraphy Group Report PD 84/266).

A section in Whitley Beck, immediately to the east of Sefton's Farm contains exposures of one of the *I. subglobosum* marine bands and the *Homoceras beyrichianum* Marine Band. The former marine band here [5062 5671] has yielded only the eponymous goniatite, but the latter [5053 5668] has yielded the eponymous goniatite and indeterminate dimorphoceratids (Biostratigraphy Group Report PD 85/158).

The youngest rocks of the formation are seen in the Cocker Clough section to the west of the highest *I. subglobosum* Marine Band. They consist of ferruginous mudstones with thin, fine-grained sandstones.

3.7 WELLINGTON CRAG SANDSTONE

The Wellington Crag Sandstone, equivalent to the Clintsfield Grit of Moseley (1954), forms a prominent topographical feature, broken by faulting, in the extreme south-west of the sheet [510 555]. It is a cross-bedded, fine- to coarse-grained sandstone, with a proven thickness of 22.6 m in the Middle Crag Farm borehole. Loose blocks of sandstone containing rootlets probably come from a level near the top of the sandstone. A borehole (SD 55 NW/6) at Middle Crag Farm [5104 5509] records coal from near the base of the unit.

3.8 DOLPHINHOLME MUDSTONE

These beds are not exposed on the present sheet, but in the River Wyre near Dolphinholme, on Sheet SD 55 SW), mudstones at this horizon have yielded *Caneyella* cf. *semisulcata*, suggesting an H_1-H_2 age.

3.9 ELLEL CRAG SANDSTONE

This sandstone is best exposed in Ellel Crag Quarry [504 550], where it consists of cross-bedded, fine- to medium-grained sandstones with thin, allochthonous coals. The fault-bounded exposures of sandstones at Welby Crag [516 568] and Mainstones [518 565] may belong to the Ellel Crag Sandstone. Exposures of cross-bedded, fine- to medium-grained sandstones occur in both these localities, but tentative assignment to the Ellel Crag Sandstone is based only on structural evidence. Current ripple lamination has also been seen at both Welby Crag and Mainstones; trough cross bedding also occurs at the latter locality.

These exposures had previously been tentatively assigned to the Brennand Grits by Wilson *et al.* (1989), but with the more recent recognition of the Mount Vernon Fault this earlier correlation now appears unlikely.

3.10 STRATA ABOVE THE ELLEL CRAG SANDSTONE

The *Reticuloceras dubium* Marine Band is thought to occur approximately 15 m above the top of the Ellel Crag Sandstone. It was discovered by Dr A.A. Wilson in the unnamed stream [5127 5781] north of Blackwood End, from where the following fauna was obtained (Biostratigraphy Group Report PD 85/158): cf. *R. dubium*, cf. *Neognathodus bassleri*, cf. *Streptognathodus lateralis*. The section exposed here, measured by Dr N.J. Riley, consists of:

Mudstone, dark grey	1.5
Siltstone, dark grey, calcareous, bioturbated, with small goniatites	0.4
Mudstone, dark grey	1.5
Siltstone, dark grey, blocky	0.33
Mudstone, shaly, dark grey	2.5
Siltstone, dark grey	0.5
Mudstone, dark grey, fossiliferous	1.0

It is estimated that a thickness of up to 250 m may be present above the *R. dubium* Marine Band in the Quernmore Syncline south of the Mount Vernon Fault. These beds are very poorly exposed, but in the best section [50 57], in the unnamed stream north-west of Thornfield, they consist of interbedded silty mudstones, siltstones and fine-grained sandstones. A small exposure [5038 5863] of silty mudstones near Mount Vernon has yielded the conodonts *Declinognathodus noduliferus* and cf. *Neognathodus symmetricus*, indicating an age no older than the *I. subglobosum* Marine Band and no younger than earliest Kinderscoutian.

4. STRUCTURE

4.1 FOLDING

In the east, the Grizedale Anticline and the unnamed syncline and anticline beneath Hare Appletree Fell [54 58] are known from the Wyresdale Tunnel section only, and have no surface expression because of the thick drift cover. These are shallow, open, symmetrical, east-north-east trending structures, with dips on the limbs of generally less than 20 degrees. Dips on the northern limb of the northernmost anticline steadily increase and this limb merges into the south-eastern limb of the Quernmore Syncline.

The north-east trending Quernmore Syncline underlies the valley of the River Conder in the west of the sheet. The structure is an asymmetrical fold, with dips of up to 50 degrees on the north-west limb and around 20-30 degrees on the south-east limb. The structure is crossed by the Mount Vernon Fault which has a throw of 550 m down to the south. Because of thick drift cover it is not known whether the axis of the syncline is offset by this fault.

The Knots Anticline is an apparently symmetrical fold situated north-west of the Quernmore Fault in the extreme north-west of the area.

4.2 FAULTING

The numerous faults marked along the line of the Wyresdale Tunnel in the east of the sheet were encountered in the tunnel section, and have no surface expression because of the thick drift cover. The amount and direction of throw of these faults is rarely known. Further west, the major fault is the arcuate Mount Vernon Fault, which has a throw of approximately 550 m down to the south-west, and throws H_2 against E_2b strata. In the south of the sheet the Mount Vernon Fault is named the Weir Wood Fault, and is joined by the Longmoor Fault, which throws down approximately 125 m to the east. South of the present sheet the Weir Wood Fault has a throw of 560 m down to the east.

South-west of the Mount Vernon Fault is an area of complex faulting dominated by four, roughly easterly trending faults, with a minor, roughly northerly trending set. These faults are mapped where major topographical features

produced by major sandstones are abruptly truncated. The southern three of the four easterly trending faults throw down by varying amounts to the south, while the northernmost fault throws down an indeterminate amount to the north. The Black Wood Fault is a scissors fault which throws down to the north in the east and to the south in the west.

The directions of throw of the two north-trending faults between Mainstones and Welby Crag [51 56] are unknown. Other faults with this trend to the south of the Mount Vernon Fault have variable throw directions and amounts.

In the extreme north-west of the sheet is the Quernmore Fault. This structure has no surface expression in the present area, but is proven to the north. The fault plane dips to the north-west, and the hanging wall has undergone south-easterly translation. The relationship of the Quernmore Fault to the Quernmore Syncline is unclear. It seems likely that the thrust is a brittle response to the compressive stresses which had previously initiated the folding of the syncline.

4.3 JOINTS

On the well exposed dip-slope of Clougha, a major, vertical joint set trends to 320 degrees. Two of these joints are so well-developed as to be clearly visible on aerial photographs. On the ground, deep gullies have formed along the lines of these joints, because of the action of glacial meltwater.

5. QUATERNARY

5.1 LANDSLIP

Minor, non-rotational landslips in steep banks of till are common throughout the area. Good examples occur along the banks of the unnamed stream [507 504] which flows westwards past Dam Head Farm, and along the unnamed stream [50 58] which joins the River Conder near Mount Vernon. Non-rotational landslips including solid material occur on the south-east bank of the glacial meltwater channel of Trough Brook [523 595 and 525 596].

Farther north [528 598 and 531 599], on the south-east bank of Trough Brook are two rotational landslips involving head and solid rock.

5.2 PEAT

Peat occurs widely throughout the higher ground of the sheet. The dip-slope of Clougha [54 59] is covered with hags up to 1 m thick, which are the highly dissected remnants of a once continuous peat blanket. The less exposed slopes of Hare Appletree Fell [54 58] and Rowton Brook Fell [54 59] have more extensive areas of peat up to 1.5 m thick, but these are also remnants of a once continuous cover.

5.3 HEAD

Thin veneers of head cover most of the steeper slopes in the area. Thick accumulations of head have been mapped on the west-facing slopes of Clougha [54 59] and in Rowdon Brook Wood [528 594]. At least 1 m of head is present in the backscar of the landslip on the south-east bank of Trough Brook [5299 5982]. The head consists of locally derived material which has moved downslope under the influence of gravity, and is composed predominantly of angular blocks of sandstone in a sandy and clayey matrix.

5.4 ALLUVIAL FAN DEPOSITS

Alluvial fans are common where changes in the gradients of tributary streams reduce the kinetic energy and load-bearing capacity of the stream. Nine alluvial fans are present along the length of the Conder valley within the sheet area. Other fans are present where Rowton Brook flows into Trough Brook

[523 594], and where Damas Gill is joined by an unnamed, westerly flowing tributary [531 587].The alluvial fan deposits consist of unsorted material of all grain sizes up to boulder size, and woody material is common.

5.5 ALLUVIAL TERRACE DEPOSITS

Discontinuous and commonly thin strips of alluvial terrace deposits are present along the length of the River Conder at heights of up to 4 m above the present river level. The terraces cannot be correlated and are therefore undifferentiated. On the left bank of the Conder [509 593], south of Conder Mill Farm a terrace of consisting of approximately 0.50 m of sands and small pebbles overlies siltstones and silty mudstones. On the left bank of the river [50 58], in the vicinity of Conder Side Farm, are terrace deposits consisting of well-sorted sands and gravels of unknown thickness.

5.6 ALLUVIUM

Alluvium lines the courses of all major streams and rivers of the area but its thickness is unknown. By far the most extensive are the deposits along the course of the River Conder in the west of the area. The alluvium here consists of well sorted silts, sands and gravels. Other extensive deposits of alluvium occur along the course of the River Cocker [50 55], Damas Gill [52 57], and Sparrow Gill [53 55].

5.7 GLACIOFLUVIAL SHEET DEPOSITS

In the north-west of the area [50 58, 50 59, 51 58, and 51 59], extensive deposits of glaciofluvial sand and gravel form large terraces which are significantly higher than the highest present day river deposits. The terraces are remarkably flat topped, and are confined to the south-eastern side of the Conder valley. The water from which this material was deposited almost certainly flowed down the valley now occupied by Trough Brook [52 59]. Other deposits of glaciofluvial sand and gravel occur in some of the glacial meltwater channels of the south, such as Sparrow Gill [53 56], Smithy Beck [53 56], Worm Syke [54 57] and Damas Gill [51 56].

These deposits were laid down by water which flowed at the end of the last glacial period, probably fed by melting ice. Good exposures of the sediments are present in the banks of the unnamed stream [508 588] which flows over one of the terraces to join the River Conder upstream of Mount Vernon. Here they consist of poorly sorted, commonly imbricated, sub-angular to rounded pebbles, cobbles, and boulders, including erratics, in a sandy and silty matrix. Some of the largest boulders have been moved to the sides of the fields and are up to 1 m^3 in size. The precise thickness of the deposits in the Conder valley is not known, but is likely to be greater than 12 m in places.

5.8 GLACIOFLUVIAL ICE CONTACT DEPOSITS

In the north-west of the area [51 59 and 52 59], a distinctive hummocky topography is formed by a kame-kettle moraine. The sediments within this complex vary from dense, dark grey, stony clay to well sorted sands and gravels. There are no good exposures of the deposits, but their variety is recognisable by the degree of variation of the drainage of the ground. The sands and gravels are sometimes visible in ejecta from rabbit burrows and molehills.

Discontinuous and isolated deposits of glacial sand and gravel occur throughout the area. The most extensive of these deposits occur in the extreme south-east [54 55]. A section in a small unnamed stream [5422 5510] east of Stepping Stones shows 3.5 m of sand and gravel overlying at least 1.5 m of fine sand. Other, small deposits of sand and gravel occur in a field [5192 5897] south-west of Quernmore Post Office, and immediately east [5021 5665] of Kitchen Ground.

The most interesting deposit of glacial sand and gravel occurs immediately west [50 57] of Thorncliffe. This deposit is an esker, up to 4 m high, and aligned parallel to the axis of the valley. Diggings along the crest of the esker show it to be composed of poorly sorted sands and gravels. No internal structures within the esker are visible.

5.9 TILL

Till deposits are widespread throughout the area, but are thickest in the south and east. 11.58 m of till were proven in a borehole at Lower Moor Head [5412 5615] (SD 55 NW/1), and greater thicknesses than this are likely in the surrounding area. The only large area which has no till cover is Clougha. Where visible, such as in the banks of Sparrow Gill [53 55] and Smithy Beck [53 56], the till consists of dense, dark grey stony clay, with abundant erratic material. Lower Palaeozoic rocks, probably from the Lake District, are particularly common. In the Conder valley in the west, the till is moulded into elongate ridges parallel to the valley axis, but these landforms are not fully developed into drumlins.

5.10 GLACIAL MELTWATER CHANNELS

A series of sub-parallel glacial drainage channels trench the slopes around Higher Moor Head [542 566]. The channels all originate at their northern ends as ice contact slopes, suggesting that their northern ends, at least, are ice-marginal. Their lower ends may have plunged beneath the fringe of the ice-sheet. The deepest channel is Sparrow Gill [532 559], with walls up to 25 m in height. Locally the channels incise the solid rocks, but generally the channels do not penetrate the thick till.

6. ECONOMIC GEOLOGY

6.1 SANDSTONE

This has been worked at numerous localities in historical times. Flaggy sandstones within the Ward's Stone Sandstone were once quarried for local building stone from workings [549 597] on the dip-

slope of Clougha. The Ward's Stone Sandstone was also extensively worked for building stone at Little Fell Quarry [508 599]. The Ellel Crag Sandstone has been quarried for building stone at Ellel Crag quarry [504 550], Welby Crag [515 568] and Mainstones [518 565]. Small quarries where sandstone has been quarried on a minor scale for walling stone are too numerous to mention.

6.2 COAL

The only locality where coal is known to have been mined is on the steep north-western bank of the River Conder [505 588] to the north-east of Mount Vernon. The farmer at Mount Vernon mentioned that coal was mined from here by a local merchant early this century, but the only evidence of workings are small heaps of spoil. A heap of spoil along strike to the north of here [5057 5891] marks the position of what is probably an old bell pit.
Stratigraphically this coal is in the Ward's Stone Sandstone, a horizon which is known to contain thin coals throughout the Bowland Fells. The remains of two other bell-pits [507 598] are marked by small heaps of spoil between The Grange and Little Fell Quarry. Further information on coal mining at Mount Vernon is given by Clare and Hudson (1987).

Several bell pits are known in the area [526 597] south of Rigg Plantation: these were probably unsuccessful coal trials. An old shaft, probably another coal trial, is located at the eastern end [5094 5583] of Cocker Clough Wood.

7. REFERENCES

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