British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

The geology of NY76NW (S), Cawfields, Northumberland

Geology & Landscape Northern Britain Programme
Open Report OR/07/034

BRITISH GEOLOGICAL SURVEY

GEOLOGY & LANDSCAPE NORTHERN BRITAIN PROGRAMME

OPEN REPORT OR/07/034

The geology of NY76NW (S), Cawfields, Northumberland

S. M. Clarke

Keywords

Cawfields; Hadrian's Wall; Northumberland.

Bibliographical reference

CLARKE, S. M.. 2007. The geology of NY76NW (S), Cawfields, Northumberland. *British Geological Survey Open Report*, OR/07/034. 28pp.

Keyworth, Nottingham British Geological Survey 2007

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

1:10 000-scale geological sheet NY76NW (S) was surveyed by S. M. Clarke in 2005 and constitutes part of the resurvey of BGS 1:50 000-scale geological map of Hexham (England and Wales Series Sheet 19). This report summarises the geology of NY76NW (S) and includes a synopsis of field notes by the author. This work is an output of the Northern England – Alston Block Project (E2007S71).

Grid references

The area covered by this report lies within Ordnance Survey British National Grid square NY. References given to specific exposures and locations are quoted to six or eight figures as appropriate. In all cases, the prefix NY is omitted from the reference and should be assumed.

Acknowledgements

The author gratefully acknowledges the co-operation of all landowners within the area.

Contents

Summary

This field report provides a summary of geological information to accompany the recently resurveyed 1:10 000-scale sheet NY76NW (S), Cawfields, Northumberland. It should be consulted in conjunction with the published geological standard maps and fieldslips corresponding to this area.

The area comprises Carboniferous sedimentary rocks of the Northumberland Trough, an asymmetrical basin and Carboniferous depocentre of the 'block and basin' structure of northern England. These strata dip by up to 15° towards the south and towards the southern margin of the Northumberland Trough. The early Permian Great Whin Sill is exposed at surface, thus forming a prominent ridge through the area. Superficial deposits originating from the late Devensian glaciation and subsequent Holocene processes intermittently blanket the bedrock.

1 Introduction

This report describes the geology of the southern half of Ordnance Survey 1:10 000-scale sheet NY76NW, Cawfields, Northumberland, re-surveyed by S. M. Clarke in 2005. The area constitutes part of the re-survey of BGS 1:50 000 Sheet 19 (Hexham). The northern half of the sheet was surveyed by D. V. Frost in 1973 as part of Sheet 13 (Bellingham); details of the geology of this area are included in Frost and Holliday (1980).

1.1 GEOGRAPHY

The area (Figure 1) covers 12.5 km^2 of countryside in south Northumberland approximately 2 km north of the town of Haltwhistle. The area includes the southernmost reaches of the Northumberland National Park, and the Hadrian's Wall World Heritage Site. No significant settlements are present within the area, but it does include some of the best preserved sections of Hadrian's Wall, the Vallum and the old Roman road (now the B6318). Today, the area is largely rural and the economy is driven by farming, and the tourism and leisure industries.

The landscape is dominated by a series of strong ridges trending roughly east – west that are formed by the Carboniferous bedrock and have steep north-facing scarp slopes with shallower angle, south-facing dip slopes. This cuesta landscape is dominated by one ridge formed by the outcrop of the Great Whin Sill and along which Hadrian's Wall was built. One major river, the Haltwhistle Burn, traverses the area from south to north and cuts down through the cuesta landscape forming a steep gorge.

1.2 PREVIOUS WORK

The area (Figure 1) was surveyed on the 1:10 560 scale by K. Burns and is represented by the first edition geological standard map of the Northumberland County Old Series Sheet 83, published in 1879. Northumberland County New Series sheets 89 and 92 also cover the area and were surveyed around 1940 (authorship unknown) with additional notes by T. Robertson from 1946-1949. All of these sheets depict the Visean limestones and major sandstones in acceptable detail, but do not subdivide the later strata; only key limestones are depicted. The detail of superficial deposits is variable; the limits of glacial till are defined and some alluvium and river terrace deposits are delimited, but with few peat deposits shown. Peat deposits that are shown are generalised and not depicted at a resolution commensurate with the scale of the mapping.

The BGS 1:50 000 England and Wales Series Sheet 19 (Hexham) is derived from a map originally published at the 1 inch-to-the-mile scale and based on the County Series standard maps. The sheet shows little in the way of detail in the post-Visean strata, and superficial deposits are not depicted.

The aims of the present survey of northern England, of which the area covered by this report forms part, are primarily to revise and subdivide the post-Visean strata, and to survey the superficial deposits. The Visean strata and structure of the area were resurveyed on the 1:10 000-scale as part of the process.

2 Geological summary

Structurally, the area lies within the Northumberland Trough (Figure 2), a major, asymmetrical basin and depocentre of the Carboniferous 'block and basin' structure of northern England (Chadwick et al., 1995). The Northumberland Trough is bounded to the south by the major basin-controlling fault system of the Stublick and Ninety Fathom faults that separate it from the horst of the Alston Block and the corresponding high moorland of the North Pennines. To the north, the Trough becomes progressively shallower and is bounded by the Cheviot Massif. Carboniferous sedimentation within the Northumberland Trough was influenced by continued extension on the basin-controlling faults and a succession of marine, coastal and fluviatile sediments accumulated within it that now dips southwards towards the basin margin.

The Carboniferous strata exposed at the surface today (Section 3) are of Visean to ?Serpukhovian (Mississippian) age. The southerly orientated dip to these strata exposes progressively older Visean strata northwards and preserves progressively younger post-Visean strata on the hilltops towards the south. Shafts and boreholes penetrate Visean rocks beneath those seen at surface, but rocks older than Carboniferous age have not been proved within the area.

The early Permian intrusive dolerite of the Great Whin Sill (Section 4) is well exposed as a prominent ridge crossing the north of the area from east to west and forming near vertical cliffs on its north-facing side. It is intruded into the upper Visean strata and, over most of the area, is generally concordant with those strata, but it does show evidence of transgressing the succession in several places.

The area is crossed by a few late Carboniferous faults with displacements in the order of a few metres (Section 5). These faults are generally of short length and result in only local disruption to the outcrop patterns of the Carboniferous strata.

Superficial deposits resulting from the last glaciation and subsequent Holocene processes are present throughout the area and intermittently blanket the bedrock (Section 6). The presence and nature of superficial deposits, combined with the weathering characteristics of bedrock where not blanketed by superficial deposits, strongly control the present day landscape. Glacial scouring of the constituent lithologies of the Carboniferous strata, accentuated by modern weathering, has created a cuesta landscape in which the more competent bedrock lithologies form strong ridges with steeply dipping north-facing scarp slopes and shallowly dipping south-facing dip slopes. The less competent lithologies form flat-lying and poorly exposed ground between ridges in which superficial deposits are commonly preserved. To the north of the outcrop of the Great Whin Sill, superficial deposits are more abundant, thicker and show depositional morphologies, although some expression of the underlying bedrock is still evident. Feature mapping and structural projection are therefore the primary survey tools in this area.

3 Carboniferous bedrock

The Carboniferous strata throughout the area consist of interbedded units of limestone, sandstone and siltstone with subordinate coal seams. The stratigraphical order of these lithologies is predictable and represents repeated shallowing-upwards Yoredale cyclothems consisting of marine limestone and siltstone, coastal sandstone passing into fluvial sandstone, seatearth, and culminating in coal. This cyclic and predictable nature of the Carboniferous sedimentary rocks is most notable within the Visean strata where in this area six major cyclothems crop out, each displaying most of the constituent lithologies, although the coal is commonly absent. The cyclic nature is less evident in the post-Visean strata which consist predominantly of units of interbedded siltstone and sandstone with subordinate coals and poorly developed and laterally discontinuous limestones. Many of the sandstone units are fluviatile and the environment has less of a marine influence than that of the Visean stage. The fluvial nature of the sandstones and the impersistence of limestones can make regional correlation between widely spaced outcrops of post-Visean strata problematic. However, the nature of the topography has facilitated the correlation of several post-Visean sandstone units locally within the area covered by this report.

3.1 CYCLOTHEMS AND SEQUENCE STRATIGRAPHY

Modern sedimentological analysis favours the use of sequence stratigraphical principles to subdivide sedimentary successions. Divisions are drawn at major flooding surfaces within the sequence. This approach works well with other systems of the geology of northern England, most notably the Permian System, and has been adopted in modern BGS publications. Within the Carboniferous succession of northern England, flooding surfaces representing parasequences or higher order sequences correlate with the coal horizons and therefore do not coincide with the traditional cyclothem division which is taken at the base of the limestone. However, a sequence stratigraphical approach to the subdivision and description of the Carboniferous strata of northern England has not been adopted in modern BGS publications (Stone et al., *in press*), partly because the cyclothemic approach is heavily entrenched in literature, but primarily because the limited and disparate nature of the exposure and the weathering characteristics of the constituent lithologies make a sequence stratigraphical approach unworkable as a means of subdividing the succession in the field. A cyclothemic approach to the subdivision of Carboniferous strata was therefore adopted during fieldwork and the lithostratigraphy is described, in so far as it is possible to do so, in terms of Yoredale cyclothems in this report. Each cyclothem begins with the limestone member and continues through the overlying strata to the base of the succeeding limestone. Each cyclothem is named after the limestone member at its base.

3.2 CARBONIFEROUS NOMENCLATURE

The lithostratigraphical nomenclature used in this report is that of the review of the Carboniferous lithostratigraphical nomenclature of northern Britain (Waters et al., 2006; Waters and Davies, 2006). All Visean age rocks exposed or proved with the area, and the Great Limestone and underlying strata at the base of Serpukhovian Stage, are included within the Alston Formation (formerly the Alston Group). All Carboniferous strata exposed within the area that are younger than the Great Limestone are included within the Stainmore Formation (formerly the Stainmore Group). The Alston and Stainmore formations, together with the underlying Tyne Limestone Formation (not proved within the present area) form the Yoredale Group.

3.2.1 Correlation of limestones with the Bellingham district

The northern half of NY76NW falls within the area of BGS 1:50 000 England and Wales Series Sheet 13 (Bellingham). On this sheet, a number of thin limestones have been interpreted to crop out along the southern edge and to penetrate into the area covered by this report. These strata are named in accordance with stratigraphical nomenclature developed in north Northumberland and used on the Bellingham Sheet (Frost and Holliday, 1980). However, the names do not correspond with those used on Sheet 19 (Hexham) of which the present area forms part.

The following correlation, based on outcrop data and the log of the Steel Rigg borehole, is used in this report and on the accompanying geological standard of NY76NW (S):

BGS Sheet 13 (Bellingham)	**=**	**BGS Sheet 19 (Hexham) & NY76NW (S)**
Limestone 'A' or Upper Bath-House Wood Limestone	=	Scar Limestone (upper leaf)
Limestone 'A' or Lower Bath-House Wood Limestone	=	Scar Limestone (lower leaf)
Limestone 'B'	=	Cockleshell Limestone
Limestone 'C' or Colwell Limestone	=	Single Post Limestone
Dallabank Limestone	=	(Not recognised)
Limestone 'D' or Barrasford Limestone	=	Tynebottom Limestone

The lithological succession and stratigraphical classification of the Carboniferous strata of the area are shown in Figure 3.

3.3 VISEAN (MISSISSIPPIAN) ROCKS: ALSTON FORMATION

Strata from the Tynebottom Limestone up to the top of the Great Limestone crop out within the northern half of the described area, to both the north and south of the Great Whin Sill and Hadrian's Wall.

These strata, and older Visean rocks, are proved in one borehole within the area:

Shaft / Bore	**Easting**	**Northing**	**BGS BJ**	**Strata penetrated**
Steel Rigg	7492	6755	4	Scar to Tynebottom limestones

3.3.1 Strata of the Jew and Tynebottom limestone cyclothems

On the basis of the correlation given in Section 3.2.1, strata of the Jew Limestone cyclothem were penetrated in the Steel Rigg borehole, below the Tynebottom (Barrasford) Limestone. These strata represent the oldest Visean rocks proved within the present area and consist of grey, silty mudstone with ironstone nodules and shells, overlain by 3.5 m of sandstone interbedded with siltstones. The sandstone becomes ganisteroid in the top 0.7 m.

This succession is followed by the Tynebottom Limestone cyclothem. The lower part was proved in the Steel Rigg borehole. The Tynebottom (Barrasford) Limestone is 2 m thick and comprises grey to dark grey, bioclastic limestone with small corals and *Girvanella* haloes. It is succeeded by 7 m of pale grey, fine-grained sandstone that is bioturbated with mudstone bands containing bivalves and ostracods towards the base, followed by 60 m of interbedded siltstone, sandstone and thin limestones that comprise the remainder of the cyclothem; they are the correlatives of the 'Alternating Beds' on the Alston Block (Clarke, 2007a;b). This sequence contains three thin limestones and therefore almost certainly represents at least three subordinate cyclothems within the Tynebottom Limestone cyclothem. The upper two limestones are the Single Post (Colwell or Limestone C) and Cockleshell (Limestone B) limestones of the Alston Block (Dunham, 1990; Clarke, 2007a;b). The lower limestone is 1.25 m thick, pale grey and finely bioclastic. It is named in Steel Rigg borehole as the Dallabank Limestone and, with the Barrasford Limestone, is also correlated with Tynebottom Limestone. Whilst two leaves to the Tynebottom Limestone is plausible, some 10 m of strata separate them, including 7 m of sandstone. It follows that this limestone may represent an extra subordinate cyclothem within the Alternating Beds here that is generally not recognised further south in the North Pennines (Clarke, 2007a;b). Indeed, in the Dufton area of the North Pennines, three limestones have been

recognised within the Alternating Beds with the lowermost of these known as the Maize Beck Limestone (Dunham, 1990), although these localities are separated by some considerable distance and no correlation between the two limestones is implied.

In the Steel Rigg borehole, the Dallabank Limestone is overlain by 4.7 m of dark grey mudstone with ferruginous and sandy laminae, shelly ironstone nodules and brachiopods, followed by 3 m of sandstone interlaminated with silty mudstone. The sandstone becomes ganisteroid towards the top and is overlain by a 6 cm thick coal. 2.2 m of interbedded siltstone and sandstone follow, overlain by a grey to brown, finely bioclastic limestone that is the Single Post (Colwell) Limestone.

The sequence overlying the Single Post Limestone is not exposed within the present area but is interpreted to crop out to the north of the Great Whin Sill based on data on the Bellingham Sheet. It is penetrated in the Steel Rigg borehole where 8 m of siltstone and mudstone immediately overlie the Single Post Limestone followed by a major sandstone unit 15 m thick that most likely correlates with a persistent, if weak, feature that can be traced through East Cawfields Farm [7187 6725]. The following description of this sandstone is taken from the Steel Rigg borehole:

	Thickness
Siltstone and mudstone	
Sandstone, off-white, fine grained and massive	3.6
Sandstone, medium grained	6
Sandstone, coarse grained and felspathic with sharp, irregular base	1
Sandstone, medium grained	1
Sandstone, coarse grained and felspathic	1.4
Sandstone, medium grained	0.6
Sandstone, coarse grained and felspathic	0.9
Sandstone, off-white, fine grained and massive	3.5
Mudstone	

Limonitic staining is common within the coarse-grained fraction and within associated strong vertical fractures.

The sandstone is overlain by 7.5 m of interbedded mudstone, sandstone and siltstone measures that contain a thin (5 cm) coal and culminates in a finely bioclastic and argillaceous limestone that is the Cockleshell (Limestone B) Limestone.

Strata of the upper part of the Tynebottom Limestone cyclothem, above the Cockleshell Limestone and including a strong sandstone unit approximately 7 m thick, crop out and are exposed to the north of Hadrian's Wall. The sandstone unit is exposed in small quarry [7259 6718] where it comprises yellow to brown, cross-bedded, fine- to medium-grained sandstone. It is overlain by approximately 7 m of interbedded siltstone and sandstone that culminate in 3 m of pale-brown, massive and highly ganisteroid sandstone that form the top of the cyclothem.

3.3.2 The Scar Limestone cyclothem

The Scar Limestone cyclothem crops out both to the north and south of the Great Whin Sill. To the north of the Sill, the Scar (Bath-House Wood) Limestone at the base of the cyclothem is exposed in Caw Burn [7192 6697] where it forms a small waterfall with the underlying ganisteroid sandstone at the top of the Tynebottom Limestone cyclothem. It is a dark grey to brown, highly arenaceous wackestone in beds 20 cm thick. In the Steel Rigg borehole, two leaves of the Scar Limestone are recognised (the Upper and Lower Bath-House Wood Limestone) separated by 3 m of sandstone.

The outcrop of the Scar Limestone to the north of the sill is largely a construction based on the one exposure in Caw Burn and the interpretation on the Bellingham Sheet as no further exposures are recorded.

The remainder of the Scar Limestone cyclothem to the north of the Sill is unexposed and is not penetrated by the Steel Rigg borehole. It is interpreted to consist of up to 30 m of measures in

which a thin sandstone unit is present near the base. The outcrop of this unit [727 670] is interpreted over a short distance on the basis of featuring and small pits.

In the north-west of the area, a further thin limestone within this measures succession is interpreted to crop out on the basis of data on the Bellingham Sheet (13) to the north, the Brampton Sheet (18) to the west, and a concentration of limestone blocks within the stream bed and banks of the Caw Burn [7130 6678]. The correlation of this limestone with either the Hexham stratigraphy or the Bellingham stratigraphy is unclear. No exposures are recorded in situ within the north-west of the present area.

To the south of the Great Whin Sill escarpment, varying thicknesses of the upper part of the Scar Limestone cyclothem crop out. At the eastern edge of the present area, at East Bog [7470 6718], the Scar Limestone is interpreted to crop out for 300 m, immediately overlying the Great Whin Sill, based on featuring, vegetation and data from outwith the present area. This is overlain by approximately 50 m of unexposed measures representing the remainder of the cyclothem. Westwards, towards Cawfields Quarry, only the top 20 to 25 m of this sequence are interpreted to crop out as the Great Whin Sill has been intruded upwards through the stratigraphy. The sequence contains a sandstone approximately 10 to 15 m from the top that can be interpreted on the basis of featuring and small pits [719 667]. No exposures are present but several sandstone blocks at surface attest to its presence. On the basis of featuring, the unit is probably 5-8 m thick.

3.3.3 Five Yard Limestone cyclothem

Strata of the Five Yard Limestone cyclothem crop out from west to east across the area through the slack ground south of the Great Whin Sill escarpment and north of the B6318 Roman road. They are almost entirely unexposed but key units may be interpreted on the basis of featuring and secondary evidence.

The Five Yard Limestone, at the base of the cyclothem, is interpreted to crop out in the unexposed ground to the immediate south of the Vallum. Indeed, the presence of relatively hard limestone here may have influenced the course of the Vallum, especially in the central part of the area where there is a conspicuous correlation between the course of the Vallum and the outcrop of the Five Yard Limestone. A small feature, accompanied in places by sinkholes [724 666] and strong springs [7153 6646] and generally covered in well drained, short, green grass, marks the course of the Five Yard Limestone. One exposure is recorded [7310 6669] where a small abandoned quarry in the dip slope of the feature exposes dark grey extremely hard limestone in 10 cm beds. The exposure weathers with calcareous characteristics but is also quite blocky and highly fractured with planes spaced by approximately 10 cm. It is possible that the hardness of the lithology and the fracturing result from the proximity of the Great Whin Sill intrusion.

The Five Yard Limestone is overlain by between approximately 35 and 40 m of measures that comprise the remainder of the cyclothem. To the west of Shield On The Wall [727 666] a strong sandstone is present within the uppermost 25 m of the cyclothem and its course westwards can be interpreted on the bases of a feature and spring line. No exposures exist, but sandstone blocks in a small abandoned and overgrown quarry [719 664] attest to its lithology.

To the east of Shield On The Wall, an exposure of orange to brown, medium-grained sandstone in 10 cm to 30 cm thick beds in a small quarry is probably the same sandstone; here it can be traced by virtue of a small feature for no more than 300 m. This unit may correlate with the Six Fathom Hazle of the Alston Block (Clarke 2007a;b; Dunham, 1990).

A few metres of measures may overly the sandstone to complete the cyclothem as a small stretch of flat and boggy ground is present to the south of the sandstone feature.

3.3.4 Three Yard Limestone cyclothem

Strata of the Three Yard Limestone cyclothem crop out to the east of Cawfields Quarry, with an west - east trend across the area, through extremely poorly exposed ground.

The Three Yard Limestone is interpreted on the basis of data to the east of the present area and a weak but persistent feature that extends westwards from the eastern edge. This feature becomes less distinctive around Shield On The Wall but the outcrop of the Three Yard Limestone may be interpreted on the basis of extensive workings here in the overlying strata. There are no recorded exposures of the Three Yard Limestone.

Extensive measures overlie the Three Yard Limestone. The lower part of this succession is siltstone dominated and contains many clay ironstone nodules, an impure form of siderite. These strata have been worked extensively in the 19th century (Lawrence et al., 2006) from shallow quarries [719 663 and 730 664] between Cawfields Quarry and Shield On The Wall.

A 5 to 10 m thick sandstone overlies the ironstone-bearing siltstones and forms a strong ridge [724 663] in which many small abandoned and overgrown quarries are present. Numerous sandstone blocks attest to the lithology. Stonegate, an old Roman path, follows the top of the feature for part of its course, demonstrating the strength of this feature and its dominance over the local landscape.

A few metres of siltstone-dominated strata are interpreted to overlay this sandstone, and complete the cyclothem, on the basis of tracts of flat and boggy ground between the sandstone feature and a strong, dominant feature formed by the outcrop of the Four Fathom Limestone.

3.3.5 Four Fathom and Iron Post Limestone cyclothems

Strata of the Four Fathom Limestone cyclothem crop out from west to east across the present area. The B6318 Roman road traverses the Four Fathom Limestone and the lower part of the cyclothem from the western edge to the Milecastle Inn [7158 6602] before veering slightly to the north.

The Four Fathom Limestone, at the base of the cyclothem, is the oldest of the Visean strata to form a very dominant ridge through the landscape. It has been worked in numerous places along its outcrop and, consequently, a number of exposures exist.

In a small quarry 100 m south of the Milecastle Inn, almost the entire thickness (8 m) is exposed. Here it consists of a blue to grey, wackestone in beds 20 cm to 70 cm thick and with slightly wavy bedding surfaces. Some quartz mineralization is present on joint surfaces and many of the beds contain chert. Similar chert nodules have been reported within the Four Fathom Limestone of the Alston Block (Dunham, 1990). Such nodules are rare in other limestones of the North Pennines and Northumberland and serve as a good control on stratigraphical position.

1.4 km to the east of the Milecastle Inn, another small quarry exposes the Four Fathom Limestone. Here it is a blue-grey wackstone in beds approximately 40 cm thick. The unit forms a strong feature and a number of deep sinkholes at the base of the dip slope position the unit's top. From here westwards, the outcrop of the Four Fathom Limestone is marked by a prominent ridge, several small quarries and a strong spring line.

To the west of the Milecastle Inn, the Four Fathom Limestone is almost certainty exposed in the streambed of the Haltwhistle Burn where the burn flows under the B6318. This section is inaccessible today as major engineering works have taken place to construct a modern bridge and channel way for the burn. Exposures of limestone are recorded on the fieldslips of the previous survey (Northumberland New Series 89).

To the west of the Haltwhistle Burn, the Four Fathom limestone is concealed beneath superficial deposits, largely glacial till, but its outcrop is marked by a persistent, if weak, feature that continues to the western edge of the present area.

The Four Fathom Limestone is overlain by a succession of siltstone and sandstone. These strata are largely unexposed as the lower reaches of the Haltwhistle Burn are choked with modern-day alluvium. However, at the time of the previous survey the section through the burn was almost entirely exposed and T. Robertson reported the following sequence:

	Thickness
Limestone (Great)	
Gap (probably dominantly siltstone)	6
Siltstone	0.4
Sandstone, massive	4.5
Sandstone, bedded	1.8
Sandstone with brachipods	1.5
Sandstone, bedded	3.8
Siltstone, shaly	3.6
Limestone (Four Fathom)	

The 7.1 m of sandstone reported within the middle of this sequence can be correlated with exposures of sandstone in the eastern bank of the burn and with a small but prominent feature through the fields just to the south of the Milecastle Inn and Milestone House. A quarry in this feature [7246 6614], 300 m to the east of Milestone House, reveals numerous sandstone blocks but no in situ exposure. Given its stratigraphical position between the Four Fathom and Great limestones, it is likely that this sandstone is the correlative of the Quarry Hazle of the Alston Block (Clarke, 2007a; Dunham, 1990).

On the Alston Block, the Quarry Hazle marks the top of the Four Fathom Limestone cyclothem (Clarke, 2007a; Dunham, 1990). The overlying strata are attributed to the Iron Post Limestone cyclothem, named after a thin and extremely hard limestone that immediately overlies the Quarry Hazle. In the present area, no such limestone has been noted during the present or previous surveys. Consequently, strata attributed to the Iron Post cyclothem on the Alston Block are considered here as part of the Four Fathom cyclothem. Nevertheless, the presence of a sandstone unit that may be the correlative of the Quarry Hazle does suggest at least one subordinate cycle within the Four Fathom cyclothem.

Small exposures in the Haltwhistle Burn and featuring in the hillsides to the east suggest that the Four Fathom Limestone cyclothem culminates in 6-7 m of measures. There are no exposures through this sequence and the presence of a thin sandstone unit at the very top of the cyclothem that may correlate with the Tuft Sandstone of the Alston Block cannot be ascertained.

3.3.6 Great Limestone

In the lithostatigraphical classification scheme adopted in the current survey and within this report (Waters et al., 2006; Waters and Davies, 2006), the top of the Great Limestone is taken as the top of the Alston Formation. For this reason, the Great Limestone is described separately from the remainder of the Great Limestone cyclothem in this account, with the overlying beds described as components of the Stainmore Formation.

The Great Limestone, first named by Forster (1809) on the Alston Block, is the thickest limestone that crops out within the area. It has a profound influence on the landscape forming a strong and persistent ridge from east to west, with a steep and often craggy northerly scarp slope and shallower angle southward dip slope. It is similar in character to the other limestones of the Alston Formation being a grey-blue, fine-grained packstone / wackestone and breaking easily into beds, known locally as ‘posts’, varying from a few tens of centimetres to approximately two metres thick (Dunham, 1990). On the Alston Block, to the south of the present area, the internal bedding distribution of the Great Limestone and the presence of shaly partings are surprisingly consistent (Fairbairn, 1978).

The uppermost 4 to 5 m of the Great Limestone contain a number of shaly siltstone partings ranging in thickness from a few centimetres to 0.5 m thick. These siltstone beds with their

interbedded limestone posts have been termed the Tumbler Beds (Forster, 1809). The thickness and frequency of siltstone partings within this sequence increases upwards and the thickness of limestone posts decreases such that the Tumbler Beds are effectively transitional with the overlying strata.

Forster (1809) recognised two further thin siltstone partings within the remainder of the Great Limestone. The lowermost beds of the Great Limestone are separated from the remainder of the unit by a thin shaly siltstone horizon approximately 4.5 m above the base. Similarly, a second shaly siltstone horizon is present 10 to 11 m above the base. The presence of these two siltstone partings divides the section below the Tumbler Beds into three segments known from the base upwards as the low-, middle-, and high-flats (Forster, 1809; Dunham, 1990).

Fairbairn (1978, 2001) recognised further consistency to the internal stratigraphy of the Great Limestone on the Alston Block. Based on the variation in macrofossils, colour and degree of dolimitisation he recognised four separate divisions, in addition to the Tumbler Beds, which he named (in ascending order) the *Bench Posts, Main Posts, Fossil Posts* and *Top Posts*. On the Alston Block, the top of the Great Limestone is diachronous, with the Fossil Posts progressively passing northwards into the Tumbler Beds and then into fossiliferous shaly siltstone (Fairbairn, 1978; 2001). In the Northumberland Trough, north of the river Tyne, the Tumbler Beds are absent (Fairbairn, 1980; Lebour, 1875) and Fairbairn (1980) revised his divisions of the Great Limestone to include these lithological variations:

- The **Bench Posts** (as per the Great Limestone on the Alston Block) comprising four posts of planar-bedded, dark-grey limestone that is commonly impure and dolomitic. These posts are so named as they were commonly left unworked by quarrymen and formed a base or 'bench' to large quarries in the Great Limestone.
- The **Main Posts** (as per the Great Limestone on the Alston Block) characterised by wavy-bedded, paler grey limestone in which macrofossils are scarce.
- The **Transitional Posts** which are the equivalent of the lower half of the Fossil Posts on the Alston Block.
- The **Tumbler Bed facies**. The highest beds of limestone in the Northumberland Trough but almost certainly laterally equivalent to the upper half of the Fossil Posts of the Alston Block and containing numerous partings of siltstone.

Within the present area, there are no exposures of the full thickness of the Great Limestone and it is estimated at 15 to 20 m thick based on featuring. Exposures through the lowest few metres (Bench and Main posts) are present in abandoned quarries behind the Milecastle Inn [716 659] where they comprise 2 to 3 m of blue-grey wackestone in beds ranging from 50 cm to 1 m. The base of the quarry is interpreted to coincide with the base of the limestone on the basis of landscape featuring to the east. Similar extensive quarrying activities along the strong feature to the east of the Milecastle Inn define its outcrop but these are largely overgrown and exposures greater than 1 m in extent are rare. The southerly dipping slope to the feature, where developed and not obscured by superficial deposits, is well drained and carpeted in green grass implying that it is a dip slope in the Great Limestone.

The best sections through the Great Limestone expose the upper part of the Transitional Posts and the Tumbler Bed facies (Fairbairn, 1980) in an abandoned quarry just to the south of the Haltwhistle Burn [712 658]. The 5 m-high section comprises 2 m of grey, highly argillaceous wackestone in beds up to 80 cm thick, interbedded with siltstone. The thickness and frequency of the siltstone beds increase upwards. The interbedded limestone and siltstone are overlain by 3 m of dark grey, thickly laminated, fissile siltstone to complete the section. The presence of siltstone at the top of the quarry face implies an anomalous relationship between the landscape featuring and the outcrop of the Great Limestone here. The southerly dip slope of the feature is not limestone and consequently the outcrop pattern on the map appears thin.

In the Haltwhistle Burn [7198 6580], the top of the Tumbler Bed facies is thrown down into the stream bed by a small fault. The beds are up to 80 cm thick with interbeds of siltstone reaching 20 cm thick. The limestone beds are extremely arenaceous and weather dark brown. Towards the top of the section the limestone beds become increasingly argillaceous and are transitional with the overlying strata.

The western bank of the Haltwhistle Burn is blanketed in till and there are no exposures of the Great Limestone. Its outcrop may be inferred on the basis of a strong and persistent feature that passes through fields to the south of Four Laws and crosses the road at an oblique angle just to the north of the site of a Roman camp [7050 6578].

3.4 SERPUKHOVIAN TO BASHKIRIAN (NAMURIAN) ROCKS: STAINMORE FORMATION

Strata younger than the Great Limestone crop out with an east-west orientated trend over the south of the present area.

In addition to the strata between the Great and Little limestones, which belong to the Great Limestone cyclothem but fall within the Stainmore Formation, one, well-developed and regionally correlatable cyclothem is recognised: the Little Limestone cyclothem. Consequently, for the purposes of this description, strata younger than the Little Limestone cyclothem are described together.

Strata of the Stainmore Formation are penetrated by the following boreholes:

Shaft / Bore	Easting	Northing	BGS BJ	Strata penetrated
Bayldon Farm	739	658	7	(no details)
Melkridge Shaft	7392	6552	-	Little Limestone

3.4.1 Strata between Great and Little limestones

Strata overlying the Great Limestone and belonging to that cyclothem crop out from east to west across Oaky Knowe Crags in the south of the area.

The Tumbler Bed facies (Fairbairn, 1980) of the Great Limestone are overlain by approximately 2 m of interbedded siltstone and fine-grained sandstone units in 0.5 to 2 cm beds. This succession is best exposed in the Haltwhistle Burn [7908 6580] and the proportion of sandstone beds increases upwards through this exposure.

The succeeding strata comprise 5-8 m of orange to yellow, fine- to medium-grained sandstone in thin laminae but with some beds that reach 10 cm thick. Laminae / bedding thickness increases upwards along with the frequency of siltstone interbeds. Some of the sandstone beds show fine cross-lamination, ripple lamination and very small, centimetre-scale channels. One or two extremely argillaceous and highly ‘smutty’ laminae and thin beds are present, particularly within the lower part of the sequence. These strata are best observed in a cliff section of the Haltwhistle Burn [7097 6568] where the upper, thicker sandstone beds commonly show strong ripple marks.

The cyclothem culminates in 3-5 m of siltstone-dominated strata in which a strong coal, the Little Limestone Coal, is present, overlain by a few metres of sandstone at the very top of the cyclothem. The Little Limestone Coal has been worked intensely within the present area. The remains of a chimney and engine block from extensive subsurface workings are visible on the east bank of the Haltwhistle Burn [7096 6560] and the adits of South Tyne Colliery are present in the landscape of Oaky Knowe Crags [7180 6584; 7197 6583; 7225 6588]. The outcrop of the Little Limestone Coal is well marked between these two localities and to the east of Oaky Knowe Crags by a conspicuous line of surface workings.

3.4.1.1 CORRELATION WITH THE ALSTON BLOCK

The strata between the Great and Little Limestones of the Alston Block are siltstone dominated in which up to two thin sandstones, known as the Lower and Upper 'Coal Sills', are present. A strong coal overlies either or both of the 'Coal Sills' (Clarke, 2007a; Dunham, 1990). The presence of at least one strong coal within this sequence, both within the present area and on the Alston Block has lead to extensive exploration and a strong understanding of this part of the Carboniferous succession. The correlation of the Little Limestone Coal in the present area with the Little Limestone Coal (one or both seams) on the Alston Block is unequivocal.

However, the general succession between the Great and Little limestones of the present area differs from that on the Alston Block by the proportion of sandstone within it. The strata of the present area are sandstone-dominated and in which a thick sandstone unit is present only 2 m above the Little Limestone.

3.4.2 The Little Limestone cyclothem

Strata of the Little Limestone cyclothem crop out from east to west across the southernmost kilometre of the area.

The Little Limestone, at the base of the cyclothem, is poorly exposed throughout the length of its outcrop with two notable exceptions; Haltwhistle Burn and Melkridge.

In the Haltwhistle Burn, the Little Limestone is exposed in the east bank [7093 6556] next to the public footpath through the fields to the south of The Holme. Here, one bed 80 cm to 1 m thick of grey, fine-grained and extremely arenaceous limestone, rich in Bryozoa, is exposed. It is difficult to distinguish the Little Limestone here from the overlying strata which consist of calcareous sandstone, but are more thinly bedded. A further section is present in the west bank [7087 6552] where a thin bed of limestone is exposed again overlain by calcareous sandstone. In both exposures the base of the Little Limestone is not visible.

Near Melktridge Tilery [7268 6561] a small cutting for an adit exposes approximately 2 m of arenaceous limestone representing the Little Limestone, overlain by extremely calcareous, thinly bedded sandstones. The unit is likely to form the roof of the decline, which would put its total thickness at least 3 m.

The Little Limestone is unexposed between the Haltwhistle Burn and Melkridge, although its outcrop is well marked by a prominent low ridge and a conspicuous line of surface workings on the underlying Little Limestone Coal.

The Little Limestone is overlain by approximately 60 m of measures that are strongly sandstone-dominated. The Haltwhistle Burn provides sections through these strata at various localities and from which the following is a composite summary:

	Thickness
Limestone (Oakwood)	
Coal (Oakwood)	0.1
Siltstone	1
Fireclay	1.5
Sandstone, medium to thickly bedded and massive (Jackdoor Crags)	12
Fireclay with a thin coal	1
Sandstone, thickly bedded to massive (Lower Leeshall Quarry)	16.5
Siltstone	2
Sandstone, massive	18
Sandstone, thinly bedded and calcareous, interbedded siltstone	7.5
Limestone, highly arenaceous (Little)	

Thinly bedded and calcareous sandstone with poorly defined bedding planes and some interbedded siltstone directly overlie the Little Limestone. The best exposures through this part of the succession are to be found in the eastern bank of the Haltwhistle Burn [7093 6556]. This

unit is a comparatively small proportion of the whole succession and it is overlain by two massive sandstones, 18 m and 12 m thick respectively, that are separated by a thin, 2 m thick, siltstone.

The upper of these two sandstones, known locally as the 'Lower Leeshall Quarry Sandstone', is best exposed in Leeshall Quarry [7069 6512] where it comprises 5 to 6 m of brown to orange, medium- to coarse-grained sandstone in beds 0.5 to 1 m thick. The breakdown of minerals within the sandstone gives it a flecked iron appearance. Small rootlets are present and become much more prevalent towards the top. The unit is overlain by dark, thickly laminated and highly organic siltstone and a 20 cm thick coal.

The succeeding strata are well exposed in the same quarry but are inaccessible. They comprise 6 to 8 m of planar-bedded sandstone known locally as the 'Jackdoor Crags Sandstone'. Beds are 10 to 40 cm thick with some thin siltstone interbeds, particularly towards the bottom.

The cyclothem culminates in approximately 1 m of siltstone and a thin (0.1 m thick) coal known as the Oakwood Coal. This sequence is poorly exposed within the Haltwhistle Burn, just to the south of the present area (Jones, 1995).

The Melkridge Shaft penetrated the lowermost 12.5 m of the Little Limestone cyclothem. 6 m of the Little Limestone were penetrated and provide the only definitive data on its thickness within the area, overlain by 6.5 m of sandstone. No Lithological details are available.

3.4.2.1 CORRELATION WITH THE ALSTON BLOCK

This section is significant for the clear contrast in lithology it displays to sections through the Little Limestone cyclothem on the Alston Block (Clarke, 2007a;b), where a siltstone-dominated succession overlies the Little Limestone and contains at least two, and sometimes three, sandstones several metres thick. The uppermost of these sandstones, the Firestone Sandstone, is medium- to coarse-grained, massive, cross-bedded and planar-bedded (Clarke, 2007a;b). It represents a strong channel system and locally cuts down into the underlying siltstones. The Firestone Sandstone is immediately overlain by a thin siltstone succession containing a coal, followed by the Crag Limestone cyclothem.

The coal in the succession of the Alston Block can be correlated with the Oakwood Coal of the Tyne valley and the present area. Based on this correlation, the Firestone Sandstone of the Alston Block correlates with the Jackdoor Crags Sandstone of the present area. However, lithologically, the Firestone Sandstone shares many characteristics with the Lower Leeshall Qauarry Sandstone. Thus the correlation of the Firestone Sandstone of the Alston Block with the sandstones of the Little Limestone cyclothem of the present area is somewhat equivocal, if indeed it is possible to correlate these successions directly at all.

3.4.3 The Oakwood Limestone and overlying strata

The Oakwood Limestone, overlying the Oakwood Coal and the probable correlative of the Crag Limestone on the Alston Block (Clarke, 2007a;b; Dunham, 1990), is not exposed within the present area. Exposures have been reported in the Haltwhistle Burn, approximately 100 m off the southern edge of the present area. The limestone is highly argillaceous and forms a unit in the river that is 2 to 3 m thick (Jones, 1995).

The outcrop of the Oakwood Limestone across Oaky Knowe Crags to the east of Haltwhistle Burn is not shown on the current survey. The unit does not appear to form any featuring within the landscape, probably because its high argillaceous content results in weathering characteristics somewhat similar to the siltstone-dominated measures that over- and underlie it.

The Oakwood Limestone is overlain by approximately 10 to 12 m of siltstone in the middle of which another thin coal is present. This sequence is overlain by an orange to brown, flaggy, coarse-grained sandstone in beds averaging 5 cm thick with irregular bedding surfaces. Laminae within the beds are picked out by grain size and colour contrasts. This unit forms a strong ridge with extensive southerly dip slope to the south of Moorfield House [714 652].

4 Igneous rocks

The early Permian (Stone et al., *in press* and references therein) Great Whin Sill crops out as an east to west-trending prominent ridge that dominates the landscape and on top of which Hadrian's Wall was built.

The Great Whin Sill is a quartz dolerite intrusion that in most places within the area is approximately concordant with the bedding of the Carboniferous strata. Consequently many of the exposures are of the southerly facing dip slope and represent the top or near-top of the sill. The actual contacts with both the underlying and overlying Carboniferous strata are everywhere concealed below superficial deposits.

The best exposures are to be found within Cawfields Quarry [714 666], a former paving and roadstone quarry that is now a local tourist attraction. Here, sections through the upper half of the sill are exposed on the south side of the car park, and through the lower half in the back faces of the quarry. Crude columnar jointing is prevalent and the joint planes become closer together and less regular upwards through the section. Joint surfaces dip with an orientation that is perpendicular to the southerly dip slope of the feature implying that the dip slope is subparallel to the cooling surface. Samples of dolerite taken from the surface of the dip slope, compared with those taken from the car park, close to the middle of the sill, show a marked reduction in grain size. Conspicuous vesicles are also present throughout the upper part of the sill although apparently concentrated in bands at several levels roughly parallel to the dip slope and top of the sill. Excellent examples are exposed behind the toilet block in the car park [7125 6655]. Many of the vesicles reach over 1 cm in diameter and some are filled with clear, crystalline calcite. The magnetic iron sulphide mineral pyrrhotite is also prevalent disseminated throughout the rock mass in these exposures.

The outcrop of the Great Whin Sill of Cawfields Quarry is clearly offset from the remainder of the outcrop and exposure to the east [7155 6665]. This may imply a large fault with an easterly throw between the two exposures but this hypothesis is not supported by featuring in the Carboniferous strata to the south of the Great Whin Sill, in which no clear offset is evident. It is therefore likely that the Great Whin Sill is not faulted here but has transgressed upwards through the Carboniferous strata. A large raft of Carboniferous rocks is entrained within the sill at this point and is well exposed in the face of the quarry and within the southerly dip slope [7156 6661]. Small exposures reveal light coloured siltstone with interbedded very fine-grained sandstone in thin, extremely hard beds. Clasts and larger fragments of dolerite are entrained within the sediment and all are heavily stained with iron oxide.

To the east of Cawfields Quarry, dolerite is exposed almost continuously along the north-facing scarp slope and intermittently within the south-facing dip slope. Towards Winshields [742 669] the angle of the dip slope and the dip of subparallel internal joints increases from 10° observed at Cawfields to approximately 20°. This is almost certainly not a true reflection of the dip of the Carboniferous strata to the north and south of the sill and the sill is less concordant here than further west. A small quarry at Winshields [7410 6682] exposes the closest outcrop to the contact of the sill with the overlying Carboniferous strata. Here the sill is extremely fine grained with calcite-filled vesicles up to 5 mm in diameter.

To the west of Cawfields, the Great Whin Sill is concealed beneath superficial deposits. Its course is marked by a strong, if rolling, feature that is clear both in the landscape and from the air suggesting that relief on the sill is reflected in the overlying superficial deposits. The sill does not reappear as a line of conspicuous crags until Walltown Crags, approximately 1.5 km off the western edge of the present area.

5 Structure

The area covered by this report lies on the southern edge of the Northumberland Trough (Figure 2), a Carboniferous asymmetrical basin and depocentre bounded to the south by the Stublick – Ninety-Fathom Fault System and the Alston Block, and to the north by the Cheviot Massif.

Carboniferous sedimentation within the Northumberland trough was heavily influenced by continued extension on the Stublick – Ninety-fathom Fault System and Carboniferous sedimentary rocks exposed at the surface today thicken and dip generally towards this basin controlling fault system.

5.1 REGIONAL DIP AND FOLDING

The dip azimuths of Carboniferous strata within the present area are exclusively orientated towards the south and ranges in magnitude from 10° to 15°. Magnitudes higher than these are displayed by the southerly dip-slope of the Great Whin Sill, and by internal joint surfaces that are assumed to be subparallel to the cooling surface, in the vicinity of Winshields, on the eastern edge of the present area. These dips probably represent a slight discordance of the sill with the Carboniferous strata rather than a marked increase in dip in this area.

No significant folding is observed within the area and the regional strike of all strata is east – west. The only small-scale variations in this trend observed represent localised normal drag into small faults.

5.2 FAULTING

The area is cut by several late Carboniferous faults with displacements of a few metres. Three orientations are recognised; north-west to south-east and north-east to south-west, that together form a crude rectilinear pattern, and east to west.

5.2.1 East- to west-orientated faults

A lengthy fault is interpreted to traverse the area in a roughly east – west orientation through slack and poorly exposed ground to the south the of the Great Whin Sill escarpment. This fault is largely subparallel to the strike of the Carboniferous strata and its presence is somewhat equivocal. There is little evidence on the ground for such a structural feature and it has been interpreted on the basis of data outwith the present area, the depiction of a similar structure on the Northumberland County New Series maps, and in order to correlate the Visean strata between the Hexham, Brampton and Bellingham sheets. Whilst alternative interpretations could correlate the Visean strata, the interpretation of a fault does provide a plausible and admissible geological interpretation for the area and provides some explanation for the poorly exposed and laterally discontinuous featuring seen.

A further small splay fault is interpreted through the slack ground approximately 200 m north of the Milecastle Inn [718 662] on the basis of landscape featuring, the truncation and offset of the Four Fathom Limestone [7255 6618], and the truncation of the prominent feature formed by a sandstone within the Three Yard cyclothem [722 663].

5.2.2 North-west- to south-east-orientated faults

Several faults orientated from north-west to south-east and with offsets in the order of a few metres are well known from subsurface workings, principally from workings on the Little Limestone Coal. Most of these are within the southern half of the area and crop out on Oaky Knowe Crags; an area of excellent exposure and featuring in which the outcrops of the faults are clearly evident in the landscape.

The most westerly of these faults cuts and displaces strata from the Great Limestone to the Oakwood Limestone and is known from workings of Haltwhistle Colliery. Its surface outcrop through the higher strata is followed in part by the course of the road from Haltwhistle to the Milecastle Inn [7132 6550]. At the southern edge of the present area, throw on this fault is 4.4 m to the south-west in subsurface workings and a similar throw is evidenced at surface by the offset of the Lower Leeshall Quarry and Jackdoor Crags sandstones. Throw on the fault reduces north-westwards and it is interpreted to tip out between the outcrop of the Four Fathom and Great Limestones in the vicinity of New Bridge [711 658]. Displacement and local disruption of the Tumbler Bed facies of the Great Limestone cyclothem on this structure is exposed in the Haltwhistle Burn [7108 6580].

A further three north-west-trending, sub-parallel faults cut the strata of Oaky Knowe Crags. The most westerly of these [7225 6550] is known from subsurface workings of South Tyne Colliery in the Little Limestone Coal, where it has a throw of 1.2 m to the south-west. The remaining two [632 656; 741 653] are evident at surface from offsets in the outcrop pattern of the Little Limestone Coal and higher coals.

5.2.3 North-east- to south-west-orientated faults

One north-east-trending fault is recognised within the area [724 654]. It is significant for the offset it produces in the outcrop patterns of the Little Limestone and younger strata and because it forms the eastern limit of workings on the Little Limestone Coal within South Tyne Colliery. At the southern edge of the present area, throw on this fault is 15.5 m to the north-west, reducing north-eastwards to a just few metres by the outcrop of the Four Fathom Limestone [731 662]. A combination of the magnitude of throw and the interaction between the strata and the landscape in the region Melkridge has offset the outcrop of the Little Limestone and associated coal laterally by 150 m across this structure.

5.2.4 Other minor faults

Several additional small faults cut and displace the Great Whin Sill and adjacent Carboniferous strata. Most are small and evidenced by offsets in the strong features produced by key strata within the Visean succession.

One of these faults cuts the Great Whin Sill at Thorny Doors [7218 6682] producing a marked steep-sided gully in the dolerite. Further offsets on the strong ridges produced by sandstone units within the Scar and Five Yard limestone cyclothems are evident in the ground to the immediate south of the sill escarpment.

5.2.5 Subsurface structures

Where faults are known and have been recorded in subsurface workings within the area their subsurface position is indicated on the standard map. In most cases, subsurface faults have a corresponding surface expression and their outcrop can be positioned with accuracy. Within the workings of the South Tyne Colliery, a number of small faults with throws of less than 2 m are indicated within the subsurface but for which no surface outcrop is shown. These faults are of short length and do not cause significant mappable disruption of strata at the surface. However, they have affected, and in some cases limited, the workings of South Tyne Colliery on the Little Limestone Coal and are therefore indicated on the map face for their economic significance.

6 Superficial deposits

Over the extent of the area covered by this report, a three-fold subdivision of the glacial and post-glacial superficial deposits was adopted during field survey.

6.1 GLACIAL TILL

Late Devensian glacial till blankets all of the bedrock to the north of the Great Whin Sill escarpment, and patchy areas to the south of it, notably to the west of Haltwhistle Burn and to the north-east of Oaky Knowe Crags.

Within the present area, the till is generally dark blue/grey, silty, sandy clay, occasionally with orange oxidisation speckles, possibly resulting from the weathering of sandstone gravel within it. It has a yellow-brown to pale grey upper weathering profile, and is stiff to very stiff with sub-rounded to angular clasts of limestone and sandstone.

Till deposits to the south of the Great Whin Sill are undulatory and tend to reflect relief in the underlying Carboniferous strata with the result that till covered areas display smooth elongate, east – west orientated ridges with lower angle north-facing scarp slopes than those of the bedrock features. To the north of the Great Whin Sill, extensive drumlins are present showing long axes orientated roughly east – west. There is little evidence for an overprint of any underlying relief in the Carboniferous strata.

6.2 ALLUVIUM AND ALLUVIAL TERRACES

The upper reaches of the Haltwhsitle Burn, near the southern edge of the present area, flow largely over exposed Carboniferous bedrock. However, further downstream towards the B6318 and south of that road, extensive alluvium is present in the streambed. Much of this is of cobble grade and reflects the high-energy nature of this stream during times of high run-off. Sand and silt-grade alluvial deposits are also common in areas of lower energy, particularly the inside of meander beds.

Holocene river terraces are present to the south of the B6318 and particularly in the region of Cawfields [710 664]. In general, terraces show normal grading from cobbles overlain by sand and silt, the last representing flood plain deposits. A number of terraces of different levels and ages can be identified. These have been mapped individually on fieldslips but are shown on the standard map as undifferentiated deposits but with the back-scarp features of individual separate terraces depicted.

6.3 PEAT

Small- to medium-size areas of Holocene peat are present in many of the low areas, slack ground and topographical lows underlain by siltstone, particularly between the major ridge features formed by outcrops of the limestone and sandstone of the Carboniferous strata and the Great Whin Sill. Several of these are ancient ‘mires’ of Northumberland and provide internationally important wildlife habitats for which Hadrian’s Wall Country is well known. Excellent examples include Cawfields [716 668], The Loddams [702 662] and Shield On The Wall [736 666]. On occasion, peat deposits of significant thickness have also formed on hilltops. One such example is Hill Top [735 659].

6.4 EROSIONAL FEATURES AND MELT-WATER CHANNELS

The fantastic cuesta landscape of Hadrian's Wall Country in general and of the present area specifically, is the result in part of glacial scouring by the Tyne Ice Stream flowing from west to east during the last glaciation. The passage of ice has scoured the Carboniferous bedrock and accentuated the scarp and dip-slope geometries, particularly in the region of Oaky Knowe Crags in the south of the area.

The Great Whin Sill escarpment has been subject to the same glacial erosion and shows over steepened scarp slopes as a consequence. A number of deep, smooth-sided gaps observed regionally within the Whin Sill are attributed to erosion by subglacial melt-waters. Excellent examples of groves most likely attributable to this origin can be seen near Walltown Tower, approximately 1.5 km to the west of the present area. Within the area, only two gaps of any significance are present within the escarpment; Thorny Doors and Caw Gap. The former is the site of a small fault and the gap in the crags is probably the result of differential weathering of the weakened dolerite produced by this structure. The latter is not known to coincide with any structure and may well represent a subglacial melt-water channel.

7 Mass-movement and Artificial deposits

7.1 LANDSLIDE

There are no significantly large areas of slipped ground within the present area and only two areas of small landslide are recorded.

In the east-facing slopes of the Haltwhistle Burn, an area of slipped ground approximately 100 m by 100 m represents movement of superficial deposits over the bedrock. It is most probably the result of rapid incision of the Haltwhistle Burn and over-steepening of the till-covered west bank.

In Slaty Sike, a west-bank tributary of the Haltwhistle Burn, a small area of slipped ground is noted in the north bank. Again, this slip is most likely attributed to the movement of superficial deposits over the underlying bedrock as the result of stream incision.

7.2 ARTIFICIAL GROUND

A legacy of Roman occupation, ironstone working and, more recently, mining and quarrying within the area has resulted in significant areas of both worked and made ground.

7.2.1 Worked ground

Mapped areas of worked ground can be attributed to quarrying activities in outcrops of Great Whin Sill, limestone and sandstone, small-scale surface workings of coal, or Roman fortifications.

Within the area, previous commercial extraction is limited to the dolerite of the Great Whin Sill at Cawfields Quarry. Here significant tonnages of rock were removed for use in paving and as a roadstone. The quarry is now abandoned and used as picnic area and tourist attraction.

Small-scale quarry workings are present in many of the limestone units. Many contain limekilns as the principal function of these quarries was to provide limestone for the production of lime for use as a fertiliser. Examples of limestone quarries can be found the length of the Great Limestone outcrop over Oaky Knowe Crags [720 660] and in the Four Fathom Limestone at the Milecastle Inn [717 661].

A large number of small sandstone quarries exist in sandstone strata of the Little Limestone and Oakwood Limestone cyclothems, particularly in the region of Oaky Knowe Crags [715 655]. These workings may have provided stone for local buildings although it is unclear as to whether the primary purpose of many of these quarries was for sandstone or for the coal seams that underlie many of the sandstone units.

Coal workings, most notably in the Little Limestone Coal but also on seams higher up in the succession, generally result in mappable areas of made ground (spoil and waste) rather than areas of worked ground. However, some worked areas are present, notably in the fields behind the Milecastle Inn [716 658] where extensive worked areas are present on the surface outcrop of the Little Limestone Coal, and at The Holme [711 655] where extensive workings in the scarp face of a sandstone ridge are almost certainty for the underlying coal seam.

The Roman Vallum traverses the area from east to west and between Cawfields [713 665] and Winshields [743 668] and represents extensive areas of worked ground within the outcrop of the measures at the top of the Scar Limestone cyclothem. Workings for ironstone near Shield On The Wall, some of which may be quite ancient, represent extensive areas of worked ground within the outcrop of the measures of the Three Yard Limestone cyclothem.

7.2.1.1 SUBSURFACE WORKED GROUND

Extensive areas of the subsurface have been worked out in the exploitation of the Little Limestone Coal in South Tyne and Haltwhistle workings. The limits of these areas are well known from abandonment plans and are shown on the geological fieldslips of the area by green hatching.

7.2.2 Made ground

Made ground deposits within the area relate to Roman fortification or to waste and spoil heaps from quarry operations in sandstone, limestone and coal.

The sites of a number of Roman forts to both the north and south of the Wall are recorded on the Ordnance Survey maps and are evident as raised areas on aerial photography. These areas constitute much of the made ground to the north of the B6138. To the west of Cawfields [713 665] the Roman Vallum has been back-filled and constitutes a significant area of made ground in this region.

To the south of the B6318, spoil and waste heaps from workings in the limestone and sandstone ridges of Oaky Knowe Crags, and the Little Limestone Coal, constitute made ground. The biggest examples are close to the outcrop of the Little Limestone Coal on Oaky Knowe Crags [717 708] and from workings in sandstone and coal of the Little Limestone cyclothem of The Holme [711 656].

8 Economic geology

8.1 DOLERITE ('WHINSTONE')

The dolerite of the Great Whin Sill has properties that make it particularly sought-after as a roadstone. Its outcrop locally is currently worked at three large quarries: Keepershields, Barrasford and Divethill. It was formerly worked for setts and roadstone at Walltown Quarry, approximately 2 km to the west of the present area, and for setts at Cawfields Quarry within the present area [714 666]. Both these quarries are now landscaped picnic areas and tourist attractions.

It is extremely unlikely that any of the Great Whin Sill outcrop within the present area will be commercially exploited in the near future as all of it now lies within the limits of Northumberland National Park and the Hadrian's Wall World Heritage Site.

8.2 COAL

All commercial coal working within the present area has now ceased. The South Tyne and Haltwhistle workings on the Little Limestone Coal were small scale compared with other commercial enterprises on the same coal within the Tyne valley and remaining deposits were probably rendered uneconomic by faulting.

Coals within the Little Limestone and Oakwood Limestone cyclothems are thin and poorly developed by comparison and were worked within the present area for local subsistence use only. It is highly unlikely that there will be renewed economic interest in coal extraction within the area.

8.3 IRONSTONE

Many small workings in the poorly exposed ground between the Great Whin Sill escarpment and the B6138 around Shield On The Wall are for ironstone within the measures of the Three Yard Limestone cyclothem. This impure form of siderite can be refined to produce iron.

The former workings within the area are small scale and some are possibly quite ancient. The strata of the Three Yard Limestone cyclothem do not provide significant tonnages of ironstone to warrant any modern-day commercial extraction and any further working of iron ores within the area would appear extremely unlikely given that most of the target strata fall within the limits of the Northumberland National Park or within the field of view of Hadrian's Wall World Heritage Site.

8.4 LIMESTONE AND SANDSTONE

Limestone is used extensively in the aggregate and cement industries but the limestone outcrops of the present area do not offer much economic potential for these industries. Outcrops are not that large and do not offer great potential for mechanised extraction, especially as significant deposits of larger size exist locally within the Tyne valley.

The former extraction of limestone was principally for use as a fertiliser or for mortar. There is little call for limestone-based fertiliser and mortar today, although the sites of old quarries may offer commercial opportunities for the production of traditional lime mortar to support the growing restoration industry, and for archaeological preservation of Roman structures.

The outcrops of sandstone in the area do not offer the properties sought after by modern building industries. Many of the units are too thinly bedded to provide suitable stone for building, and the dip of the strata renders extraction of any commercial-scale tonnages difficult. However, many of the former quarries that exist in outcrops of sandstone probably provided building stone locally for farm buildings, small settlements, walls, stone floors and roofing flags. As these buildings are restored and developed, there is an increasing demand for local stone to match existing building work and to offer visual characteristics in keeping with the surrounding man-made structures. If the source of stone used in existing buildings can be identified to have come from a particular quarry or strata, there is economic potential in many of these former quarries.

8.5 PEAT

There is no evidence within the present area of peat extraction either for use as a fuel or as a soil improver. Commercial interest is unlikely given that much of the peat mires lie within the boundaries of Northumberland National Park, where they provide internationally important wildlife habitat.

9 Environmental issues

9.1 COAL MINING

Workings on the Little Limestone Coal at South Tyne and Haltwhistle collieries were extensive. The dip of the strata makes most of these workings quite deeply below the present day landscape and this, combined with good roof rocks minimises the potential for the development of surface collapse features over these workings. The remainder of workings on coal are surface excavations that pose few environmental problems. No significant collapses over coal workings are reported from the area.

Surface workings on the Little Limestone Coal [722 658], 500 m south-east of the Milecastle Inn, may present a minor environmental hazard. These workings are quite ancient and overgrown. There is evidence of some small pits or possible shafts within the workings and the extent of these below the present day surface, or the extent of waste material and loose rock within the workings, is not known.

9.2 CONSERVATION

Much of the area north of the B6138 lies within the Northumberland National Park and Hadrian's Wall World Heritage Site. Conservation, management and interpretation of the geological features within the National Park are addressed within a comprehensive Geodiveristy Audit and Action Plan (Lawrence et al., 2007). Both the course of, and the construction principles behind, Hadrian's Wall and the Vallum through the present area are heavily influenced by the local geology and the area offers great potential for geologically related historical conservation and geo-tourism.

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.

CHADWICK, R A, HOLLIDAY, D W, HOLLOWAY, S & HULBERT, A G,. 1995. The structure and evolution of the Northumberland-Solway Basin and adjacent areas. *Subsurface Memoir of the British Geological Survey*, ISBN 0 11 884501 2.

CLARKE, S.M. 2007s. Geology of 1:10 000 sheets NY74NE, NW and NY75NE, SW and SE, Alston, Cumbria. *British Geological Survey Internal Report*, IR/07/109.

CLARKE, S.M. 2007b. The geology of NY74SE, Nenthead, Cumbria. *British Geological Survey Internal Report*, IR/07/110.

DEAN, M.T. 2007. Palaeoecology of Chaetetes-Band: a marine biostrome in the Carboniferous, basal Namurian (basal Serpukovian) Great Limestone of northern England. *British Geological Survey Internal Report*, IR/07/023R.

DUNHAM, K C. 1990. Geology of the North Pennine Orefield Volume 1 Tyne to Stainmore. *Economic Memoir of the British Geological Survey*, Sheets 19 and 25 and parts of 13, 24, 26, 31, 32 (England and Wales.) ISBN 0 11 884471 7.

FAIRBAIRN, R.A. 1978. Lateral persistence of beds within the Great Limestone (Namurian E1) of Weardale. *Proceedings of the Yorkshire Geological Society*, Vol. 41, 533-544.

FAIRBAIRN, R.A. 1980. The Great Limestone (Namurian) of South Northumberland. *Proceedings of the Yorkshire Geological Society*, Vol. 43, 159-167.

FAIRBAIRN, R.A. 2001. The stratigraphy of the Namurian Great/Main Limestone on the Alston Block, Stainmore Trough and Askrigg Block of northern England. *Proceedings of the Yorkshire Geological Society*, Vol. 53, 265-274.

FORSTER, W. 1809. *A treatise on a section of strata from Newcastle-upon-tyne to the mountain of Cross Fell in Cumberland, with remarks on mineral veins in general*. Forster, Alston.

FROST, D.V. and HOLLIDAY, D.W. 1980. Geology of the country around Bellingham. *Memoir of the British Geological Survey*, Sheets 13 (England and Wales.) ISBN 0 11 884137 8.

JONES, M. 1995. Carboniferous rocks of the Roman Wall and Haltwhistle Burn. In: SCRUTTON, C. (ed.) *Northumbrian rocks and landscape.* Ellenbank Press, Cumbria, ISBN 1 873551 11 8.

LAWRENCE, D.J.D., ARKLEY, S.L.B., EVEREST, J.D., CLARKE, S.M., MILLWARD, D., HYSLOP, E.K., THOMPSON, G.L. and YOUNG, B. 2007. Northumberland National Park. Geodiveristy audit and action plan. *British Geological Survey Commissioned Report* CR/07/037N. ISBN 978 0 85272 599 3.

LEBOUR, G.A. 1875. On the 'Gret' and 'Four Fathom' limestones and their associated beds in south Northumberland. *Proceedings of the North of England Institute of Mining Engineers*, Vol. 24, 133-150.

STONE, P. *in press*. Northern England British Regional Geology Fifth Edition. *British Geological Survey.*

WATERS, C.N., and DAVIES, S.J. 2006. Carboniferous: extensional basins, advancing deltas and coal swamps. In: BRENCHLEY, P.J. and RAWSON, P.F. (eds.) *The Geology of England and Wales, 2nd Edition.* The Geological Society, London, ISBN 10 1 86239 199 8.

WATERS, C.N., BROWNE, M.A.E., DEAN, M.T. and POWEL, J.H. 2006. BGS Litholstratigraphical framework for Carboniferous successions of Great Britain (onshore). *British Geological Survey Research Report*, RR/05/06.

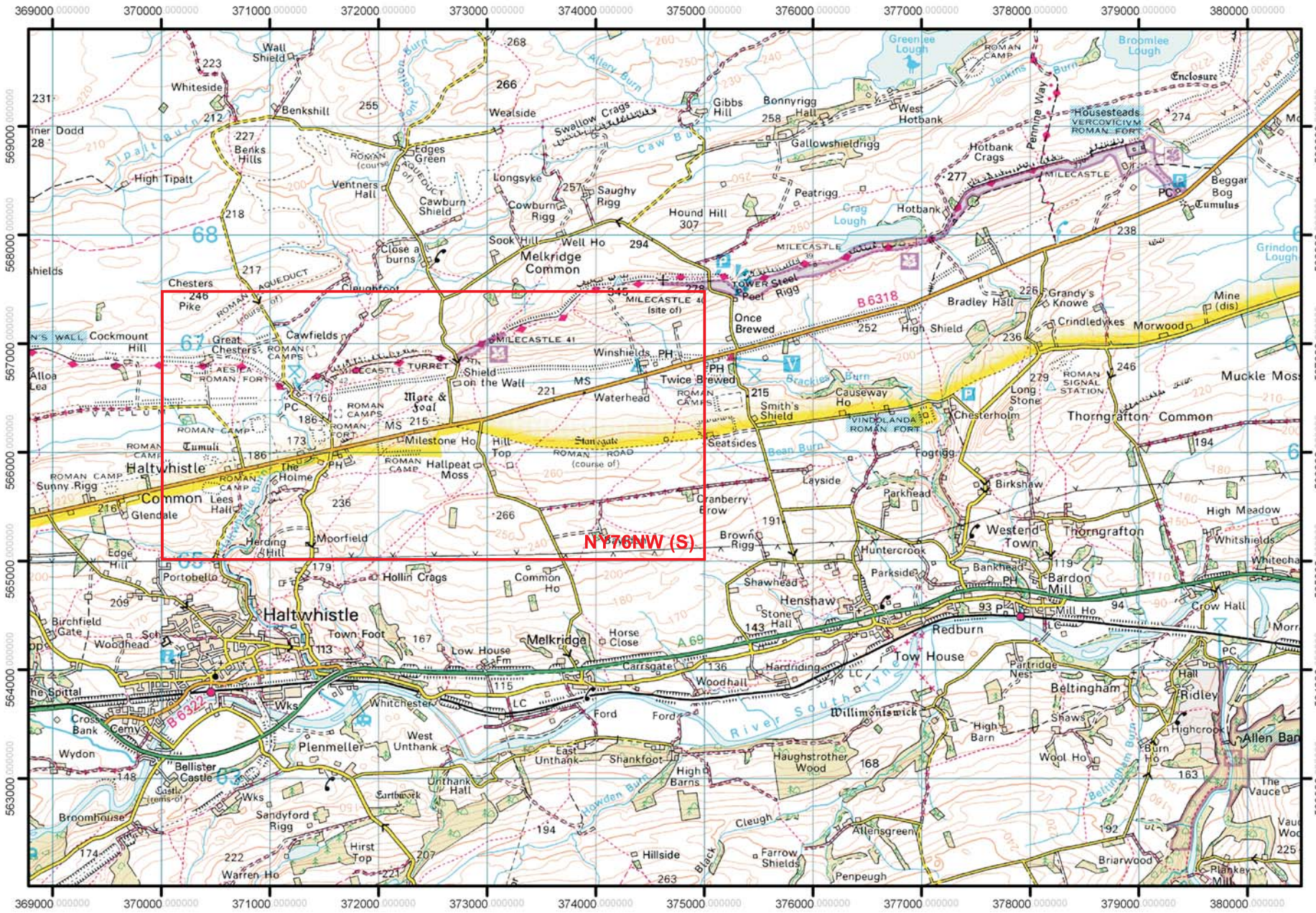

Figure 1. The geography of the area and the 1:10 000-scale sheet covered by this report

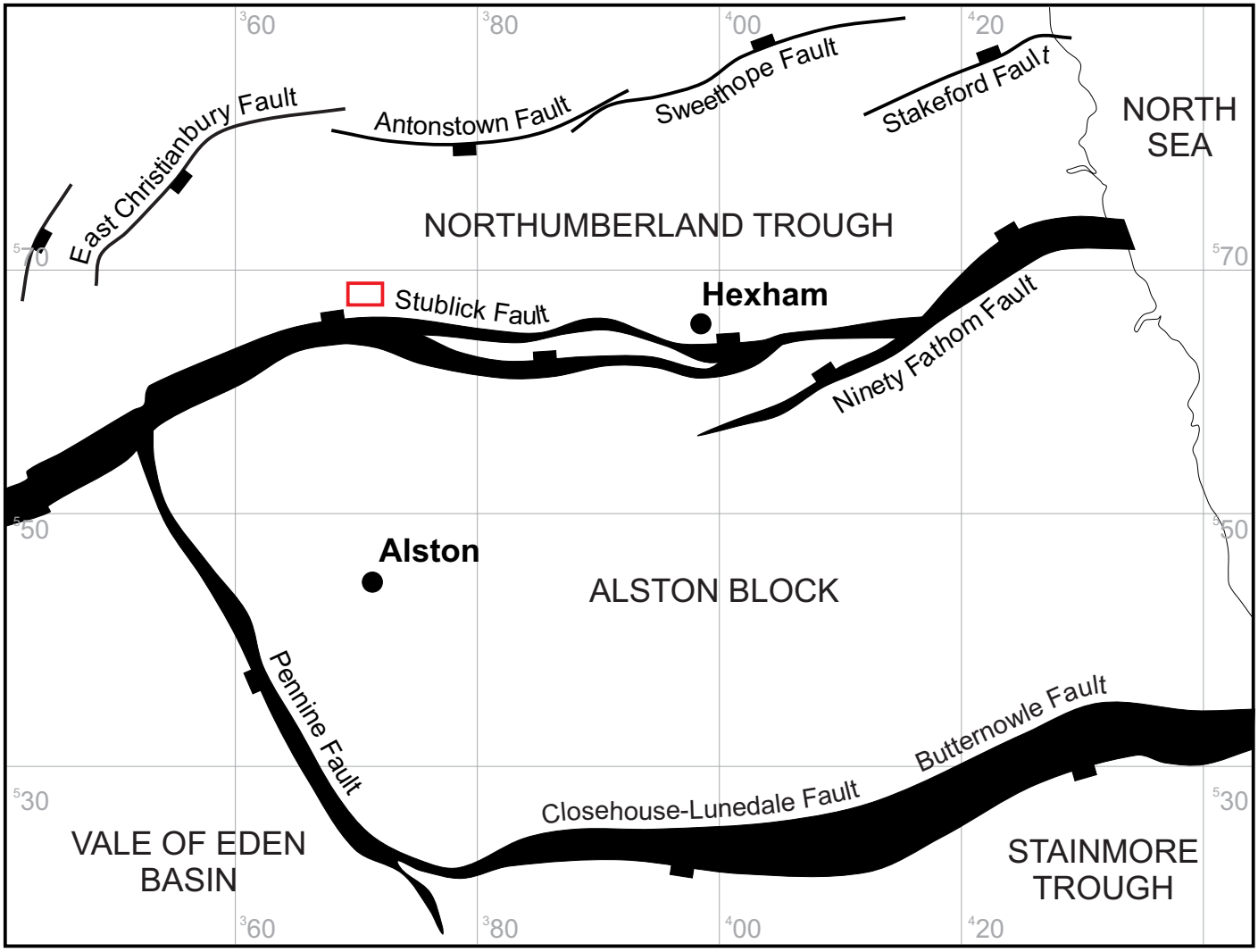

Figure 2. The regional structural geological setting of the study area

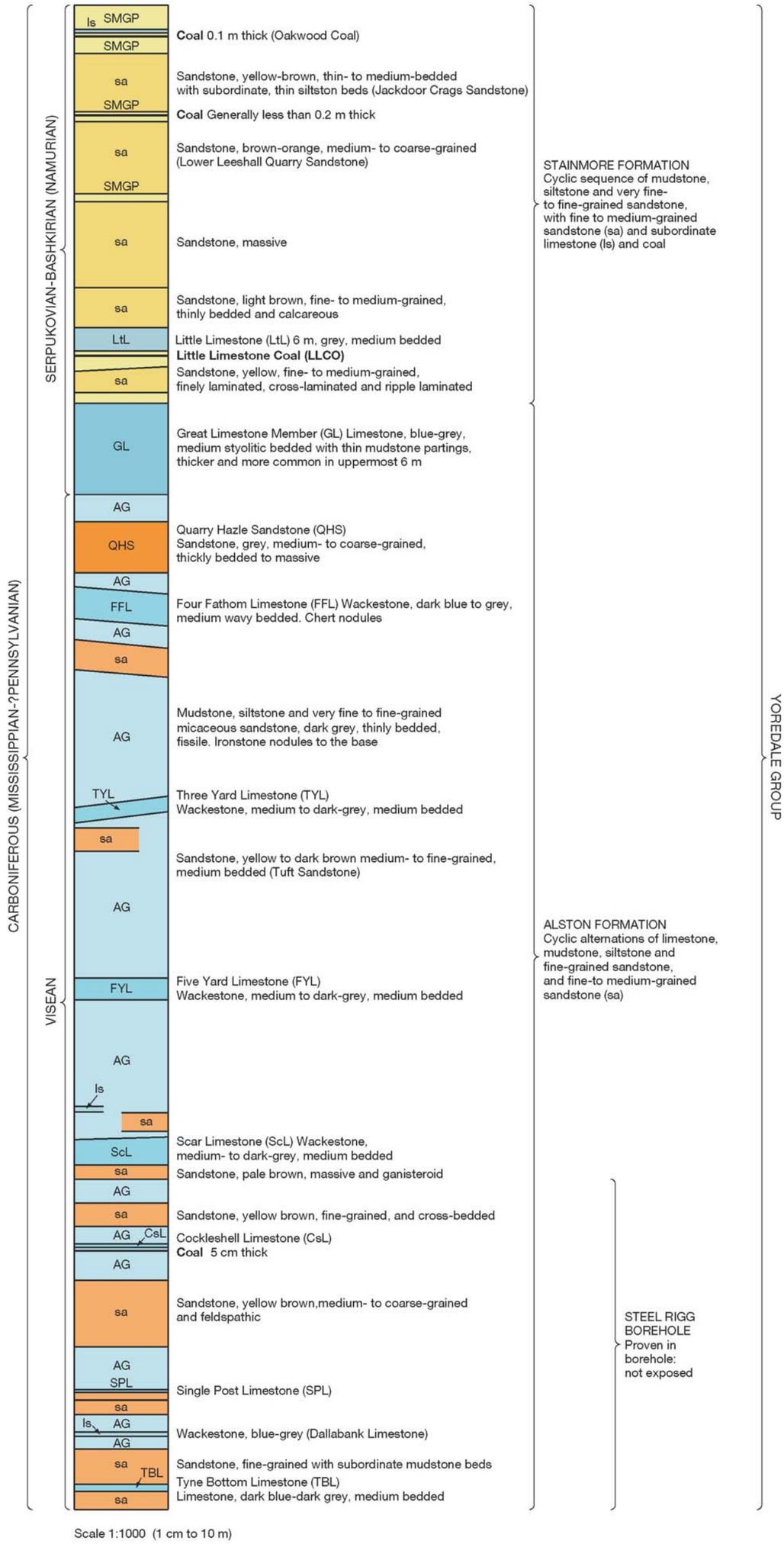

Figure 3. Representative generalised vertical section through the southern part of NY76NW