The structure and stratigraphy of Nidderdale between Lofthouse and Dacre.

Thompson, A. T.

THE

STRUCTURE AND STRATIGRAPHY

OF

NIDDERDALE

BETWEEN

LOFTHOUSE AND DACRE

BY

A. T. THOMPSON, B.Sc, F.G.S.

Thesis submitted for the degree of Doctor of Philosophy in the University of Durham(Durham Division)

ABSTRACT

The geology of the south-east corner of the Askrigg Block and part of the Craven Basin surrounding Nidderdale, Yorkshire is described. The succession, more than 1,200 feet thick in the north and twice this thickness south of the North Craven Fault, ranges from the base of the Millstone Grit to the base of the Permian, and is of Namurian and Westphalian age. The stratigraphy of each horizon is described in detail, attention being drawn to the following new finds: (i) the continuation of the Cockhill Marine Band, containing Cravenoceras cowlingense, (ii) Tylonautilus nodiferus in the Colsterdale Marine Series, (iii) shelly fossiliferous phases in the Upper Follifoot Grit, the Libishaw Sandstone, the Bewerley Shales and the First Brimham Grit, (iv) Reticuloceras circumplicatile group in the Cayton Gill Shell Bed and Reticuloceras aff. pulchellum in the overlying shales, (v) an unconformity at the base of the First Brimham Grit, south of the North Craven Fault, (vi) two Lingula bands and a band with Gastrioceras cumbriense in the Winksley Shales, the position of the latter suggesting the local absence of the R_2 Stage, (vii) the presence of the basal Coal Measures, including a Lingula band near the base. The succession is correlated with neighbouring areas. Structurally, the district includes a northern area with gentle eastward dips and a southern area of shallow E.N.E. folds crossed by folds of N-S trend. The North Craven Fault, which approximately coincides with the junction of the two areas, is shown to have been active during R_1 times in this district, but not subsequently. Its relation to the edge of the Askrigg Block is examined. The petrography of the sediments is described, a general absence of microcline and garnet from the sandstones of the E Stage being noted. Aspects of the water supply and mineral products of the area are mentioned and an appendix of borehole records incorporated.

Frontispiece

Gouthwaite reservoir, Nidderdale - looking north westwards towards Middlesmoor. The hills in the background are made up of an ascending succession of the Millstone Grit from the Grassington Grit Group to the Cayton Gill Shell Bed.

TABLE OF CONTENTS

	Page
Preface and Acknowledgements	i
List of Text Figures	iii
List of Plates	iv
List of Enclosures	vi
List of Maps	vii
CHAPTER I, INTRODUCTION	1
General	1
Geology - Regional Setting	3
Geological Sequence	5
Field Relations	6
Geological History	7
History of Research	8
CHAPTER II, THE GRASSINGTON GRIT GROUP	12
General	12
Stratigraphy	12
Details	14
Correlation	19
CHAPTER III, THE COCKHILL MARINE BAND	22
General	22
Stratigraphy	22
Details	25
Palaeontology	27
CHAPTER IV, THE NIDDERDALE SHALES	29
General	29
Stratigraphy	29
Details	32
CHAPTER V, THE RED SCAR GRIT	39
General	39
Stratigraphy	39
Details	41
CHAPTER VI, THE COLSTERDALE MARINE SERIES	47
General	47
Stratigraphy	47
Details	51
Palaeontology	55
CHAPTER VII, THE NAR HILL BEDS	59
General	59
Stratigraphy	59
Details	60
CHAPTER VIII, THE FOLLIFOOT GRITS	66
General	66
Stratigraphy	67
Details - The Lower Follifoot Grit	70
Follifoot Shales	74
Upper Follifoot Grit	75

Page

CHAPTER IX, THE BEDS BETWEEN THE UPPER FOLLIFOOT GRIT AND THE FIRST BRIMHAM GRIT 81

General 81
Stratigraphy 86
Details - The Shell Bed and underlying shales 91
Agill Sandstone 100
Libishaw Shales 101
Libishaw Sandstone 103
Bewerley Shales 106
Palaeontology - Cayton Gill Shell Bed 107
Libishaw Shales 109
Scot Gate Ash Marine Band 109
Zonal Succession 110
Faunal Lists 111

CHAPTER X, THE BRIMHAM GRITS 115

General 115
The relation of the First Brimham Grit to the underlying rocks 115
Stratigraphy 118
Details - First Brimham Grit 122
Brimham Shales 133
Second Brimham Grit 135

CHAPTER XI, THE BEDS ABOVE THE SECOND BRIMHAM GRIT 138

General 138
Stratigraphy 138
Details 139

CHAPTER XII, CORRELATION WITH SURROUNDING AREAS 144

CHAPTER XIII, STRUCTURE 158

General 158
Faults 161
Folds 168
Joints 171
The boundaries of the Askrigg Block in the south and east 172
Summary of the earth-movements in this area 174

CHAPTER XIV, PETROGRAPHY 176

General 176
Sandstones of the Grassington Grit Group 177
Sandstone lenses within the Nidderdale Shales . . . 179
The Red Scar Grit 180
Sandstone lenses within the Nar Hill Beds 180
The Follifoot Grits 181
Cayton Gill Shell Bed 183
Libishaw Sandstone 184
The Brimham Grits 184
Conclusions 185

CHAPTER XV, ECONOMIC GEOLOGY 187

General 187
Water Supply 187
Building Stone 188
Roadstone 188

Page

CHAPTER XV, ECONOMIC GEOLOGY cont'd.

Coal 188
Lead Ore 189
Iron Ore 189
Silica 189
Ganister 190
Petroleum 190
Peat 192
Sand and Gravel 192
Mineral springs 193

APPENDIX 1, Borehole Records 194

LIST OF WORKS TO WHICH REFERENCE IS MADE 218

PREFACE AND ACKNOWLEDGEMENTS

The research work for this thesis was carried out between August, 1954 and August, 1957 in the Department of Geology, Durham Colleges, under the supervision of Professor K. C. Dunham, F.R.S., D.Sc., PhD, S.D., M.I.M.M., F.G.S.. Of this period, approximately 13 months were spent in Yorkshire on field survey, based on Lofthouse, Pateley Bridge and Kirkby Malzeard, and the remainder of the time in the Science Laboratories of the University.

The work was undertaken primarily at the instigation of The Shell Petroleum Company Limited, to whom the author is indebted for the award of a Studentship as well as the personal interest in the work taken by Mr. A. E. Gunther.

He is grateful also to the staff and students of the Department of Geology, Durham Colleges, for helpful discussion on many of the problems associated with the work. In particular, thanks are due to Mr. A. A. Wilson who surveyed adjacent ground to the north and Dr. G. A. L. Johnson who has been a source of constant encouragement on palaeontological problems and other aspects of the study. Some of the more critical fossil identifications were undertaken by Dr. W. H. C. Ramsbottom, Mr. W. S. Bisat and Mr. J. Selwyn Turner and to them the author records his sincere appreciation for their unstinting help.

In the course of the study, reference has been made to several unpublished PhD theses; for permission to consult these the author is obliged to Professor W. Q. Kennedy of the Department of Geology, University of Leeds, and Professor T. S. Westoll of the Department of Geology, King's College, Newcastle.

Numerous boreholes have been sunk in this area; for access to the records of these, the writer is indebted to the Water Department of The Geological Survey, J. T. Hymas Limited of Burton Leonard, Leeds Corporation Waterworks Department, Bradford Corporation Waterworks Department, The British Petroleum Company Limited and Associated Silicas Limited, Smelthouses. Thanks are also due to the many landowners, tenants, keepers and quarry managers who have so readily granted permission to walk over their ground and examine rock outcrops.

The photographic reproductions in this thesis are the work of Mr. C. Chaplin. To him and the remainder of the technical staff of the Department of Geology, Durham Colleges, the author expresses his sincere thanks.

Finally, to Professor K. C. Dunham, who originally suggested the subject of research and who has throughout offered unlimited help, advice and criticism, the author would record his indebtedness and appreciation for all that he has done.

LIST OF TEXT FIGURES

		Page
1.	Sketch-map showing the general geological relations of the area.	1
2.	Comparative sections of the Grassington Grit Group in this area.	12
3.	Comparative sections of the Grassington Grit Group in the Central Province.	19
4.	Map illustrating the occurrence of the Cockhill Marine Band in this area	23
5.	Comparative sections of the Nidderdale Shales	30
6.	Isopachyte map of the Red Scar Grit	40
7.	Map illustrating the occurrence of the Colsterdale Marine Series in this area	50
8.	Comparative sections of the Nar Hill Beds	60
9.	Composite section of the beds between the Upper Follifoot Grit and the First Brimham Grit	86
10.	Sketch-section illustrating the overstep of the First Brimham Grit from Simonseat to Greenhow	84
11.	Comparative sections of the strata exposed in the Scot Gate Ash Quarries	104
12.	Table summarising the varying nomenclature applied to the beds between the Lower Follifoot Grit and the Second Brimham Grit	82
13.	Isopachyte map of the beds between the top of the Cayton Gill Shell Bed and the base of the First Brimham Grit	116
14.	Composite section of the beds above the Second Brimham Grit	140
15.	Comparative sections of the Millstone Grit and Lower Coal Measures in Nidderdale and adjoining areas	145
16.	Comparative sections of the Namurian in the Northern Province	146
17.	Structure contour map of the country between Grassington and Fountains Abbey	159
18.	Sketch-map illustrating the structure of the area	160
19.	Statistical analysis of structural trends	162
20.	Comparative sections of the boreholes sunk by Associated Silicas Limited, Smelthouses	195
21.	Log of the British Petroleum Company's Sawley borehole	200
22.	Log of the Aldfield borehole and section of the Burn Tunnel	201
23.	Comparative sections of the Leed's Corporation boreholes at Carlesmoor and Laverton	206
24.	Location map of the boreholes at Carlesmoor and Laverton	207

LIST OF PLATES

Plate			Page
I	A.	View over Gouthwaite reservoir from Heathfield	2
	B.	View of Meugher from Rather Standard	2
II	A.	The Cockhill Marihe Band, Backstean Gill	24
	B.	Concretionary limestone in the Cockhill Marine Band . .	24
III	A.	A septarian nodule of Cockhill Limestone	26
	B.	A polished surface of Cockhill Limestone	26
IV	A.	Acoras Scar, Backstean Gill	33
	B.	Jointing in the Nidderdale Shales	33
V	A.	Great Wolfrey Crag, Gate-up Gill	40
VI	A.	Weathering in the Red Scar Grit	44
VII	A.	The Colsterdale Marine Series, Backstean Gill	47
	B.	The Colsterdale Marine Series, Old Quarry, Wath . .	47
VIII	A.	A mudcracked surface of Colsterdale shale	51
	B.	A bedding plane of Colsterdale shale	51
VIII-1	A.	Cravenoceratoides nitidus - from the Colsterdale Limestone	55
	B.	Tylonautilus nodiferus - from the Colsterdale shales . .	55
VIII-2	A.	Ventral view of Cravenoceratoides nitidus	56
	B.	Lateral view of Cravenoceratoides nitidus	56
IX	A.	Burn Edge, Heathfield Moor	61
	B.	West Gill, Stean Moor	61
X	A.	Trails in the Nar Hill Beds	63
XI	A.	The Upper Follifoot Grit, Horse Pasture Quarry, Dacre .	77
XII	A.	Prospect Farm Quarry, Hartwith	86
XIII	A.	The bedding surface of a Schizophoria band	88
	B.	A transverse section of a Schizophoria band	88
XIV	A.	Scot Gate Ash Quarry	89
	B.	Slumped bedding in the Libishaw Sandstone	89
XV	A.	Brimham Rocks from the south	118
	B.	The Baboon's Head, Brimham Rocks	118
XVI	A.	London Crag, Warsill	120
XVII	A.	Heyshaw Moor Quarry	131
	B.	High Crag Ridge, Heyshaw	131
XVIII	A.	Old Quarry near Blazefield	133
	B.	Klondyke Quarry, Warsill	133
XIX	A.	View across Nidderdale to hillside above Pateley Bridge .	165
	B.	View of Wilsill syncline	165
XX	A.	Fault in Backstean Gill	167
	B.	Fault in Ramsgill Beck	167
XXI	A.	False bedding in the First Brimham Grit	176
	B.	Wavy bedding in the First Brimham Grit	176
XXII	A.	Weathering in the First Brimham Grit	181

			Page
XXII-1	A.	Microphotograph of the Colsterdale Limestone	183
	B.	Microphotograph of the locally calcareous division of the Libishaw Shales	183
XXIV	A.	Eavestone Lake, Grantley	192
	B.	Clip'd Thorn Hill Gravel Pit, Aldfield	192

LIST OF ENCLOSURES

1. Geological map of Nidderdale between Dacre and Lofthouse and the surrounding ground between Grassington and Fountains Abbey.

2. Horizontal sections: 1) Between Meugher and Winksley.
2) Between Bishop's Moor and Burnt Yates.

LIST OF MAPS

The area surveyed is covered by the following six-inch quarter sheets, published by the Ordnance Survey:-

Yorkshire (West Riding)

99 S.E.			
116 N.E.	117 N.W. N.E.	118 N.W. N.E.	119 N.W.
	S.W. S.E.	S.W. S.E.	S.W.
	135 N.E.	136 N.W. N.E.	137 N.W.
	S.E.	S.W. S.E.	S.W.

It is covered by the following geological maps published by the Geological Survey:-

Scale: 6 inches to the mile - numbers as above.

Scale: 1 inch to the mile - Sheet 97 S.E. (Old Series)
Sheet 92 N.E. (Old Series)
Sheet 62 (New Series)

Additional publications of the Geological Survey are:-

A memoir accompanying Sheet 62 (New Series)
Horizontal sections - Sheets 98 & 129
Vertical sections - Sheet 28

Cover is provided by the following Ordnance Survey sheets on a scale of 1:25,000:-

44/06	44/16	44/26
44/07	44/17	44/27

The relevant sheets on the scale 1:63,360 are:-

90, Askrigg and Settle
91, Ripon

CHAPTER I
INTRODUCTION
General

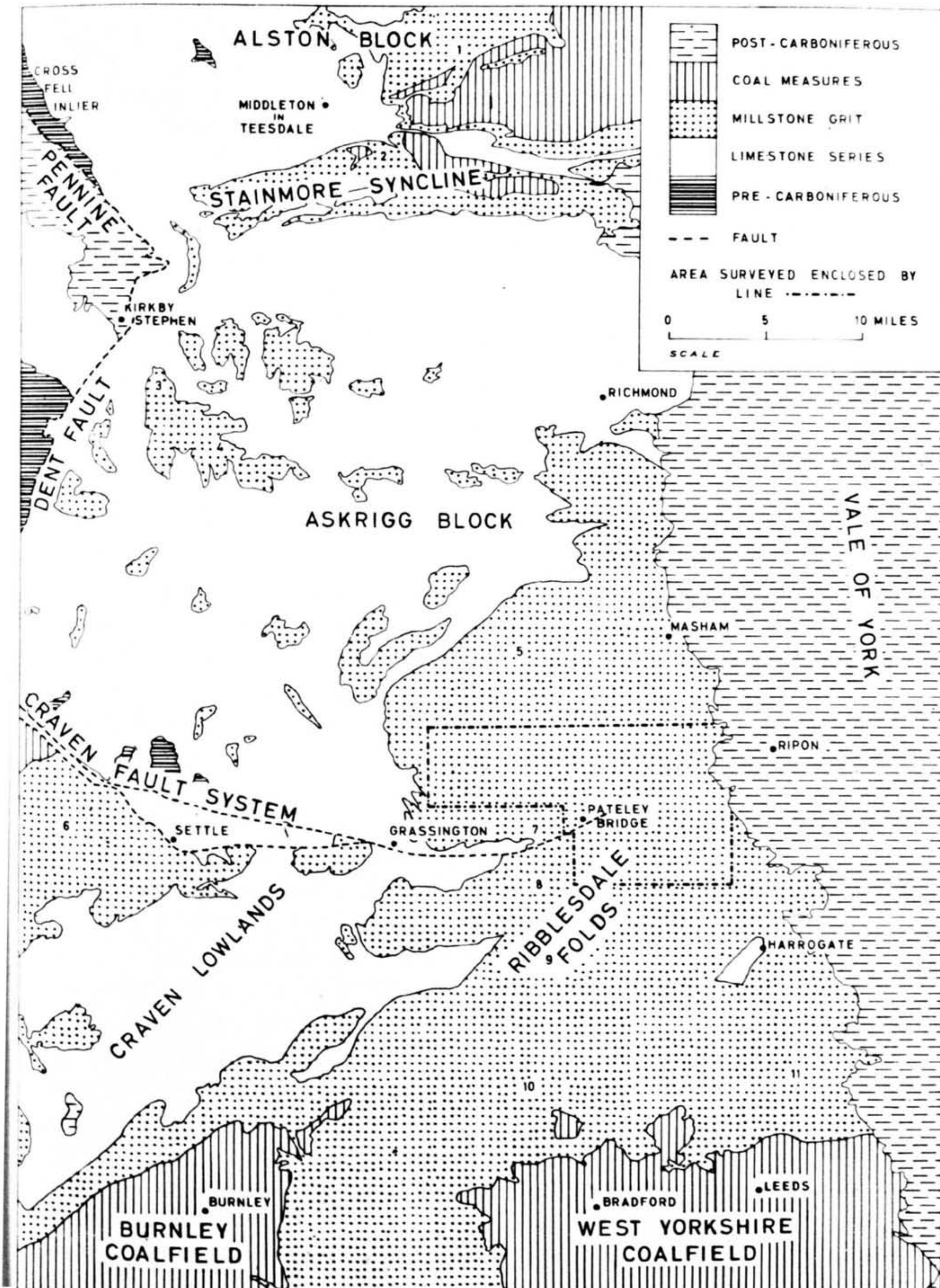
Extending down the centre of England as a broad ridge of highland, almost from the Cheviots to the Midland Plain, the Pennines constitute perhaps the most dominant feature in the physiography of northern England. They are an impressive range when viewed from the east, rising gradually from the Vale of York towards the high fell country which characterises their central portion and standing boldly athwart the prevailing westerly winds. On the west they descend abruptly to the great Lancashire-Cheshire plain and its northern extremity the Vale of Eden so not inaptly have they been described as the "backbone of England". A glance at the map will reveal that in their northern part they have the appearance of an uplifted block, tilted in an easterly direction and deeply dissected by a number of easterly flowing rivers. The rivers rise in barren moorland, much of it over 2,000 feet O.D., and for the upper part of their courses flow in steep-sided U shaped valleys, known locally as dales. These dales are one of the attractions of the Pennine uplands, for besides being lines of communication and containing the larger settlements, they are also acknowledged beauty spots drawing great numbers of visitors every year. In this account the geology of a section of one of the dales is described, together with the ground surrounding it on the east and west.

The dale, Nidderdale in the West Riding of Yorkshire is probably one of the least known of the Yorkshire Dales, differing from those north of it by its N.W.-S.E. course. It is situated south of Wensleydale and east of Wharfedale, traversing the district described in this account in its central part, the district being bounded on the north by the recently described tract of Upper Nidderdale(Wilson, 1957), on the south-west by the moorland areas of Greenhow(Dunham and Stubblefield, 1945) and Simonseat(Hudson, 1939) and on the east by the base of the Magnesian Limestone; its other boundaries are quite arbitrary, enclosing portions of the drainage systems of three of the major Pennine rivers, the Wharfe, the Nidd and the Ure. The dale is picturesque and possesses of exceeding charm, much of it due to the siting of a reservoir between Ramsgill and Wath(Plate I A), but in other respects it has beauty which is well deserving of its local name, "the Switzerland of England". On either side it is flanked by desolate moors, those on the west leading up by a series of escarpments to the inhospitable fells surrounding Meugher(1,880') and Great Whernside(2,310'), and those on the east descending gradually

Figure 1. Sketch map to show the general geological relations of the area described in this account. The numbers relate to areas recently surveyed and to which reference is made in the text.

1. Teesdale (Jones, 1957)
2. Stainmore Syncline (Reading, 1954)
3. Tan Hill to Swarth Fell (Rowell, 1953)
4. Swarth Fell to Rogans Seat (Scanlon, 1955)
5. Upper Nidderdale and Colsterdale (Wilson, 1957)
6. Keasden (Moseley, 1956)
7. Greenhow (Dunham & Stubblefield, 1945)
8. Simonseat (Hudson, 1939)
9. Beamsley (Jones, 1943)
10. Bradford and Skipton District (Bradford Memoir, 1953)
11. Leeds District (Leeds Memoir, 1950)

The map is based on the published maps of The Geological Survey



ALSTON BLOCK
CROSS FELL INLIER
MIDDLETON IN TEESDALE
PENNINE FAULT
STAINMORE SYNCLINE
POST-CARBONIFEROUS
COAL MEASURES
MILLSTONE GRIT
LIMESTONE SERIES
PRE-CARBONIFEROUS
FAULT
AREA SURVEYED ENCLOSED BY LINE
0
5
10 MILES
SCALE
KIRKBY STEPHEN
DENT FAULT
RICHMOND
ASKRIGG BLOCK
VALE OF YORK
MASHAM
CRAVEN FAULT SYSTEM
RIPON
PATELEY BRIDGE
SETTLE
GRASSINGTON
RIBBLESDALE FOLDS
CRAVEN LOWLANDS
HARROGATE
BURNLEY
BRADFORD
LEEDS
BURNLEY COALFIELD
WEST YORKSHIRE COALFIELD

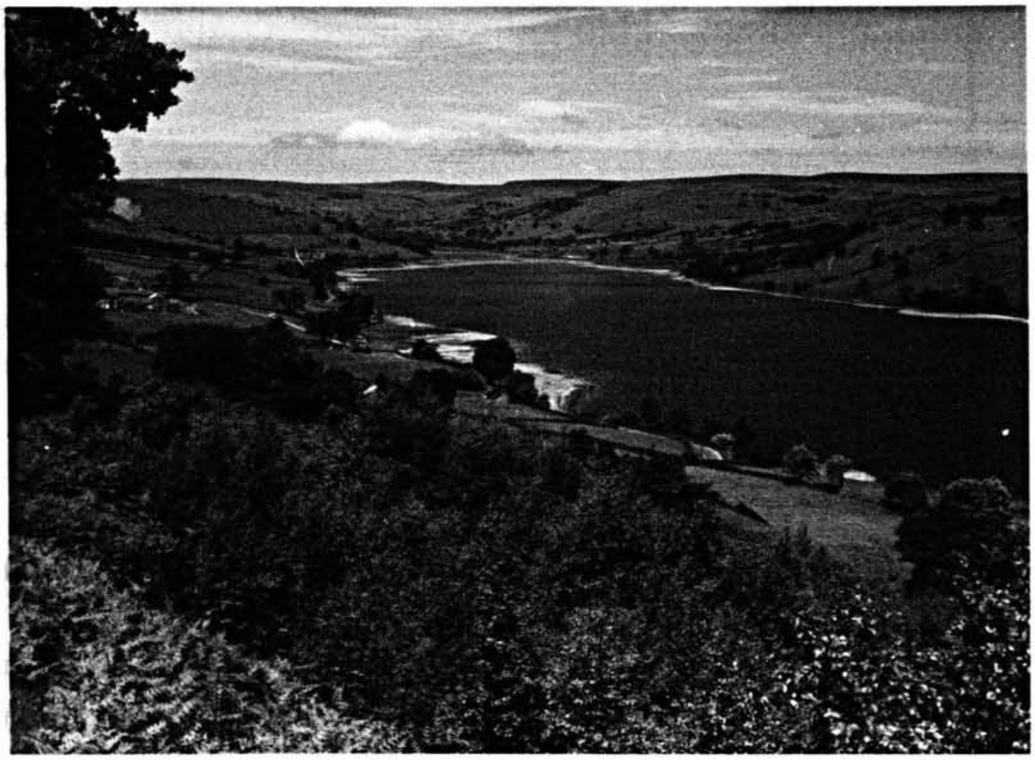
towards the Vale of York, passing progressively through lowland pasture into highly fertile ploughland. This easterly slope of the country is a feature of the northern Pennines as a whole and results in appreciable climatic differences in an E-W direction, the rainfall for instance in this district decreasing from nearly 60 inches per annum in the west to less than 30 inches per annum in the east.

For the most part the country is moorland, that on the west being the highest and the least accessible. The moorlands are typically flat-topped and peat covered, intersected throughout by a number of deeply incised fast flowing streams. Above 1,700 feet O.D. the characteristic vegetation is tussocky acidic grass accompanied by cotton grass moss, the latter owing its abundance to the boggy conditions so common on the north Yorkshire moors. This gives way below 1,700 feet to heather which provides cover and pasture for the hardy mountain sheep, red grouse, plover and curlew that inhabit it. These heather moors form the bulk of the area and though somewhat monotonous in appearance for the major part of the year, can be extremely attractive in late summer when the heather is in bloom. They in turn give way to lowland pasture at about the 900 feet contour, a change rather strikingly accentuated by the almost coincidental topographic change that takes place: from the long flat dip slopes and abrupt escarpments of the moorlands to the rolling fields of the lowland pasture, partitioned by an intricate pattern of stone walls. This contrast results from the thick mantle of glacial drift on the lower ground which has effectively obliterated most of the original geological features, the moorlands still however reflecting the alternating shale/sandstone character of the sediments. In the extreme south-east the lowest ground is reached, that lying between 250 feet and 350 feet O.D.. This part consists of highly fertile ploughland, and completes the W-E topographical range of the district, from barren moorlands more than 1,900 feet high to arable ploughland less than 300 feet O.D..

On the eastern side of Nidderdale the high moorlands are dissected by the upper feeder streams of the River Nidd with in the extreme west, part of the area coming just within the drainage system of the River Wharfe. West of Nidderdale, the ground rises sharply and across the watershed, the drainage system includes two of the easterly flowing tributaries of the Ure, the Laver and Skell, together with a few small streams which lead eventually into the Nidd.

The main town in the area is Pateley Bridge, a former market town of moderate size(Pop. 2,000). North and south of it in the dale are a number of other small villages, all connected by the main Harrogate to Pateley Bridge road(B.6165). The least accessible part is that north of Pateley Bridge where

A



View over the Gouthwaite reservoir from Heathfield. The sides of Nidderdale rise steeply and pass quickly from lowland pasture to grouse inhabited heather moors.

B

The desolation of the higher moors is typified by this view of Meugher from Rather Standard, Grassington Moor. Meugher itself is capped by an outlier of the Lower Follifoot Grit.

only one road running up the dale to Middlesmoor serves the area, a road that has no good connecting links with the country to the north, west or east so that Upper Nidderdale is in effect closed at its head. In the eastern part of the area a number of other small settlements occur, the number increasing as the Vale of York is approached. These too are connected by a good network of secondary roads, and with Pateley Bridge in the west bynthe main road from Ripon(B.6265). Overall however, the district is essentially one of scattered farms.

As would be expected from the above description, the most important pursuit of the people is agriculture, dairy farming in particular. Formerly, a not insignificant number were employed in mining and quarrying, but these industries have long since been defunct and are now remembered by only a few of the local inhabitants. The only industries operating within the district today are a few scattered leather, rope and flour mills in Nidderdale and two small quarries for silica-rock and ganister near Smelthouses. Another source of employment however, is in the shops and offices of the larger West Riding towns such as Harrogate and Ripon, to which a daily commuting traffic is now quite considerable. Tourism is an industry as yet incompletely exploited, in spite of the wealth of the local scenery and attractions such as the gorge in Howstean Beck, Brimham Rocks and the fine mediaeval ruin of Fountains Abbey. These unusual places make the district one of considerable appeal, quite apart from the geological changes that take place in it, which as will be shown in the succeeding account are of no small interest in themselves.

Geology - Regional Setting

Geologically, the Pennine uplands can be divided readily into three major regions on the basis of their structure. In the north is a fault-bounded block of gently dipping strata known as the Northumbrian Fault Block(Versey, 1927), itself divisible into a northern or Alston Block(Trotter and Hollingworth, 1928) and a southern or Askrigg Block(Hudson, 1938). This part of the uplands constitutes the northern Pennines. South of it, and separated from it by the North Craven Fault is the mid-Pennines, a region of N.E.-S.W. folds(Ribblesdale folds) extending as far south as a line joining Burnley to Harrogate. Finally in the south is the southern Pennines, a region consisting of a major, northerly pitching N-S anticline which at its southern end opens up into a broad uplift, in the inner part of which the rocks have little or no dip(Hudson and Cotton, 1943). These three divisions reflect the deep-seated structural pattern of northern England, established before Carboniferous times and probably initiated during or shortly after the Caledonian orogeny. The effect of the structural pattern is discernible in the sedimentation of the Carboniferous rocks, of which the Pennines are largely composed, the strata thickening markedly when traced southwards from the northern Pennines into the mid-Pennines and thinning again when followed farther to the south. In addition to this thickness change a remarkable facies change also takes place at the southern boundary of the northern Pennines, the Great Scar Limestone and its overlying Yoredale Series passing laterally into the Bowland Shales. These changes, whilst broadly understood, are not in every case known in detail. For instance in the extreme east of the uplands at the junction of the north and mid-Pennines, no large scale geological mapping has been attempted since the primary survey, thus leaving a conspicuous gap in the knowledge of this boundary built up farther west by the researches of such authors as Garwood and Goodyear(1924), Anderson (1928), Hudson(1939), Dunham and Stubblefield(1945), Black(1950) and Rayner (1953). One of the purposes of the present investigation has been to fill in this gap and to determine the exact nature of the changes taking place at the junction of the north and mid-Pennines east of Greenhow, as well as the line along which they occur. The district surveyed thus includes part of the south-east corner of the Askrigg Block, a region with gentle eastward dips, and part of the Craven Basin of sedimentation, an area of E.N.E.- W.S.W. folds crossed by folds of N-S trend.

The rocks are all of Carboniferous age, ranging from the base of the Millstone Grit to the base of the Permian. They are entirely sedimentary in their origin and include part of the Namurian Series and part of the Westphalian Series. The following table gives a summary of the stratigraphical succession established during the present survey, the thicknesses being generalised from data collected throughout the area. On the map(Enclosure 1) the shales and sandstones of the Coal Measures are distinguished by a separate colour and within the Millstone Grit, the sandstones above the First Brimham Grit have been separately distinguished. Where possible on the map, individual beds have been indicated by the appropriate initials and in the case of the three main marine bands, a separate colour has been used for each. The range of thickness of individual beds gives some idea of the change in thickness that takes place across the North Craven Fault, though not in every case are these figures strictly a reflection of that only. In general however, the succession more than doubles in thickness when traced southwards across the North Craven Fault.

Geological Sequence

Horizon	COAL MEASURES	Feet
	WINKSLEY SANDSTONE: coarse quartzitic sandstone . . .	25
	WINKSLEY SHALES: grey shale with <u>Lingula</u> Band near middle .	70
	MILLSTONE GRIT SERIES	
	LAVERTON SANDSTONE: coarse quartzitic sandstone with coal near top	120
G_1	LAVERTON SHALES: grey shale, marine near middle with <u>Gastrioceras cumbriense</u>	65
	<u>Non-or condensed sequence</u>	
	SECOND BRIMHAM GRIT: coarse pebbly sandstone, lower part felspathic, upper part quartzitic	40 - 70
	BRIMHAM SHALES: grey sandy shale	15 - 90
	FIRST BRIMHAM GRIT: coarse pebbly felspathic sandstone with shale parting near middle	35 - 400
	<u>Unconformity</u>	
R_1	BEWERLEY SHALES: grey shale with Scot Gate Ash Marine Band (ca. 5 feet of shelly siltstone) near top . . .	30 - 55
	LIBISHAW SANDSTONE: medium-grained subgreywacke, locally quartzitic sandstone	25 - 200
R_1	LIBISHAW SHALES: grey shale, marine near base with <u>Reticuloceras</u> aff. <u>pulchellum</u>	35 - 55
	AGILL SANDSTONE: quartzitic sandstone, locally shaly near base	15 - 55
R_1	CAYTON GILL SHELL BED: shelly siltstone, locally calcareous towards top; contains <u>Reticuloceras</u> <u>circumplicatile</u> group	29 - 42
	CAYTON GILL SHALES: grey shale	11 - 25
	UPPER FOLLIFOOT GRIT: coarse quartzitic sandstone, locally felspathic	15 - 140
	FOLLIFOOT SHALES: grey shale	13 - 90
	LOWER FOLLIFOOT GRIT: coarse quartzitic sandstone, locally felspathic	30 - 145
	NAR HILL BEDS: grey shales with impersistent beds of sandstone	119 - 243
E_2	COLSTERDALE MARINE SERIES: fossiliferous shales with thin bed of limestone near base containing <u>Cravenoceratoides</u> <u>nitidus</u>	10 - 23

Horizon		Feet
	RED SCAR GRIT: coarse quartzitic sandstone, locally felspathic	30 - 120
	NIDDERDALE SHALES: grey shales with thin impersistent beds of sandstone and impure limestone	217 - 304
E_2	COCKHILL MARINE BAND: fossiliferous shales with septarian bullions of limestone containing <u>Cravenoceras</u> <u>cowlingense</u>	4
	GRASSINGTON GRIT GROUP: variable group of coarse sandstones with intercalated shales and one coal at top . .	117 - 307
	BOWLAND SHALES(Sawley Borehole only)	25

<u>Unconformity</u>

C A R B O N I F E R O U S L I M E S T O N E S E R I E S

Field Relations

As noted above the district is divisible into a northern area of gently dipping sediments and a southern area of folded strata. In the northern part the succession is complete from the Grassington Grit to the Winksley Sandstone, the beds suceeeding each other quite conformably and dipping gently to the east. West of Nidderdale well exposed stream sections reveal the lower half of the sequence, from the Grassington Grit to the Cayton Gill Shell Bed, the exposures being almost complete in some of the sections and permitting of detailed thickness and lithological comparisons. On the intervening moorlands, clearly defined features reflect the alternating shale/sandstone character of the sediments and enable lithological junctions to be traced with relative precision. East of Nidderdale the whole succession is present, ranging from the Grassington Grit in the bottom of the dale to the Laverton Sandstone on the highest ground and finally in the extreme east to the basal strata of the Coal Measures. Exposures here are on the whole comparatively poor owing to the heavy drift cover on the lower ground, but in the tributary streams of the Nidd and in the valleys of the rivers Laver and Skell some stream outcrops occur, and throughout, a number of old quarries contain important sections.

In the southern part of the district, south of a line joining Wath to Fountains Abbey, the strata are folded on shallow E.N.E. and N-S axes. The rocks exposed at the surface, once more rather infrequently owing to the drift cover, range from the Nidderdale Shales to the Second Brimham Grit, but in the main they include only the beds between the Upper Follifoot Grit and the First Brimham Grit. Near Heyshaw, west of Nidderdale, a small faulted patch of Red Scar Grit and lower beds occurs, which is succeeded to the east by a long dip slope in the Follifoot Grits extending as far as the valley of the Nidd. Farther east across the dale, the faulting is locally quite complex making interpretation somewhat difficult, a position further troubled by the poor exposure and the presence of an unconformity at the base of the First Brimham Grit. The mapping however, reveals extensive tracts occupied by the First Brimham Grit on the higher ground and smaller areas composed of the beds down to the Upper Follifoot Grit in the valleys.

Geological History

The record commences with a sedimentational break, marking the base of the Millstone Grit and of the Namurian. Thereafter sedimentation appears to have been continuous up to the top of the Bewerley Shales, some 1,800 feet of alternating shales and sandstones being depositéd. The character of these sediments, their lithology and sedimentary structures, indicates that they are the product of aqueous deposition, most probably in the setting of a subsiding delta. At five separate intervals during the period however, marine conditions became established and resulted in the laying down of fossiliferous shales and limestones. These marine bands alter in a northerly direction, both in lithology, thickness and faunal content suggesting that they are the results of marine incursions from the south and that shallower water conditions of deposition existed in the north. In the latter part ofthe period, the marine environment appears to have been particularly close, because fossils are foùnd at a number of levels in the sequence between the upper part of the Upper Follifoot Grit and the top of the Bewerley Shales.

Throughout, the influence of the "rigid block" is apparent, the sediments thickening markedly when traced southwards across the North Craven Fault. This is exceptionally well seen in the Follifoot Grits in Nidderdale and can be discerned in the older strata also, though at that level the information is confined to borehole evidence only. No change in facies comparable to the Lower Carboniferous takes place, but at the level of the Libishaw Shales, a fossiliferous phase is known south of the North Craven Fault only.

Following the deposition of the Bewerley Shales, the area south of the North Craven Fault appears to have been uplifted and subjected to earth-movements, some minor folds being produced in the neighbourhood of Bishop Thornton. Erosion also took place and resulted in the formation of an uneven surface upon which the basal deposits of the First Brimham Grit were laid down. The Brimham Grits are coarse pebbly sandstones rich in microcline and garnet, minerals rare if not absent from the younger sediments of the Namurian so that a change in the rocks exposed to erosion in the source area is indicated, most probably initiated at the beginning of Lower Follifoot Grit times. Shortly after the uplift at the beginning of First Brimham Grit times the North Craven Fault itself became active, displacing the strata to the southa distance of approximately 400 feet. This movement gives no indication of having taken place abruptly, but rather of having taken place in stages throughout the deposition of the First Brimham Grit. It would seem to have ceased entirely by mid-R_1 times because no displacement of the Second Brimham Grit, east of Pateley Bridge is discernible at the surface.

Above the First Brimham Grit, right up to the Winksley Sandstone the beds appear to represent a continuous sedimentation sequence. Faunally however, a considerable hiatus is discernible at the base of the Laverton Shales, no fossils of the R_2 Stage being found in this area. As the beds of this Stage are 700 feet thick on Rombalds Moor to the south(Stephens and others, 1942), a remarkable change in the eastern part of the Central Province during late Namurian times is implied. This change could possibly take the form of a tilting of the Askrigg Block in a southerly direction, the process commencing in as early as late E_2 times in the north.

Following the deposition of the Winksley Beds the whole area appears to have been uplifted and to have become a positive area, no later sediments of Carboniferous age being present here. This uplift was succeeded by the main earth-movements of post-Carboniferous age, which produced in this area a cognate system of joints, a series of E.N.E.-W.S.W. folds crossed by folds of N-S trend and an irregular pattern of faults. The area was then partially overwhelmed by the Permian marine transgression, the Magnesian Limestone resting unconformably on folded Carboniferous beds, in the form of both a main outcrop in the east and a number of outliers near Markington.

No evidence of the history of the area between Permian and Pleistocene times is available locally, but the evidence from other areas suggests that in Tertiary times the region was tilted in an easterly direction and that some renewed movement along earlier faults took place. In Pleistocene times much of the district was covered by ice, with the consequent laying down of a thick mantle of glacial drift on the lower ground, consisting chiefly of boulder clay and glacial sands and gravels. The detailed history of this period has not been completely unravelled, but the evidence suggests that a self-contained glacier existed in Nidderdale and that in the east the district lay at the fringe of the Vale of York glacier. Retreat stages of both these glaciers can be detected by a study of the terminal moraines and periglacial phenomena associated with the retreat and confirm Raistrick's(1927, 1931) analysis of the glacial history.

History of Research

The earliest published account of the geology of this area is that by John Phillips(1836), an account both comprehensive and stimulating in its description of the rocks and their structural disposition. Phillip's treatise was regional in its scope and therefore lacking in some of the finer details of the local succession, but nevertheless it is remarkable for the compass of its information and the acuteness of observation it reveals. Following Phillip's work, a considerable interval elapsed before the next important contribution was made, and this by the Rev. J. Stanley Tute(1868) of Ripon dealt specifically with the local succession, particular reference being made to the Cayton Gill Beds. The text was accompanied by a small geological map on the 1 inch scale, which though noticeably dissimilar to subsequent maps does include some important information and deserves recognition on account of its primacy.

In the year succeeding the publication of Tute's paper, the detailed geological mapping of the district on the 6 inch scale was commenced by the Geological Survey and continued until 1878. Most of the mapping was done by J. Lucas, with some support in the west from J. R. Dakyns and in the east from C. Fox Strangways, the latter part falling just within the Harrogate district(Fox Strangways, 1874) and thus being included on N.S. Sheet 62. Two important marker horizons were established by the Survey, the Tesselated Limestone overlying the Red Scar Grit and the Cayton Gill Shell Bed, with the possible existence of a third, the Top Limestone of Greenhow; in addition to these stratigraphical discoveries, the ground south of the latitude of Pateley Bridge was shown to consist of a series of N.E.-S.W. folds, locally complexly faulted. No memoir describing the geology was issued, but four short papers by Dakyns(1890, 1892, 1893, 1903) contain the salient features, and the maps were published on both the 6 inch and 1 inch scales(part of O.S. Sheets 97 S.E. and 92 N.E.).

Since the primary survey a number of other papers on aspects of stratigraphy have been added: these include two by Tute(1886, 1887) and others by W.S. Bisat(1914), L. H. Tonks(1925), L. R. Chubb and R. G. S. Hudson(1925) and C. T. Walker(1952). Most of these have really only mentioned the area in passing and added few new details, but Walker's paper is important for the recognition of an unconformity at the base of the First Brimham Grit south of Pateley Bridge, as well as the extension to this area of the Otley Shell Bed.

In 1907 the systematic palaeontological study of the fossiliferous horizons was commenced by Hind(1907) and later expanded by the same author (1914) and T. N. George(1932), several new species of molluscs being identified from the Cayton Gill Beds. The publication of Bisat's(1924) classic account of the goniatite faunas of the Namurian in 1924 enabled a zonal system to be applied to the beds of this district and this has been further refined at the level of the E_2 Stage by Hudson(1944, 1945), and at the level of the R_1 Stage by Bisat and Hudson(1943).

Work on the glacial history of the area was begun by the visit of H. Carvill Lewis(1894) in the late 19th. century and has subsequently been extended by the researches of A. Raistrick(1926, 1927, 1931), E. Tillotson (1933), J. S. Gayner and S. Melmore(1937) and W. Edwards(1938). P.F.Kendall and A.E.Wroot(1924) too have made a valuable contribution to the knowledge on this subject as also to other aspects of the geology.

During World War II the district was re-examined for petroleum possibilities by the British Petroleum Company Limited, and as a result two boreholes were drilled for oil near Sawley. Neither hole yielded any oil, but the geological information they have provided(as yet unpublished) has proved to be of considerable value in determining the extension of the mid-R_1 unconformity to the area east of Nidderdale, as well as the thickness changes across the North Craven Fault.

The only other published records of work in this area, apart from an early paper by J. Dixon(1852) on the trails in the Nar Hill Beds, and a discussion of the easterly extension of the North Craven Fault by P.F. Kendall (1911) concern two brief visits paid by organised geological parties: one by the Geologists Association in 1938(Hudson and others, 1938) and the other by the Yorkshire Geological Society in 1953(Palmer and Versey, 1953). In neither case however was anything new discovered.

The position therefore at the commencement of the present survey was that the Colsterdale Marine Series and Cayton Gill Shell Bed were known at a number of exposures in the district and the Cockhill Marine Band in the extreme west only. In adjoining areas these horizons were also known together with several others, which included at:Simonseat(Hudson, 1939) one of H age in the Follifoot Shales and two of R_1 age in the beds between the Upper Follifoot Grit and the Second Brimham Grit; Upper Nidderdale(Wilson, 1957) one of H age in the Ganister Series and fossiliferous phases in the Agill Sandstone, Libishaw Sandstone and Brimham Shales. The present survey has now shown the existence of some of these in this area as well as others which are known farther south on Rombalds Moor(Stephens et. al.,1942). The following is a summary of the new stratigraphical finds:

(i) the continuation of the Cockhill Marine Band(E_2) containing <u>Cravenoceras cowlingense</u>

(ii) <u>Tylonautilus nodiferus</u> in the Colsterdale Marine Series

(iii) shelly fossiliferous phases in the Upper Follifoot Grit, the

Libishaw Sandstone, the Bewerley Shales and the First Brimham Grit. The marine band in the Bewerley Shales was recognised first by Walker(1952) who termed it the Scot Gate Ash Marine Band and suggested its equivalence with the Otley Shell Bed of Rombalds Moor, a view supported here.

(iv) Reticuloceras circumplicatile group in the Cayton Gill Shell Bed and Reticuloceras aff. pulchellum in the Libishaw Shales. The latter marine band appears to be the northern representative of the Addlethorpe Marine Band of Rombalds Moor.

(v) the extension of the unconformity at the base of the First Brimham Grit south of Pateley Bridge, first discerned by Walker(1952) in Nidderdale, to the area east of Nidderdale.

(vi) two Lingula bands and a band with Gastrioceras cumbriense in the Winksley Shales, the position of the latter suggesting the local absence of the R_2 Stage.

(vii) the presence of the basal Coal Measures, including a Lingula band near the base.

With regard to structure, a structure contour map Fig. 17, shows a northern area with gentle eastward dips and a southern area of E.N.E. folds crossed by folds of N-S trend, the latter being recognised for the first time. The North Craven Fault which enters this area from the Greenhow district as a strike fault of comparatively small throw(Dunham and Stubblefield, 1945, p.247) is shown to have been active during R_1 times but not subsequently. Its relation to the edge of the Askrigg Block is discussed in the section dealing with Structure(Chapter XIII). One other discovery has been made and that is a general absence of microcline and garnet from the sandstones of the E Stage in this area, a feature noted farther north at the same level by Rowell(1953) and Jones(1957).

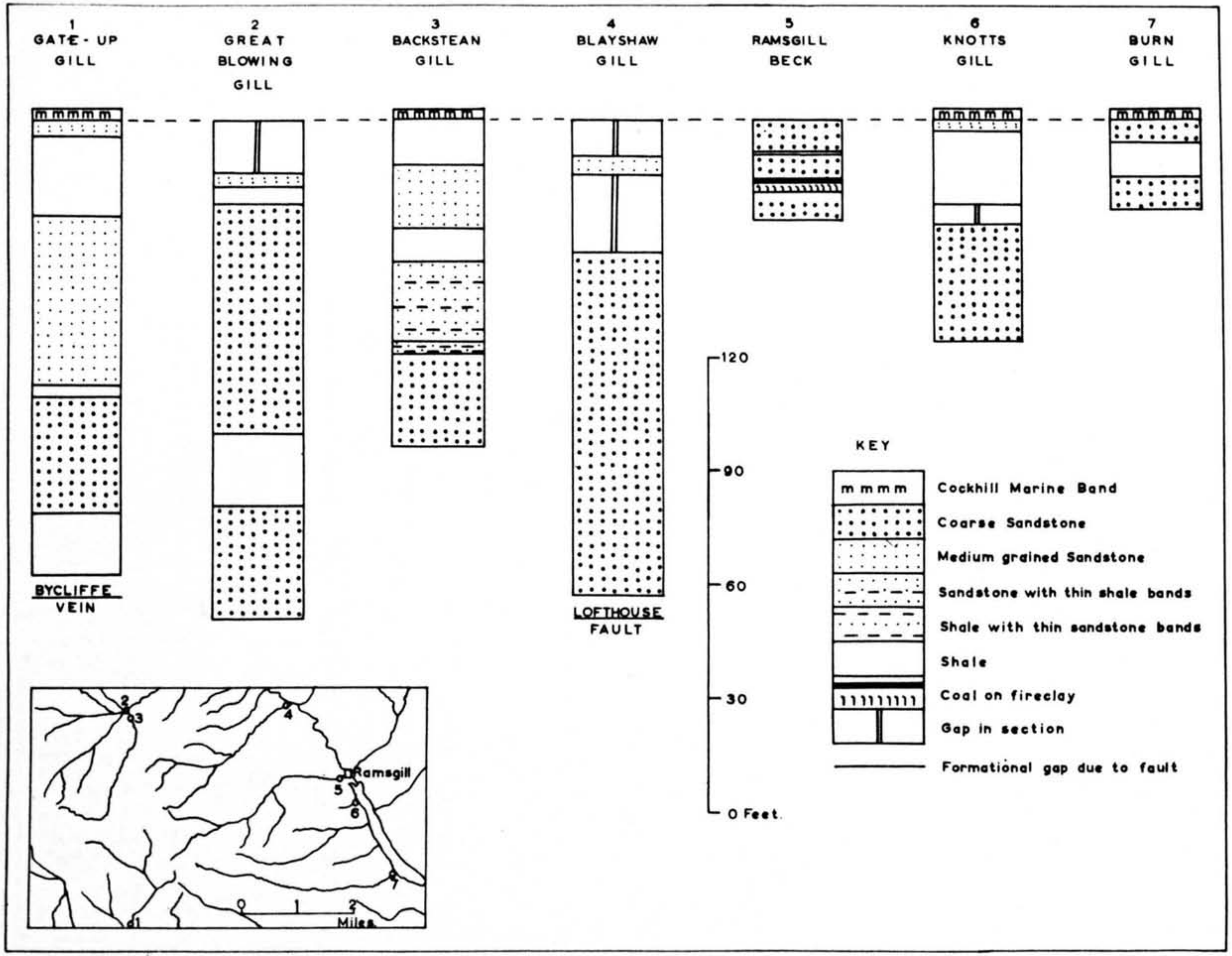


Figure 2. Comparative sections of the Grassington Grit Group.

CHAPTER II
THE GRASSINGTON GRIT GROUP

The term "Grits of Grassington Moor" was first used by the officers of The Geological Survey to describe the dominantly arenaceous beds immediately overlying strata of Yoredale facies in the vicinity of Wharfedale and Upper Coverdale. This designation was incorporated in the key to Geological Sheet 97 S.E.(Old Series), but Dakyns(1890) in his short account of the area also uses the miner's terms "Bearing or Basement Grit" and "Top Grit" to describe the main sandstone beds of this horizon. These terms were perpetuated by Bisat(1914) and Tonks(1925), though in amended form, the term "Bearing Grit" being extended to cover the complete group of sandstones at this stratigraphic level. Later workers however, including Hudson(1939), Dunham and Stubblefield(1945) and Wilson(1957) have reverted to the term "Grassington Grit Group" and this term is retained in the present account.

Stratigraphy

The Grassington Grit Group has been shown to be transgressive by Chubb and Hudson(1925). In a diagrammatic section(p. 280) they indicate an overlap of the Upper Bowland Shales on to the Lower Carboniferous rocks as a logical prelude to the Millstone Grit transgression. The Upper Bowland Shales in turn were overlapped by the basal beds of the Millstone Grit, so that in Upper Nidderdale coarse sandstone rests unconformably on Lower Carboniferous strata. In this area the Upper Bowland Shales are nowhere exposed at the surface, but the British Petroleum Company's borehole at Sawley (Fig.21) passed through a series of shales between the Grassington Grit and the Lower Carboniferous rocks, which from their lithology were considered to be the equivalent of the Upper Bowland Shales. The available evidence suggested that the shales rested unconformably on the Yoredale rocks and passed upwards into the Grassington Grit by the incoming of thin beds of coarse sandstone. Comparable shales were not penetrated in the same Company's borehole at Aldfield (Fig.22), 2 miles further north, the Grassington Grit there resting unconformably on Lower Carboniferous limestone. It would appear likely therefore that the overlapping relations at the base of the Millstone Grit, discernible in the Grassington area (Chubb and Hudson,1925; Black,1950) are present much further east also, but the scanty information available precludes any detailed comment on the extent of the overlap. In view of the transgressive nature of the Grassington Grit Group, the base is taken as the horizon where coarse sandstone first appears above strata of Yoredale aspect. The upper limit however is constant and is defined with precision as the base of the Cockhill Marine Band. In terms of the goniatite succession, the Grassington Grit Group occurs below the first known marine band containing Eumorphoceras bisulcatum Girty and is therefore referred to the E 1 Stage of the Namurian.

The group comprises a variable series of coarse - medium grained sandstones and shales with one coal near the top. Lithological variation, both on a local and regional scale is characteristic of the group and is notable for the rapidity with which the change occurs. The complete group is present at only one locality within the area and is here 117 feet thick. At this point (Lolly Scar 109724), the basal sandstone rests directly on the Three Yards Limestone(Wilson,1957) though the actual unconformable junction is obscured. The group is at its minimum thickness here and must thicken rapidly to the north, because Wilson(1957) quotes a figure in excess of 200 feet for the group in Howstean Beck. Elsewhere within the area, incomplete sections only are seen, chiefly confined to the upper part of the group, but the evidence from Greenhow (Dunham and Stubblefield, 1945) suggests that considerable thickening must take place in a southerly direction. In general, the lower part of the group, where seen, consists of coarse felspathic sandstone, locally pebbly, whilst the uppermost beds are flaggy and medium grained sandstones. Shale partings occur throughout the group and tend to be of local distribution, never exceeding 21 feet in thickness and generally containing thin lenses of flaggy sandstone. Current bedding characterises the sandstones at this level and shows a predominant N.N.W. direction, whilst ripple marking and other minor sedimentary structures occur in the flaggy sandstones.

The outcrop of the Grassington Grit Group is confined to the north western part of the area, the best exposures occurring in the streams descending from Riggs Moor and the high ground around Meugher. South of Meugher on Grassington Moor, the main sandstone horizon is mineralised and has been extensively mined and quarried for lead ore. The beds dip gently to the east and reappear in the lower reaches of the streams that drain into Nidderdale, between Lofthouse and Wath. This easterly dip carries the beds underground east of the Gouthwaite reservoir, but 307 feet of strata, referred to the Grassington Grit Group were penetrated by the Sawley borehole, thus indicating a notable thickening of the group when traced towards the south west.

Details

Howstean Beck to Blayshaw Gill - The section of the Grassington Grit Group exposed in Howstean Beck has been mentioned by several earlier workers (Phillips, 1836; Bisat, 1914; Wilson, 1957), who have drawn attention to the thick development of coarse sandstone in this locality. This coarse pebbly, almost conglomeratic sandstone is exposed in the cliffs flanking Howstean Beck, just below its junction with Backstean Gill. The pebbles, up to ½ inch in diameter are generally rounded and consist of both quartz and felspar. The quartz is predominantly the common white variety, but rose coloured crystals do occur and in some of these it is possible to detect crystal faces. The felspar (chiefly orthoclase with subordinate albite/oligoclase) is white and anhedral and forms a notable contrast to the large crystals of pink microcline so characteristic of the Brimham Grits.

At the confluence of Great Blowing Gill Beck and Howstean Beck (054728), a shale parting 19 feet 2 inches thick is exposed. This bed contains several thin beds of flaggy sandstone as well as some coal smuts and is apparently exposed further downstream(Wilson, 1957) where it carries a coal. It is overlain by a coarse, massive, current bedded sandstone which crops out in the bed of the stream for over half a mile in Straight Stean Beck. In Great Blowing Gill Beck, this sandstone contains a further shale parting 4 feet 6 inches thick towards the top of the sequence.

In Little Blowing Gill Beck, coarse massive sandstone is exposed in the lower reaches of the stream, but there is a short distance where the rocks are unexposed before the Cockhill Marine Band is seen resting on 3 feet of grey shale. At this point medium grained sandstone occurs in the bed of the stream, but this is only visible during periods of drought when the level of the stream is low.

The massive sandstone which is exposed in the cliffs flanking Howstean Beck is traversed by a mineral vein at the lower end of Backstean Gill(056728). This sandstone passes up into interbedded shale and streaky medium grained sandstone, which is in turn overlain by a coarse massive slightly felspathic sandstone containing thin lenses of shale and shale nodules. This sandstone becomes finer grained upwards and contains well developed ripple marks on bedding surfaces. A shale parting which occurs in this sandstone demonstrably thins when traced downstream in the cliffs flanking the stream. The sandstone is overlain by a further bed of pyritic shale which forms the upper bed of the group in this vicinity, being directly overlain by the Cockhill Marine Band.

Fragments of shale were found in the tips from the trial holes for lead sunk on Stean Pasture near Moor House(090728), indicating the presence of a shale parting towards the top of the group in this vicinity. It is questionable whether this shale parting is the same as that exposed in Howstean Beck as suggested by Wilson(1957), because the latter parting is 84 feet below the top of the group, whereas the inferred parting on Stean Pasture is much higher in the sequence.

The wooded gorge of Blayshaw Gill reveals a most impressive section of coarse, massive, current bedded sandstone lying in juxtaposition to the Five Yards Limestone and separated by the Lofthouse Fault. More than 60 feet of this pebbly felspathic sandstone are exposed here, now slickensided and well jointed. The exposure is not complete in this stream, but a bed of thinky bedded, medium grained sandstone crops out further upstream and suggests that the strata are of finer grain towards the top of the group.

West side of Nidderdale from Blayshaw Gill to Burn Gill - At Lolly Scar (109724) the basal member of the group is represented by blocks of coarse felspathic sandstone immediately overlying rocks of Yoredale aspect. The lowest bed visible here is the Five Yards Limestone which crops out in the bed of the River Nidd and is overlain by ca.13 feet of black calcareous fossiliferous shale. Towards the top of the shale blocks of limestone occur, which are thought to be the basal representative of the Three Yards Limestone(Wilson, 1957). This latter bed is directly overlain by the Grassington Grit, but the unconformable junction is unfortunately covered by slipped material. A small scar, 20 feet above the river exposes coarse sandstone, but the remainder of the sequence is obscured and the upper limit of the group is determined by the presence of blocks of Cockhill Limestone in Near Piece Gill. The tip from Lolly Mine consists almost entirely of blocks of coarse sandstone and is notable for the absence of limestone fragments which suggests that the Grassington Grit must thicken rapidly to the north and probably transgress locally on to lower horizons of Yoredale strata. If this were not so, the regional dip to the east would have ensured that the Yoredale strata exposed at Lolly Scar would have been penetrated by the adit at Lolly Mine. It is noteworthy that the Yoredale rocks should appear at the surface in an area of minimum thickness of the overlying Grassington Grit Group and indicates an uneven surface prior to the deposition of the Millstone Grit.

Phillips(1836 p. 29) quotes a list of the strata exposed in Ramsgill Beck below Lofthouse, which includes more than 30 feet of Yoredale beds, but this record must be mistaken because the lowest bed exposed in the stream is a coarse sandstone. The sandstone is a well cemented rock, full of white felspar and carries a coal which varies from 11½ to 17 inches in thickness when traced upstream. The bed is well jointed and weathers out in thick posts, exceeding 6 feet in thickness. A parting of grey mudstone occurs higher in the succession, which must thicken to the south where it is represented by a prominent bed of shale in Knotts Gill. The coal present in this section appears to be at a higher horizon than the one in Howstean Beck(Wilson, 1957), but is probably equivalent to the upper coal at Greenhow(Dunham and Stubblefield,1945). The primary surveyors were culpable of serious error in this vicinity as noted by Kendall and Wroot(1924 p. 858). In their published maps they showed the Grassington Grit passing underground just north of Ramsgill and hence correlated the sandstone exposed in the lower reaches of Ramsgill Beck with the Priest's Tarn Grit, an interpretation which cannot be supported on the basis of regional dip or lithological characteristics. In fact the Grassington Grit Group does not pass underground until just south of Burn Gill and the sandstone exposed in Ramsgill Beck is unusual for its coarse grain, the sequence being towards the top of the group.

The upper beds of the group are exposed in Knotts Gill and consist of sandstone with a thick parting of shale. The sandstone below the shale parting is coarse, massive and felspathic, whilst that above is flaggy and micaceous and is more correctly termed a subgreywacke. This latter bed is only 3 feet 6 inches thick and is directly overlain by the Cockhill Marine Band.

The section of the group exposed in Colthouse Gill is only fragmentary and consists of a small outcrop of shale due north of Colt House which is probably a continuation of the Knotts Gill Shale parting, together with a thin bed of grey ganisteroid sandstone under the bridge(123697). This latter bed is directly overlain by the Cockhill Marine Band.

The Grassington Grit Group is presumed to be represented in Riddings Gill and Stubnook's Gill because of the presence of blocks of Cockhill Limestone in the lower reaches of these streams but no strata are exposed and it is thought likely that the uppermost beds are argillaceous in this vicinity.

The change in dip due to the prolongation of the Greenhow anticline is responsible for the presence of the Grassington Grit Group in Burn Gill. Only the upper 25 feet of the group are present and they consist of coarse, massive, current bedded sandstone with a 10 feet parting of grey shale near the middle. The easterly dip must be considerable here because there is no record of the group being penetrated by the boreholes sunk by Bradford Corporation in connection with the construction of the Gouthwaite dam(Tillotson,1933) and hence the group must pass underground just south of Burn Gill.

East side of Nidderdale - Exposures of the Grassington Grit Group on the eastern side of Nidderdale are confined to an Old Quarry and the stream adjacent to it, south east of Low Sikes Farm(112726). A well jointed coarse felspathic sandstone is the only rock seen here, which in hand specimen has a speckled appearance due to the presence of limonite flacks.

A considerable thickness of strata assigned to the Grassington Grit Group was penetrated by the British Petroleum Company's Sawley borehole(Fig.21). The log indicates an upward passage from the Upper Bowland Shales into the Grassington Grit Group by the incoming of thin beds of coarse sandstone. Two thick beds of coarse sandstone, near the base and at the top respectively are seen to be separated by a series of shales with thin beds of fine grained sandstone. The absence of the Cockhill Marine Band in this area forbids precise definition of the top of the group, which is therefore taken at the point where sandy shales succeed the upper bed of sandstone.

In the case of the Aldfield borehole(Fig.22) stratigraphical interpretation is very uncertain because of the absence of diagnostic marker horizons and borehole cores. The borehole occurs in close proximity to a powerful fault which is thought to cross the hole and thus account for the condensed sequence encountered. The coarse felspathic sandstone which unconformably overlies the Lower Carboniferous limestone is thought to be the Grassington Grit here carrying a coal(probably equivalent to the lower coal at Greenhow) and upwardly terminated by the fault. If the bed of light grey limestone penetrated at a depth of 250 feet in the Colsterdale Limestone,here thicker than in Nidderdale, it would mean that the major part of the Grassington Grit Group and the Nidderdale Shales is absent at this point. Any interpretation is of necessity tentative, but a comparison of the lithology of individual beds with the known succession in Nidderdale, 8 miles to the west, suggests this to be the most acceptable explanation in contra distinction to lateral thinning and facies change of individual stratigraphical groups.

Grassington and Hebden Moors - The Grassington Grit Group is exposed in Gate up Gill, immediately north of the Bycliffe Vein, a fault of considerable throw to the south. The lowest bed is seen in a thick parting of shale, locally carbonaceous and containing thin beds of flaggy sandstone. It is this horizon which separates the "Bearing Grit" and "Top Grit", following the classification of the early miners. The "Top Grit" is a current bedded, ripple marked sandstone, predominantly medium grained though tending to be coarser in the lower part. Just below the Bullfront Waterfall, the current bedding is developed on a large scale and has an inclination of 16 degrees in a S.S.E. direction. In Gate up Gill, the upper beds of the sequence are not exposed, but in the tributary stream, Long Band Nick, 20 feet 11 inches of grey shale overly the "Top Grit" and pass upwards into a thin bed of poorly cemented medium grained greenish sandstone. This latter bed is the highest bed in the sequence and is directly overlain by the Cockhill Marine Band.

On Game Ing Flat, immediately west of Gate up Gill there are a number of shallow pits which have been excavated in coarse felspathic sandstone speckled with flacks of limonite. These exposures suggest that the "Top Grit" becomes coarser when traced to the west and this is supported by the evidence forthcoming from the thin tongue of sandstone which extends along the northern edge of the Bycliffe Vein to the point where it crosses Groove Gill. The sandstone here is brecciated, slickensided and veined with quartz and is apparently overlain by shale in Groove Gill. A block of Cockhill limestone was found in Groove Gill which suggests that the uppermost bed of the group in this locality is shale.

Numerous tips from mine shafts on the east side of Deep Cut(040677) contain blocks of mineralised coarse orthoquartzite together with fragments of crinoidal limestone and shale. These shafts must have penetrated the complete Grassington Grit Group, with the exception of the upper few feet and indicate a predominance of coarse material in the sandstone beds. In Deep Cut, immediately north of the Bycliffe Vein, coarse, massive, yellow, pebbly felspathic sandstone is exposed in the stream banks and persists for more than half a mile upstream in occasional outcrops.

To the west of Blea Beck on Grassington Moor, there are a number

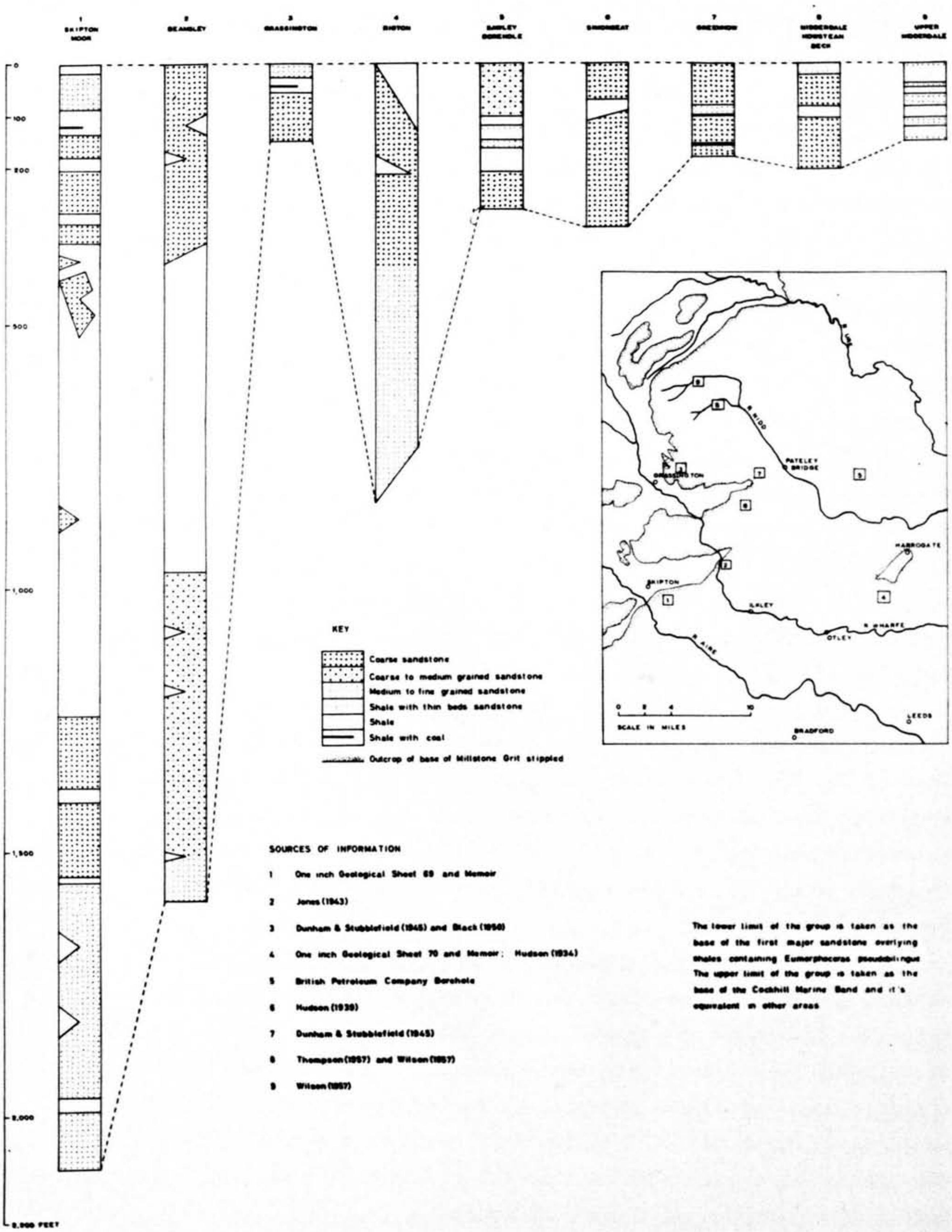


Figure 3. Comparative sections of the Grassington Grit Group and its equivalents in the eastern half of the Central Province.

of shallow pits containing fragments of shale together with blocks of coarse sandstone. In the Old Quarry(032680), 27 feet 4 inches of sandstone are exposed, the basal 11 feet of which are pebbly and felspathic and pass upwards into a flaggy medium grained sandstone. Fragments of shale are present in the weathered stratum just below the ground surface and suggest that the uppermost bed in this locality is shale, now in an advanced state of removal by the normal processes of erosion. The tips from the Bycliffe and Peru Mines contain a large proportion of coarse felspathic sandstone known locally as the "Bearing Grit", because as its name implies, it was the chief mineralised horizon. These shafts penetrated to the underlying Carboniferous Limestone and thus passed through a more or less complete section of the Grassington Grit Group which averages 150 feet on Grassington Moor (Dunham and Stubblefield,1945 p.236).

Correlation

In Nidderdale, the Grassington Grit Group rests unconformably on sediments of Yoredale facies, but in areas further south sedimentation was continuous throughout the Pendleian stage. In these areas the base of the equivalent of the Grassington Grit Group is rather arbitrary and is defined as the horizon where coarse sandstone first appears above shales containing <u>Eumorphoceras pseudobilingue</u>(Bisat). This horizon however is not constant, because the lowest sandstone succeeds the underlying shales(Upper Bowland Shales) at different levels in different areas, so that it is impossible to distinguish a basal sandstone(Bradford Memoir p. 18). The position is further complicated by the presence of thick lenses of medium grained sandstone in the Upper Bowland Shales near Grassington(Black, 1950) whilst the basal sandstones on Skipton Moor are not coarse grained. Because of this diachronism and facies change, correlation of the base of the group in other areas is unsatisfactory and is therefore of a tentative nature only. On the other hand, recent work has established the widespread occurrence of marine sediments containing <u>Eumorphoceras bisulcatum</u> Girty, the equivalent of the Cockhill Marine Band, so that the top of the group can be correlated with precision over a wide area. The accompanying diagram (Fig. 3) attempts to summarise the variations within the group in the eastern part of the Central Province and is intended to supplement earlier isopachyte maps of the Namurian Stages in the Central Province(Moseley, 1953). The Grassington Grit Group is correlated with the Skipton Moor Grits of Beamsley(Jones, 1943) and Rombalds Moor(Stephens et al, 1942; Geological Sheets 69 & 70 with accompanying memoirs), the Lindley

Moor Grit of Rigton(Geological Sheet 70) and part of the Harrogate Grits (Hudson, 1934) south of Harrogate.

A maximum thickness for the group appears to attained on Skipton Moor, where 2,400 feet of sandstones with interbedded partings of shale occur. Medium grained sandstones form the lower beds, whilst the arenaceous members in the higher parts of the group are largely coarse, pebbly felspathic sandstones with a top division of flagstone. To the N.E. of this district in the Beamsley area there is a slight reduction in thickness though the main lithological characters are retained. Further north at Grassington a drastic reduction in thickness has taken place, the group averaging only 150 feet and consisting of two main beds of sandstone separated by a shale parting. In the vicinity of Rigton, the group comprises 725 feet of sandstone with a thin localised shale parting towards the top. Immediately north of this area(Hudson, 1934) stratigraphical interpretation is a bit confused, but it would appear from recent revision in adjacent areas that slight thinning has taken place and the group consists of a lower flaggy sandstone - shale series, overlain by about 200 feet of coarse pebbly sandstone. This northerly thinning must persist because only 307 feet of strata are assigned to the Grassington Grit Group in the log of the Sawley borehole (Fig.21). In the Simonseat area(Hudson,1939), west of Sawley a similar thickness of beds is referred to the Grassington Grit Group, which here consists of two thick beds of coarse felspathic sandstone separated by up to 40 feet of shale. Due north of Simonseat at Greenhow(Dunham and Stubblefield, 1945) measured sections from the Cockhill and Gillfield' adits indicate a thickness of 180 feet for the group. Coarse felspathic sandstones predominate, but thin beds of shale and medium grained sandstone occur throughout the sequence. As stated above the group thins rapidly when traced further north and attains its minium thickness just south of Lofthouse. Thereafter in a northerly direction it thickens, but this is only of local significance, because in Upper Nidderdale and Coverdale a thickness of 125 feet for the group is recorded(Wilson, 1957). In this latter area the thinning is accompanied by a distinct change of facies, apparently due to the rapid lensing out of coarse sandstones in the lower half of the group so that the sequence is predominantly shaly in character.

The regional picture therefore indicates a steady thinning of the group when traced northwards from Rombalds Moor, with a final deterioration of the sandstone members in Coverdale. Sandstone, chiefly coarse and felspathic is the predominant lithology, though beds of medium grained sandstone, shale and coal occur throughout the sequence. Individual lithological groups are rarely persistent over wide areas and the beds are notable for the rapidity with which they commence, thicken, thin, split, unite and die out. In field relations therefore, the coarse sandstones of the E 1 Stage appear to differ from similar sediments of R 1 age which are held to be generally thin and have a wide lateral persistence(Walker, 1952 pp 97 - 101). Sections 3, 7 8 and 9 are taken from points north of the North Craven Fault, ie on the Askrigg Block, the remainder being south of this line of dislocation. The change from "rigid block" to "basin" conditions of deposition is not as abrupt as would have been expected and is rather of the nature of a steady change initiated along the line of the fault.

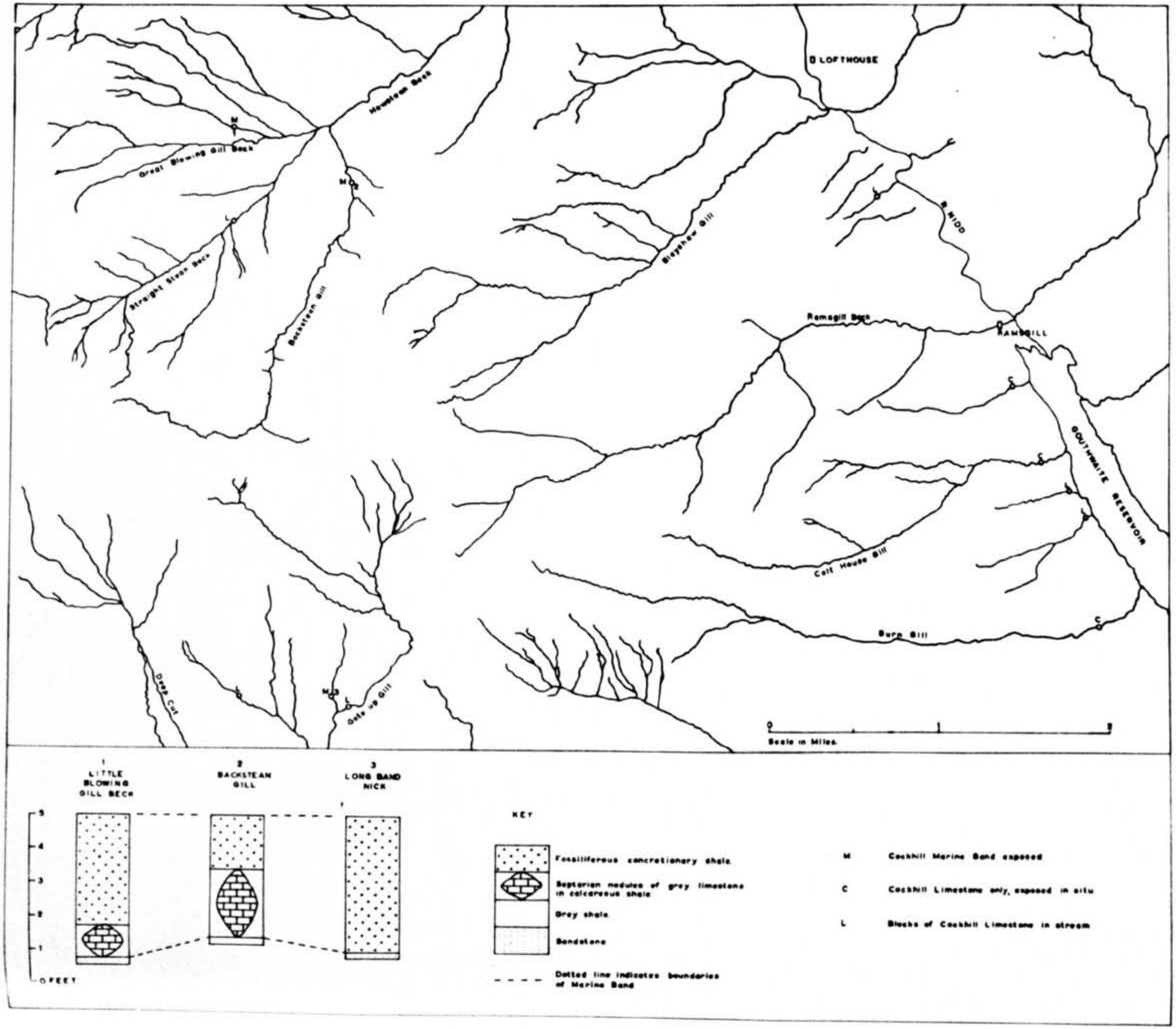
CHAPTER 111

THE COCKHILL MARINE BAND

It may fairly be claimed that the Cockhill Limestone is one of the earliest known Namurian limestones in Yorkshire, being first recorded by Nathan Newbold(Mss. 1805) in his section of the strata exposed in Cockhill level, Greenhow. This bed, named the "Top Limestone" by Newbold was correlated by Dakyns(1893) with a similar limestone encountered in the shaft at Gate-up Gill, but no indication was given that he thought the bed was of widespread occurrence in this district. Tonks(1925) took the matter a stage further by discovering marine shale and calcareous ironstone in Upper Nidderdale, which he took to be the equivalent of the Top Limestone of Greenhow in a degenerate condition, but faunal collecting yielded no specimens of zonal significance so that accurate correlation with areas to the south was still only tentative. Further information was not forthcoming until Dunham and Stubblefield(1945) re-examined the Greenhow sections and described the limestone in detail, both lithologically and faunally. Amongst other fossils Cravenoceras cowlingense Bisat was recorded thus confirming the E 2 age of the beds and permitting approximate correlation with the Mirk Fell Beds in the north and the Edge Marine Band in the south. Later work by Wilson(1957) extended the known outcrop of these beds to a wide area in Upper Nidderdale and Coverdale and supported Tonks' original correlation. The "Top Limestone" had been re-named the "Cockhill Limestone" by Dunham and Stubblefield, but this was modified to "Cockhill Marine Band" by Wilson because of the impersistence of the limestone in Upper Nidderdale. In addition the C. cowlingense fauna present was examined thoroughly by him and as a result certain correlations were suggested with localities on the Askrigg Block and as far distant as Edale and the Lancaster Fells.

Stratigraphy

In this area the Cockhill Marine Band would appear to bear close affinities to the equivalent horizon in Upper Nidderdale and Greenhow, in a sense representing an intermediate stage between the two. The limestone is the dominant member of the band, but is not everywhere present as at Greenhow. On the other hand the septarian nodules of limestone which characterise the division in this area are much larger than in Upper Nidderdale, achieving a diameter of more than 3 feet 6 inches and a thickness of 2 feet 1 inch(Plate 111A)



LOFTHOUSE
Howstean Beck
Great Blowing Gill Beck
Straight Stean Beck
Backstean Gill
Blayshaw Gill
R. NIDD
Ramsgill Beck
RAMSGILL
GOUTHWAITE RESERVOIR
Colt House Gill
Burn Gill
Deep Cut
Gate up Gill
0
1
2
Scale in Miles.
1
LITTLE BLOWING GILL BECK
2
BACKSTEAN GILL
3
LONG BAND NICK
5
4
3
2
1
0 FEET
KEY
Fossiliferous concretionary shale.
Septarian nodules of grey limestone in calcareous shale
Grey shale
Sandstone
Dotted line indicates boundaries of Marine Band
M Cockhill Marine Band exposed
C Cockhill Limestone only, exposed in situ
L Blocks of Cockhill Limestone in stream

Figure 4. Map illustrating the occurrence of the Cockhill Marine Band in thiś area, together with some comparative sections.

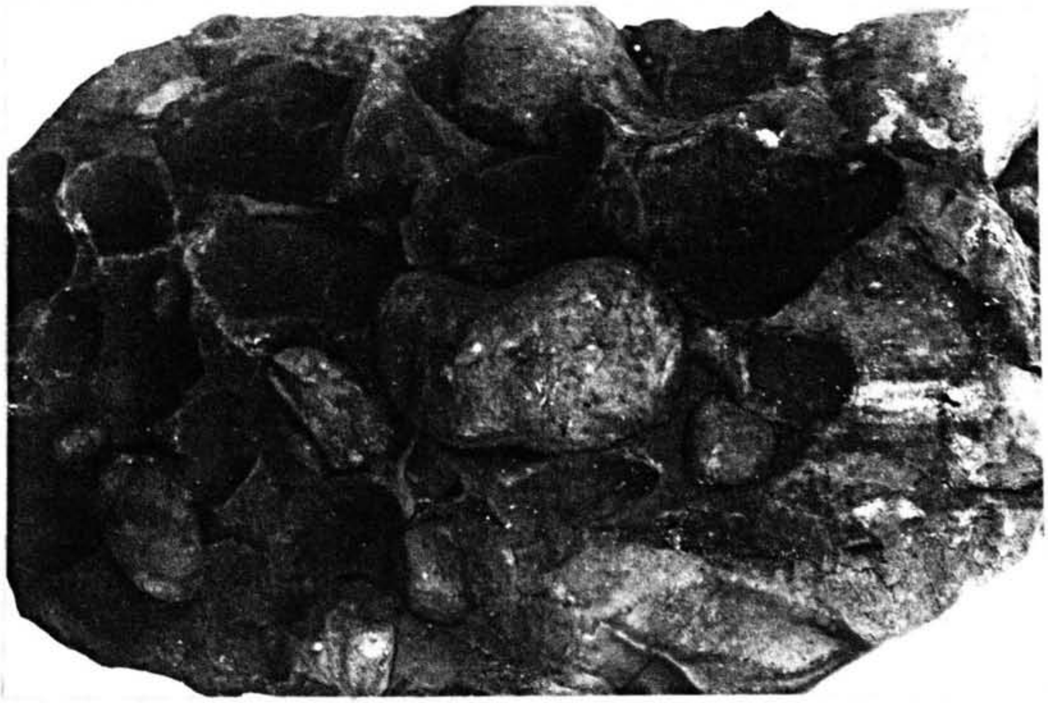
They appear to be confined to one horizon only, sometimes in contact with each other, but elsewhere separated by a few feet of fossiliferous calcareous shale (Plate 11 A). In stream sections solution-etching has produced a typical fluted surface on the limestone, blocks of which frequently occur in profusion along the stream bed below the main outcrop. Polygonal shaped cracks infilled with clear crystalline calcite are a notable feature of these blocks, whilst cone-in-cone structure and recemented fractures are occasionally seen. The rock is a dark grey, finely crystalline limestone which breaks with a sub-conchoidal fracture. In thin section it is seen to consist of a mosaic of calcite(average grain size 0.03 mm.) streaked with a brown oily pigment and occasional concentrations of pyrite. Scattered grains of quartz also occur as well as spherical objects made of clear crystalline calcite whose nature still remains obscure(see Dunham and Stubblefield, 1945 p.237 & Moseley,1956). These latter objects, up to 0.6mm. in diameter rarely have any suggestion of wall structure though their margins are generally darkened and have the appearance of organic affinity, but it cannot yet be said that this is firmly established. Goniatites are present in all stages of growth ranging from 0.5mm to 35 mm. diameter, often partially filled with a thick oily fluid. A filling of clear crystalline calcite is more usual however and in some of the larger specimens the body chamber is crushed and juvenile forms occur within it. Great difficulty is frequently experienced in extracting these goniatites, but in one instance the limestone was found to be more silty than usual and as a result of weathering was decalcified to a depth of half an inch on the outer surface so that solid goniatites could be prised out of the "skin" of the nodule.

Nowhere in this area have fossiliferous strata been found below the limestone, though they are generally present above and attain a maximum thickness of 3 feet 3½ inches. They consist of compact, black micaceous shales full of rounded irregularly shaped concretions, which range from disk-like to nearly spherical forms, rarely exceeding half an inch in diameter. The surface of these concretions is usually pitted and rough, occasionally developing a regular pattern, but in some cases it is smooth and shows evidence of slickensiding. Fossils are rare and in the main limited to goniatite impressions and posidonid lamellibranchs together with ubiquitous plant remains. These shales constitute the complete band in one locality confirming the impersistence of the limestone as noted by Wilson(1957). Elsewhere they

A

The Cockhill Marine Band, Backstean Gill(058723). The section consists of an upper 10' of grey pyritic mudstone; 1' 7" of black sparsely fossiliferous shale with concretions; a discontinuous band of septarian nodules, 2' 1" thick, containing a goniatite - lamellibranch fauna; a lower 10' of grey micaceous shale.

B



Muddy limestone with concretions, Colthouse Gill(122697). The bed, immediately overlying the Cockhill Limestone is only locally calcified and contains occasional fossils.

are partially calcified and present a conglomeratic appearance to the upper part of the limestone(Plate 11 B). At only three localities is the complete division exposed, ranging in thickness from 3 feet 8 inches to 4 feet 6 inches; usually only the limestone is seen, but this is largely the result of poor exposure at this level and is not thought to indicate localisation of the argillaceous members.

The outcrop of the Cockhill Marine Band is confined to the north western part of the area, the best exposures occurring in the streams descending from Riggs Moor and Grassington Moor. The band is picked up in numerous streams on the western flank of Nidderdale(Fig. 4), but passes underground near Wath and is not seen again in the area. No sign of it was found on the eastern flank of Nidderdale and rather disappointingly it was not recorded in the log of the Sawley borehole.

Details

The occurrence of the Cockhill Marine Band in this area is summarised in Fig. 4. Individual exposures are described in three groups: those occurring respectively on Riggs Moor, on Grassington Moor and in Nidderdale.
Riggs Moor - The band is exposed in Little Blowing Gill Beck, 15 yards downstream from an outcrop of medium grained sandstone taken to be the top of the Grassington Grit Group. The base of the limestone is not seen, but observations suggest that it cannot be more than 6 inches above the top of the sandstone. Large septarian nodules, decalcified on the outer surface and full of goniatites occur in the bed of the stream and are overlain by the following strata :-

	Grey unfossiliferous micaceous shale
2½"	Black carbonaceous mudstone containing flattened impressions of *Posidonia vetusta*
4½"	Black micaceous shale - no fossils seen.
3' 3½"	Black shale with concretions - deeply weathered and apparently unfossiliferous.
	Septarian nodules of limestone

Between Little Blowing Gill Beck and Backstean Gill the only occurrence of the band is in Straight Stean Beck where blocks of Cockhill limestone occur in the stream, but no "in situ" exposure has been found.

In Backstean Gill the division has an extensive outcrop owing to modification of the dip by faulting. Large septarian nodules of limestone up to 3 feet 6 inches in diameter and over 2 feet thick occur scattered along the bed of the stream and in the banks(Plate 11 A). They contain goniatites in all stages of growth up to 35 mm. diameter, the most common form being Cravenoceras cowlingense. Occasional specimens are filled with a thick oily fluid, but the majority have an infilling of coarsely crystalline calcite. The limestone is overlain by 1 feet 7 inches of black, sparsely fossiliferous micaceous shales containing concretions which are much harder than their shale matrix, but show no effervescence with acid.

Grassington Moor - As noted above Dakyns(1893) encountered a thin bed of limestone in the shaft at Gate-up Gill which he correlated with the "Top Limestone" of Greenhow. In addition he recorded "calcareous shale with fossils" on his 6 inch map(Yorks.116) north of the Bycliffe Vein. This latter exposure was examined first by Tonks and later by Dunham and Stubblefield (1945, p. 238) and found to contain fragmentary goniatites suggesting Eumorphoceras bisulcatum Girty and Cravenoceras sp. A further discovery by the present author of a block of limestone containing C. cowlingense at 058674 now confirms the presence of the band in Gate-up Gill.

The tributary stream of Gate-up Gill, Long Band Nick, contains a complete section of the rocks at this level and indicates that the limestone has locally died out.

		Grey micaceous siltstone
Cockhill Marine Band	3' 11½"	Black fossiliferous shale with concretions - fossils chiefly posidonid lamellibranchs.
Grassington Grit Group	(4' 7"	Poorly cemented greenish medium grained sandstone.
	(20' 10½"	Grey shale.
	(	Coarse massive sandstone in bed of stream.

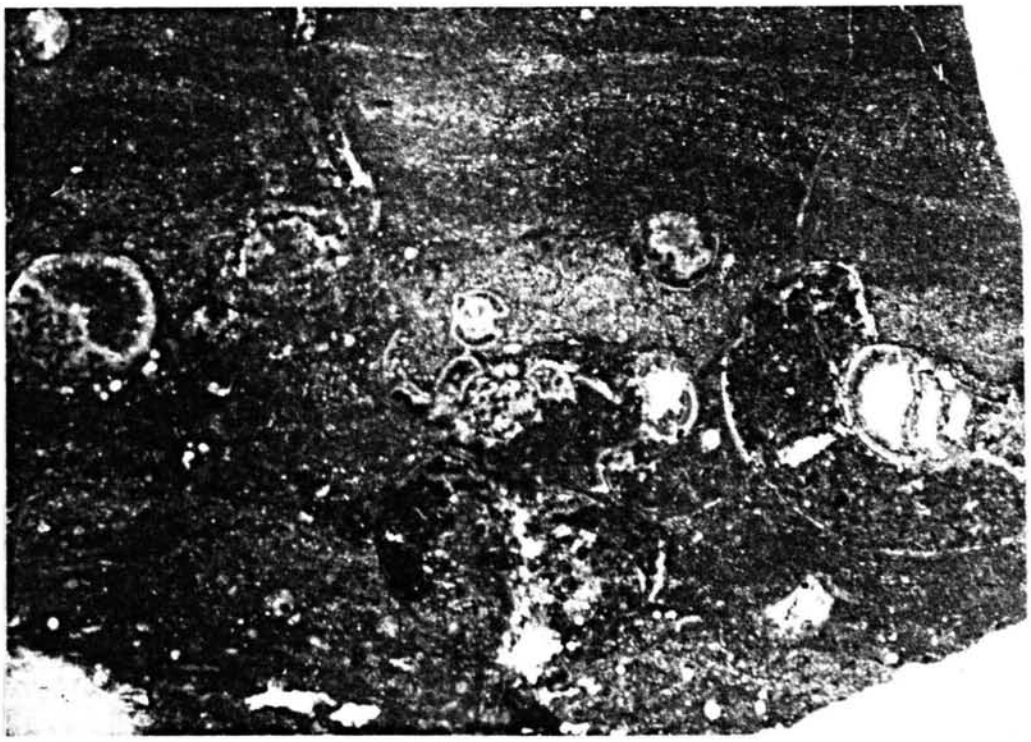
No record of the Cockhill Marine Band occurs in data secured from mining enterprises on Grassington Moor, but a block of the limestone containing goniatites was found in Groove Gill, just north of the Bycliffe Vein indicating an extension of the bed on to Grassington Moor.

Nidderdale - Septarian nodules of fossiliferous limestone occur in most of the streams that drain the western flank of Nidderdale. They are found in place in Knott's Gill, Colthouse Gill and Burn Gill, but only blocks of the bed occur in Near Piece Gill, Riddings Gill and Stubnook's Gill. Most of the sections show an excellent development of polygonal shaped cracks in the limestone infilled with coarsely crystalline calcite, whilst cone-in-cone structure is present in Colthouse Gill. At this latter locality, the upper 4 inches of the limestone consist of irregularly shaped concretions set in a calcareous matrix and pass upwards into 6 inches of shale with concretions

A

A septarian nodule of Cockhill Limestone, Backstean Gill. The nodules, up to 3' 6" in diameter and over 2' thick contain goniatites in all stages of growth, ranging from 0·5 mm. to 35 mm. diameter.

B



A polished surface of the Cockhill Limestone, showing the abundant occurrence of goniatites(predominantly Cravenoceras cowlingense) at this horizon. A small area of pyrite occurs in the bottom left hand corner.

containing flattened impressions of Posidonia vetusta. Nowhere else have argillaceous members of the band been found, in fact poor exposure is characteristic of this level in Nidderdale and accounts for the scanty details available.

Palaeontology

The fauna that characterises the Cockhill Marine Band in this area includes the goniatite Cravenoceras cowlingense together with thin shelled lamellibranchs and orthocone nautiloids. The occurrence of C. cowlingense in the Central Province has been fully described by Wilson and as a result certain correlations have been suggested all of which are followed here. The specimens of this goniatite found by the present author differ very little from the type material in respect of shape and ornament, but show a longer prolongation of the saddle in the suture. Anthracoceras paucilobum(Phillips), a form present at Greenhow(Dunham and Stubblefield, 1945), but not in Upper Nidderdale(Wilson, 1957) occurs in the limestone, but no specimen of Eumorphoceras bisulcatum Girty has been found.

The most common lamellibranch is the coarsely ornamented form Posidonia vetusta(J. Sowerby). It occurs in both the limestone and the shale, generally in the form of flattened impressions in the latter and is an exclusive form in the shale at Little Blowing Gill Beck, there achieving larger than normal dimensions. The other fossils are only individually represented but show greater affinity to the Greenhow records than Upper Nidderdale.

Faunal List

"L" denotes preservation in limestone, unlettered numbers in shale.

Plant remains, 1, 4

Crinoid ossicles, 2L, 4L

Lingula mytiloides J. Sowerby, 1L
------- squamiformis Phillips, 4L

Posidonia vetusta (J. Sowerby), 1, 1L, 4, 4L, 6
Posidoniella laevis (Brown), 4, 6

Cravenoceras cowlingense Bisat, 1L, 2L, 3L, 4L, 5L, 7L
------------ sp., 1L, 4L

Anthracoceras paucilobum (Phillips) 1
------------ sp., 4L

Orthoconic nautiloid indet., 2

Index of localities for the above

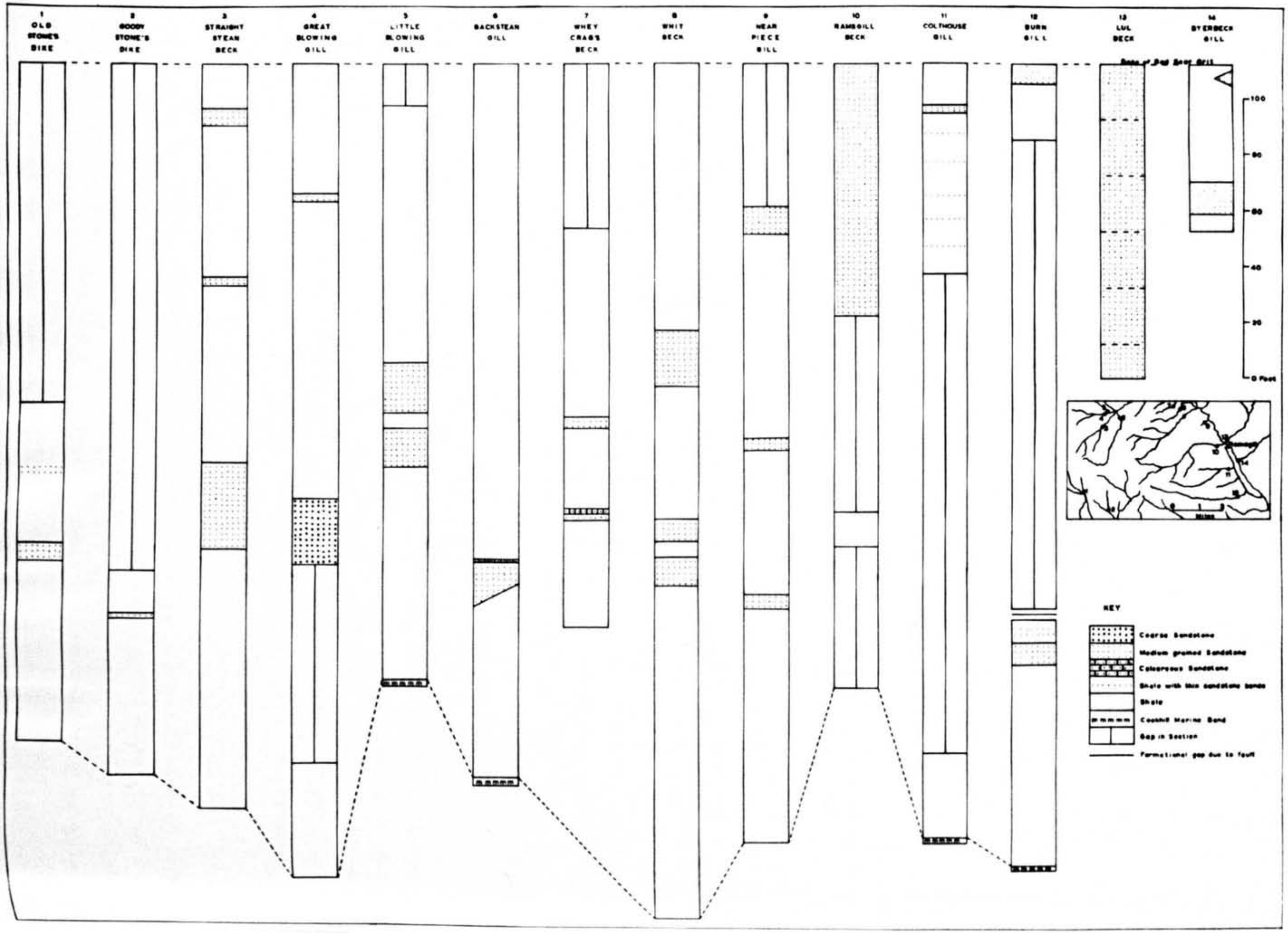
1.	Backstean Gill.	058723
2.	Colthouse Gill.	123698
3.	Near Piece Gill.	107722
4.	Little Blowing Gill Beck.	047728
5.	Burn Gill.	128682
6.	Long Band Nick.	056675
7.	Gate-up Gill.	057674

CHAPTER IV
THE NIDDERDALE SHALES

The term "Nidderdale Shales" was coined by Phillips(1836) to distinguish the predominantly shaly sequence of rocks above the main limestone from the predominantly shaly sequence below(Bolland Shales). As originally defined this term appears to embrace the complete sequence of strata between the highest sandstone of the Grassington Grit Group and the base of the First Brimham Grit and is therefore of very restricted value. However, further subdivision by Phillips resulted in a Lower Plate Group which extended from the coal exposed in Ramsgill Beck to the base of the upper leaf of the Red Scar Grit in Upper Nidderdale, clearly revealing the importance he placed on the value of coals as correlation horizons. No distinctive name was given to the beds between the Top Grit of Grassington and the Red Scar Grit by Dakyns(1890), though a sandstone occurring near the middle of the group was named the Priest's Tarn Grit after a locality on Grassington Moor. Bisat(1914) gave the name "Basement Shales" to the beds between the Bearing Grit and the Colsterdale MarineBand, thus including the Red Scar Grit, a group separated in earlier accounts. Following the widespread practice of adopting local names for stratigraphical groups Hudson(1939) designated the variable set of beds between the Grassington Grit Group and the Red Scar Grit, the Harden Grit and Shale Group because of their excellent exposure in Harden Gill on the southern flank of the Simonseat anticline. This name was not perpetuated by Wilson(1957) who reverted to Phillips original term "Nidderdale Shales" and amended its connotation, thus including only those beds between the top of the Cockhill Marine Band and the base of the Red Scar Grit. The practice of incorporating an earlier term in a differing context is not subscribed to by the present author, but in view of the precedent, Wilson's term is retained together with the connotation ascribed to it by him.

Stratigraphy

The earliest account of the Nidderdale Shales is contained in Nathan Newbold's section of the strata exposed in Cockhill level(Phillips, 1836, p.62), where they are shown to consist of a lower series of shales with an upper group of alternating sandstones and shales. These observations were extended by Phillips(1836) to surrounding areas and incorporated in a vertical



1 OLD STONE'S DIKE
2 GOODY STONE'S DIKE
3 STRAIGHT STEAN BECK
4 GREAT BLOWING GILL
5 LITTLE BLOWING GILL
6 BACKSTEAN GILL
7 WHEY CRAGS BECK
8 WHIT BECK
9 NEAR PIECE GILL
10 RAMSGILL BECK
11 COLTHOUSE GILL
12 BURN GILL
13 LUL BECK
14 BYERBECK GILL
Base of Red Scar Grit
100
80
60
40
20
0 Feet
Miles
KEY
Coarse Sandstone
Medium grained Sandstone
Calcareous Sandstone
Shale with thin sandstone bands
Shale
Cockhill Marine Band
Gap in Section
Formational gap due to fault

Figure 5. Comparative sections of the Nidderdale Shales.

section of the rocks exposed in Upper Nidderdale, though no further details were given. More than 40 years later The Geological Survey published the results of its primary survey and revealed that the group comprised a series of shales with interbedded lenticular sandstones, one of which was considered to be persistent over a wide area and designated the Priest's Tarn Grit. Detailed work by more recent workers has indicated a northerly thinning of the division when traced from Simonseat to Upper Nidderdale and expanded the lithological description of the series. Thus sandy limestones are a feature of the lower part in Greenhow(Dunham and Stubblefield, 1945) and the middle part in Upper Nidderdale(Wilson, 1957), whilst in this latter area the lowest 100 feet are almost always shales.

In the area described in this account, the Nidderdale Shales are a persistent set of beds of lower Arnsbergian age, varying in thickness from 217 feet to 304 feet. They consist primarily of shales and micaceous siltstones intercalated with which are thin beds of sandy limestone and medium to coarse grained sandstone. The shales are generally iron grey in colour, well jointed and characterised by "box structure". This arises from their siderite content, which on exposure to the atmosphere becomes oxidised to limonite, a process facilitated by the excellent nature of the joints, so that a box structure of limonite is formed surrounding a core of unaltered shale. Impersistent sandy limestones occur throughout the group and range from bands 2 feet 6 inches thick to a thin line of discontinuous nodules a few inches thick. In thin section they are seen to be made up of angular grains of quartz set in a matrix of calcite and usually containing fragments of plant remains. Apart from these no other organic remains have been found in them and there seems no reason to doubt their non marine origin. The thicker bands often have a tesselated appearance owing to solution along the joints and frequently show rounded weathering at the surface. The beds of sandstone are also impersistent, but reach greater proportions than their calcareous counterparts, some attaining a thickness of over 100 feet and a lateral extent of more than a mile. One of these in the vicinity of Ramsgill appears to bear close resemblance to the bar finger wedges of sandstone described from the Mississipi delta(Fisk et al, 1954). It achieves a thickness of 112 feet in a W.S.W. - E.N.E. direction passing through Lul Beck and Ramsgill Beck and thins rapidly when traced to the north and south, passing laterally into shales. No evidence has been found to support the mapping of a continuous arenaceous horizon such as the Priest's Tarn Grit. In fact on Grassington Moor, the type locality of this bed, the thickest sandstone encountered was only 6 feet 6 inches thick and this thinned further when traced to the south. It does not seem possible either, to restrict the horizon of the interbedded sandstones as at Simonseat (Hudson,1939), though in general the basal 60 feet of the group consist of shale with thin beds of limestone. Above this, sandstonesoccur at varying levels, but as in Upper Nidderdale(Wilson,1957) the upper 100 feet are the most variable, being entirely arenaceous in some sections and entirely argillaceous in others. In the main the sandstones are medium grained and flaggy containing a significant proportion of felspar and mica and are therefore more correctly described as subgreywackes. A coarser sandstone comparable with one of the Harden Ridge Grits(Hudson, 1939) is present in two places within the area and forms a notable contrast to the subgreywackes, being more of an orthoquartzite in type. Some of the sandstones have been quarried on a small scale for building stone, whilst one record occurs(see below) of a sandstone having been exploited for its content of iron ore.

The group has a wide outcrop in the west, occurring as a long gradual slope on Riggs Moor and Grassington Moor only interrupted by the impersistent features of intercalated sandstones. The beds dip gradually to the east following the course of Howstean Beck towards Nidderdale and there form the major part of the bold flanks of the dale. They pass underground just south of Wath, but reappear at the surface near Woodmanwray on the southern limb of the Simonseat anticline. As explained earlier(Chapter II), these beds are missing in the Aldfield borehole, but are present in the Sawley hole where they appear to have a similar thickness and lithology to the main outcrop in Nidderdale. Complete sections of the Nidderdale Shales do occur in the N.W. of the area, but elsewhere they are rare. In this area deeply incised gulleys in the shales are common and encourage detailed examination of the beds. Throughout mapping has been greatly assisted by the bold feature generally present at the base of the Red Scar Grit, whilst numerous outcrops of the Cockhill Marine Band have enabled the base of the series to be fixed precisely.

Details

West side of Nidderdale(Little Blowing Gill to Pateley Bridge) - An almost complete section of the group is exposed in Little Blowing Gill Beck consisting of well jointed grey silty shale with a thick bed of flaggy micaceous sandstone near the middle. No exposures of the group occur in Sandy Sikes Gill and West Dike, but a small outcrop of shale in Staining Gill Beck occurs just below the base of the Red Scar Grit.

In Great Blowing Gill Beck, much of the lower part of the series is obscured, but towards the middle, a bed of sandstone occurs, which is thought to be the continuation of the arenaceous horizon in Little Blowing Gill Beck. This bed, both here and in Bain Grain Beck is coarse and bears erosive relations to the underlying shales. It is overlain by a thick series of shales and micaceous siltstones which contain a thin bed of flaggy sandstone towards the top.

West of Straight Stean Beck the ground rises sharply to 1,800 feet and at this height a plateau of Red Scar Grit forms the watershed between Nidderdale and Wharfedale. This even slope between Great Blowing Gill Beck and Straight Stean Beck is dissected by a number of small streams incised in the Nidderdale Shales. The three streams Near Land Gutter, Rotten Heath Wham and Far Land Gutter all occurring in close proximity and exhibiting well exposed sections illustrate the lenticular nature of the thin beds of sandstone in this formation. Each contain up to three beds of flaggy sandstone, none exceeding 2 feet 6 inches in thickness, yet it is impossible to trace any one bed through to the next stream.

A complete section of the group is exposed in Straight Stean Beck. Well jointed grey shales and micaceous siltstones with thin beds of flaggy sandstone form the lower part of the series and pass upwards into a thick bed of flaggy sandstone. Just below Far Land Gutter, the sandstone is disturbed by a small fault whose trend is almost coincident with that of the stream and may be the result of solifluction rather than tectonic forces. The remainder of the section is argillaceous except for two beds of flaggy sandstone near the top, both of which can be traced into Friar Hood Gill. Three steep asymmetric anticlines of a minor category occur in this beck and have a N.N.W.-S.S.E. trend, but these appear to be without tectonic explanation also.

The streams that drain into Straight Stean Beck from the south all exhibit good sections of the group. In South Gill two thin bands of sandstone occur near the top, the lower one ganisteroid and the upper one calcareous. In Cross Gill there are four beds of sandstone interbedded with the shales, the thickest being 7 feet and consisting of flaggy micaceous material. The middle two of these appear to be the representatives of the thick bed of

A

Acoras Scar, Backstean Gill. The section consists of more than 70' of Nidderdale Shales overlain by the Red Scar Grit.

B

Well developed jointing in the Nidderdale Shales, Backstean Gill.

sandstone in Straight Stean Beck. Further north, "Red Scars" is the name given to two deep incisions into the upper shales of the group, here channelled into by the basal beds of the Red Scar Grit.

Between Straight Stean Beck and Backstean Gill there are 7 features in the middle of the outcrop of the Nidderdale Shales, none of which is continuous for more than 350 yards and all are notable for the rapidity with which they commence and die out. It is thought likely that these impersistent features, so characteristic of this group are associated with the lenticular sandstones that occur throughout the division.

Backstean Gill is another stream which contains a completely exposed section of the Nidderdale Shales. The basal 60 feet consist of well jointed, pyritic shales which are overlain by a bed of calcareous sandstone, 7 feet 9 inches thick in the scar above the stream at 059723, but twice this thickness a short way further upstream. This latter bed is affected by two faults throwing to the south, which combined with the coincidence of the stratal dip and the thalweg of the stream account for its long outcrop in the bed of the stream. The remainder of the group consists of shales with occasional thin sandstones well displayed in Acoras Scar where they are capped by the Red Scar Grit.

The group dips towards the east amd swings down the slope below Flaystones, here broken by two prominent features(the upper one a spring line) and reappears in Wising Gill where only the lower part of the group is exposed, consisting of shales with thin beds of sandstone.

The tributary stream of Howstean Beck which passes through Stean (Whey Crag's Beck in Fig.5) contains a well exposed section of the middle part of the group comprising a series of shales with two beds of sandstone, the lower one calcareous and both about 6 feet thick. Between this gill and Whit Beck 6 feet of micaceous sandstone are exposed just above the Bradford Corporation aqueduct(083730) on Stean Pasture. This sandstone appears to be a continuation of the lower band in Whey Crag's Beck, but it may well be another lens at a lower level.

In Whit Beck an almost complete section of the group is exposed, which here consists of 304 feet of grey shales with three beds of flaggy micaceous sandstone near the middle. The group attains its maximum thickness at this point, but this is not thought to be of regional significance because throughout the area local variations in thickness frequently take place in very short distances.

The outcrop of the group in Blayshaw Gill is confined to a 10 feet bed of micaceous carbonaceous sandstone, probably a continuation of the lower band in Whit Beck. East of the stream below Blayshaw Crags(097725) a good feature runs for about 300 yards and fragments of micaceous sandstone from rabbit holes above the feature suggest that this band continues for some distance, though it is not present in the stream above Lolly Mine. In this latter stream the majority of the lower part of the group is present and was measured as follows :-

7' 7"	micaceous sandstone
96' 9"	shale
3' 6"	micaceous sandstone
46' 0"	shale
3' 0"	micaceous sandstone
75' 6"	shale
	Cockhill Marine Band

The three sandstones thicken to the south and are each present in Near Piece Gill maintaining the same subgreywacke lithology. The upper bed has been quarried for building stone but the Old Quarry is now largely overgrown and only blocks of the bed occur at the entrance.

On Ramsgill Bents there are a great number of shallow pits seen to best advantage in an aerial photograph. The origin of these pits, each of which contains fragments of shale remained a bit of a mystery until the following extract from Speight(1894) was seen. "Upon this high and exposed tract of uncultivated land known as Blayshaw(Ramsgill) Bents are a number of shallow pit holes of various sizes, extending in a zig zag line for a good half mile east and west along the edge of the moor. They are said to owe their origin to the ancient Britons who excavated them for the foundations of their dwellings, but from their position facing due north, this is not likely. In fact the key to their true origin was accidentally discovered in the year 1876 by a farm man, who while digging for stone sent his pick through one of the holes, which fortunately for the light of the discovery afforded, has retained its roof intact while the others had all fallen in. Upon carefully removing the sur ace material, it was found to be an old iron stone pit some 20 feet deep; the apex being bell shaped and widening at the middle to about 7 feet and at three feet from the bottom to 12 feet. The pit like the others had been excavated in clayey shale, while the floor of this particular one was composed of a rich iron stone; the pick marks of the ancient miners being as visible and distinct as the day they were made. Close beside these curious bell pits are many large heaps of slag, called "baal hills" which show that the ore had been smelted by peat fires; the requisite blast being furnished by the high winds that continually sweep over these breezy heights. This interesting collection of pits in all probability originated with the monks of Byland Abbey ...".

It would appear from this description that the source of iron ore is one of the lenticular beds of sandstone in the Nidderdale Shales. This is interesting because no other records of this bed being used for this purpose in Nidderdale are available and in any case the content of recoverable iron in the sandstone is so low that its exploitation would not have been thought worthwhile.

In Ramsgill Beck the outcrop of the lower part of the group is confined to a small exposure of shale, 200 yards W.S.W. of Broad Carr Lathe. The upper 100 feet of the group however are completely exposed and consist entirely of flaggy micaceous sandstone. It is this bed which formed the source of iron ore on Ramsgill Bents, but what is most notable is that in less than a mile to the north this bed has lensed out completely except for three beds of sandstone, none of which is thicker than 8 feet.

The upper part of the group is still predominantly arenaceous in Riggs Gill(111706) but the bed of sandstone is considerably thinner here than in Ramsgill Beck. Between this point and Colthouse Gill there are a number of scars of shale, referred to the lower part of the group, one of which is more than 20 feet high, above Binks Wood. The outcrop of the upper part of the group is obscured, but the available evidence suggests that the sandstone has lensed out completely before reaching Colthouse Gill. In this latter stream the middle part of the group is covered, the section consisting of grey blocky shales at the base and interbedded sandstone and shale at the top.

In Riddings Gill a spectacular section of the upper part of the group, channelled into by the Red Scar Grit is visible from the Lofthouse road. Five thin beds of impure limestone occur in the section which otherwise consists entirely of shale.

The little streams descending from Colt Plain are poorly exposed, but the base and top of the group can be traced clearly, and indicate little change in overall thickness between Riddings Gill and Burn Gill.

In Burn Gill a bed of sandstone occurs in both the lower and upper part of the group. A fault crosses the gill in Park Hagg Wood which therefore prevents accurate measurement of the section, but it appears likely that a thickening is taking place in a southerly direction towards Greenhow where the average thickness on the north side of the anticline is 350 feet (Dunham and Stubblefield, 1945 p.239). On the southern side of the gill below Colt Sike Crag an adit has been driven into the hillside and as there is no indication of a mineral vein in this vicinity its origin remain obscure.

On the south side of Burn Gill, west of Eanings Farm(128680) blocks of coarse sandstone occur at the surface and point to an arenaceous horizon below. This is substantiated by the section in the Old Quarry, 100 yards S.W. of West Wood House where a bed of medium to coarse grained sandstone is exposed. The sandstone is of an unusual lithology for the Nidderdale Shales, being nearer to an orthoquartzite, but is comparable in lithology and position to the bed of coarse sandstone in Great Blowing Gill Beck.

The group passes underground about half a mile N.W. of Pateley Bridge, but the upper part is exposed in a number of streams on the hillside west of Wath where it consists wholly of shales and micaceous siltstones.

East side of Nidderdale - North west of Lul Beck exposures of the Nidderdale Shales are confined to a little stream, S.E. of Low Sikes Farm(114728) which contains a section in grey shales assigned to the middle of the group.

In Lul Beck only the upper 112 feet of the group are present and here consist entirely of medium grained flaggy sandstones with occasional partings of shale. More massive beds up to 6 feet thick are present and alternate with the thinner bedded micaceous sandstones. As noted earlier this thick group of sandstones is laterally equivalent to the bed of sandstone in Ramsgill Beck and behaves in a similar manner when traced to the north and south, lensing out rapidly.

Only the upper part of the group is present in Byerbeck Gill and comprises a series of shales with two beds of sandstone, one at the base and one at the top. The upper bed is demonstrably lenticular in form passing into well jointed grey shales upstream.

Between Byerbeck Gill and Wath exposures of the group are infrequent, the major ones being confined to the small streams below Pheasant Cock Hall(136690) and the stream below the Old Quarry, Wath(146684). In each of these sections thin beds of calcareous sandstone occur in the shales, individual beds of which never exceed 2 feet in thickness.

In Dauber Gill only the upper beds of the group are seen, here consisting entirely of grey shale. The beds are displaced by the Wath fault and under the influence of the regional dip pass underground less than half a mile south of Wath.

Sawley borehole - In this section the Nidderdale Shales are 312 feet thick and comprise a series of dark sandy shales with thin beds of fine to coarse grained sandstone, many of which are calcareous and tend to be more common in the middle of the group.

Woodmanwray - The coarse massive felspathic sandstone which forms Dent Crag Ridge (150614) and Broad Crags on the southern flank of the Simonseat anticline is considered to be the Red Scar Grit on the basis of lithology. The strata dip to the south and are underlain by a series of shales which crop out in the stream passing through Foldshaw Lane Bottom(158609) which must therefore be the Nidderdale Shales. Exposures are infrequent, but grey mudstone is the only lithology seen.

Grassington and Hebden Moors - In Gate up Gill the Cockhill Marine Band is overlain by a series of shales containing thin discontinuous bands of limestone nodules. The remainder of the beck is largely obscured, but shales with a 6 feet bed of flaggy micaceous sandstone occur just below the base of the Red Scar Grit and must represent the upper beds of the Nidderdale Shales in this vicinity.

Only the lower part of the group is exposed in High Hill Dike and Long Band Nick, both of which are incised in grey shales with a thin band of calcareous nodules near the middle. Incomplete sections are also seen in Goody Stones Dike(Fig. 5) and Sleet Moor Dike and comprise a series of shales with a thin bed of ganisteroid sandstone 55 feet above the base.

In Old Stones Dike and Straight Grainings the lower part of the group is well exposed and includes a similar bed of sandstone to that exposed in Goody Stones Dike, but at a slightly higher level. This bed of sandstone is found in Crag Grainings also where only 2 feet of it are exposed. On the basis of blocks of medium grained sandstone on the surface of Priest's Tarn, Dakyns expanded the thickness of this bed and designated it the Priest's Tarn Grit, but shale fragments abound in this vicinity and it is questionable whether this interpretation is correct.

CHAPTER V

THE RED SCAR GRIT

The term "Red Scar Grit" dates back to the primary survey of Yorkshire by The Geological Survey and owes its origin to the tendency of the bed to form "red scars"(Dakyns,1890). It was preceded by Newbold's term "Sandgill Grit" and Phillip's term "Middle Grit", but in view of its common usage throughout this century the later term is retained in this account.

Stratigraphy

The division was given more than usual emphasis by Dakyns(1892, 1893) in his description of the area, the main outcrops together with lithological and thickness variations being summarised by him. Later workers have added little new information with respect to this area, but reference must be made to the notable contribution by Wilson(1957) to our knowledge of the adjacent region in the north. There, the Red Scar Grit consists of an upper and lower leaf of sandstone locally separated by a shale parting which carries an impersistent coal. A faunal phase has been discovered in both the shale parting and the upper leaf of sandstone, neither of which are known at Greenhow and do not appear to extend into the present area. Where the shale parting is absent the Red Scar Grit is not usually divisible into two component leaves and is then a single felspathic sandstone comparable with the horizon described from other districts further south.

The Nidderdale Shales give place abruptly upwards to the Red Scar Grit, the junction generally forming a bold feature and not infrequently a spring line. When seen in stream sections this junction is usually an erosive one, the underlying shales being channeled into by the basal beds of sandstone. The upper limit is rarely so clearly defined in the field, but occasional exposures of the overlying Colsterdale Marine Series enable it to be placed with relatively constant precision. Over most of its outcrop the bed is a coarse, locally pebbly felspathic sandstone with a peculiar reddish tinge. It is not infrequently a quartz sandstone, ganisteroid in parts and with a marked tendency to this development near the base and at the top. Under the microscope the rock is seen to consist of a sutured mosaic of subangular quartz, full of inclusions, together with small amounts of felspar, mica and clay minerals. More than 90% of the rock is generally composed of quartz, whilst in some sections this proportion reaches as high as 98·5%. In the main the

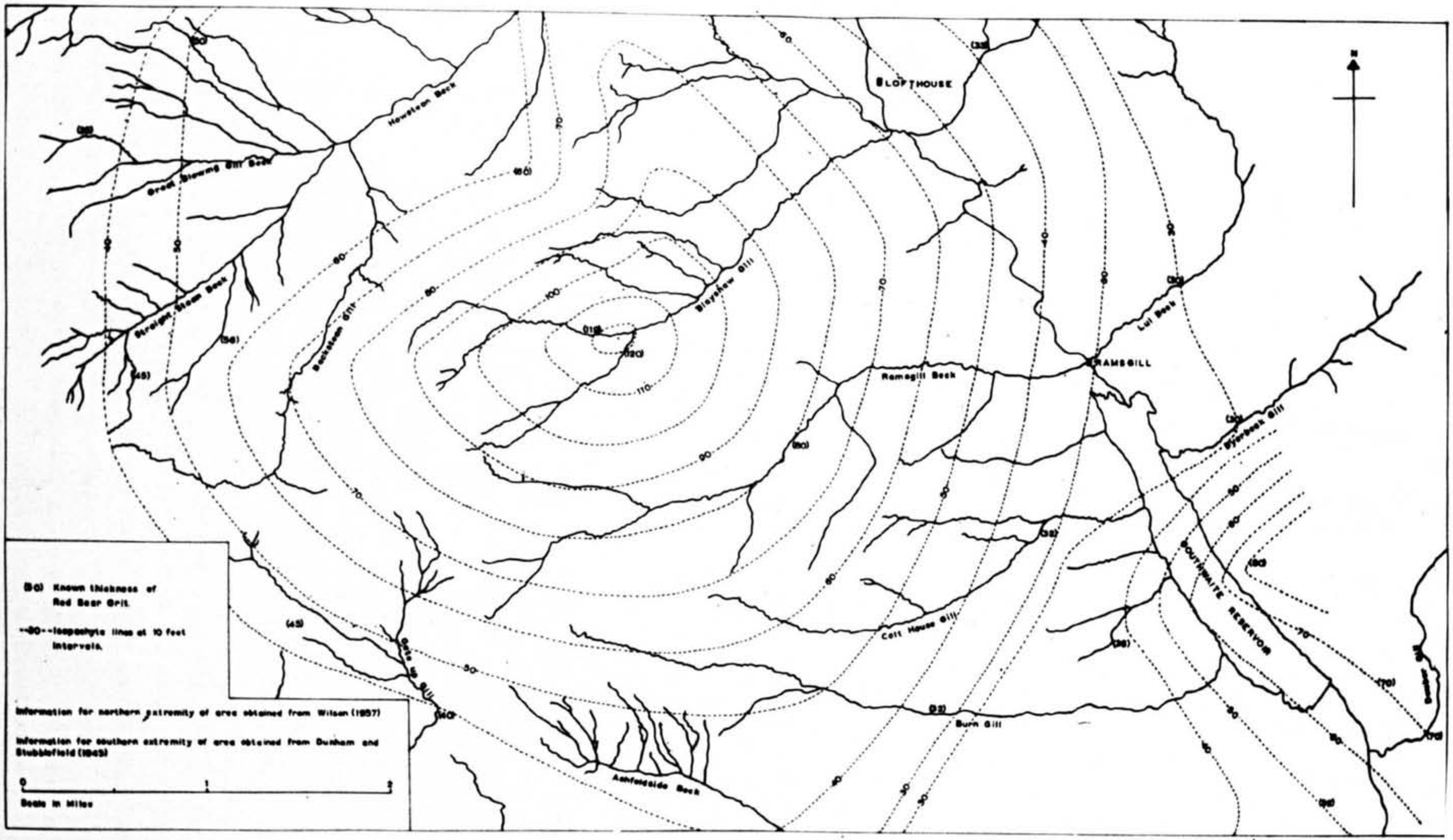


Figure 6. Isopachyte map of the Red Scar Grit.

sandstone is a compact, well jointed rock frequently current bedded and occasionally ripple marked. It outcrops in the form of large scars such as Flaystones and Wolfrey Crags(Plate V) or may occur merely as scattered blocks on the moor surface. Waterfalls and rapids characterise its outcrop in stream sections, attesting to the durability of the rock and revealing the massive nature of the current bedding units. Shale partings are rare, never exceeding 4 feet 6 inches in thickness. They are distributed randomly throughout the division. Fragments of coal also occur, on Riggs Moor and in South Gill(037708) about 35 feet above the base of the sandstone, but they are not seen elsewhere in the area and must represent the imperfectly developed Woogill coal better known farther north. A feature of especial interest on Rather Standard is the peculiar weathering of the bed(Plate VI). Large rectangular blocks of sandstone crop out on this otherwise barren moor and are notable for their rough, irregular surface. The origin of this structure was originally thought to be associated with the calcite content of the bed, but examination of a thin section showed that this mineral was not present and in fact the rock consisted almost entirely of quartz. The alternative explanation would therefore seem to be patchey silica cementation of the grains in the original rock.

The thickness of the bed varies from 30 feet to 120 feet,appearing to follow a regular pattern which is summarised in Fig.6. An area of maximum subsidence occurs at the junction of Blayshaw Gill and West Gill and passes eastwards into a region of minium sedimentary thickness. Information is not available for the north eastern part of the area, but a trend of rapid thickening, appreciable in the vicinity of Gouthwaite reservoir probably persists further eastwards because the group is assigned a thickness of 180 feet in the Sawley borehole.

The division has an extensive areal outcrop in the western part of the region, forming long dip slopes in several instances. It runs north westwards from Wolfrey Crags on Hebden Moor up Rather Standard to Ragstaff Hill. Thence by way of the high ground around Meugher it swings north eastwards across Stean Moor to Nidderdale. In the vicinity of Flaystones its outcrop is disturbed by a number of small normal faults most of which are attested to by the displacement of the bold feature at the base of the group. The bed can be traced down both sides of Nidderdale before passing underground just north of Pateley Bridge and is not then seen again until it re-appears

Great Wolfrey Crag, Gate up Gill(062673). The massive sandstone which forms the crags is the Red Scar Grit, a formation which yields readily to weathering processes because of the excellent development of joints, thus accounting for the numerous boulders of sandstone strewn over the hillside below.

on the southern limb of the Simonseat anticline near Heyshaw.

Details

Hebden Moor to Backstean Gill - North of the Bycliffe Vein the Red Scar Grit forms the impressive scar of Wolfrey Crags. The crags, about 30 feet high are formed of a well jointed, coarse massive sandstone locally felspathic, but chiefly quartzitic. Harder bands of coarser material weather out on the surface and give the rock a fluted appearance which is enhanced by the current bedding so excellently developed here. The beds dip to the north and can be traced down to Gate-up Gill where the base of the sandstone forms an irregular junction with the underlying shales. A parting of shale, 7 feet 4 inches thick and full of rounded blocks of coarse sandstone occurs just above the base in the stream and is overlain by a 2 inch coal. The remainder of the section is poorly exposed, but two outcrops near the middle of the division consist of medium grained sandstone full of plant remains and with curly cylindrical markings on the bedding planes.

The bed swings north-westwards across Rather Standard where it is characterised by a persistent series of crags at its base and numerous blocks of sandstone on the moor surface. The sandstone here is chiefly a coarse pebbly orthoquartzite, only locally felspathic, but two features of the sandstone call for comment. The first is the high(29°) W.S.W. dip of the sandstone at the eastern end of Goody Stones(052685) which is too persistent to be explained by slip and yet cannot be explained in terms of subsequent tectonic modification. The alternative explanation is one of original sedimentation probably large scale current bedding, but even this is not wholly satisfactory. The other item of interest is the peculiar weathering of large pavement blocks of sandstone(Plate VI) on the top of the moor at Rather Standard End(047687), the origin of which is thought to be related to differential cementation of the original rock.

The bed is thrown up by a fault just north of Sleat Moor Scar and continues as a wide band round Ragstaff Hill towar s Straight Stean Beck. Here it consists of a coarse massive pebbly sandstone which in Meugher Dike has a ripple marked surface. Large pavement blocks of the sandstone occur on the moorland tract west of Meugher and in the upper reaches of Straight Stean Beck, but in South Gill and the stream adjacent to it the sandstone is seen in situ. Fragments of coal occur in these streams at a point 35 feet above the base of the sandstone and must represent the southern continuation of the Woogill coal.

Similar fragments are also found on the flat plateau(033720) N.N.W. of South Gill which is composed of Red Scar Grit and forms the watershed between Wharfedale and Nidderdale. On this plateau blocks of coarse pebbly sandstone are scattered over the surface of the moor whilst in the upper reaches of Great Blowing Gill Beck and Bain Grain Beck the basal few feet of the division are well exposed, here channeling into the underlying Nidderdale Shales. The beds dip gently to the east and can be followed by the prominent feature at the base of the sandstone towards Low West Moor. In this vicinity exposures are infrequent and apart from the ubiquitous blocks of coarse sandstone the only stream with a solid outcrop is Staining Gill Beck where 12 feet of poorly cemented coarse sandstone occur, referred to the middle of the division.

Fragmentary exposures of the bed occur in Cross Gill(044729) indicating that the steady trend of thickening towards Blayshaw Gill which is summarised in Fig.6 has already commenced. The outcrop continues to the north east forming a featureless plateau from which numerous little streams run down towards Straight Stean Beck and Backstean Gill. Just south of Acoras Scar the beds are thrown down to the south by a fault which is prominently displayed in Backstean Gill. Here the beds are exposed in a long section consisting of current bedded coarse yellow sandstone with two shale partings, one 4 feet 6 inches thick near the middle and the other 1 foot thick near the top.

<u>Backstean Gill to Ramsgill Beck</u> - Proceeding towards Whey Crags the strata are dislocated by a number of small faults on Little Stangate, the presence of which can be clearly demonstrated by the displacement of the feature at the base of the sandstone. Flaystones is a distinctive scar overlooking Howstean Beck on which good ripple marking is displayed on bedding surfaces of the coarse well jointed sandstone. A similar lithology is displayed at Whey Crags and Stott Crags, where there are again large areas of well exposed rock. The beds continue to the south in a wide band below Stock Ridge and are seen at the surface as blocks in Green Sike and a prominent line of crags west of the Shooting Box on Stock Ridge Bottom. They are affected by two faults in this vicinity which accounts for the duplicated outcrops in West Gill, the lower one of which consists of a fully exposed section of current bedded pebbly sandstone. A similar section is seen in Blayshaw Gill, waterfalls and rapids being common throughout the outcrop of both. The sandstone is at its maximum thickness in this locality, thinning steadily when traced towards Nidderdale.

It caps the broad spur between Blayshaw Gill and Ramsgill Beck, being quarried at Blayshaw Crags where 30 feet of poorly bedded quartzitic sandstone are exposed. An old Shaft is indicated on the 6 inch map, 300 yards S.W. of Blayshaw Crags, but this is now completely overgrown and it remains a matter of speculation whether this was once sunk to extract a representative of the Woogill coal for there are no fragments of coal or shale in the vicinity. On Bracken Knott at the eastern tip of this dip slope, large pavement crags of reddish tinged quartzitic sandstone occur at the surface and have a trace of the peculiar weathering already described from Rather Standard. The beds continue to the south, cropping out in Ramsgill Beck. Here the base of the division consists of a lens of poorly cemented coarse sandstone which has channeled into the upper strata of the Nidderdale Shales. The overlying sandstone forms a waterfall at Ravescar where it is a massive felspathic sandstone embellished with fucoid markings on bedding surfaces. It is abruptly terminated by a fault 100 yards downstream from the junction with Cross Gill and is not seen again in this beck.

Ramsgill Beck to Pateley Bridge - The sandstone forms the broad plateau of Dewhurst Allotments, the base being fashioned into a series of crags just above the cut and cover water pipeline in Raygill House Plantation and also at High Pasture. Its outcrop has the shape of projecting tongues in the ground between Knott's Gill, Colthouse Gill and Riddings Gill, the good feature at the base persisting and many blocks of massive orthoquartzite lying scattered about on the surface of the land. Just south of the Rabbit Warren on Colt Plain the bed is displaced by a fault and reappears in Burn Gill where it is prominently displayed in Colt Sike Crag. The complete division is not visible in the stream, but 25 feet of coarse, massive current bedded sandstone exposed in the crags must represent the major part of the formation in this district. The strata run along the edge of Burn Gill for some distance and are seen again at the surface on The Riggs overlooking Nidderdale. Before reaching this point however, blocks of coarse sandstone in the tip in front of the Bradford Corporation Measuring Chamber on Burn Edge(119679) indicate that the formation was penetrated during the construction of the Burn Tunnel. The engineer's section of this tunnel is illustrated in Fig.22 and reveals an anticlinal structure under Heathfield Moor, the core of which consists of hard sandstone referred to the Red Scar Grit. This interpretation is supported by the considerable amount of fossiliferous Colsterdale shale and limestone found in the tip of Burn Edge as well as on the dumps near the covered chamber on the north side of Ashfoldside Beck(Dunham and Stubblefield, 1945 p.239).

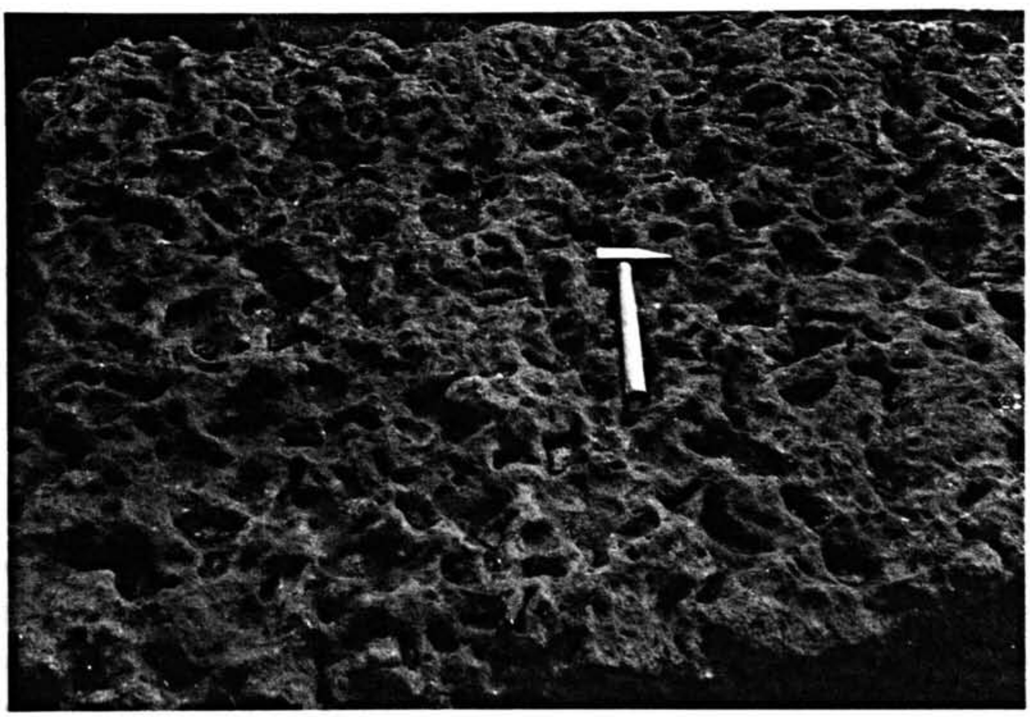
The Red Scar Grit has been extensively quarried in time past on The Riggs, but unfortunately most of these outcrops are now completely overgrown. The bed can still be seen however in an Old Quarry on the side of the road from Gouthwaite Hall to Heathfield and here consists of well jointed coarse felspathic sandstone. At a point 30 yards north of this quarry on the road side, coarse massive sandstone is exposed in contact with slickensided shale, the boundary being demonstrably tectonic and coincident with the line of the Wath fault. The beds swing south eastwards at this point and run parallel with Nidderdale, the base of the sandstone being exposed in several streams between Pie Gill Farm and Peggy Wood. These sections together with the two quarries in the vicinity indicate that the coarse felspathic nature of the sandstone is still being retained throughout.

South of Heathfield the strata are affected by another fault downthrowing to the south and resulting in an extensive outcrop of the Red Scar Grit in Foster Beck, Ashfoldside Beck, Mosscar Beck and Brandstone Beck, The base of the division is not seen so no figure for the thickness is obtainable, but only 30 feet of beds occur in Gillfields adit(Dunham and Stubblefield, 1945) and 32 feet in Burn Gill so it is unlikely that any increase has taken place here. The sandstone is coarse, occasionally pebbly and locally very felspathic, but nothing approaching an arkose as described by Wilson(1957) from Upper Nidderdale has been seen. In Brandstone Beck at Throstle Nest Bridge(134656) an adit possibly connected with Perseverance Level has been driven through thinly bedded flaggy sandstone, which is overlain by coarse pebbly orthoquartzite further upstream. This flaggy bed is probably the equivalent of the shale parting encountered in Wonderful Level and illustrated on the geological map of Greenhow(Dunham and Stubblefield,1945), but if so a facies change has commenced and the bed is becoming coarser eastwards. A little higher up Ashfoldside Beck the Red Scar Grit is displaced by the Bycliffe Vein and reappears much higher in the stream. The bed crops out in the base of the stream and forms a series of rapids consisting of coarse pebbly, locally ganisteroid sandstone overlain by the Colsterdale Marine Series. Between here and Pateley Bridge there are no surface indications of the Red Scar Grit, but the regional disposition of the beds suggests that it passes underground just north of Pateley Bridge.

A

The Red Scar Grit weathers out in rectangular blocks which have a peculiar surface structure on Rather Standard(048689). The origin of this weathering structure is not clear, but it is thought to be related to differential cementation of the original rock.

B



A close up of one of the above blocks.

East side of Nidderdale - The base of the Red Scar Grit is exposed in Lul Beck resting on an uneven surface of flaggy sandstone, one of a series of lenses in the Nidderdale Shales. The higher beds of the division are not seen, but their total thickness can be fairly accurately estimated to be just over 30 feet. Between here and the Lofthouse fault, the bed is nowhere exposed at the surface, but blocks of quartzitic sandstone in Longside Wood attest to its presence. Passing southwards, 6 feet of coarse sandstone crop out in the small stream above Hollin Hill Farm(128711) and constitute the only solid exposure before Byerbeck Gill. Here the formation is well displayed, consisting of coarse felspathic sandstone fashioned into a series of three waterfalls along the limited outcrop. A prominent feature, coincident with the base of the division runs intermittently throughout the length of the Gouthwaite reservoir and is clearly visible from the Lofthouse road. Exposures are poor however and apart from blocks of coarse sandstone on the surface are confined to two small streams S.W. of Pheasant Cock Hall, where the basal few feet are visible. A southerly thickening of the group is apparent along this hillside and is substantiated by the section in the Old Quarry, Wath(146683) where 51 feet of coarse speckled sandstone were measured, the base being an unknown distance below this. Another old quarry 170 yards further south is now largely overgrown, but blocks examined in the quarry suggest that the base of the Red Scar Grit is here a medium grained sandstone. A comparable lithology occurs at this level in Dauber Gill where it is strongly brecciated due to the proximity of the Wath fault. The upper beds, more than 60 feet of which are exposed are made up of coarse quartzitic sandstone disposed in massive posts along the sides of the stream, and cut into four impressive waterfalls. South of the Wath fault, highly disturbed sandstone is exposed in the lower reaches of Black Dike, but nothing further is seen of the bed before it passes underground north of Pateley Bridge.

The Aldfield borehole as stated in earlier chapters passed through a sequence of strata disturbed by faulting and therefore the Red Scar Grit is not represented in the log of the hole. In the Sawley borehole (Fig.21) however, 180 feet of beds are referred to this division and comprise coarse grained sandstones with a thin parting of sandy shale near the base.This increase in thickness from Nidderdale may only be of local importance, but it is significant that the equivalent horizon attains a thickness of more than 400 feet in the vicinity of Rigton, south of Harrogate.(Leeds Memoir,1950).

Woodmanwray, Dacre - The coarse felspathic sandstone forming Dent Crag Ridge (150614) was shown by Hudson(1939) to be the continuation of Palley Crags and hence Red Scar Grit, bounded on the north by the Nar Hill Fault. This interpretation must be considered questionable in the light of the high felspathic content exhibited by the Upper Follifoot Grit in this region and in the absence of a diagnostic marker horizon such as the Colsterdale Marine Series, cautious judgement is preferred. It is recalled that comparable difficulty was experienced by Dunham and Stubblefield(1945) in positively identifying this bed at Greenhow, wherever the Colsterdale Marine Series was absent. For the present therefore the rocks exposed on Dent Crag Ridge and at Broad Crags are only tentatively assigned to the Red Scar Grit. They consist of coarse felspathic sandstone, well jointed and current bedded now dipping steeply (average 15°) to the south. Many blocks of the bed occur at the surface and together with the extensive quarrying formerly conducted, the ground is now only rough pasture land.

CHAPTER Vl
THE COLSTERDALE MARINE SERIES

The thin limestone overlying the Red Scar Grit has long been known as a field marker horizon. It was used as such by the Primary Geological Survey and named the "Tesselated Limestone"(Dakyns, 1892) in view of the structural pattern developed by solution along the joints. Before this however, the bed had been mentioned by Phillips(1836) in his section of Brownbeck colliery, Colsterdale and shown to be of marine origin by the occurrence of fossils recorded on the authority of Danby. The Geological Survey traced the bed over a wide area between Wharfedale and Colsterdale noting a change in lithology and thickness towards Colsterdale, a change amplified by the later work of Bisat(1914). This author observed that in Nidderdale the beds consist of less than 10 feet of fossiliferous shale with a thin limestone, but towards Colsterdale they thicken to about 80 feet, primarily due to the incoming of thin beds of fossiliferous sandstone. Wilson(1957) has recently elaborated this picture and shown that whilst Bisat's conclusions are basically correct, the marine series contains 40 feet of beds more correctly assigned to the Red Scar Grit.

In this area the marine series has only a limited outcrop, most of the exposures having been visited by earlier workers. Thus Dakyns(1892) mentioned the occurrence of the bed in Henless Beck and Meugher Dike, whilst Bisat(1914) incorporated a photograph of the section in Backstean Gill in his account and stated that the bed could be traced down both sides of Nidderdale. The composite faunal lists accompanying Bisat's paper included no less than three fossil localities from this area and later work by Tonks(1925) summarised the outcrop of the bed in this region illustrating its occurrence on a small sketch map. Three separate names were used to describe this horizon by Bisat (op. cit.) viz., the "Colsterdale Marine Beds", "Colsterdale Fossil Beds" and "Colsterdale Marine Band", but only the latter was perpetuated by Tonks (op. cit.) in his account of the strata in Nidderdale. This name has now been amended to "Colsterdale Marine Series" by Wilson (op. cit.) in view of the considerable thickness of the beds in the type area. This amended designation is retained in this account.

Stratigraphy

The Colsterdale Marine Series comprise a set of fossiliferous

A

The section of the Colsterdale Marine Series exposed in Backstean Gill(050704). The section consists of an upper 7' 7" of dark grey fossiliferous shale; 1' 2" dark grey fossiliferous limestone; 1' 8" dark grey fossiliferous shale; 9" coarse sandstone; 1' grey unfossiliferous shale; coarse sandstone in the bed of the stream.

B

Old Quarry, Wath(146684). The section consists of an upper series of sandy shales; 15' 4" black fossiliferous shale with a layer of limestone nodules near the top; 1' 8" dark grey fossiliferous limestone; 5' 7" dark grey fossiliferous shale; ca. 30' coarse massive sandstone(Red Scar Grit).

strata of E 2 age, varying in thickness from 10 feet 7 inches to 23 feet. They consist predominantly of black shales and grey mudstones with a thin limestone near the base, which locally degenerates into a thin band of calcareous nodules. The area of minimum thickness occurs in the vicinity of Meugher, but the beds thicken rapidly when traced to the south and south east, the change being most noticeable in the shales above the limestone. For convenience they are divided into three sub-groups, here described in ascending order.

i) Shales below the limestone - Immediately succeeding the Red Scar Grit and lying below the Colsterdale limestone is a sequence of compact slaty shales, varying in thickness from 1 foot 0½ inch to 5 feet 11 inches, the minimum thickness occurring in the north west and the maximum in the south east of the outcrop. They are fossiliferous throughout, the fossils being preserved either as pyritic impressions or in bas relief and including Anthracoceras paucilobum and numerous posidonid lamellibranchs. A notable discovery in these beds has been the presence of Tylonautilus nodiferøus(Armstrong) a fossil characteristic of the E 2 Stage and formerly recorded from the Shunner Fell Beds(Scanlon,1955) and the Harlow Hill Limestone(Green, 1954), both lateral correlates. Variants of this otherwise consistent lithology include a thin bed of ganisteroid sandstone near the base in the vicinity of Wath and a mud cracked surface in Backstean Gill overlain by a thin discontinuous band of coal(Plate V111 A). Bisat(1933 B) has already suggested that Anthracoceras associated with Tylonautilus is an indicator of semi-est-uarine conditions and this recent evidence from Backstean Gill may well be held to support this contention.

ii) The Colsterdale limestone - The limestone is a hard, dark grey calcite mudstone averaging 1 foot thick, but locally reaching 1 feet 8 inches and in one instance degenerating into a line of nodules only a few inches thick. It is generally banded due to the presence of more silty layers and broken up by a well developed set of joints to produce a characteristic tesselated pattern. Cone-in-cone structure is a rare phenomenon, but irregular cracks infilled with clear crystalline calcite occur throughout the rock both on a macroscopic and microscopic scale. The horizon is fossiliferous, fossils being randomly distributed throughout the rock, but occasionally concentrated into distinct bands. In its fresh condition they are difficult to extract, but when the bed occurs on dip slopes, eg. west of Meugher, the limestone weathers to a gingerbread rottenstone from which a considerable fauna can be collected. Goniatites are the most common fossil, Cravenoceratoides nitidus being a characteristic form, but posidoniellid lamellibranchs and plant remains also occur. In this section the rock is seen to consist of a finely divided mesh of calcite streaked with a brown oily pigment, much more opaque than the Cockhill Limestone. Scattered grains of quartz, shell fragments and areas of pyrite also occur as well as thin veinlets of clear crystalline calcite (av.grain size 0.2 mm.) which follow no regular pattern. The percentage of quartz varies considerably, appearing to be responsible for the banding of the limestone, but overall it is only a minor constituent and the rock is consistently a calcite mudstone.

iii) The shales above the limestone - These beds are the most variable in thickness ranging from 7 feet 4 inches to 18 feet, the maximum occurring in the south. They consist of thin paper shales, sometimes more compact, but fossiliferous throughout (it has not been possible to confine the fauna to specific bands, though parts of the sequence appear almost barren of organic remains). The fauna is a goniatite lamellibranch one, typified by Anthracoceras paucilobum and small posidoniellids, which in one instance crowd the bedding planes(Plate VIII B). A layer of limestone nodules occurs towards the top of the shales in one locality, but this cannot be said to be usual.

The Colsterdale Marine Series has a thin outcrop extending over about a third of the area. It can be traced from Wolfrey Moss on Hebden Moor across Henstone Band to Meugher Dike, where it has a long outcrop in the stream, at the same time encircling the high ground around Meugher. From here it runs in a north easterly direction across Stean Moor, round Stock Ridge reappearing in West Gill where it is duplicated by faults and then in a south easterly direction gradually getting lower and lower before finally passing underground near Pateley Bridge. Its presence can be traced by infrequent exposures along the eastern flank of Nidderdale and is known farther east also by the records of the boreholes at Aldfield and Sawley.

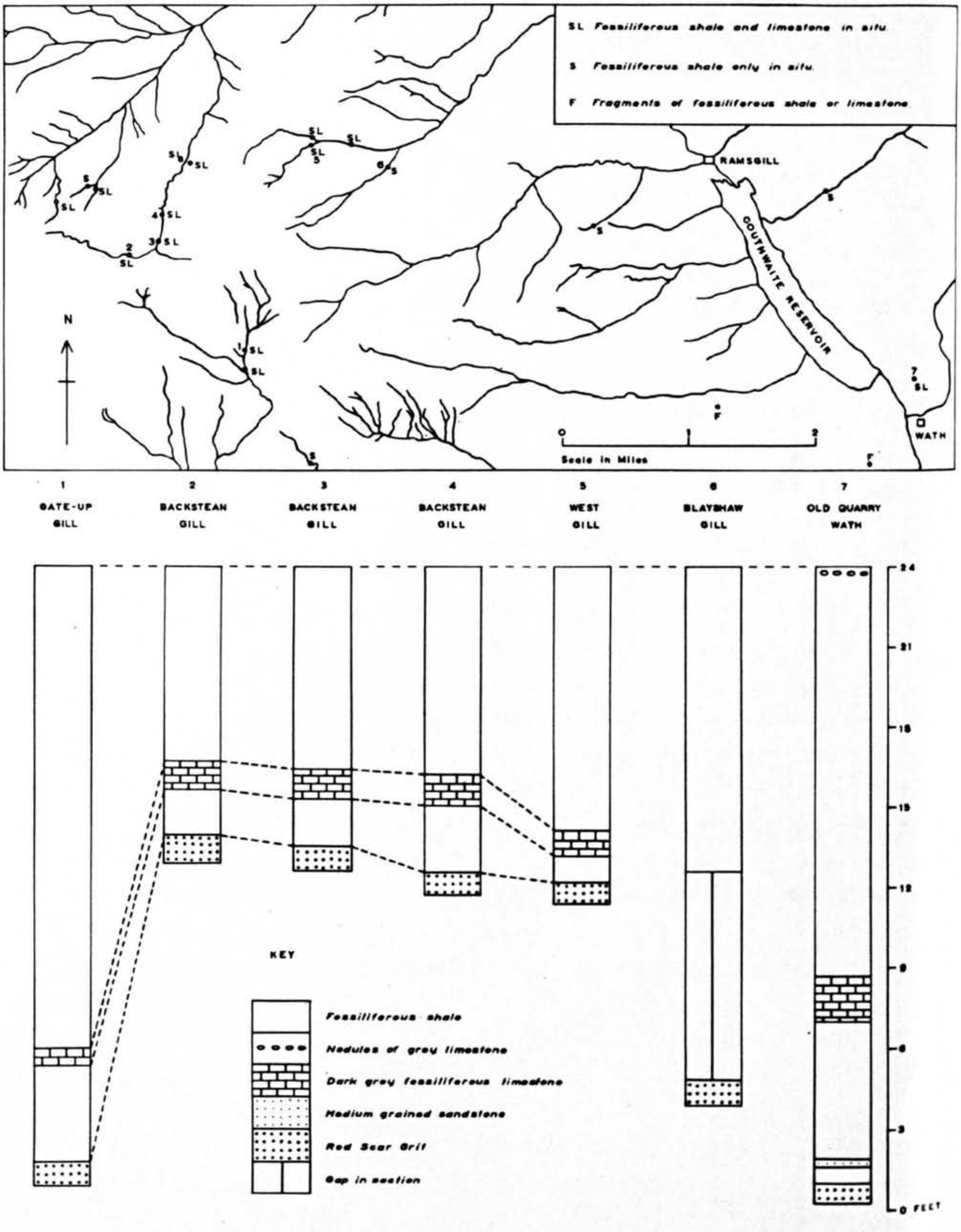

SL Fossiliferous shale and limestone in situ.
S Fossiliferous shale only in situ.
F Fragments of fossiliferous shale or limestone.
RAMSGILL
GOUTHWAITE RESERVOIR
WATH
N
Scale in Miles
0
1
2
1
GATE-UP GILL
2
BACKSTEAN GILL
3
BACKSTEAN GILL
4
BACKSTEAN GILL
5
WEST GILL
6
BLAYSHAW GILL
7
OLD QUARRY WATH
KEY
Fossiliferous shale
Nodules of grey limestone
Dark grey fossiliferous limestone
Medium grained sandstone
Red Scar Grit
Gap in section
24
21
18
15
12
9
6
3
0 FEET

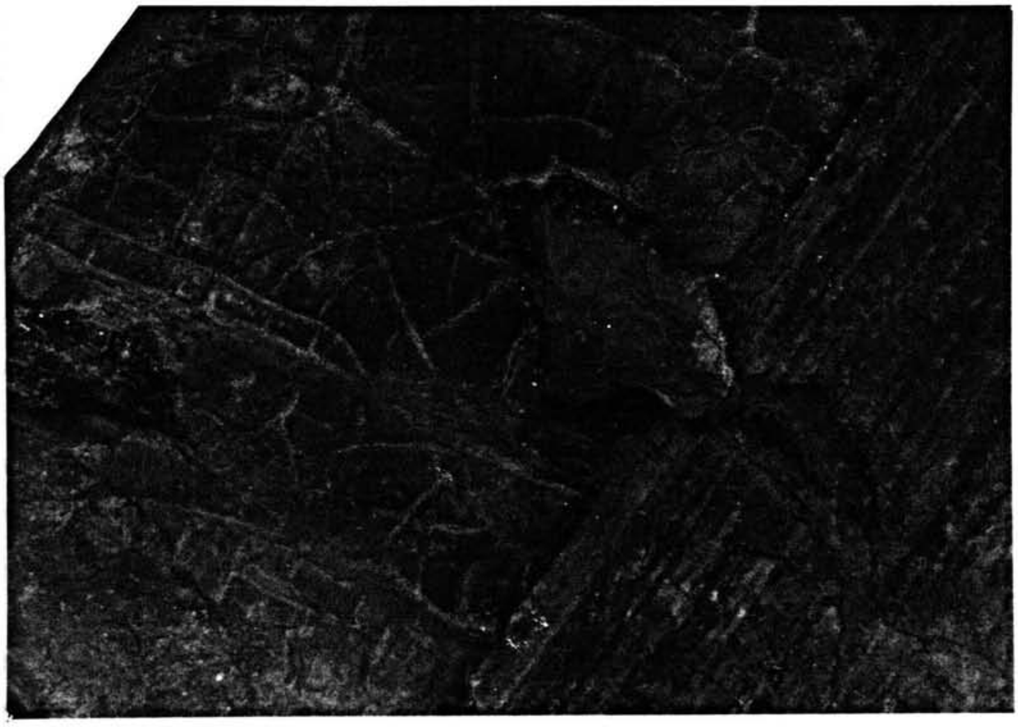
Figure 7. Map showing the occurrence of the Colsterdale Marine Series in this area together with some comparative sections.

Details

The occurrence of the Colsterdale Marine Series in this area is summarised in Fig. 7. Individual exposures are described in order under two headings, namely those occurring west and east of Nidderdale respectively.
West side of Nidderdale: Hebden Moor - Meugher - Nidderdale - 3 feet of grey soapy shale are seen in the small tributary stream of Ashfoldside Beck(093670) about 6 feet above coarse sandstone in the bed of the beck and probably represent the fossiliferous shales above the limestone. Some dumps west of this stream associated with trial holes for lead contain fragments of fossiliferous shale indicating that the shallow shafts penetrated at least to the top of the marine series. The bed is next seen 1½ miles to the west in Sikes Dike on Wolfrey Moss, where 2 feet of black fossiliferous shale crop out in the small stream which is deeply incised in peat. No sign of the limestone was found here, but as it is known at Greenhow(Dunham and Stubblefield, 1945) and in Gate-up Gill there seems no reason to question its presence here.

In Gate-up Gill the division has an extensive outcrop owing to the coincidence of stratal dip and the thalweg of the stream. 3 feet 6 inches of grey fossiliferous mudstone overlie the Red Scar Grit and are in turn overlain by a thin bed of well jointed limestone. The section is not complete and owing to the uncertainty of the dip cannot be pieced together with accuracy, but approximately 18 feet of marine shales containing Anthracoceras paucilobum and occasional lamellibranchs are thought to succeed the limestone. The group runs up the side of Henless Beck, being thrown up by a fault near Henstone Band and reappears in Meugher Dike. The section there is a long one, extending for nearly a mile in the bed of the stream and later in the banks. Its length permits a close examination of any changes in thickness or lithology, both of which appear to take place. Thus the shale below the limestone varies in thickness from 1 feet 8 inches to 2 feet 7 inches and contains a small lens of limestone 2 inches thick near the top. The beds are fossiliferous throughout, containing an abundance of small posidonid lamallibranchs together with Tylonautilus nodiferus, indeterminate orthoconic nautiloids and goniatite impressions, Many of the fossils are preserved in pyrite in a lithology which may be said to be more of a hard slaty shale indifferent to dilute acid. At one point mud cracks occur on the surface and are overlain by a thin discontinuous band of coal (Plate Vlll A) suggesting shallow water conditions of deposition. In the northern end of the section (Plate Vll A) the limestone

A



A mudcracked surface of shale on which a thin coal has been developed, in the Colsterdale Marine Series, Backstean Gill. Small lamellibranchs are present on the surface and indicate that conditions of shallow water marine sedimentation must have existed during the deposition of this bed.

B

A bedding plane of Colsterdale Shale, Green Grooves Gill(069713). An abundance of small posidoniellid lamellibranchs characterises this horizon.

is a persistent band 1 feet 2 inches thick, but it degenerates into a band of nodules only a few inches thick, a short distance west of Calside Beck. The rock is a dark grey calcite mudstone banded by impure layers of limestone and breaking with a sub-conchoidal fracture. Fossils are scarce and when present difficult to extract, but Cravenoceratoides nitidus has been identified, Cone-in-cone structure is excellently developed near the junction with Calside Beck extending to a depth of 2½ inches near the top of the limestone, whilst the characteristic tesselated jointing is also present here. The shales above the limestone maintain a fairly constant thickness of 7 feet 7 inches and consist of thin paper shales less fossiliferous than their counterparts below, but including goniatite impressions and posidonid lamellibranchs amongst the fauna.

The beds encircle the high ground around Meugher, no sign of them being found on the barren moor, though contorted grey unfossiliferous shales are present higher up Meugher Dike. They reappear in South Gill(037706) where 2 feet of grey fossiliferous shales with calcareous nodules occur overlying the Red Scar Grit. Scattered blocks of limestone are also present, consisting of grey impure silty material, much more fossiliferous than the bed in Backstean Gill and weathering on the surface to a ferruginous gingerbread. The fossils are fairly well preserved, comprising an abundance of goniatites, the most common form being Ct. nitidus and a variety of lamellibranchs. Comparable blocks of limestone together with 1 foot of fossiliferous shale also occur in the two source streams of Cross Gill and there yield a considerable fauna.

The series dip to the east, swinging down across Stean Moor. They are displaced by a fault at the southern end of Acoras Scar in Backstean Gill and can be seen in the banks of that stream. Thereafter they encircle Stock Ridge passing along Little Stangate where a prominent feature is thought to coincide with the base of the division. They are next seen in Green Grooves Gill and West Gill, where owing to the dip they have an extensive outcrop. The two sections are much the same, but West Gill is the more complete and there the following section was measured:

Nar Hill Beds
9' 9 "fossiliferous grey shale
1' 0½"fossiliferous limestone
1' 0½"black fossiliferous shale
Red Scar Grit

The shale below the limestone is similar in lithology to the comparable bed in Backstean Gill, the fossils being preserved in bas relief, but a feature of the grey mudstone above the limestone is the prolific occurrence of small posidoniellid lamellibranchs(Plate Vlll B). Posidoniella laevis is the most common and occurs with Cravenoceratoides nitidus and Anthracoceras paucilobum a little higher in the succession. The limestone is a persistent horizon banded by impure layers and tending in Green Grooves Gill to a rounded shape, the shales being "balled up" around it. In its fresh condition fossils are rarely extracted, but goniatites do occur and can be seen in cross section on weathered blocks of the bed in the stream.

The division is displaced by a fault in West Gill, reappearing a short distance downstream. At this point(075713) the following section was recorded, no change in lithology or fauna being noted.

	Gap
3' 1"	fossiliferous shale
7"	fossiliferous tesselated limestone
7' 8"	gap
	coarse massive pebbly sandstone

Thereafter the beds follow the contour round the hill, the normal easterly dip apparently being upset by the fault a short distance to the north and are seen again in Blayshaw Gill where the following outcrop occurs.

	Nar Hill Beds
11' 1"	fossiliferous grey shale
8' 0"	gap
	coarse massive pebbly sandstone

The fossiliferous shales are thin paper shales, sparsely fossiliferous, but yielded goniatite impressions and posidonid lamellibranchs after intensive search.

The strata swing down across Ramsgill Moor and are dislocated by a fault near Ramsgill Beck so do not appear in that stream, but can be followed by a good basal feature across Dewhurst Allotments to Riggs Gill. Here(106702) the upper few feet of the division are exposed, overlain by the Nar Hill Beds. They are folded on a minor scale, the trend of the axis suggesting that solifluction forces are responsible and from these black shales A. paucilobum and some posidoniellid lamellibranchs were collected.

The formation continues across Colt Plain no sign of it being found in Burn Gill, but on the tip in front of the Measuring Chamber on Burn

Edge(119679) numerous blocks of fossiliferous shale and limestone indicate that the bed was encountered here during the construction of the Burn Tunnel. Similar blocks were discovered by Dunham and Stubblefield(1945 p. 239) on the dumps near the covered chamber in Ashfoldside Beck, suggesting that an anticlinal structure exists under Heathfield Moor, an interpretation supported by the engineer's section (Fig 22).

Between here and Pately Bridge exposures are limited and indeed confined to fragments of shale containing posidoniellid lamellibranchs discovered on the side of the old flue chimney(140671) leading from Heathfield Smelting Mills in Foster Beck to the moor above.

East side of Nidderdale - The series is only infrequently seen on the east side of Nidderdale, a former record attesting to its presence however occurs in the faunal lists accompanying Bisat's(1914) paper where a specimen of Lingula mytiloides is recorded from Lul Beck. This section is now obscured, no sign of marine strata having been found here nor indeed at any point farther north. In Byerbeck Gill after prolonged search one lamellibranch was found and it is thought that here also the marine series proper is unexposed. Farther south, this band was found in the Old Quarry, Wath(146684) where a complete section of the series is available for study and consists of the following beds (Plate V11 B):

	Nar Hill Beds
3½"	black fossiliferous shale
1 "	band of nodules of grey limestone
14' 11½"	black fossiliferous shale
1' 8 "	fossiliferous limestone
5' 1 "	grey fossiliferous shale
4 "	ganisteroid sandstone
6 "	dark grey fossiliferous shale
	coarse massive pebbly sandstone

The shales are hard black compact beds fossiliferous throughout, but noticeably so in the basal 1 feet 6 inches below the limestone. The fossils include Anthracoceras paucilobum and a variety of lamellibranchs all preserved in bas relief.

In the Sawley borehole (Fig 21) interpretation is necessarily tentative in the absence of diagnostic fossil evidence, but the thick bed of coarse sandstone near the middle of the section considered to be the Red Scar

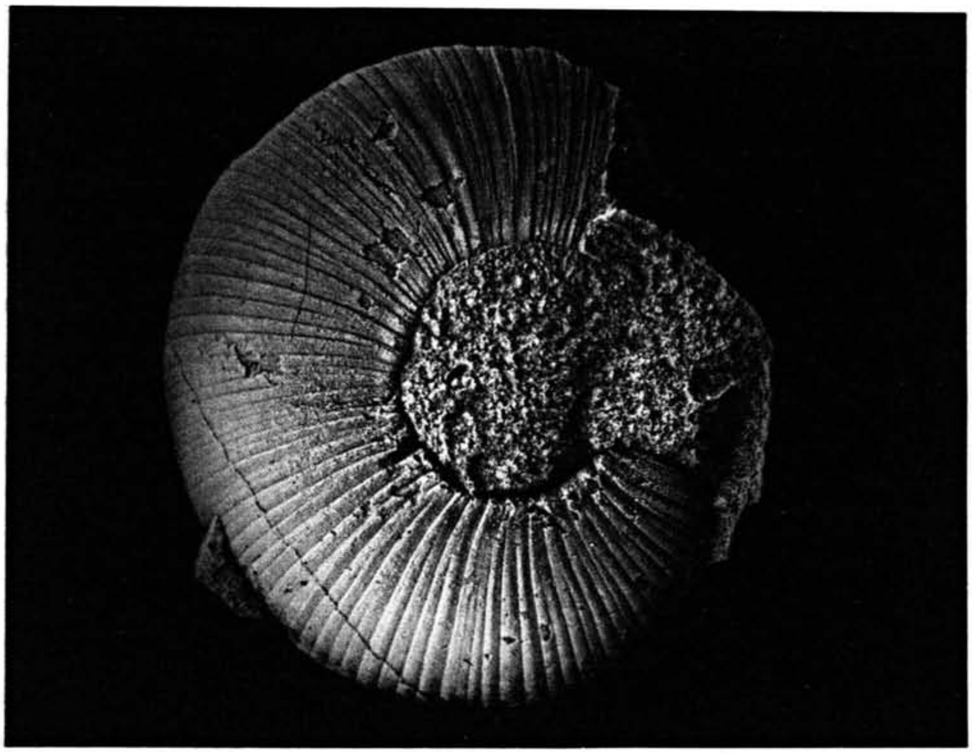
Grit is overlain by 10 feet of calcareous shales containing two thin beds of limestone. Above this comes 100 feet of shales, marine at two levels and succeeded by a thick(17') bed of grey fossiliferous limestone. On lithological grounds it would seem that this thick bed of limestone is the lateral equivalent of the Colsterdale limestone but a comparison of the succession with other areas militates against this interpretation. Thus, further north in Colsterdale (Wilson, 1957) a maximum of 35 feet of fossiliferous shales occur between the Colsterdale limestone(1' thick) and the Red Scar Grit, whilst on Rombalds Moor (Stephens et al, 1942) to the south the Marchup Marine Beds immediately overlie the equivalent of the Red Scar Grit. However even if the shales with thin limestone directly succeeding the Red Scar Grit in the borehole are correlated with the Colsterdale Marine Band a problem still exists of finding an equivalent for the thick limestone in the middle of the Nar Hill Beds elsewhere. South of Harrogate(Hudson, 1934) more than 600 feet of beds occur between the equivalent of the Red Scar Grit and the Lower Follifoot Grit and contain five marine bands covering the upper part of the E 2 Stage and the lowest part of the H Stage (Stephens et al,op. cit.). It seems easier to compare the Sawley succession with these beds, but clearly nothing definite in the way of interpretation can be suggested in the absence of faunal evidence. A similar problem exists in the borehole at Aldfield(Fig.) where 15 feet of grey limestone occur in the section and may be the equivalent of the Sawley limestone and hence in the Nar Hill Beds or else of Colsterdale age, but once again lithological correlation is inconclusive.

Palaeontology

The fauna of this series has been dealt with in extreme detail by Wilson(1957) and as a result certain correlations with other areas have been suggested, all of which are followed here. In order therefore to avoid duplication, only the more salient features of the fauna in this area will be mentioned.

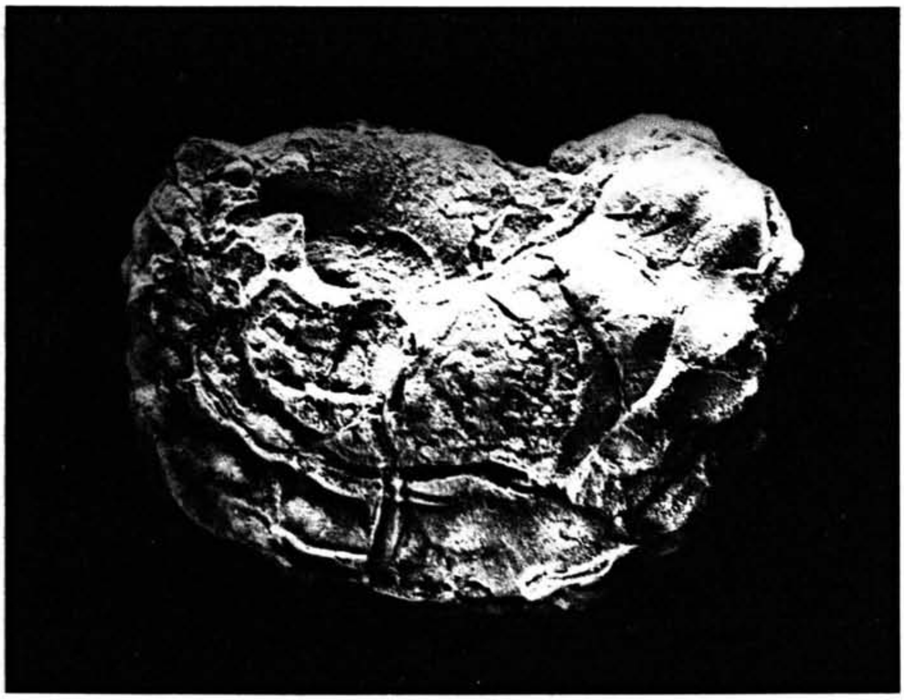
Cravenoceratoides nitidus(Plate V111 C) is the most common goniatite in the limestone and occurs subordinately in the shales above. It differs very little from the type material in respect of shape, size or ornament and as usual is accompanied by Anthracoceras paucilobum in both the limestone and the shales. Solid specimens of both species, infilled with clear crystalline calcite have been found in the limestone, but only fragmentary impressions occur in the shales.

C



Cravenoceratoides nitidus(Phillips) x 6 - from the Colsterdale limestone.

D



Tylonautilus nodifer~~o~~us(Armstrong) x 2 - from the shales below the Colsterdale limestone.

Tylonautilus nodiferus is a newcomer to the faunal lists of the Colsterdale Marine Series, though it has been widely recorded before from equivalent horizons in other areas, eg. the Harlow Hill Limestone of Northumberland(Green, 1954), the Shunner Fell Limestone of North Yorkshire (Scanlon, 1955), the shales above the Ct. nitidus limestone in the Lancaster Fells(Moseley, 1953) and north of Harrogate(Jackson, 1946) as well as beds in North Wales, Derbyshire and Scotland. The specimen collected by the present author(Plate V111 D) is smaller than the other specimens examined, being approximately half the size of Jackson's(1946) figured specimen and a third the size of Scanlon's(1953) specimen, but in external ornament it is closely comparable with the former.

The other major group of fossils is the lamellibranchs which occur in profusion in some localities(Plate V111 B). Posidonia aff membranacea is less abundant than the other posidonids and posidoniellids, whose determination is rendered difficult by the variation in individual species. Nevertheless they are the most common class in the shales, both below and above the limestone and must have flourished in that environment rather than a more calcareous one.

Following the practice of Moseley(1953) and Wilson(1957) a check was made on the percentage occurrence of the main fossils and it was found that in the north of the area, figures almost identical with those of Wilson were obtained(Cravenoceratoides, 45; Anthracoceras, 34; Posidonia and Posidoniella, 21), whilst in the south Ct. nitidus was overwhelmingly the most common form. It is not considered useful to draw a conclusion about environment pattern from this data because the localities collected from and the aggregate number of fossils examined were relatively few in number, but nevertheless it remains an interesting fact.

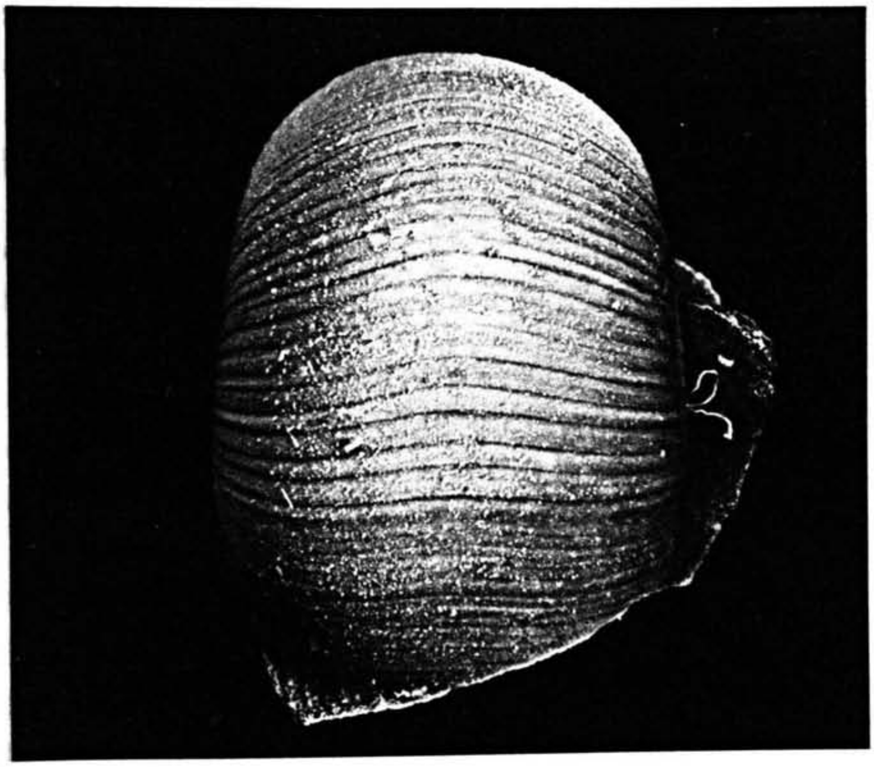
Cravenoceras holmesi has not been found in this area, indeed it has not been possible to zone the succession in a manner comparable with the mid Pennines(Hudson, 1944; Moseley, 1953), but it seems likely that had coring taken place in the Sawley borehole it would have been possible to recognise individual zones there.

Faunal Lists

Shales below the limestone

Plant remains, 1, 2, 3, 5

Posidonia corrugata (R. Etheridge), 1, 2, 5



Ventral and lateral views of Cravenoceratoides nitidus(Phillips).

Specimens from Colsterdale limestone x 8.

Posidonia aff. *membranacea* (McCoy), 1, 5
Posidoniella laevis (Brown), 1, 2, 3, 4, 5
----------- *sulcata* Hind, 1, 3, 4
----------- *variabilis* (Brown MS) 1
----------- cf. *kirkmani* (Brown), 1
Anthracoceras paucilobum (Phillips) 5,
------------ sp. 1, 2, 5
Tylonautilus nodiferous (Armstrong) 1,
Orthocone nautiloids 1, 2, 5
Fish scales and teeth, 1

Index of localities for the above

Backstean Gill, Meugher.	051704
2. West Gill.	069713
3. Green Grooves Gill.	069714
4. Cross Gill.	042708
5. Old Quarry, Wath.	146684

Colsterdale Limestone

Plant remains, 1, 2
Myalina peralata de Koninck, 1
Posidonia corrugata (R. Etheridge), 1
Posidoniella laevis, (Brown) 2,
Cravenoceratoides nitidus (Phillips), 2, 3
Anthracoceras paucilobum (Phillips), 2, 3
Cycloceras sp, 2
Fish scales and teeth, 2, 3
Crinoid ossicles 2, 3

Index of localities for the above

1. Backstean Gill, Meugher.	051704
2. Cross Gill, Meugher.	042708
3. Old Quarry, Wath.	146684

Shales above the limestone

Plant fragments, 1, 2, 3, 7
Posidonia corrugata (R. Etheridge), 1
-------- aff. *membranacea* (McCoy), 1
-------- *trapezoedra* Ruprecht 6
Posidoniella laevis (Brown), 1, 2, 5

Posidoniella sulcata Hind, 1

Cravenoceratoides of nitidus (Phillips), 2, 7

Anthracoceras paucilobum (Phillips), 2, 4, 7

Orthocone nautiloid, 7

Index of localities for the above

1.	Backstean Gill, Meugher.	051704
2.	West Gill.	069713
3.	Green Grooves Gill.	069714
4.	Riggs Beck.	106702
5.	Heathfield.	140672
6.	Byerbeck Gill.	135706
7.	Old Quarry, Wath.	146684

CHAPTER VII

THE NAR HILL BEDS

The Colsterdale Marine Series is succeeded by a thick sequence of shales and impersistent sandstones, included by Phillips(1836) in his Upper Plate Group, though they were earlier named the Ellenscar Plate by Newbold (Mss.). Later authors have tended to say little about these barren shales, confining the major part of their remarks to the sandstones and marine bands of the succession, but Hudson(1939) describing the strata exposed in the Simonseat anticline named the beds between the Colsterdale Marine Series and the Lower Follifoot Grit, the "Nar Hill Sandstones". They were part of his Upper Washburn Group and as the name implies, predominantly arenaceous, but this lithology is not maintained farther north and therefore Wilson(1957) amended the name to "Nar Hill Beds", a name perpetuated in this account.

Stratigraphy

The group comprises a variable series of shales, flaggy sandstones and impure limestones ranging in thickness from 119 feet to 243 feet. They tend to follow no regular pattern either in lithology or thickness, though the minimum thickness occurs in the west and is attended by a rapid increase when traced to the east, thereafter subject to a number of minor fluctuations. Shales constitute the major part of the sequence and are the least variable members, though they are frequently micaceous and locally characterised by the "box structure" so common at a lower stratigraphic level. The arenaceous horizons on the other hand are subject to very rapid changes, particularly in thickness which varies from a few inches to 28 feet. For the most part they are not persistent horizons, it having rarely proved possible to trace the same bed between two adjacent streams, yet in lithology they are consistent sub-greywackes. Under the microscope they are seen to be well sorted rocks(av.grain size 0.175mm.) composed predominantly of quartz, mica and felspar in that order of abundance. Hydrobiotite is the most common mica, disposed in the form of sinuous exfoliated flakes and largely responsible for the flaggy nature of the rock, whilst orthoclase is six times as abundant as plagioclase.

A feature of the sandstones at this level is the frequency with which they contain curious trail markings on bedding surfaces(Plate X). Some of these can be closely allied with annelid trails, but others are more problematical and may well represent molluscan movements. As yet the classified

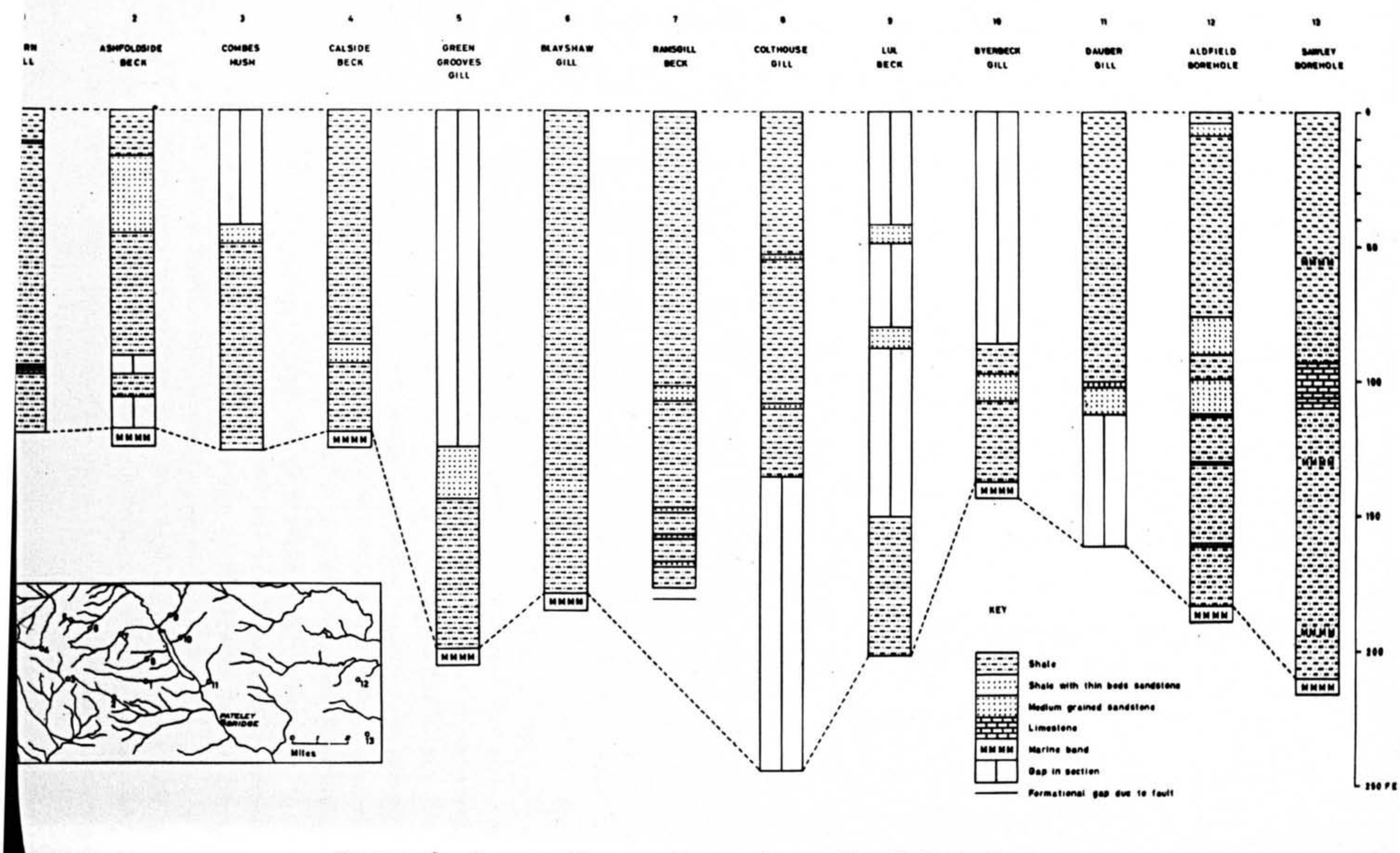


Figure 8. Comparative sections of the Nar Hill Beds.

records of organic trails are far from complete and because of this, very little further can be said about those occurring in these beds. Plant remains are also very common, but generally are only of fragmentary occurrence and therefore unidentifiable.

The impure limestones are described as such because they possess most of the field features characteristic of that lithology, eg. rounded weathering, tesselated jointing etc. yet in reality they are more correctly described as calcareous sandstones, the calcite content averaging 16%. They are confined to no specific level, occurring as thin bands rarely more than 1 foot thick throughout the sequence and occasionally in the form of chalybite nodules, but are then much more calcareous. The interpretation of the Sawley borehole is unavoidably tentative in the absence of palaeontological evidence, but if that put forward in Fig.8 is correct, a bed of limestone 17 feet thick occurs near the middle of the group which would be the thickest bed of this lithology ever recorded from this horizon. Marine bands are also encountered in the Sawley borehole, but these have not been found elsewhere and for the major part of the area the group is thought to be entirely of non marine origin.

Impersistent field features are a distinctive characteristic of the outcrop of this division and are thought to represent intercalated beds of sandstone. In some places however these associated with an irregular hummocky topography indicate landslipping, a phenomenon not uncommon near the top of the formation(Plate IX).

In terms of the goniatite succession, the Nar Hill Beds occur above the Colsterdale Marine Series (E 2) and below the Follifoot Shale, known to contain Homoceras beyrichianum and therefore of Sabdenian age. For convenience the E2; H boundary is generally drawn at the base of the Lower Follifoot Grit, which means that this division is included in the E 2 Stage of the Namurian.

The group has an extensive outcrop in the north western part of the area, descending gradually from the high ground around Meugher to Pateley Bridge where it is displaced by the North Craven Fault. It occurs on the eastern flank of Nidderdale also, passing underground to the east, but is brought to the surface in the vicinity of Risplith in the form of a faulted inlier.

Details

Comparative sections of the Nar Hill Beds are illustrated in Fig.8.

Individual outcrops are described in two parts, namely those occurring west and east of Nidderdale respectively.

West side of Nidderdale; Ashfoldside Beck - Meugher - Pateley Bridge - The group has a long outcrop in Ashfoldside Beck(090675), the upper part being particularly well exposed in the numerous tributary streams that descend from Gouthwaite Moor. It comprises a lower part which is essentially argillaceous, but contains occasional bands of chalybite nodules together with an upper part, more than half of which consists of current bedded medium grained flaggy sandstone. The shales are iron grey in colour and characterised by the limonitic box structure more typical of the Nidderdale Shales, whilst the beds of flaggy sandstone carry wavy markings on their bedding surfaces thought to represent annelid trails. A fault crosses the section near the main waterfall displacing the strata to the west and causes a certain amount of minor folding farther upstream.

The beds dip to the east, but can be traced in a westerly direction along Wig Stones Swamp where they lie in abrupt juxtaposition to the Upper Follifoot Grit and separated from it by the Bycliffe Vein. Thence up the edge of Gate-up Gill, they appear in an almost complete section in Sikes Grain where approximately 100 feet of shales and micaceous siltstones interbedded with thin lenses(2" thick) of flaggy sandstone are exposed. A partial section occurs farther north in Combes Hush and the gill south of it revealing a comparable succession to Sikes Grain, but with thicker beds of flaggy sandstone(up to 7' thick) and bands of chalybite nodules in the lower half. In Sower Beck grey shale is the only lithology seen, but once again the beds are only just over 100 feet thick, maintaining an area of regional minimum thickness.

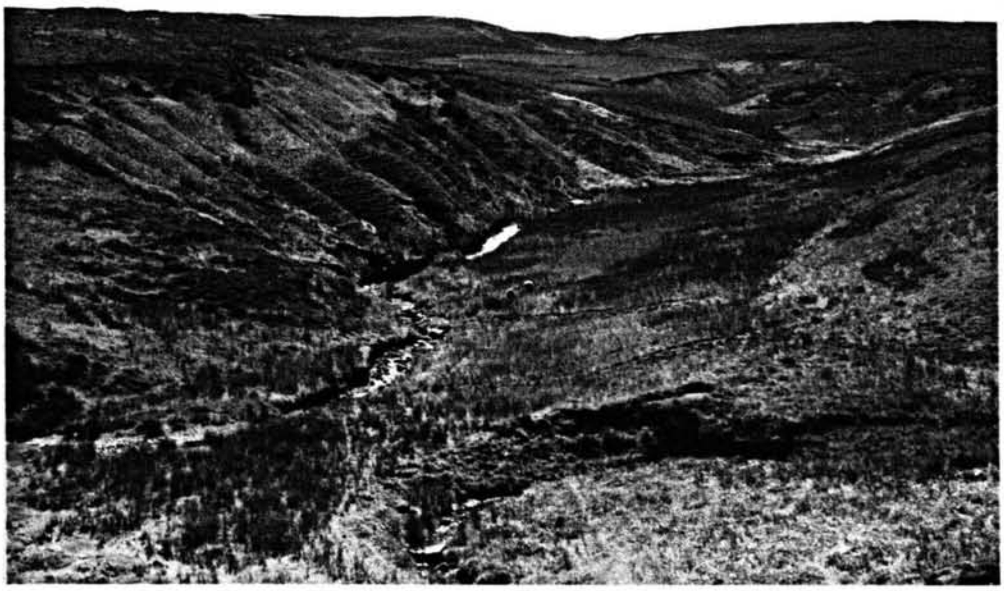
The formation continues up Henstone Band Side where it is thrown up by a fault just north of Sower Beck and characterised by a persistent feature half way up the outcrop, probably associated with a lenticular bed of sandstone. Another bold feature in this vicinity coincides with the base of the Lower Follifoot Grit and it is the abrupt termination of this that gives the clue to the fault at Henstone Band End. The beds reappear in Calside Beck, a tributary of Backstean Gill where a dominantly shaly section is exposed which includes a thin bed of medium grained sandstone covered with wavy trail markings.

West of Backstean Gill the strata show signs of thickening and in the vicinity of Meugher they average 140 feet. Here they have an irregular outcrop, roughly concentrical with Meugher(044705), the lower part of which is

A

Burn Edge, Heathfield Moor. The Lower Follifoot Grit forms an extensive dip slope on Heathfield Moor, a section of which is seen at Burn Edge. The hummocky topography in the centre of the picture is due to landslipping of the underlying Nar Hill Beds. The Measuring Chamber on the left forms the entrance to the Bradford Corporation Waterworks' Burn Tunnel, much of which was cut in the Red Scar Grit and Colsterdale Marine Series as evidenced by tip in front of the Chamber.

B



West Gill, Stean Moor. A stream incised in the gently dipping shales of the Nar Hill Beds.

exposed in Backstean Gill and consists of interbedded shale and flaggy sandstone. Elsewhere most of the ground is ill drained and boggy thus limiting exposures, but 12 feet of grey shale near the base of the division occurs in Cross Gill. Two bold features encircle Meugher probably representing intercalated sandstone beds, but corroborative evidence is lacking and this suggestion is only tentative.

East of Meugher the strata run along Great Stangate reappearing in Green Grooves Gill where the lower part of the succession is exposed. The basal few feet consist of interbedded shale and sandstone passing up into grey shale with occasional chalybite nodules, in turn overlain by a thick bed of bluish-grey micaceous sandstone.

A prominent feature runs from below the Shooting Box on Great Stangate to Blayshaw Gill and was originally thought to indicate an arenaceous horizon, but this could not be substantiated by the section in West Gill(Plate lX B) which consists entirely of shales differentiated only by a layer of calcareous nodules near the base. Rather unexpectedly the capping of Stock Ridge is composed of these argillaceous beds, exposed in a small gulley 200 yards north of the trigonometric point, but it is possible that the flaggy sandstone which occurs in Green Grooves Gill forms the uppermost beds.

The section in Blayshaw Gill is similar to West Gill, being composed entirely of shales and micaceous siltstones deeply incised in the form of a gulley. The beds dip to the east, encircling Brown Hill and reappearing in Ramsgill Beck. Here grey shales with thin lenticular beds of sandstone and bands of chalybite nodules are folded into minor anticlines and synclines, the result of enclosure between two powerful faults, both of which are exposed in the stream. The upper beds are involved in a landslip towards the top of the stream, probably the result of a lubricated junction with the overlying Lower Follifoot Grit.

The strata continue down the side of Ramsgill Beck and are next seen in Sandy Dike where the upper part of the division is exposed, composed mainly of grey shales and micaceous siltstones. Irregular impersistent features characterise the outcrop on Swine Beck Knotts and Gouthwaite Hill which from their disposition, indicate a certain amount of landslipping near the base of the group. A long section of the upper beds occurs in Colthouse Gill, the formation achieving its maximum thickness here. The beds are dominantly argillaceous, but contain thin beds of medium grained sandstone rich in plant remains, some of which are calcareous and tend to be of noduler shape.

The formation has thinned considerably by the time it reaches Burn Gill there consisting of a lower series of dark grey shales with two bands of impure limestone and several thin arenaceous horizons. The upper beds are mainly grey shales but contain a bed of impure limestone 3 feet thick near the top. The sandstone and limestone bands tend to lens out laterally, the former being characterised by the prolific occurrence of curious trail markings on bedding planes (Plate X).

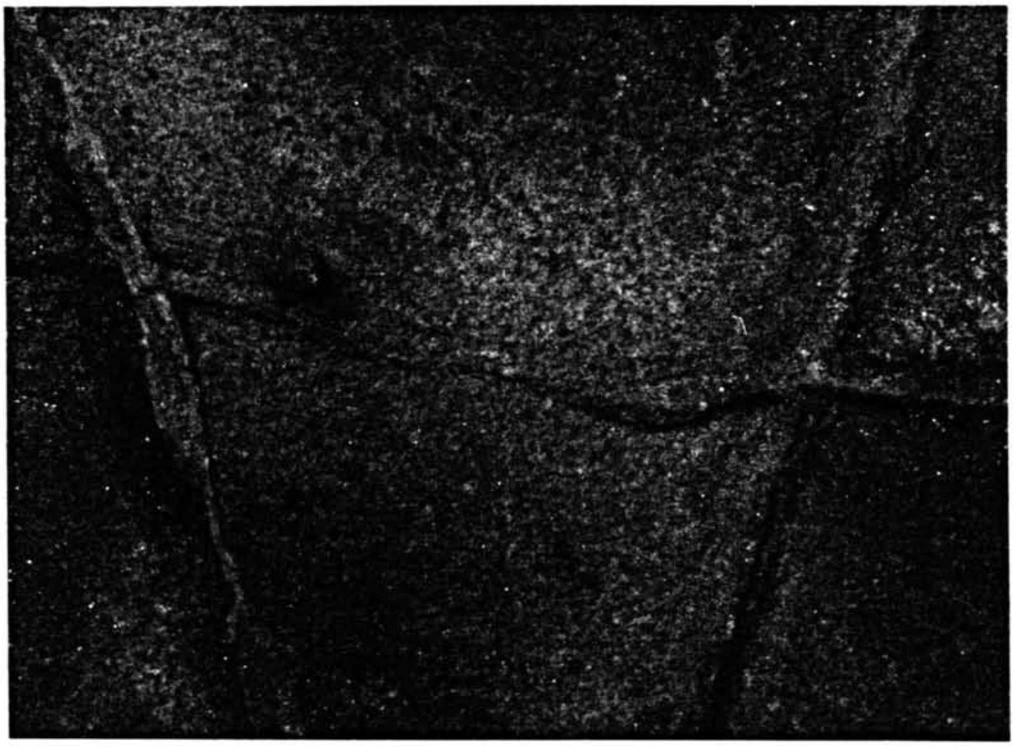
The strata dip towards Nidderdale, passing along Burn Edge where once again landslipping relations are prominently displayed. The upper junction with the Lower Follifoot Grit can be traced accurately along here running eastwards into a persistent feature near Heathfield. A tributary stream running down by the Shooting Box on Burn Edge reveals an 8 feet bed of flaggy sandstone in an otherwise consistently argillaceous section, whilst the engineer's section of the Burn Tunnel(Fig.22) shows that the southern half of the tunnel passed through Nar Hill Beds a considerable portion of which are arenaceous.

Near Heathfield the beds are affected by a fault thus accounting for their failure to form a long dip slope outcrop here, but they reappear on the other side of the hill above Ashfoldside Beck where they are only fragmentarily exposed. Thus 2 feet of shale with a thin bed of flaggy sandstone cropping out in the stream near Westfield House(132667) constitutes the only exposure of the group between Heathfield and Pateley Bridge.

East side of Nidderdale - The outcrop of the group forms a thin band down the eastern flank of Nidderdale, but exposures on the whole are poor and permit of only passing comment.

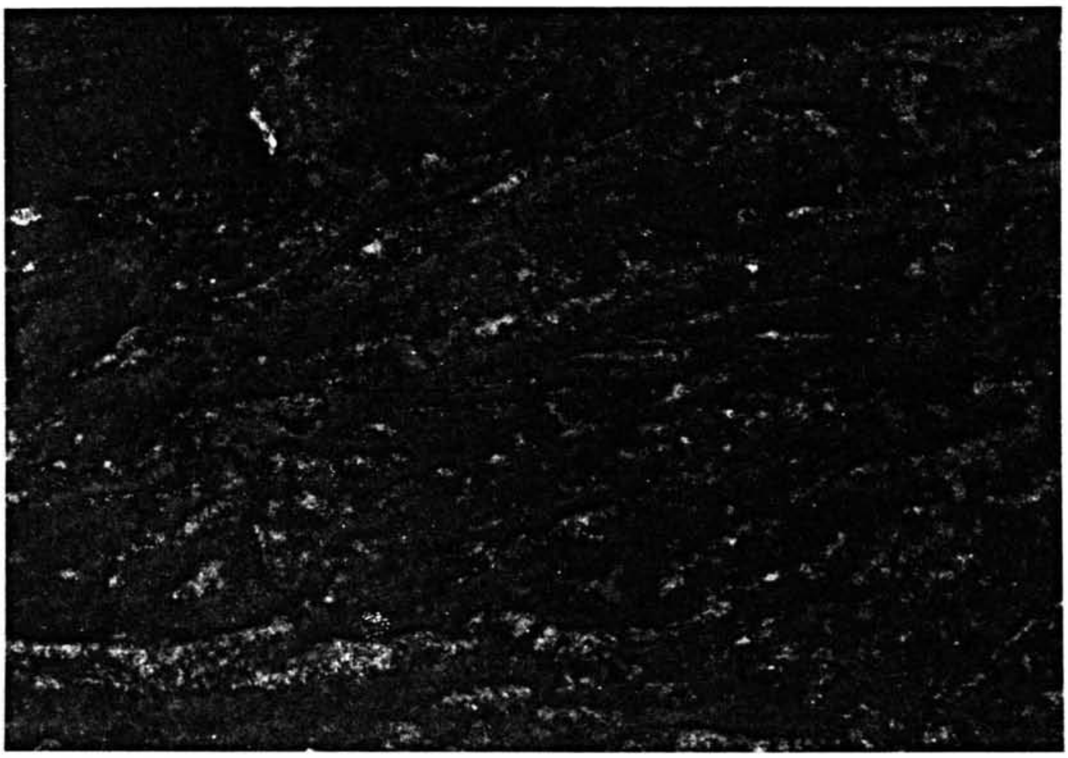
The lower part is seen in Lul Beck comprising a series of micaceous shales with thin bands of chalybite nodules and flaggy sandstone. Two other beds of medium grained sandstone occur higher in the succession, most of which is obscured, but an interesting observation concerns the disturbed strata in Helks Wood. The section suggests a fault, but supporting evidence for a line of dislocation is not forthcoming from the surrounding ground and therefore the disturbed dip must be related to movement initiated by solifluction forces.

The group is next seen in Byerbeck Gill where the basal beds are exposed and maintain a similar lithology to the comparable horizon in Lul Beck.



A

The flaggy sandstones present in the Nar Hill Beds frequently contain organic trails on their bedding surfaces. Two contrasting types of these trails are featured here, the one above being almost certainly associated with annelid movements.



B

Passing southwards, numerous impersistent features occur at this stratigraphic level above Gouthwaite reservoir indicating intercalated sandstone beds, one of which is exposed in Yates Wood(145685) and consists of medium grained speckled sandstone, but otherwise no exposures were found until the Old Quarry, Wath(146684). Here the basal 30 feet of the group are seen, consisting of shales with thin, lenses of flaggy sandstone. The complementary part of the succession is partially exposed in Dauber Gill where it is seen to consist entirely of shales apart from a bed of sandstone, calcareous at the top, near the middle. Chalybite nodules also occur in the shales near the top, 30' of which are exposed below Sigsworth Grange. Nothing further is seen of the division before it passes underground near Pateley Bridge, but the horizon was encountered in the borehole at Aldfield and Sawley and reappears at the surface near Risplith in the form of a faulted inlier.

The problem of establishing the base of the division in the Aldfield borehole(Fig.22) has already been reviewed in Chapter VI where the case is stated for accepting the thick bed of limestone near the middle of the log as the equivalent of the Colsterdale limestone. If this is correct, the greater part of the 180 feet of shales overlying the limestone must be referred to the Nar Hill Beds, here consisting of an upper and lower series of shales separated by an arenaceous horizon. Thin beds of limestone also occur in the lower half, whilst above this, chalybite nodules are infrequently present, and a further bed of medium grained sandstone occurs just below the top.

In the Sawley borehole a comparable problem of defining the limits of the formation also turns on the identification of the Colsterdale Marine Series. Proceeding on the interpretation favoured in Chapter VI, the Nar Hill Beds are 210 feet thick here and composed essentially of dark soft micaceous shales separated by a thick bed of grey shelly limestone near the middle. Three marine horizons were penetrated by the borehole at this level, but unfortunately no coring was done and therefore palaeontological interpretation is severely impaired and as a consequence correlation made impracticable.

In the vicinity of Risplith the First Brimham Grit is known to occur a short distance from Grantley Hall in a quarry overlooking the River Skell(246691). Less than a mile south west of this point the Aldfield borehole penetrated Follifoot Shale at the surface, indicating that the two localities are separated by a fault. Passing through Gill Beck(249688), this fault brings to the surface Nar Hill Beds, the lower part of which are exposed in the stream.

Dark grey pyritic shales with chalybite nodules constitute the section, less than 20 feet thick, but unfortunately the successful manner in which the drift cover obliterates the solid geology, this outcrop is all that is seen of the beds in this vicinity, except for 2' of micaceous shales in the stream by the Blackamoor's Head Inn(242685).

CHAPTER VIII
THE FOLLIFOOT GRITS

The Nar Hill Beds are succeeded by a dominantly arenaceous group, easily divided into two persistent sandstones separated by a parting of shale over most of their outcrop. The lower one of these sandstones was first named the "Top Grit" by Newbold(MS.1805), but Phillips(1836) did not perpetuate this name, including the bed in his "Upper Plate Group" and the remaining strata in his "Upper Grit Group". Some 40 years later the Primary Geological Survey proposed the term "Grits of Follifoot Ridge" for this group and it is this term that has remained to the present day modified only by the abbreviation to "Follifoot Grits". Subsequent workers however have incorporated a preceding qualifier "upper" or "lower" to identify the two arenaceous horizons, though the shales are still known as the "Follifoot Shales".

Dakyns(1890, 1893) was the first to give a general outline of the lithology and field occurrence of these beds and since his time virtually no new information with respect to this area has been added. The surrounding ground however has been dealt with in detail and provides a background to the regional variations at this level. Thus in Upper Nidderdale(Wilson, 1957) the Lower Follifoot Grit thickens locally from 11 feet to 75 feet, at Greenhow (Dunham and Stubblefield, 1945) it maintains a constant 40 to 50 feet, at Simonseat it is 80 feet thick and farther south still, in the country covered by Geological Sheet 70 (Leeds Memoir) it varies from 50 to 150 feet thick. The changes are no less spectacular in the upper sandstone and the parting of shale, though the latter is better known for the marine fauna occurring near the base of the division. This is characterised by the goniatite Homoceras beyrichianum, a form that has been found in as widely separated localities as Upper Nidderdale(Wilson, 1957) and Derbyshire (Hudson and Cotton, 1943) and therefore serves as a useful marker horizon. Over this region the lithology is on the whole fairly consistent, the arenaceous beds being medium to coarse grained quartzitic sandstones with occasional shale partings and coals, whilst the shales are usually grey mudstones. In Upper Nidderdale(Wilson, 1957) however, the Upper Follifoot Grit deteriorates into a series of ganisters and shales and there correct interpretation was made possible only by the discovery of the Homoceras fauna in the sequence.

Stratigraphy

The Follifoot Grits comprise a clearly defined sequence of an upper and lower bed of sandstone separated by shales. In terms of the goniatite succession, the boundary between the E 2 Stage and the H Stage is arbitrarily drawn at the base of the Lower Follifoot Grit and between the H Stage and the R 1 Stage at the base of the Cayton Gill Shales, so that the whole of this group is referred to the Sabdenian Stage of the Namurian. The beds vary in thickness from 100 feet to 360 feet and for convenience are best divided into their three main lithological units, here described in ascending order.

Lower Follifoot Grit - This bed has an extensive lateral outcrop in the area described in this account. It forms the capping to Meugher and Great Stangate in the west, gradually descending towards Nidderdale in the form of a long dip slope outcrop on Raygill House and Heathfield moors. It runs down the eastern flank of Nidderdale, being displaced by the North Craven Fault near Pateley Bridge and quickly reappears at the surface a short distance to the south. From here it can be traced down the valley of the Nidd to Dacre, passing underground to the east but reappearing at the surface in the Risplith inlier.

The bed varies from 30 to 130 feet in thickness. In the north it is nearly 90 feet thick near Lofthouse, but thins gradually towards Wath reaching a minimum of 30 feet in that district. To the west it thickens slightly, averaging 40 feet on Heathfield Moor, whilst to the south it thickens rapidly, attaining a maximum of more than 130 feet near Smelthouses. This must be a localised area of subsidence however, because farther east at Aldfield and Sawley it is only 30 feet thick.

The formation consists of three main lithological types, which appear to have no definite relationship to each other in either time or space. These are quartzitic sandstone, felspathic sandstone and subgreywacke, each ranging in grain size from coarse to fine and presumably grading into each other. Shale partings are common throughout the sequence and of random distribution, never exceeding 10 feet in thickness and occasionally of demonstrably lenticular form. Plant remains are also common, sometimes being so abundant as to make the rock a highly carbonaceous sandstone, whilst a coal occurs near the base. This coal is probably the equivalent of the Thornthwaite coal mentioned by Dakyns(1893) from the area to the south. False bedding is not as characteristic of this formation as other Millstone Grit horizons, likewise pebbly sandstones are also rare, the rock generally being a well sorted sandstone composed of sub-rounded grains. A feature seen in hand specimens however, is small graded bedding, but this is usually of confined occurrence only and can never be traced very far in the field.

On account of its locally pure quartz content, the Lower Follifoot Grit is quarried for silica near Smelthouses, though it may be noted that lithological variations (increasing felspar and carbonaceous content) severely impair its suitability for commercial processes. Other natural properties are responsible for its extensive use as a building stone, chiefly for walling purposes, but occasionally also for house construction.

The Follifoot Shale is on the whole a very poorly exposed horizon. It occurs west of Nidderdale in the upper reaches of Ramsgill Beck and Burn Gill as well as east of Nidderdale averaging 25 feet in thickness throughout, locally thinning to as little as 13 feet. South of Pateley Bridge the bed thickens rapidly achieving a maximum of 90 feet in the vicinity of Smelthouses, but this quickly decreases to the east, south and west from here.

In lithology, the bed is usually a monotonous grey sandy shale, occasionally less silty and then containing chalybite nodules. No indications of the marine band containing Homoceras beyrichianum have been found in this area, but this is attributed to the poor exposure at this level and not to its non occurrence. It is noted however that a marine band was encountered in the Sawley borehole(Fig.21) at this horizon and this may well be the lateral equivalent of the band found at Blubberhouses(Hudson, 1938) and Upper Nidderdale (Wilson, 1957), though in the abesence of cores the suggestion is inconclusive.

The Upper Follifoot Grit can be traced throughout the area described in this account, though as noted by Wilson(1957) it degenerates to the north into a series of ganisters and shales. It occurs west of Nidderdale where it is only 15 feet thick on Gouthwaite Moor and consists of medium grained flaggy sandstone, ganisteroid towards the top, whilst on the eastern flank of the dale it thickens from 25 feet near Lofthouse to 40 feet in Lul Beck, maintaining this thickness to Pateley Bridge. White quartzitic sandstone is the dominant lithology here, more flaggy and ganisteroid towards the top, suggestive of a transitional stage between the massive beds farther south and the Ganister Series(Wilson, 1957) in the north.

South of Pateley Bridge the bed thickens rapidly to 80 feet near

Wilsill, 100 feet near Smelthouses and 140 feet above New York, thereafter in a southerly direction maintaining a thickness of 130 feet. To the west near Heyshaw, boreholes indicate a thickness of 80 feet for the group whilst to the east(Sawley borehole) 70 feet is an approximate figure, but this decreases northwards to 35 feet near Risplith. West of the dale the bed forms a broad band parallel with the valley, which, increasing in lateral extent southwards eventually forms an extensive dip slope outcrop in the environs of Heyshaw and Dacre. A similar broad banded outcrop occurs east of the dale and can be traced as far south as Burnt Yates, passing underground to the north, but reappearing at the surface in Lurk Beck, Thornton Beck, Spa Gill and Cayton Gill.

As in the case of the Lower Follifoot Grit, the Upper Follifoot Grit is composed of three dominant lithological types, viz. felspathic sandstone, quartzitic sandstone and subgreywacke. The former appears to predominate, but it seems likely that they grade laterally into each other. Each is evenly graded, the quartzitic sandstone consisting of up to 99·9% quartz in the form of a sutured mosaic of interlocking grains, whilst the felspathic sandstone contains up to 11% of felspar, chiefly microcline and microperthite, but a significant proportion of plagioclase, near oligloclase in composition is usually present. The onlt other mineral of importance is mica, occurring as flakes of white mica and hydrobiotite in all three rocks, locally in abundant amounts though particularly so in the subgreywacke. This is the least common lithological type at this horizon and indeed almost confined to Spa Gill near Fountains Abbey. It is easily recognised in the field by its limonitic stained surface and invariable fine to medium grain size and is characterised by a decreasing proportion of quartz(av. 75%) and an increasing proportion of felspar mica and clay minerals.

Also like the Lower Follifoot Grit, shale partings are common throughout the sequence, never exceeding 10 feet 10 inches in thickness and occasionally containing chalybite nodules. Thin coals are also developed locally near the base as well as the commercially valuable ganister, exploited near Smelthouses.

An important discovery during the present re-survey has been the occurrence of a fossiliferous phase towards the top of the division. This has been noted in the upper few feet of the bed near Dacre and in loose blocks east of Brimham Rocks, in both cases the fossils being unidentifiable. The sandstone is only sparsely fossiliferous, well worn brachiopods and lamellibranchs being the chief forms, but they weather quickly and in their fresh condition are only extracted with difficulty. The origin of these fossils is not certain, they being either indigenous or derived. Their worn condition supports the latter explanation, but their position a short distance below the Cayton Gill Shell Bed suggests them to be the precursors of the marine conditions which characterised the deposition of that formation.

Details

Lower Follifoot Grit

Area west of Nidderdale: north of the N.Craven Fault - The most westerly outcrop of the Lower Follifoot Grit occurs on Meugher(044705) where the highest ground is composed of this bed. Large blocks of coarse quartzitic sandstone rest on the surface of the hill and indicate a thickness of 35 feet for the division here, the base coinciding with a prominent feature. The strata dip to the east, reappearing the other side of Backstean Gill on Great Stangate where for much of their extensive outcrop they form a featureless peat covered dip slope. They are more than 40 feet thick here consisting essentially of coarse quartzitic sandstone, though the felspar content becomes appreciable in the crags on Henstone Band. The base of the group is exposed in West Gill, Blayshaw Gill and the tributaries of Ramsgill Beck where it is a very coarse (av. grain size 2 mm.) current bedded sandstone enclosing shale fragments and ferruginous nodules. The bed becomes finer grained upwards, but passes abruptly into the coarse quartzitic sandstone which forms Aircliffe Crags and Henstone Band Crags, eminences standing out boldly on the moor. Three faults all downthrowing to the south affect the outcrop in this vicinity resulting in an outlier on Brown Hill and the preservation of Cayton Gill Beds on Gouthwaite Moor.

From Henstone Band Side the formation runs down Combes Hill towards Ashfoldside Beck and Heathfield Moor, but it can be traced down the other side of Raygill House Moor also. Coarse quartzitic sandstone is exposed in the tributary streams of Sower Beck(062692) where it is brecciated by the fault in close proximity to the north and can be seen again in Combes Rush, this time slightly felspathic. The upper tributaries of Ashfoldside Beck all contain outcrops of thinly bedded flaggy sandstone, medium grained and frequently ganisteroid. The bed is thrown up by a fault just east of North

Grain, but continues down Heathfield Moor towards Nidderdale retaining a similar lithology and averaging 40 feet thick.

On Raygill House Moor, the division appears in Ramsgill Beck in faulted relations with the Nar Hill Beds and consisting of massive and flaggy medium grained sandstone, locally ganisteroid and brecciated. The basal beds form a series of crags on the hillside south of the stream and are well exposed in one of the deeply incised tributaries that descend from the moor. Only blocks of coarse sandstone occur in Cross Gill and on the dip slope outcrop of Broadstone Rigg further east, but they are particularly abundant in this latter locality and consist of bleached ganisteroid sandstone. Raygill House Wig Stones are a group of crags composed of massive current bedded quartzitic sandstone disposed in the form of a prominent landmark and referred to the upper part of the formation.

The lower beds of the division are well displayed in Colthouse Gill, overlying the Nar Hill Beds in the banks of the stream for more than ½ a mile before they themselves become the bed rock of the stream. Flaggy ganisteroid sandstone is the dominant lithology, but towards the top the strata become coarser and are now in the form of poorly cemented sandstone stained with limonite along the joint planes and folded on a minor scale.

An almost complete section is exposed in Burn Gill and Burn Grain consisting of massive current bedded sandstone with a lens of shale 1 feet 8 inches thick near the base and local areas of medium grained sandstone. The beds dip to the east forming an extensive dip slope on Heathfield Moor, but exposures are poor and apart from the basal section on Burn Edge(Plate IX) confined to blocks of medium grained sandstone on the surface. Between here and Pateley Bridge the formation occurs as two outliers, one between Ashfoldside Beck and Brandstone Beck and the other a short distance farther east on Ladies Riggs. It has been quarried in both localities, where it is a consistent medium grained quartzitic sandstone, but glacial action has obscured the basal feature and considerable difficulty is encountered in accurately placing this on the ground.

The faulted ground west of Pateley Bridge is partially composed of this bed, but very little of it is exposed at the surface, the outcrops being confined to blocks of medium grained sandstone by the side of the small reservoir on Strawberry Hill(157652) and blocks of coarse orthoquartzite on the road below Red Brae Bank(156651).

East side of Nidderdale, north of Pateley Bridge - The Lower Follifoot Grit is prominently displaced by the Lofthouse fault on the eastern flank of Nidderdale (118739) and south of that structure forms a line of crags composed of current bedded quartzitic sandstone. The bed can be traced through Horse Helks (125722) where the crags of coarse sandstone are 20 feet high to Lul Beck by a prominent feature at the base. Here, the formation is well exposed, being nearly 90 feet thick and forming cliffs of white orthoquartzite flanking the stream for several hundred yards. It runs southwards from here and is quarried at two localities near Mount Pleasant Farm. In the northernmost quarry, 21 feet of coarse current bedded felspathic sandstone, disposed in beds up to 3 feet 6 inches thick and separated by more thinly bedded flaggy bands include a 6 inch shale parting 4 feet from the top. The other quarry, also near the base of the division is made up of well bedded flaggy medium grained sandstone, apparently used in time past for roof slates. The beds thin to the south and in Byerbeck Gill whilst not exposed can only be about 40 feet thick. They have a marked northerly dip above Swinelops Wood probably the result of the fault in the neighbourhood and the scree of blocks which rests on the surface of the outcrop suggests a further decrease in thickness to 35 feet. The formation is not seen again before the Old Quarry in Tenement Wood(141688) where 24 feet of sandstone are exposed, the lower half flaggy and medium grained, the upper coarse and in thicker beds. In Dauber Gill a little over 30 feet of massive medium grained sub-greywacke containing some thin shale partings constitutes the horizon and crops out in the stream and as blocks on the hillside above. Between here and Pateley Bridge exposures are poor and confined to 5 feet of flaggy ganisteroid sandstone on Bishopside Brae(153678) and blocks of medium grained sandstone on Silver Hill(153666).

Nidderdale, south of the North Craven Fault - The bed is displaced by the North Craven Fault and south of Pateley Bridge is first seen in an Old Quarry by Castlestead Farm(167647) where the following section, near the top of the division is exposed.

15' 1½"	coarse massive quartzitic sandstone
1' 1½"	black carbonaceous shale
13' 1 "	coarse massive slightly felspathic sandstone

Massive beds of sandstone are also seen in the banks of the Mill Race by Glasshouses Mill and farther downstream in the banks of the River Nidd (179639) where the following section was measured :

12'		fine grained sandstone, flaggy in parts
9'		shale
3'	9 "	well bedded fine grained sandstone
	$4\frac{1}{2}$"	shale
1'	3 "	well bedded fine grained sandstone
4'	3 "	grey shale

The bed passes underground here, but is thrown up by a fault to the north and reappears in Righouse Gill, Smelthouses where just above the village, flaggy sandstone is folded into a series of steep anticlines in the bed of the stream, attesting to the nearby dislocations. Coarse pebbly felspathic sandstone is the dominant lithology farther upstream appearing in the forms of crags on both sides of the beck. The formation has been exploited for its pure silica content in this vicinity, in which connection extensive quarrying operations are now taking place above the stream. The main quarry face is approximately 25 feet high, revealing variation in grain size from fine to coarse in a rock mainly pure orthoquartzite, but locally slightly felspathic. Areas rich in plant remains, ripple marked surfaces and shale lenses, some very carbonaceous all occur in the section and hinder the straightforward exploitation of the rock. Several boreholes were originally sunk by the Company to ascertain the reserves of silica rich rock at their disposal and these have in turn provided invaluable information about litholigical variation within the formation. They(Fig.20) indicate that the bed is at least 130 feet thick here and subject to very rapid changes both in grain size and the incoming of shale lenses. Carbon rock, ie. areas rich in plant remains occur throughout the sequence, but only one coal is present, near the base. An interesting feature of these borehole logs is the evidence they provide to support a fault, already suggested by other factors in the neighbourhood. Thus the strata encountered in hole 6 demonstrably differ from the other holes west of it, indicating a line of dislocation between it and them. This fault combined with another displaces the outcrop to the south, the bed being next seen in the valley of the Nidd below Low Laithe.

East of the river Nidd exposures are limited, but between Low Laithe and Summerbridge fairly frequent outcrops indicate a variation from medium grained orthoquartzite to very coarse felspathic sandstone. A small quarry occurs at the entrance to New York Mills exposing 10 feet of medium grained orthoquartzite. South of this blocks of coarse quartzitic sandstone with a sugary texture occur on the surface in Clough Gill(203618) and below

Dowgill Farm, a short distance to the south. West of the Nidd the formation has an extensive outcrop, once again varying from medium grained orthoquartzite to very coarse felspathic sandstone. It has been quarried in Gill Wood (193626) where 15 feet of massive well jointed sandstone are still displayed in the quarry face and the railway line south east of this was cut through a comparable lithology. A short distance to the south the bed appears in Smelt Maria Dike above Dacre Banks and farther south still by Low Hall Farm, 15 feet of coarse slightly felspathic sandstone occur in the banks of the River Nidd.

Several boreholes for water in this vicinity have penetrated the group and whilst providing little additional information about lithology serve as a guide to the thickness of the bed(the borehole logs are recorded in the Appendix). Thus 90 feet of yellow sandstone were encountered in a hole at East Heads Farm, Wilsill(190643), ½ mile west of the Silica Quarries Smelthouses; 95 feet of hard sandstone were penetrated by a borehole at the Royal Oak Hotel, Dacre(197619), and the formation was just entered by the holes at Lanefoot Road Quarry(183613) and Dinmore Farm, Burnt Yates(241608).

The formation passes underground to the east, but re-appears in a faulted inlier near Risplith. It was also included in the list of strata passed through by the boreholes at Aldfield and Sawley. In the inlier the beds dip steeply to the north, exposures being confined to 2 feet of medium grained speckled sandstone in Hungate Dike(234689), but the Aldfield borehole(Fig.22) is sited ½ mile S.W. of this and passed through 44 feet of fine to coarse grained felspathic sandstone with a coal near the top. At Sawley (Fig.21), 2 miles farther south the group has changed little, being 40 feet thick and composed of white pebbly sandstone separated by a shale parting near the middle.

Follifoot Shale

Area north of Pateley Bridge - West of Nidderdale the Follifoot Shale has a thin outcrop on Gouthwaite and Raygill House Moors, its most westerly occurrence being in Ramsgill Beck where it averages 25 feet thick and consists of grey unfossiliferous shale. It is only partially exposed here and is not seen again until Burn Gill where it maintains a similar lithology, though it has thinned to 13 feet. Further indications of the bed west of Nidderdale are limited to fragments of black shale on the cliff below Red Brae Bank(156651) before it is displaced by the North Craven Fault near Pateley Bridge.

East of Nidderdale exposures are also limited, but 18' of grey shale in Lul Beck are referred to the division, the total thickness of it being about 25 feet in this vicinity. Between here and Pateley Bridge the bed retains a fairly constant thickness, but is nowhere exposed at the surface, except for shale fragments on Bishopside Brae(153678), its only indication on the surface of the outcrop being an occasionally developed marshy slack.

Area south of Pateley Bridge - South of the North Craven Fault the Follifoot Shale is rarely exposed at the surface, its main indications being from boreholes and the outcrop of the two Follifoot Grits above and below. Fragments of black shale occur 100 yards north of Castlestead Farm(166648), but otherwise no exposure occurs in the valley of the Nidd, nor indeed west of the river. The bed appears to thicken rapidly when traced to the south east from Pateley Bridge attaining a maximum of nearly 90 feet in the vicinity of Smelthouses, thereafter thinning to about 50 feet near Dacre. The two boreholes(Appendix) at Sunny House Farm(192610) and Dinmore Farm(241608) indicate that the group is over 60 feet thick west of Dacre and composed of blue/grey shale, whilst near Burnt Yates 47 feet of beds are referred to the division.

The horizon is brought to the surface the other side of Brimham Rocks in Shaw Beck(221645), but only 3 feet 8 inches of it appear, consisting of grey shale with calcareous nodules. Farther east near Dobson House, Bishop Thornton(267645) a small inlier occurs, but once again only fragments of grey shale are seen.

No surface exposures of the bed occur in the Risplith inlier, but grey sandy shale was the first horizon penetrated by the Aldfield borehole (Appendix). The bed is about 40 feet here, but thins to the south because only 22 feet of Follifoot Shale were encountered in the Sawley borehole (Appendix). A marine band was found near the base, but no coring was done so palaeontological details are unavailable to support an extension of the *Homoceras* fauna to this area. The shales seem to pass upwards through interbedded sandstone and shales into the overlying Follifoot Grit and make precise definition of the boundary difficult.

Upper Follifoot Grit

Area north of Pateley Bridge - West of Nidderdale the Upper Follifoot Grit has a long dip slope outcrop on Gouthwaite Moor averaging 15 feet in thickness and on the whole well exposed. It is first seen in Ramsgill Beck consisting of medium grained greenish flaggy sandstone, a lithology which it retains unaltered elsewhere in this vicinity, except in Burn Gill where it becomes ganisteroid towards the top. Blocks of sandstone lie scattered over the moor surface and there appear to have a more massive form than in the peat incised streams.

East of Nidderdale the formation is a persistent horizon first seen just south of the Lofthouse Fault(120727) where it has an intermittent feature at its base, generally accompanied by a line of crags composed of white felspathic sandstone. The bed is only about 25 feet thick near the fault, but thickens to just under 40 feet in Lul Beck where, like in Sypeland Gill, the basal part of the division is well exposed. Flaggy fine graimed quartzitic sandstone is the dominant lithology, becoming more massive towards the top and therefore responsible for the two waterfalls below the Masham road.

The beds continue to the south and are next seen near Mount Pleasant Farm(132717) where 6 feet of white quartzitic sandstone are exposed in the face of a small quarry. Along much of the outcrop between Lul Beck and Byerbeck Gill exposures are limited, control over the boundaries of the bed and any lithological variation being therefore almost wholly dependent on the scattered blocks of quartzitic sandstone at the surface. Crags of white sandstone occur in the cliffs above Byerbeck Gill and also intermittently between there and Dauber Gill indicating a fairly constant thickness and lithology. South of Dauber Gill, below Yeadon Farm(154678) the strata are downthrown to the south by the Wath Fault and in this vicinity an old quarry reveals 20 feet of steeply dipping fine grained quartzitic sandstone. Between here and Pateley Bridge 3 feet 5 inches of medium grained speckled sandstone are exposed on Bishopside Brae(154673) and 6 feet of fine grained ganisteroid sandstone on Silver Hill(156666), but otherwise nothing further is seen, north of the North Craven Fault.

Area south of Pateley Bridge - West of Nidderdale the Upper Follifoot Grit forms a broad banded outcrop parallel with the valley, which increasing in lateral extent southwards eventually forms an extensive dip slope in the environs of Heyshaw and Dacre. Apart from blocks of white quartzitic sandstone in Bale Hill Rush(180637) and the railway cutting near Harewell Hall(187638) however little is seen of the bed north of Low Laithe, but south and west of that village indications of it are abundant. It was formerly quarried near Ingleby Siding where 8 feet of coarse slightly felspathic sandstone are still visible in the quarry face and sandstone of a similar lithology crops out intermittently in the bed of Loftshaw Gill. A feature of this latter section is the occurrence of a thin shale parting towards the top of the formation which contains randomly distributed chalybite nodules. South of this gill the strata are thrown up to the south by a fault running parallel with the stream and it is in this region that crags and old quarries are most abundant. The beds are massive, individual posts being several feet in thickness and for the most part composed of coarse, locally pebbly felspathic sandstone, though medium grained quartzitic sandstone is also common. They dip to the east, but just west of Heyshaw this regional dip flattens out and becomes a westerly one on Nanny Black Hill indicating a subsidiary fold axis at right angles to the main structure of the Simonseat anticline.

Passing to the east the formation is next seen in North Woods where it is bounded on three sides by faults and the Cayton Gill Beds on the other. Medium grained orthoquartzite is the consistent lithological type here broken only by a 2 feet shale parting in Loftshaw Gill and a 10 feet 10 inches parting in Smelt Maria Dike. A feature of outstanding interest in this vicinity is the discovery of a fossiliferous phase in the upper few feet of the formation above Smelt Maria Dike(190621). Well worn brachiopods and lamellibranchs are the chief fossils, unidentifiable because of weathering, but indicative of the onset of the marine conditions that characterised the deposition of the Cayton Gill Beds.

West of Dacre much of the ground is rough pasture covered with large blocks of fine to coarse grained felspathic sandstone, several times seen in quarry sections. The quarry at Horse Pasture Crags(Plate XI) may be said to be typical of others in this district, 30 feet of well jointed medium grained slightly felspathic sandstone constituting the section. The sandstone is false bedded and overlain by an 8 feet shale parting apparently succeeded by more sandstone farther north. The beds dip to the east at a steady 10 to 16 degrees and can be traced right down the hillside to the River Nidd, the ground slope approximately coinciding with the stratal dip. This dip slope outcrop means that only the upper part of the formation is exposed at the surface so that no estimate of the thickness can be given, but the borehole at Lanefoot Road Quarry(Appendix) passed through more than 80 feet of beds referred to this horizon. This borehole log together with the one at Sunny House Farm(Appendix) indicates the common occurrence of shale partings throughout the sequence of sandstones, one of which is exposed in a little

The section of the Upper Follifoot Grit exposed at Horse Pasture Quarry, Dacre(179609). The quarry face is more than 30' high and shows the beds dipping in a northerly direction.

gulley near Hill Top Farm(191618).

East of Nidderdale little is seen of the Upper Follifoot Grit between Pateley Bridge and Smelthouses though it is apparent that the bed thickens from 40 feet near Pateley Bridge to more than 80 feet near Wilsill, thinning again slightly near Righouse Gill. Blocks of coarse quartzitic sandstone crop out on the hillside below Brimham Rocks in the vicinity of Low Wood and High Wood Farm(204647) indicating a thickness of the order of 100 feet for the formation there. This increases further to the south attaining a maximum of 140 feet above New York.

The basal beds are well exposed in Granny Wood Quarry near Low Laithe where they are exploited for ganister, a lithology well developed here. The quarry is in close proximity to a powerful fault thus accounting for the steep northerly dip exhibited here as well as a slight amount of slickensiding. The following section was measured here and is quoted in full to give some idea of the lithological variation at this level.

7'	4 "	massive fine to coarse grained pebbly quartzitic sandstone
1'	1 "	black carbonaceous shale
	1½"	fine grained sandstone
	1½"	coal
	1½"	ganisteroid sandstone
	2 "	coal
	8 "	white fine grained ganisteroid sandstone
	8 "	coal
1'	1 "	fine grained ganisteroid carbonaceous sandstone
2'	4 "	coarse, locally pebbly quartzitic sandstone
	1½"	black carbonaceous shale
4'	5 "	grey fine grained sandstone - locally ganisteroid
	1 "	shale
5'	10 "	grey fine grained sandstone - occasional large quartz grains.
	3 "	shale
1'	4½"	fine grained ganisteroid sandstone
	3½"	micaceous carbonaceous shale
2'	7 "	coarse massive pebbly sandstone - slightly felspathic

Just above this quarry a further quarry reveals the following section :

23'	4 "	fine to coarse grained sandstone – locally ganisteroid	
2'	0 "	obscured	
2'	0 "	black carbonaceous shale	
3'	6 "	coarse massive locally pebbly sandstone	
2'	8 "	fine grained sandstone)	sandstone has slumped on shale
	3 "	lens coal)	and is now rolled and mixed with it giving brecciated appearance.
1'	10 "	coarse quartzitic sandstone	

Blocks of coarse slightly felspathic sandstone occur along the eastern flank of the dale above the Harrogate road between Low Laithe and Hartwith enabling the approximate boundaries of the formation to be plotted and indicating that a thickness in excess of 130 feet is maintained over this distance. On Hartwith Hill the upper part of the formation is exposed in the form of pavement crags of white quartzitic sandstone, slickensided and noticeably ganisteroid.

The strata are displaced by a north-south fault near Hartwith and reappear just above the Harrogate road by Spence Dam(228608). Large pavement crags, up to 12 feet high and of coarse pebbly quartzitic sandstone occur below the road and above Dinmore Farm(241608) where a borehole(Appendix) suggests that the bed has thinned to little more than 40 feet. The dip is to the east here, but a southerly component is demonstrably apparent by the occurrence of the formation in Lurk Beck(234624) and Thornton Beck(235634) to the north. Only the upper few feet of the division are exposed in these streams consisting of medium grained flaggy sandstone with an 8 feet parting of grey shale, 5 feet below the top. The formation also occurs lower down Thornton Beck(274618) where it is brought to the surface in the core of an anticline, but only blocks of slightly felspathic sandstone are exposed here.

Just east of Brimham Rocks the formation crops out in Shaw Beck (219644) and the wood adjacent to it there consisting of white quartzitic sandstone with a fossiliferous phase near the top. This latter phase is only seen in blocks of the bed in the wood and once again whilst worn brachiopods and lamellibranchs are present, none are identifiable.

Near Bishop Thornton a small inlier of the bed occurs, poorly exposed however because of the variable drift cover. Blocks of fine grained speckled sandstone occur in Cishole Wood(273647) and on the road side by Dole Bank(276641), whilst in Barsneb Wood(279636) large blocks of ganisteroid sandstone litter the eastern flank of Cayton Gill. The Sawley borehole(Fig.21) was sunk in this vicinity and serves as a valuable guide to thickness variation, though in the absence of cores, interpretation is necessarily tentative. At the site location the surface rocks are coarse felspathic sandstones, well exposed in nearby streams and almost certainly correctly referred to the First Brimham Grit. This horizon is known to be a transgressive one and taking into consideration the surface evidence from surrounding areas it would seem likely that here it rests on the Libishaw Shales, only three feet of which are present. The thick bed of sandstone below these shales is thought to represent the Upper Follifoot Grit and the Shell Bed, separated by some thin shales and passing downwards into the Follifoot Shales. This interpretation would mean that the Upper Follifoot Grit is of the order of 70 feet here and comprises a lower series of pebbly sandstones with thin shale partings and an upper group composed of fine grained white sandstone.

Farther north in the Risplith inlier only about 40 feet of beds are referable to this formation and crop out either side of Hungate Gill. On the southern side of the stream near Hazel Hill Farm(232685), 8 feet of fine grained slightly felspathic sandstone are exposed in the wood overlooking the gill, whilst on the other side an Old Quarry reveals 15 feet of medium grained yellow felspathic sandstone, disposed in massive beds. In this latter locality glacial gravel has penetrated gaping joints in the sandstone and overlies it also.

The Upper Follifoot Grit has an extensive outcrop near Sawley, its best exposures being in the banks of the River Skell between Spa Gill and Fountains Abbey. The positive identification of the bed in this locality is made possible by the discovery of the Cayton Gill Shell Bed at the top of the section, otherwise the lithology developed here would have suggested closer comparison with the Libishaw Sandstone. More than 70 feet of beds crop out in the section, dominantly sub greywacke in lithology and disposed in the form of massive and flaggy bands separated by impersistent shale partings. The succession in one of the small streams(263679) is typical of the section as a whole and is quoted below :

1'	6"	hard ganisteroid sandstone
15'	3"	massive medium grained sub greywacke
1'	3"	shale
5'	9"	flaggy medium grained sub greywacke
15'	0"	obscured
5'	7"	flaggy medium grained sub greywacke
5'	2"	shale
6'	0"	flaggy sandstone with some more massive bands
1'	8"	shale
5'	9"	massive medium grained sub greywacke
25'	0"	flaggy medium grained sandstone

The upper part of the formation is quarried at a place adjacent to the above stream as well as in Wainforth Wood(265674) a short distance to the south, where 20 feet of disturbed quartzitic sandstone are now exposed. Blocks of quartzitic sandstone also crop out on both sides of The Dean, the glacial spillway leading from the River Skell to Markington Beck.

CHAPTER 1X

THE BEDS BETWEEN THE UPPER FOLLIFOOT GRIT AND THE FIRST BRIMHAM GRIT

The beds described in this chapter form one of the most distinctive and important stratigraphic units in the Millstone Grit of this area. They were first mentioned by Tute(1868) in his account of the geology of the country near Ripon, an account both comprehensive and accurate in its detailed descriptions. Tute's observations centred around the Cayton Gill Beds, that peculiar shelly facies developed in this district between the Upper Follifoot Grit and the First Brimham Grit. They resulted in a triple division of the marine sequence into an upper series of thin flags full of encrinites, a middle bed full of brachiopods and other fossils, and a lower bed of fine sandstone mottled with carbonaceous markings(presumably worm chewed) and characterised by Bellerophon costatus. The fossiliferous beds could be traced from Sawley in the north to Hampsthwaite in the south and Pateley Bridge in the west, apparently of local occurrence only, suggesting deposition in a confined arm or estuary of the sea. A further paper by the same author(1886) listed the main localities where the beds are exposed at the surface as well as the fossils extracted and identified, and indicated that the name "Cayton Gill Beds" originated with Fox Strangways in view of the excellent exposure of the upper two beds of the sequence in Cayton Gill.

The results of the primary geological survey were published about this time and included the mapping of this horizon as a distinct unit, shown on the published maps in a separate colour. The detailed stratigraphy was not incorporated in a memoir, but Dakyns the chief surveyor, summarised the salient features in two short papers(1890, 1893) stating inter alia that two shell beds separated by shales could be traced in Nidderdale, the complete thickness averaging 55 feet. The next contribution came from Hind(1907) who gave a list of the fossils collected from the Shell Bed, a list which he later expanded and supplemented with a short paper(1914) describing several new species. Eight of the faunal localities listed by Hind occur within the present area and each has been visited by the author, but most are now overgrown so that further collecting has rarely been possible. Hind dealt with the palaeontology of these beds, but the stratigraphy was the work of Bisat(1914) in an area extending from Colsterdale in the north to Pateley Bridge and Fountains Abbey in the south.

<table>
<tr><th>THE GEOLOGICAL SURVEY</th><th>BISAT (1914)</th><th colspan="3">HUDSON (1939)</th><th colspan="2">JONES (1943)</th><th>DUNHAM AND STUBBLEFIELD (1945)</th><th>WILSON (1957)</th><th>THOMPSON (1957)</th></tr>
<tr><td rowspan="5">THE BRIMHAM GRITS</td><td rowspan="4">BRIMHAM GRIT GROUP</td><td rowspan="6">BRIMHAM GRIT GROUP</td><td colspan="2">COMB HILL GRIT</td><td colspan="3" rowspan="2">Top of local succession</td><td>SECOND BRIMHAM GRIT</td><td>SECOND BRIMHAM GRIT</td></tr>
<tr><td colspan="2">CAPELSHAW SHALES</td><td>SHALES</td><td>SHALES</td></tr>
<tr><td colspan="2" rowspan="3">LIBISHAW SANDSTONE</td><td rowspan="7">BRIMHAM GRIT GROUP</td><td>COMB HILL GRIT</td><td>COMB HILL GRIT</td><td>FIRST BRIMHAM GRIT</td><td>FIRST BRIMHAM GRIT</td></tr>
<tr><td>CAPELSHAW SHALES</td><td>SHALES</td><td>CAPELSHAW SHALES</td><td>BEWERLEY SHALES</td></tr>
<tr><td rowspan="7">CAYTON GILL BEDS</td><td>COLD MOSS FLAGS</td><td>LIBISHAW SANDSTONE</td><td>LIBISHAW SANDSTONE</td><td>LIBISHAW SANDSTONE</td></tr>
<tr><td>SHALES</td><td colspan="2">LIBISHAW SHALES</td><td>RAMSGILL SHALES</td><td rowspan="4">CAYTON GILL BEDS</td><td>LIBISHAW SHALES</td><td>LIBISHAW SHALES</td></tr>
<tr><td rowspan="2">THE SHELL BEDS</td><td rowspan="6">FOLLIFOOT GRIT GROUP</td><td rowspan="3">CAYTON GILL BEDS</td><td>SHALES</td><td rowspan="2">CAYTON GILL BEDS</td><td>AGILL SANDSTONE</td><td>AGILL SANDSTONE</td></tr>
<tr><td>HARD BEDS</td><td>CAYTON GILL SHELL BED</td><td>CAYTON GILL SHELL BED</td></tr>
<tr><td>SHALES</td><td>CAYTON GILL SHALES</td><td>SHALES</td><td rowspan="3">GANISTER BEDS</td><td>CAYTON GILL SHALES</td></tr>
<tr><td>UPPER FOLLIFOOT GRIT</td><td colspan="2">UPPER FOLLIFOOT GRIT</td><td rowspan="3">FOLLIFOOT GRIT GROUP</td><td>UPPER FOLLIFOOT GRIT</td><td>UPPER FOLLIFOOT GRIT</td><td>UPPER FOLLIFOOT GRIT</td></tr>
<tr><td>SHALES</td><td colspan="2">FOLLIFOOT SHALE</td><td>FOLLIFOOT SHALE</td><td>FOLLIFOOT SHALE</td><td>FOLLIFOOT SHALE</td></tr>
<tr><td>LOWER FOLLIFOOT GRIT</td><td>UPPER SANDSTONE of BARREN BEDS</td><td colspan="2">LOWER FOLLIFOOT GRIT</td><td>LOWER FOLLIFOOT GRIT</td><td>LOWER FOLLIFOOT GRIT</td><td>LOWER FOLLIFOOT GRIT</td><td>LOWER FOLLIFOOT GRIT</td></tr>
</table>

Figure 12. Table summarising the varying nomenclature applied to the beds between the Lower Follifoot Grit and the Second Brimham Grit by different authors.

Bisat re-defined the term "Cayton Gill Beds" (Fig.12) to include all the strata between the Upper Follifoot Grit and a horizon 55 feet below the First Brimham Grit(Wilson, 1957). Tonks(1925) did not follow this connotation however and indeed confused the issue by excluding the lower beds(the Ganister Series of Wilson, 1957) and including the Bewerley Shales, a group specifically left out by Bisat. Two shell beds were identified by Bisat, the lower more persistent one he correlated with the main Shell Bed of areas to the south, whilst the upper one appeared to be a local development, but was subsequently correlated by Hudson(1939) with the Hard Beds of Simonseat. This latter correlation is at variance with Bisat's however, because in the same paper Hudson also equates the Hard Beds of Simonseat with the Shell Bed of Nidderdale. The term "Cayton Gill Beds" was restricted still further by Hudson, only the beds between the top of the Upper Follifoot Grit and the lower part of the Libishaw Shales being included. The Libishaw Sandstone and the upper part of the Libishaw Shales were placed in his Brimham Grit Group, whilst the Cayton Gill Beds were for the first time placed in the Follifoot Grit Group. Fossils were found in both the shales underlying the Shell Bed(the Cayton Gill Shales) and the Comb Hill Grit (the Capelshaw Shales) making possible a more accurate application of the zonal system to the Namurian of this area.

Hudson's classification was largely followed by Jones(1943) though the boundary between the Brimham Grit Group and the Follifoot Grit Group was drawn at the top of the Upper Follifoot Grit, thus including all the strata described in this chapter in the former group. Jones's main contribution was concerned with the strata exposed in the Beamsley anticline, but in addition visits were paid to several quarries in the present area, from which comparative sections of the fossiliferous strata at this level were drawn up. His work was quickly succeeded by Dunham and Stubblefield's(1945) account of the Greenhow area, once again supporting Hudson's correlation of the two fossiliferous sandstones, the upper rich in brachiopods and the lower in lamellibranchs with the two shell beds in Colsterdale. The Colsterdale sections have now been re-surveyed by Wilson(1957) and as a result much of the uncertainty and confusion regarding the beds in that area has been dissolved. The upper shell bed of Bisat(1914) has been shown to be the partial equivalent of the Libishaw Sandstone of Greenhow and Simonseat, whilst fossiliferous beds have been found at several other levels in the sequence. A revision of the nomenclature has also been suggested, several new names having been incorporated in the

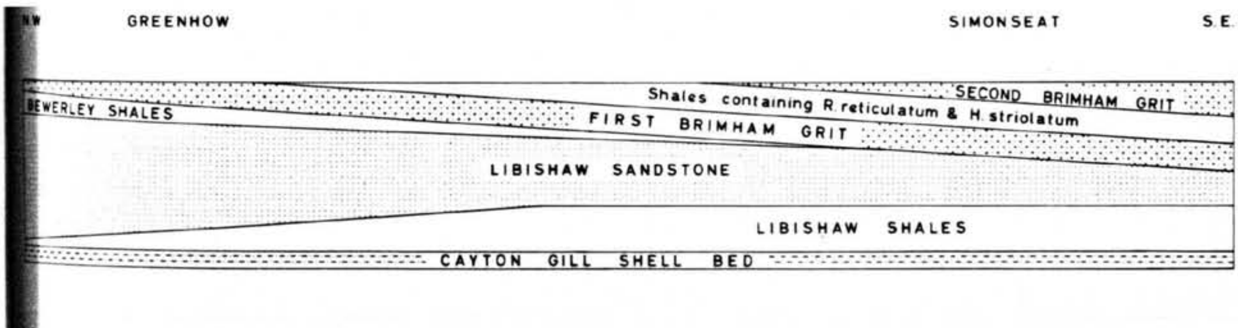


Figure 10. Sketch section to illustrate the overstep of the First Brimham Grit from Simonseat to Greenhow.

succession, but the point of major importance is that the term "Cayton Gill Beds" has been discarded entirely save with reference to the Cayton Gill Shell Bed. Wilson succession is shown in Fig.12. His terminology is retained almost unaltered in this account with the exception of the terms "Ganister Beds" and Capelshaw Shales", the former group being represented by the Follifoot Shale, Upper Follifoot Grit and Cayton Gill Shales(the term is Hudson's cf.1939). The shales underlying the First Brimham Grit however have been re-named the "Bewerley Shales" in view of a possible misinterpretation of the succession in the Simonseat anticline by Hudson(1939), first alluded to by Walker(1952). This author re-examined the section in Capelshaw Beck and found that 50 feet below the Capelshaw Shales, sandstone of the coarse pebbly type was immediately underlain by a series of fine to medium grained normal deltaic sandstones. Recalling the consistency of the Libishaw Sandstone and its lateral equivalent, the Addlethorpe Grit as a brown, flaggy, micaceous, fine to medium grained sandstone over a wide area in the Central Province (Upper Nidderdale, Wilson,1957; Greenhow, Dunham and Stubblefield, 1945; Rombalds Moor, Bradford Memoir and Leeds Memoir) as well as the unconformity at the base of the First Brimham Grit, already traced from Nidderdale to Wharfedale, he considered that the upper part of the Libishaw Sandstone was in fact the equivalent of the First Brimham Grit, whilst the Comb Hill Grit was the equivalent of the Second Brimham Grit (cf.Fig.10). This interpretation is not without support on faunal grounds either, as witnessed by a comparison of the fauna obtained from the Capelshaw Shales(Hudson, 1939) and the shales above the Caley Crags Grit (equivalent of the First Brimham Grit) on Rombalds Moor(Stephens et. al. 1942). Reticuloceras reticulatum and Homoceras striolatum are forms common to both horizons, and both also occur in the shales between the Lower and Upper Plumpton Grits(equivalents of the First and Second Brimham Grits) in the Killinghall Brick Pit(Bisat and Hudson, 1942). It is observed however that Bisat and Hudson(op. cit) did not correlate the Capelshaw Shales with them, but rather placed them at a higher level. In the existing uncertainty therefore it has been considered advisable to dispense with the term "Capelshaw Shales" and introduce a new name to describe the shales between the Libishaw Sandstone and First Brimham Grit. For this purpose the term "Bewerley Shales" is proposed because of the excellent section at this level exposed in Middle Tongue Valley, Bewerley. The additional work of Walker(op. cit.) is also important in demonstrating the extension of the Otley Shell Bed to Pateley Bridge(re-named the Scot Gate Ash Marine Band in this district) as well as the unconformity mentioned above, responsible in vicinity of Brimham Rocks for the absence of much of the succession between the Shell Bed and the First Brimham Grit. This unconformity has now been traced over a wide area east of Nidderdale and will be discussed in greater detail in Chapter X.

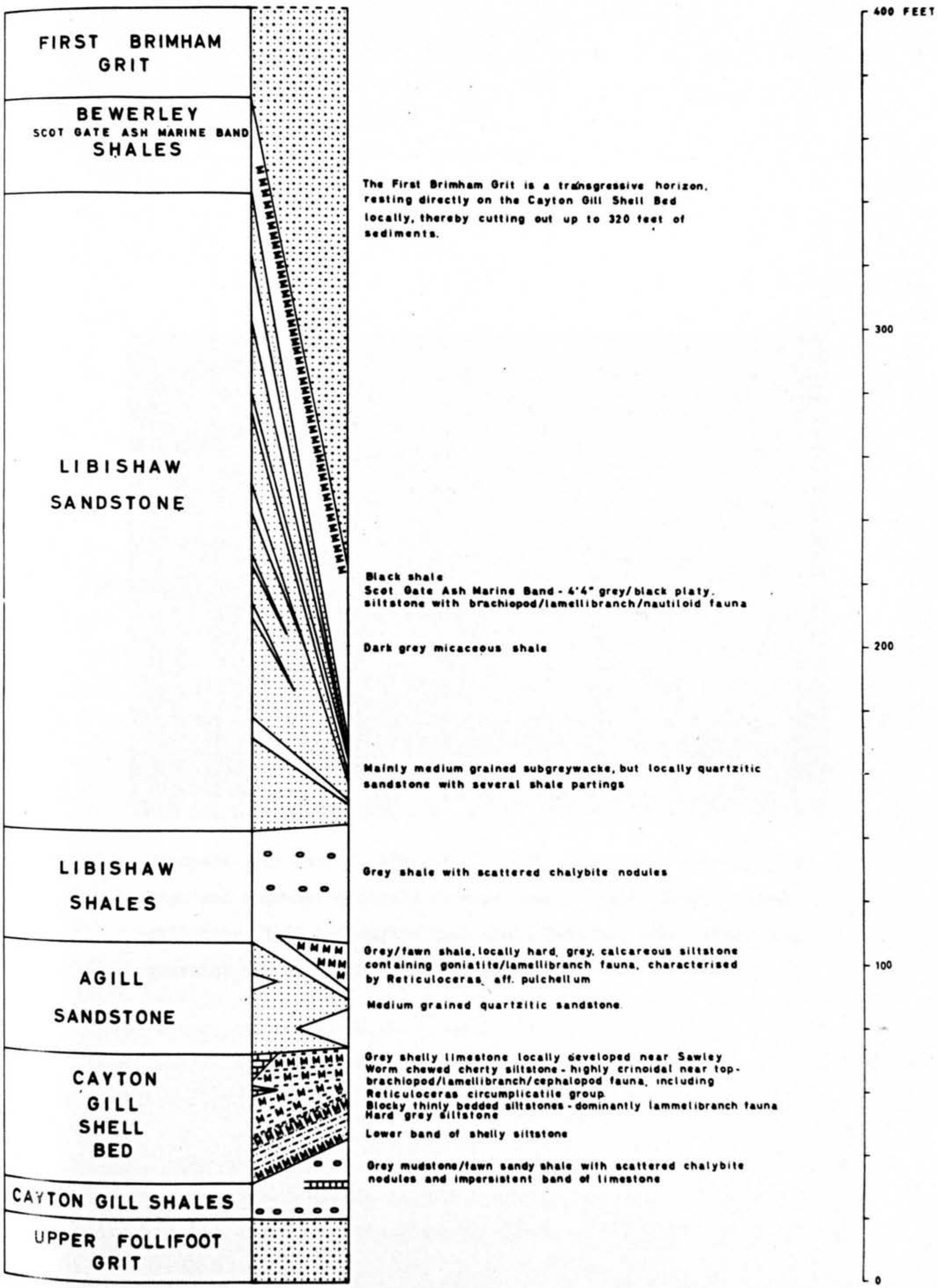
Stratigraphy

The beds described in this chapter comprise a variable set of strata about 170 feet thick in the north, thickening to 385 feet near Pateley Bridge. South of that town an increasing proportion of the upper beds is cut out by the unconformity at the base of the First Brimham Grit, but in general the southerly thickening at this level noted by Wilson(1957) in Upper Nidderdale continues to the south and is apparently maintained as far south as Rigton. This trend does not apply to the Libishaw Sandstone and Bewerley Shales however, the former thickening from Upper Nidderdale to Pateley Bridge achieving its maximum there, then thinning progressively towards the south, eventually dying out near Harewood; the latter thins from Upper Nidderdale to Pateley Bridge and is then rapidly transgressed by the First Brimham Grit to the south.

The group includes as its lowest member the Cayton Gill Shales, never seen in the north but occasionally exposed in the south. A prominent horizon, the Cayton Gill Shell Bed, overlies these shales and is succeeded by the Agill Sandstone, which may locally consist almost entirely of shale in the lower half. The higher beds are made up of the Libishaw Shales, important for the marine fauna occurring near their base, the Libishaw Sandstone, and the Bewerley Shales which near Pateley Bridge contain the Scot Gate Ash Marine Band, the northern equivalent of the Otley Shell Bed. Exposures of these beds are on the whole poor, the succession being complied from fragmentary sections throughout the area. Fortunately the Cayton Gill Shell Bed and the Libishaw Sandstone have been extensively quarried for road metal and building stone so that it has been possible to establish a comparatively detailed succession for these sub-groups, but the variations in the remainder of the sequence are only imperfectly understood.

The beds form a broad band on the eastern flank of Nidderdale, north of Pateley Bridge, passing underground to the east, but to the west occurring as a capping to the highest ground on Gouthwaite Moor. This latter outcrop is a new discovery and effectively disposes of the glacial origin

Figure 9. Composite section of the beds between the Upper Follifoot Grit and the First Brimham Grit.



400 FEET
300
200
100
0
FIRST BRIMHAM GRIT
BEWERLEY SHALES
SCOT GATE ASH MARINE BAND
LIBISHAW SANDSTONE
LIBISHAW SHALES
AGILL SANDSTONE
CAYTON GILL SHELL BED
CAYTON GILL SHALES
UPPER FOLLIFOOT GRIT
The First Brimham Grit is a transgressive horizon, resting directly on the Cayton Gill Shell Bed locally, thereby cutting out up to 320 feet of sediments.
Black shale
Scot Gate Ash Marine Band - 4'4" grey/black platy siltstone with brachiopod/lamellibranch/nautiloid fauna
Dark grey micaceous shale
Mainly medium grained subgreywacke, but locally quartzitic sandstone with several shale partings
Grey shale with scattered chalybite nodules
Grey/fawn shale, locally hard, grey, calcareous siltstone containing goniatite/lamellibranch fauna, characterised by Reticuloceras aff. pulchellum
Medium grained quartzitic sandstone
Grey shelly limestone locally developed near Sawley
Worm chewed cherty siltstone - highly crinoidal near top - brachiopod/lamellibranch/cephalopod fauna, including Reticuloceras circumplicatile group
Blocky thinly bedded siltstones - dominantly lammelibranch fauna
Hard grey siltstone
Lower band of shelly siltstone
Grey mudstone/fawn sandy shale with scattered chalybite nodules and impersistent band of limestone

Prospect Farm Quarry, Hartwith(213615). The quarry face is 8' 1" high and consists entirely of worm chewed fossiliferous cherty siltsones. This bed(Cayton Gill Shell Bed) has been extensively quarried for road metal in this area.

assigned to blocks of the Cayton Gill Shell Bed on the moors west of Nidderdale (cf. Kendall & Wroot, 1924 and Tillotson, 1933). South of Pateley Bridge the beds are affected by the structural change that takes place at the line of the North Craven Fault so that much of the upper part of the sequence is absent and the remainder is folded into shallow anticlines and synclines. The outcrop has the form there therefore of a number of inliers and outliers with a wide areal coverage in the ground between Heyshaw and Fountains Abbey.

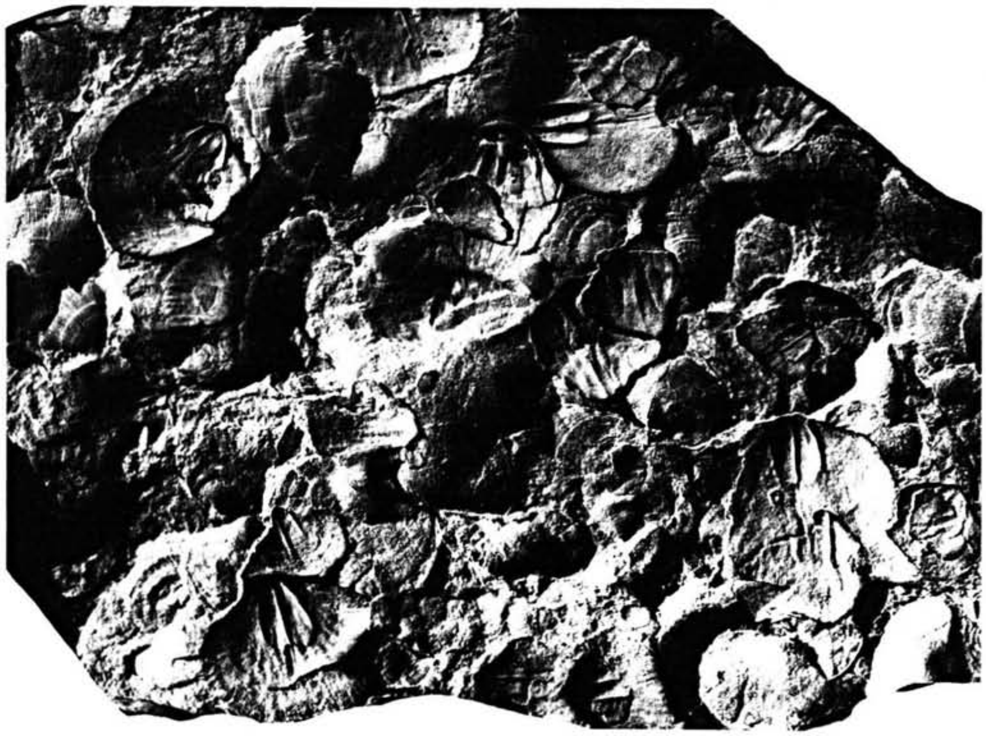
The Cayton Gill Shales are the lowest member of this stratigraphical unit and immediately succeed the Upper Follifoot Grit. They vary from 11 feet to 25 feet in thickness and consist of grey/ fawn shales with scattered chalybite nodules and an impersistent bed of limestone near the middle. Sections of this group are rare, but when they do occur have yielded no trace of the marine horizon discovered by Hudson(1939) at Simonseat.

The shales are overlain by a thin bed of fossiliferous sandstone about 2 feet thick and locally parted by a lens of shale. This bed is taken as the basal stratum of the Cayton Gill Shell Bed and has yielded a brachiopod/ lamellibranch fauna. It passes upwards into approximately 11 feet of hard blue/grey siltstones containing a fossiliferous horizon towards the top. The fauna from this horizon is a variable one, comprising an abundance of brachiopods in one locality and an abundance of lamellibranchs in another, but on the whole it is dominantly molluscan. These hard siltstones are succeeded by a group of "worm chewed" cherty siltstones ranging from 14 feet to 26 feet in thickness and characterised by a considerable brachiopod/lamellibranch/ cephalopod fauna. They have at their base a thin horizon averaging 3 inches in thickness which shows evidence of much re-working of the sediment. As noted by Jones(1943) this disturbed bedding becomes more and more intense upwards achieving its most advanced stage near Sawley, where the only structure visible in the rock is the numerous burrows of which it is composed. The disturbed bedding also results in decreasing fissility of the rock so that whilst the lower strata are thinly bedded siltstones with gently waved laminae, they pass upwards into harder beds showing greater contortion of the bedding laminae until finally near Sawley no trace of the original bedding can be discerned.

The cherty siltstones have yielded a prolific fauna mostly obtained from weathered blocks in the roadstone quarries because in its fresh condition fossils are extracted from the Cayton Gill Shell Bed, only with difficulty. The commoner forms include Derbyia gigantea, Productus carbonarius and Schizophoria hudsoni accompanied by a number of lamellibranchs and cephalopods amongst which Reticuloceras circumplicatile group is easily the most important. Schizophoria bands occur at two levels in the sequence and may well be more abundant but the incompleteness of the exposure prohibits comment on their lateral persistence. They consist almost entirely of internal and external moulds of Schizophoria hudsoni packed together in thin bands varying from 2 inches to 7 inches in thickness. No consistent orientation of the shells is apparent such as convex or concave upwards or aligned hinge lines, but what is noteworthy is the delicate preservation of the ornament. The exclusiveness of the species is also intriguing, the only form other than S. hudsoni present, being Productus carbonarius, in notably minor proportions. The origin of these local concentrations of S. hudsoni is still unsettled, but most probably connected with some inherent quality of the shell and not with its random mortification in large numbers at periodic intervals. Menard and Boucot(1951) have recently conducted experiments on the movement of shells by water and concluded that the most important factor governing initial shell transportation is effective density. Thereafter shape and size become important criteria though the smaller the effective density the more important the shape. Of the shells used in the experiments all the whole Terebratulina's were moved by currents incapable of moving the bed of sand, even though the shells weighed many thousand times more than the solid quartz grains. This seeming paradox was considered to be due to the small effective density of the shells as compared with the sand grains. On a similar basis the variation in effective density between species and individuals might easily be sufficient to result in segregation by a current of moving water, producing local concentrations of the type found in the Cayton Gill Shell Bed. For the present this explanation appears to be the most capable of fulfilling the conditions presented by these bands and is therefore accepted as the chief factor controlling their origin.

Limestone is found at two horizons in the Cayton Gill Shell Bed, one near the middle and the other at the top, both consisting of an abundance of organic shell debris preserved with scattered detrital grains of quartz in a streaky argillaceous matrix. These beds occur at Sawley only, but locally near Hartwith and Brimham Rocks the cherty siltstones become calcareous, there due largely to the incomplete replacement of the shelly calcite by secondary

A



The bedding surface of a Schizophoria band. These bands occur at at least four separate horizons in the Cayton Gill Shell Bed and are notable for the exclusiveness of their faunal content and the delicate preservation of internal ornament. Schizophoria hudsoni George is the form characteristic of this horizon, but the considerable variation in morphology suggests that other species are present. Natural scale.

B

A transverse section of a Schizophoria band showing the irregular disposition of the shells. Magnification x 2.

silica. The manner in which these limestones weather is distinctive, a white crust of tufa in concentric layers being deposited around the fresh rock, whilst secondary calcite tends to fill in the joint cracks giving a septarian effect.

The Cayton Gill Shell Bed is overlain by a bed of medium grained sandstone, the Agill Sandstone which may locally consist predominantly of shale in the lower half. The bed varies from 15 feet to 35 feet in thickness and is generally a quartzitic sandstone with carbonaceous flecks, but near Simonseat is a greenish grey medium grained sandstone full of rootlets. No trace of the fauna found at this level in Upper Nidderdale(Wilson,1957) has been found in this area.

The succeeding beds are argillaceous(the Libishaw Shales) attaining a thickness of as much as 55 feet in the north east, but more commonly averaging 35 feet. They contain several marine horizons near their base from which a goniatite/lamellibranch fauna has been obtained, characterised by <u>Reticuloceras</u> aff.<u>pulchellum</u>. This fossiliferous phase dies out within the present area however, no trace of it having been found in well exposed sections in the west and north east, though in a stream adjacent to Simonseat the basal 12 feet of shale are black and carbonaceous. In this connection it is perhaps significant that the lithology of the marine shale changes northwards becoming a banded calcareous siltstone in the neighbourhood of Fell Beck, indicative of a transition to a different environment. The marine horizon is not recorded from Simonseat(Hudson, 1939), Greenhow(Dunham and Stubblefield,1945) or Upper Nidderdale(Wilson, 1957), but farther south on Rombald's Moor(Stephens et.al. 1942) it is represented by the Addlethorpe Marine Band.

The upper shales contain scattered chalybite nodules and are overlain by the Libishaw Sandstone, a horizon which has been extensively quarried near Pateley Bridge. This bed undergoes a notable thickening southwards from Lofthouse towards Pateley Bridge achieving a maximum of 200 feet there. It then apparently thins again to the south, for it dies out near Harewood, but in this area it is transgressed by the First Brimham Grit so the change cannot be localised. The rock is a consistent well-bedded subgreywacke with occasional more massive bands and a number of shale partings. It contains scattered fossils at the top and near the middle, but nothing approaching the shelly phase developed farther north(Wilson, 1957) has been seen. In any case the base of the Libishaw Sandstone is rarely exposed so that the phase may or

A

The Libishaw Sandstone, Scot Gate Ash Quarry(160667). The section is approximately 40' high and consists and consists of well bedded and jointed medium grained sandstone, with two partings of soapy shale. The sandstone is frequently false bedded and contains well developed shallow water sedimentary structures on the bedding surfaces. The quarry is now disused, but was formerly worked on a large scale for building stone.

B

Slumped bedding in the Libishaw Sandstone, Middle Tongue Gill,Bewerley.

may not persist, but it seems likely that it dies out towards the south. Sedimentary structures such as ripple marking, rain spots, micro-current bedding, iron oxide layers and ferruginous zoning are common in the sandstones and enhance its geological interest though severely impair its commercial value as a building stone. Worm trails and fucoid markings are also characteristic of these beds and compare closely with similar organic structures seen in the Nar Hill Beds. The sandstones have been quarried primarily for their use as a building stone, in which capacity they have achieved international repute, but in addition they have been used locally for roofing slates.

They are overlain by a further shaly sequence, the Bewerley Shales which contain the Scot Gate Ash Marine Band towards the top. The shales are poorly exposed on the whole, never being seen in the north, but occasionally in the south where they consist of grey micaceous shale. Their thickness is difficult to measure, but approximately estimated on the control offered by the Libishaw Sandstone and the First Brimham Grit they thin from 55 feet near Lofthouse to 30 feet near Pateley Bridge. South of that town the horizon is rapidly transgressed by the First Brimham Grit. The Scot Gate Ash Marine Band has been found in only two localities, both of which were first discovered by Walker(1952). This worker examined the sections in the Scot Gate Ash Quarries and Middle Tongue Gill, Bewerley and concluded that the marine horizon present in the former was younger than the latter on the grounds of differing height above the Cayton Gill Shell Bed. The contrasted lithology, the former a platy siltstone and the latter a crumbly rottenstone was also considered to militate against correlation so that only the Scot Gate Ash band was equated with the Otley Shell Bed. Neither of these objections are now held to be tenable in the light of the present survey, firstly because it is known from the Cayton Gill Shell Bed that local variations in lithology coupled with prolonged weathering produce differences, frequently more accentuated than those observed in the two localities. Secondly the distance between the Scot Gate Ash Marine Band and the Cayton Gill Shell Bed in Middle Tongue Gill is not 300 feet as suggested by Walker, but between 150 and 175 feet, a distance closely comparable with that on the hillside above Pateley Bridge. The two marine bands are therefore considered to be equivalent and both are correlated with the Otley Shell Bed, a correlation supported by the discovery of trilobite Pygidia in Middle Tongue Gill, tentatively referred to the same species of

Brachymetopus (sp. nov.) as that recorded from the Otley Shell Bed(Bradford Memoir). If this suggested equivalence is correct the Scot Gate Ash Marine Band varies from 4 feet 4 inches to 5 feet 10 inches in thickness and is characterised by a brachiopod/lamellibranch/cephalopod fauna.

Details

The Shell Bed and underlying shales

Area north of Pateley Bridge - In the earlier part of the present survey, blocks of fossiliferous sandstone closely comparable with the Shell Bed were found in Ramsgill Beck and following the interpretation of Kendall and Wroot (1924 p.858) and Tillotson(1933) these were considered to be erratics of glacial origin. Further work however, revealed the presence of a thin capping to the highest ground on Gouthwaite Moor composed of these beds, thus extending the known westerly limit of the Shell Bed in this area. The upper reaches of Ramsgill Beck in particular contain numerous blocks of the Shell Bed, exceedingly abundant on the northern flank of Raygill House Moor and these have yielded a considerable fauna. The following section was measured in one of the small tributary streams flowing down from the moor(696083):

	Blocks of shelly sandstone on moor top
10' 0"	Gap
4"	shelly sandstone
2' 10"	shale
6"	shelly sandstone
22' 0"	shale with scattered chalybite nodules
	Upper Follifoot Grit

No fossils were found in the shales, but the two beds of shelly sandstone yielded a small fauna, limited because of the fresh nature of the rock. The sandstone is a medium grained greenish bed composed of detrital grains of quartz and glauconite set in a streaky argillaceous matrix. The shales underlying the shelly sandstone appear to die out to the north and south because in Ramsgill Beck itself, medium grained fossiliferous sandstone is seen directly overlying sandstone referred to the Upper Follifoot Grit. A similar relationship exists in Burn Gill also, medium grained sandstone being the highest "in situ" rock exposed, but overlain everywhere by scattered blocks of shelly sandstone.

East of Nidderdale the most northerly exposure of the Shell Bed is in Lul Beck. Here the underlying shales are not exposed, but a marshy slack on the moor above Horse Helks suggests that they are present. The following section was measured at 136731:

5' 0" massive ferruginous sandstone - sparsely fossiliferous - basal part worm chewed.
2" Schizophoria band
8' 1" thinly bedded cherty siltstones - sparsely fossiliferous.

Only a small fauna was collected from this locality, largely because of the fresh nature of the rock, but in both the cherty siltstones and the massive bed, Derbyia gigantea was found. The Schizophoria band is noteworthy because of the delicate preservation of internal muscle markings clearly defined in limonite, and set in a streaky grey fine grained sandstone less well cemented than usual and hence tending to crumble easily.

Farther south on Fountains Earth Moor nothing is seen of the beds apart from blocks of fossiliferous cherty siltstone just above the Sypeland Road(136726) until a small scar below Sigsworth Crags(137699) exposes 3 feet of hard blue/grey siltstone containing shelly fossils. A good feature in this vicinity approximately coincides with the base of the Shell Bed and assists in tracing the bed to where it is next seen in a small gulley by one of the walls running up from Dauber Gill to Howson Ridge. The following section was measured here :

4' 8" shelly siltstone - well jointed and blocky
6' 9" unfossiliferous hard blue siltstone

About 300 yards S.S.E. of this scar an Old Quarry has been worked for building stone and reveals one of the most complete sections of the beds at this level. The section is disturbed by fallen material, initially suggesting duplication of the Shell Bed, but the following succession is considered to be the true one.

9' 7" yellow medium grained flaggy ganisteroid sandstone - Agill Sandstone
9' 11" crinoidal siltstone with occasional highly fossiliferous bands including D.gigantea and Schizophoria hudsoni
10' 1" obscured
9" shelly siltstone - basal 3" strongly worm chewed
10' 7" calcareous siltstone - locally very fossiliferous
16' 0" obscured - shale fragments in slip

Upper Follifoot Grit

The calcitic preservation of the fossils in the lower calcareous siltstone is somewhat reminiscent of the Yoredale beds, productid brachiopods and thin shelled lamellibranchs being the common forms at this level.

Passing to the south the bed is next seen on Bishopside Brae

(154675) where a certain amount of trial quarrying has taken place in time past. A line of mounds composed of black shale with concretions lies along the outcrop of the shales underlying the Shell Bed, whilst blocks of hard blue siltstone and fossiliferous sandstone rest just above this. The outcrop of the Shell Bed can be traced by scattered blocks of fossiliferous sandstone southwards to Wath Lane, but beyond this nothing is seen of it north of Pateley Bridge.

Area south of Pateley Bridge - West of Nidderdale - The Shell Bed is displaced by the North Craven Fault near Pateley Bridge and south of that town first appears at the surface in Fosse Gill(157644) where the following section, steeply dipping to the north was measured:

4' 8"	shelly sandstone - worm chewed at base - contains D. gigantea
6' 6"	hard black siltstone
4' 6"	black ferruginous siltstone containing fauna of Productids.

Passing to the south, no further indications of the bed occur until the Old Quarry in Parker Wood(167637) where blocks of encrinital siltstone containing D. gigantea and productids rest in the entrance to the now overgrown quarry. At the southern end of the wood(175633) a steep cliff reveals a small scar in 10 feet of fossiliferous cherty siltstone, worm chewed at varying levels in the section. 12 feet of similar beds are exposed in the Old Quarry 500 yards E.S.E. of this point also showing disturbed bedding at several levels in the section.

The beds dip steeply to the east from here and can be traced round to Loftshaw Gill as well as eastwards where they form two small outliers in Hawkshaw Gill Wood. The first of these outliers(180633) is separated from the main outcrop by a glacial overflow channel and at the top of the hill a small quarry reveals approximately 4 feet of worm chewed cherty siltstone. A similar quarry occurs 300 yards farther north in the second outlier and here 12 feet of fossiliferous worm chewed cherty siltstone constitute the section. Loose blocks and occasional exposures enable the fossiliferous siltstones to be traced down both sides of the gill separating the two outliers, the next exposure being in Righouse Gill just above the Harrogate Road.

In Loftshaw Gill(174626) the Upper Follifoot Grit crops out in the bed of the stream and is overlain by grey shale in the banks. The thickness of this grey shale is difficult to measure because of the steep(38°) north easterly dip, but it is probably about 15 feet thick here. Overlying the shale are fossiliferous cherty siltstones containing D. gigantea, 10 feet only of which are visible, but 100 yards upstream 26 feet of these beds were measured, disturbed bedding being noticeable at several horizons.

The strata are thrown up to the south by a fault and reappear on Baal Ridge where they have been excavated and quarried for some distance along the line of their outcrop. Here again accurate thickness measurements were prevented by the steep north westerly dip, but above the crags of Upper Follifoot Grit a marshy slack is thought to coincide with approximately 15 feet of shale. Hard grey siltstones streaked with darker bands and tinged with a mauve colour on weathered surfaces form the basal beds in the quarry and have yielded a considerable brachiopod/lamellibranch fauna. These bedded siltstones are overlain by a further 13 feet 6 inches of cherty siltstone, distinguished from the lower strata by their more massive bedding and several worm chewed horizons. These massive beds are probably the equivalent of the hard beds of Simonseat, though no separating band of clay is present here. In this vicinity the strata are folded on a subsidiary anticline at right angles to the main Simonseat structure so that to the west on Nanny Black Hill a westerly dip is apparent. To the south however they are displaced by another fault and reappear in an Old Quarry near Dodd Hill Farm(172611) where now only blocks of fossiliferous cherty siltstone are seen.

A small faulted inlier occurs due west of Dacre Banks and here blocks of fossiliferous sandstone are abundant in the banks of Smelt Maria Dike(192622). Grey unfossiliferous shale overlies the Upper Follifoot Grit in the stream, and is succeeded by 8 feet of worm chewed cherty siltstone in a quarry above the stream. These fossiliferous siltstones include D. gigantea and S. hudsoni as common forms.

East of Nidderdale - South of Pateley Bridge the Shell Bed is first seen in an old Quarry on Knott Side(169650) where the now largely overgrown tip reveals fragments of shale and encrinital siltstone from which numerous productids and specimens of D. gigantea have been obtained. Another old quarry a short distance to the north east was also worked for road metal once and is similarly overgrown, but the horizon is exposed in the old quarry by Whitehouses Farm (192650). The following section was measured there:

2' 3" grey streaky siltstone, with thin lenses of limestone - basal 3" - 6" strongly worm chewed - scattered fossils chiefly brachiopods.

2 " black shale
2' 5½" blue siltstone, locally worm chewed - scattered fossils
7 " Schizophoria band
1' 6" hard blue siltstone

The beds crops out on the other side of Righouse Gill below Brimham Rocks, but to the north and south they are displaced by faults, resulting in a duplicated outcrop in Righouse Gill. In the lower exposure below Smelthouses(190639) 1 foot of steeply dipping black siltstone containing Productus carbonarius and other fossils occurs in the bed of the stream whilst by Fell Beck Mill(197654) in the small tributary stream to the north the following section was recorded:

2' 0 " yellow fine grained sandstone - Agill Sandstone
4' 1½" crinoidal siltstone containing D. gigantea
4 " Schizophoria band
1' 10 " hard blue siltstone - worm chewed and containing Bryozoa

Blocks of fossiliferous siltstone also lie on the ground surrounding the Mill Dam, but the affect of the E - W fault near here results in the bed next being seen above Low Wood Farm(201653). Here many blocks of fossiliferous siltstone are scattered about, most of the walls being constructed of this material. The beds are dipping to the north and displaced by several faults to the south so that on the hillside above Low Laithe they are repeated three times. A small quarry near Maud's Farm(207639) is important because it reveals the Shell Bed, less than 15 feet below the base of the First Brimham Grit, thus drawing attention to the unconformity at the base of that formation as well as the presence of a fault immediately west of the quarry. The section measured here was:

1' 0 " sparsely fossiliferous siltstone containing many crinoid fragments
1' 4½" worm chewed fossiliferous siltstone
7 " band of chert - full of crinoid ossicles and some brachiopods perpendicular to the bedding
3' 9 " fossiliferous siltstone packed with brachiopods
3' 10" obscured

To the south west, of the outcrop of the Shell Bed fans out into a broad band, blocks of the bed being particularly abundant in the fields above Fiddler's Green Farm(213636). 2 feet of highly crinoidal fossiliferous siltstone are exposed in the Gravel Pit on the side of the Burnt Yates Road (210636), whilst in the upper reaches of Lurk Beck just by Fiddler's Green Farm, 4 feet of grey shale are seen immediately overlying the Upper Follifoot Grit.

The beds occur on the north side of Riva Hill also, being first seen in Thornton Beck where grey shale with a thin band of limestone near the middle, crops out in the stream by Summer Wood House Farm(223649). Exposures are incomplete in this vicinity, which coupled with an uncertain dip makes thickness measurements subject to considerable inaccuracy, but just below the fence at the top of the bank a thin band of fossiliferous cherty siltstone is exposed some 35 feet above the base of the shale. To the north the Shell Bed is repeated twice at the surface by faults, the first exposure being in the quarry due east of Brimham Rocks(218651) where the following section was recorded:

6'	6"	highly fossiliferous crinoidal calcareous siltstone containing D. gigantea and Productus carbonarius
	6"	Schizophoria band
1'	1"	worm chewed limestone - sparsely fossiliferous
	4"	Schizophoria band
4'	5"	thinly bedded fossiliferous siltstones - mainly gastropod/lamellibranch fauna

The other exposures are in the old quarry on Yew Hill and the beck due south of it. In this latter locality 25 feet 1 inch of grey shale apparently unfossiliferous, but containing chalybite nodules are overlain by 8 feet of fossiliferous sandstone characterised by D. gigantea and Productus carbonarius. In the old quarry at the top of the hill(218654) higher beds in the succession are exposed as follows :

1'	4"	grey,wormchewed,hard,fossiliferous limestone(Spa Gill type)
1'	6"	fossiliferous cherty siltstone
3'	3"	gap
2'	3"	thinly bedded siltstones containing Productus carbonarius, S. hudsoni, Aviculopecten sp. orthoconic and curved nautiloids.

Returning to the eastern flank of Nidderdale, blocks of worm chewed cherty siltstone can be seen in the entrance to an old quarry in Woolwich Wood(204632) testifying to its former extraction for walling blocks in this neighbourhood. The beds continue down the edge of the dale in a narrow band thickening locally near Hartwith. 10 feet of thinly bedded unfossiliferous siltstones overlain by 3 feet of shelly siltstone are exposed in Ell Knowle Wood(209619), whilst in the quarry near Prospect Farm, Hartwith (Plate X11) 8 feet 1 inch of highly crinoidal worm chewed siltstones were measured. These siltstones yielded a considerable fauna composed mainly of brachiopods and lamellibranchs, but including also the goniatite Reticuloceras circumplicatile group, the first goniatite to be recorded from this horizon.

Many of the fossils are peculiar to this locality and in particular the quarry is of interest because of the abundance of the forms, Limipecten dissimilis and Dictyoclostus hindi, the internal muscle markings of this latter species being singularly well preserved.

The strata are displaced by a fault to the east and crop out both N. and S. of Winsley. They are first seen in a small stream gulley just above the Harrogate Road by Spence Dam(227609) where 15 feet of fawn sandy shale immediately overlie the Upper Follifoot Grit. No fossils were found in the shales, but blocks of fossiliferous cherty siltstone lie scattered along the stream bed and in the field above the stream head. Northwards in Lurk Beck grey shale again succeeds the Upper Follifoot Grit, but nothing is seen of the overlying Shell Bed before a small tributary stream near Woodfield Farm(232635). Here blocks of shelly sandstone lie on the ground surface, and farther north in Thornton Beck(231641) itself the bed is seen in situ, 1 foot 6 inches of fossiliferous sandstone being recorded.

Passing to the south east the Shell Bed appears at the surface near Bedlam where a small gulley on the north side of the Harrogate road (270616) reveals the following section:

3½"	grey/black streaky unfossiliferous siltstones
1' 10 "	shelly siltstone
3' 1½"	grey unfossiliferous shale

North of this in Thornton Beck nothing is seen of the Shell Bed, but 12 feet of grey shale with scattered chalybite nodules represent the partially exposed Cayton Gill Shales. East of Thornton Beck on Scarah Moor, a fault brings the Shell Bed to the surface and from the scattered outcrops a fairly complete section can be composed. The lowest beds exposed, consist of greenish grey streaky siltstone well seen in a quarry on Slate Rigg Plantation (282623) and farther east on Blue Bank overlooking Cayton Gill. These are overlain by blocky, worm chewed, sparsely fossiliferous siltstones containing a dominantly lamellibranch fauna, 4 feet 7½ inches of which are exposed in a quarry 230 yards south of Cayton Gill Farm(289625). Still higher beds occur 360 yards north west of this quarry consisting of 10 feet of grey shelly limestone, brecciated and veined with calcite. D. gigantea was found in these beds.

Higher up Cayton Gill the beds are again brought to the surface on the northern limb of a syncline and there the combined succession from the old quarry(277632) and the gulley south of it is:

8' 0 " fossiliferous siltstone - top 2' 6" strongly worm chewed- base highly crinoidal.
3' 11 " streaky sandy siltstone containing productids and plant remains - only sparsely fossiliferous.
2½" brown micaceous shale
3' 0 " obscured
4 " brown micaceous shale
7½" buff unfossiliferous siltstone - top inch weathered to highly ferruginous clay
1' 3½" black unfossiliferous siltstone - hard and platy.

The fossils obtained from the upper bed of fossiliferous siltstone are almost entirely brachiopods, characterised by such forms as Dictyoclostus hindi and Productus carbonarius.

Northwards, the strata are affected by faulting and are next seen on the highest ground by St. John's Church(259641) where blocks of shelly sandstone lie in an overgrown quarry. Another quarry north of this by Raventofts Head(260651) exposes 3 feet of well bedded worm chewed crinoidal siltstone containing D. gigantea and 300 yards east of this quarry blocks of shelly sandstone lie in a further overgrown trial quarry.

South west of these quarries the Shell Bed is again exposed in Thornton Beck by Strawberry Cottage(238627) where 3 feet of unfossiliferous grey siltstone are overlain by 6 feet of fossiliferous cherty siltstone. Blocks of shelly siltstone lie in the entrance to an overgrown quarry 300 yards N.W. of this point as well as by the ford(238632) a short distance upstream and are there accompanied by fragments of black shale.

Farther north on the southern bank of Hebden Beck(247657) a steeply dipping faulted inlier occurs by Shann House. Grey shale is the lowest bed seen and is overlain by approximately 15 feet of blocky fossiliferous siltstone, characterised by Productus carbonarius and other brachiopods.

Several faulted inliers of these beds occur to the north and will be described from west to east. Firstly in the vicinity of Hazel Hill Farm (233685) the Shell Bed has been quarried for building stone in time past, though now the only relics of this activity are loose blocks and a small group of crags. The crags are composed of irregularly bedded worm chewed fossil - iferous siltstone steeply dipping to the west. Blocks of fossiliferous siltstone also occur on the north eastern edge of Eavestone Lake and it remains uncertain what their origin is because large crags of First Brimham Grit crop out on the opposite bank and above them, discounting the suggestion of an in situ outcrop. They must therefore be fallen blocks though from where is equally obscure.

The beds are displaced by a fault to the east and reappear in Spa Gill on both sides of the River Skell. Fragments of black shale overlain by ca. 6 feet of platy fossiliferous siltstone occur on the western bank, while on the eastern bank the following section was measured:

3'	3"	hard, massive blue/grey limestone
7'	1"	platy fossiliferous siltstone
24'	4"	black shale - largely in the form of fragments at the surface
		Upper Follifoot Grit

Farther south the Shell Bed is exposed in a small quarry(264677) by the side of the Fountains Abbey - Sawley road where the following section was recorded:

2'	$8\frac{1}{2}$"	massive, calcareous worm chewed fossiliferous siltstone - weathers to gingerbread rottenstone and contains <u>Tylothyris</u>, <u>Chonetes</u> and <u>Dictyoclostus</u>
	$8\frac{1}{2}$"	platy fossiliferous siltstone
2'	8 "	hard worm chewed siltstone, calcareous when fresh - contains <u>D. gigantea</u> and Productids
	$10\frac{1}{2}$"	platy crinoidal siltstone

Blocks of calcareous fossiliferous siltstone also occur on the other side of The Dean above Broad Oak Wood.

The beds are displaced by a fault to the east and reappear below Rough House in the banks of the River Skell, descending gradually towards Fountains Abbey. North of Rough House(265680) the measured succession is as follows:

17'	$10\frac{1}{2}$"	boulder gravel - rounded, ice-scratched blocks of Millstone Grit and Carboniferous Limestone
1'	8 "	massive, worm chewed, fossiliferous calcareous siltstone - this bed is 2' $9\frac{1}{2}$" thick 40 yards to the east.
	10 "	platy crinoidal siltstone containing productids - carbonate film on bedding surfaces.
	9 "	massive calcareous worm chewed siltstone - no fossils found.
	10 "	fossiliferous platy siltstone
		Slip below contains many shale fragments

The shell beds can be traced some distance to the east on both sides of the River Skell and are notable for the development of a white crust of tufa in concentric layers round the fresh calcareous rock. The worm chewed layers as noted by Jones(1943) show intense re-working of the sediment, appearing as black and white streaky rocks in hand specimen, without any trace of bedding.

Agill Sandstone

The most northerly exposure of the Agill Sandstone occurs on the moor below Sigsworth Crags(140697) where blocks of brown medium grained sandstone lie scattered on the surface of the ground. The bed is seen in situ in a small quarry by the side of Dauber Gill(149691) where the following section was measured:

1' 0"	bedded medium grained sandstone
5"	shale
2"	thinly bedded medium grained sandstone
11"	shale
7"	thinly bedded medium grained sandstone
11' 4"	shale

Another quarry 560 yards to the south reveals 9 feet 7 inches of medium grained flaggy sandstone immediately overlying the Shell Bed, whilst a small scar due west of Yeadon Farm(155680) contains 8 feet of medium grained sandstone. Nothing further is seen of the horizon north of Pately Bridge.

South of Pateley Bridge the Agill Sandstone is exposed in Crook in Fosse Gill(150621) where it consists of greenish-grey medium grained sandstone. The only other indication of the bed west of Nidderdale is on the outlier near Low Laithe(182636) where blocks of medium grained sandstone lie a short distance above an impersistent feature thought to coincide with the base of the division.

East of Nidderdale the Agill Sandstone was formerly quarried near Blazefield(175651), but the two quarries are now completely overgrown. In Fell Beck by the side of the Mill(197654), some distance east of this point, 4 feet of fine grained yellow sandstone overlie the Shell Bed and higher upstream, just beyond the Ripon Road, medium grained sandstone is exposed in the bed of the stream.

Over most of its outcrop the Agill Sandstone forms a thin band, but south of Brimham Moor it spreads out into a wide dip slope outcrop upon which blocks of medium grained quartzitic sandstone are quite abundant. A north/south fault in this vicinity displaces the strata to the east so that they reappear in Lurk Beck. Here yellow medium grained sandstone, near the top of the division occurs in situ, whilst blocks of white quartzitic sandstone are common throughout the section. The upper part of the division is again exposed farther north in the stream below Brimham Lodge(229635) where 15 feet of flaggy medium grained sandstone overlying 3 feet of micaceous shale were seen. Another fault displaces the strata to the east resulting in their appearance lower down Lurk Beck where they consist of approximately 25 feet of fine grained quartzitic sandstone, ganisteroid towards the top and intercalated with which is a bed of grey micaceous shale 6 feet thick. East of this point in the stream above Block House Farm the upper beds are exposed, consisting of flaggy micaceous sandstone.

The next exposure of this horizon occurs some distance to the east in Thornton Beck(263625) where 2 feet 2 inches of steeply dipping grey ganisteroid sandstone are overlain by the Libishaw Shales. Blocks of a similar lithology are scattered about in the wood 350 yards north of Bedlam (268619) and represent the Agill Sandstone there.

The only other exposure of the bed in this area occurs in Skell Bank where thinly bedded micaceous sandstone immediately succeeds the Shell Bed. Farther downstream blocks of medium grained ganisteroid quartzitic sandstone are abundant, suggesting an upward change in lithology.

The Libishaw Shales

North of Pateley Bridge the Libishaw Shales are very poorly exposed, their positive identification being possible only on Bishopside Brae(156675). There fragments of shale and blue siltstone lie scattered on the ground surface and combined with an intermittent feature at the base of the Libishaw Sandstone indicate a thickness of 35 feet for the division.

South of Pateley Bridge, on the western side of Nidderdale the horizon is first seen in Fosse Gill(151625) where the following section was measured:

	Libishaw Sandstone
8' 11"	grey shale
11' 9"	black carbonaceous shale - no fossils found
9' 4"	obscured

The strata are affected by two faults to the south and are next seen in a small stream gulley south of Heyshaw(171614) where 6 feet of grey fossiliferous blocky shales are exposed. West of this, micaceous shale with thin bands of sandstone crops out near Hill Top Farm(194619) suggesting a more arenaceous phase towards the top of the division.

On the eastern side of the dale the only indication of the Libishaw Shales between Pateley Bridge and Fell Beck is a small exposure of micaceous shale in a gulley near Tiplady Farm(173654). Near Fell Beck however, exposures are more frequent, the best being in Pencil Dike(205659) though here the upper beds are cut out by the unconformity at the base of the First Brimham Grit. The lower beds consist of 15 feet of hard,grey, banded calcareous siltstone in which goniatites and nautiloids are quite abundant. Higher beds are brought in upstream by a fault and consist of unfossiliferous grey shales with calcareous nodules and thin sandstone bands. These same beds, 15 feet of which are present crop out in Fell Beck on the northern side of the Ripon road(194664) and are there overlain by the Libishaw Sandstone.

Fragments of hard blue/grey siltstone occur near Collar Stoop Farm(209659), but apart from these a marshy slack is the chief pointer to the Libishaw Shales north of Brimham Rocks. To the south the beds are again cut out by the transgressive First Brimham Grit, but reappear to the west, being penetrated by the borehole at Shepherd's Lodge Farm(221636) where they comprise an upper 10 feet 2 inches of yellow/blue shale and a lower 24 feet 3 inches of hard grey shale. The upper beds are seen at the surface in a small stream by Middle Farm, Warsill(227650) consisting of grey unfossiliferous shale, whilst lower beds are exposed in the stream by Little Gill Moor Farm(237641). These comprise 15 feet of grey mudstone with calcareous nodules becoming more sandy towards the top. No fossils were found in these beds.

To the south the Libishaw Shales are next seen in Lurk Beck (236625) where they appear to be about 25 feet thick. The lowest beds exposed are fawn sandy shales, 11 feet 2 inches of which were found to be fossiliferous. Shale fragments continue to abound up to the fence above the stream and a short distance upstream grey unfossiliferous shale containing calcareous nodules is exposed. West of this stream, the upper few feet of the division crop out in a small stream in Trustee Wood(247624) and there consist of grey mudstone with thin bands of flaggy micaceous sandstone. Farther west still in an old Quarry by the High Mill, Shaw Mills(252627) 6 feet of grey shale are directly overlain by the First Brimham Grit.

To the south the lowestmost beds are exposed in a small stream by Winsleyhurst(225613) where they are 3 feet thick and consist of grey unfossiliferous shale. A short distance to the west at Burnt Yates two boreholes at the Bay Horse Inn and New Inn respectively(Appendix) passed through just under 40 feet of shale referred to this horizon.

In the vicinity of Bishop Thornton a more or less complete section of the beds at this level is exposed in a stream by Hardgate Farm(267629). The lowest beds are composed of grey mudstone, 15 feet thick and pass upwards into grey blocky shale, 10 feet 3 inches of which were found to be fossiliferous. A gap occurs in the section here, but the uppermost beds are exposed upstream and consist of grey unfossiliferous shale interbedded with which are thin bands of flaggy micaceous sandstone.

Northwards the Libishaw Shales are locally cut out as suggested by the Sawley borehole(Appendix), only 3 feet of the division being present here, but in the borehole at Ashfield Farm(258660) 29 feet of grey shale were passed through, directly underlying the First Brimham Grit. Farther north still in Spa Gill(255688) the formation seems to have thickened because over 50 feet of sandy shales are exposed in a gulley on the steep southern bank, but no fossils were obtained from these beds.

The Libishaw Sandstone

The most northerly exposure of the Libishaw Sandstone occurs in Lul Beck(137735) where approximately 8 feet of flaggy micaceous sandstone are exposed. The division averages 25 feet in this vicinity and is accompanied by an impersistent basal feature, but southwards it begins to thicken and attains some 60 feet on the hillside below Sigsworth Crags(140702). Two small quarries in this neighbourhood, one near the base and the other at the top of the formation are now largely overgrown, but from loose blocks it is possible to see that flaggy micaceous sandstone is the dominant lithological type here. This lithology is maintained in Dauber Gill and its tributaries, only fragmentary exposures being seen, but it is evident that the southerly thickening is persisting because below Howson Ridge just under 100 feet of beds of this age are present. Southwards near Pateley Bridge the sandstone thickens still further attaining 125 feet and has there been extensively quarried for building stone. The most northerly of these quarries is on Bishopside Brae(157674) where the following section was measured:

2'	1"	grey medium grained bedded sandstone
7'	2"	interbedded fine grained sandstone and shale
13'	6"	massive grey medium grained sandstone
0'	6"	micaceous siltstone
5'	0"	massive medium grained sandstone

The sections in the other quarries are summarised in Fig.10 and give some indication of the rapid change in facies that takes place laterally in this formation. Sedimentary structures such as ripple marks, rain spots and ferruginous zoning as well as worm trails and fucoid markings are abundant

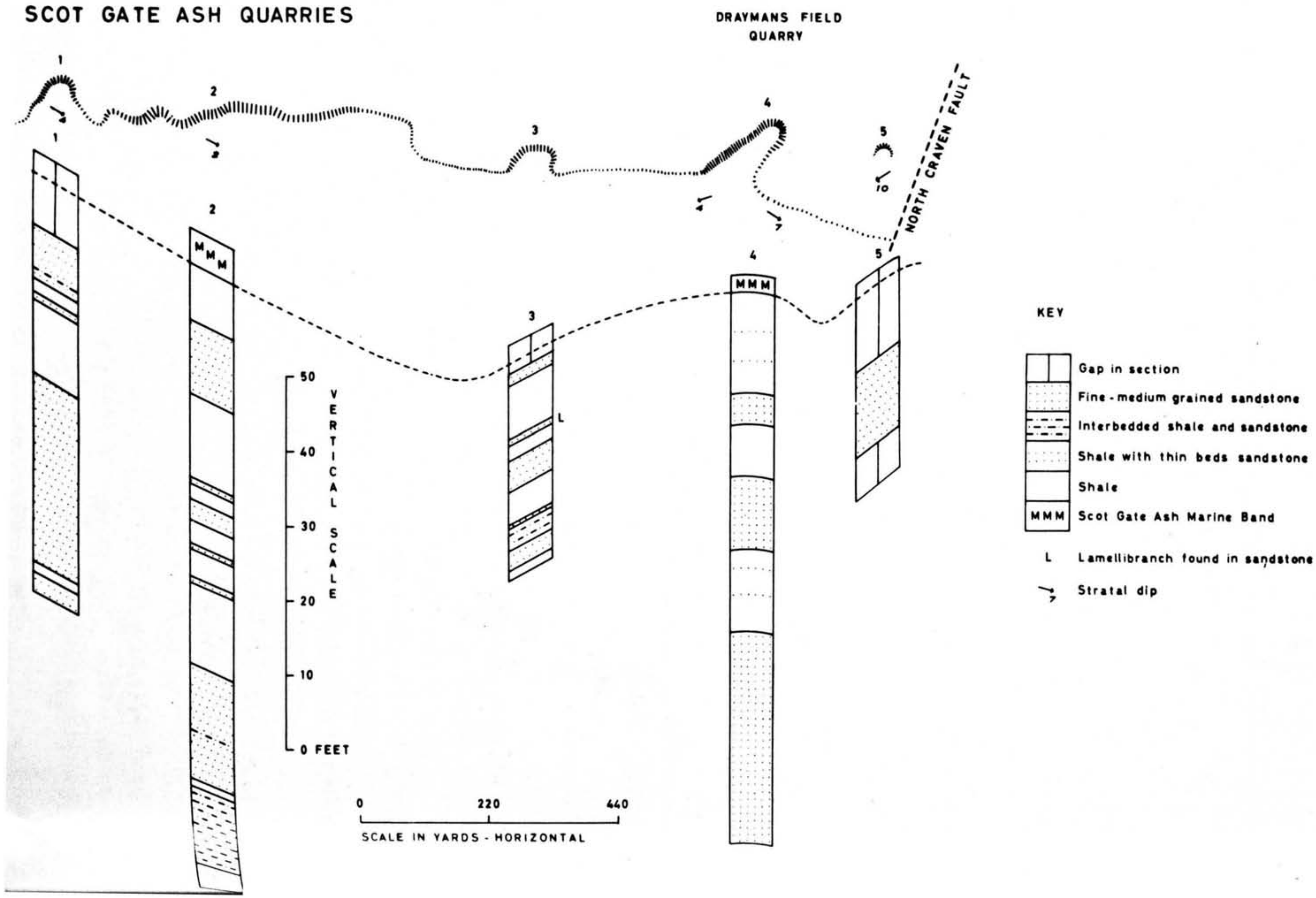

SCOT GATE ASH QUARRIES
DRAYMANS FIELD QUARRY
NORTH CRAVEN FAULT
1
2
3
4
5
MMM
L
50
40
30
20
10
0 FEET
VERTICAL SCALE
0
220
440
SCALE IN YARDS - HORIZONTAL
KEY
Gap in section
Fine - medium grained sandstone
Interbedded shale and sandstone
Shale with thin beds sandstone
Shale
MMM Scot Gate Ash Marine Band
L Lamellibranch found in sandstone
Stratal dip

Figure 11. Comparative sections of the strata exposed in the Scot Gate Ash/ Drayman's Field Quarries.

in the sandstones, most of which are medium grained sub-greywackes, though a higher quartz content is developed locally. The shales are chiefly grey and micaceous, particularly so when interbedded with thin beds of sandstone, but the upper thick bed in section 1 and its equivalent in section 2 consists of blue soapy shale. The Scot Gate Ash Marine Band occurs at the top of the section and can be seen in quarries 2 and 4, there composed of 4 feet 4 inches of grey/black platy siltstone in which fossils are relatively abundant.

South of Pateley Bridge the strata are displaced by the North Craven Fault and can be traced on both sides of the valley, though owing to the steep northerly dip it is difficult to assess their thickness. A borehole (Appendix) at Pateley Bridge Cemetry passed through 250 feet of beds which are probably all referable to this horizon owing to the steep dip here.

On the western side of the dale the first exposure of the Libishaw Sandstone occurs in a small stream running into Bewerley Park(156651) where approximately 20 feet of flaggy medium grained sandstone are seen. Fosse Gill, a short distance farther south, contains a more or less complete section of the beds at this level consisting mainly of medium grained sandstone with a few thin shale bands, but towards the top the following section was measured:

13' 1"	medium grained white quartzitic sandstone - First Brimham Grit
2' 5"	black shale - 1 Lingula found
2' 5"	grey micaceous shale
5' 7"	sandy siltstone with fossils, mainly small brachiopods - Scot Gate Ash Marine Band
5' 10"	dark grey shale - 1 lamellibranch found
3' 2"	bedded flaggy sandstone
11' 9"	grey shale
5' 5"	flaggy sandstone
11' 2"	shale with occasional thin bands of flaggy sandstone
15' 4"	flaggy micaceous sandstone

Comparable sedimentary structures to those observed in the Scot Gate Ash Quarries occur here, but a distinctive feature of one of the beds of sandstones in this section is the slumped bedding illustrated in Plate XlV B.

The formation continues to the south being partially exposed in Ravensgill Beck and an old Quarry in Shrikes Wood. In both cases medium grained flaggy sandstone is the dominant lithological type interbedded with thin bands of micaceous shale. The division is approximately 150 feet here, but thickens towards Guisecliff Wood achieving a maximum of 200 feet in that vicinity decreasing further to the south. An old quarry at the southern end of Bark Cabin Wood(173632) was worked in flaggy medium grained sandstone, and a similar lithology was encountered at the southern end of Heyshaw Moor Quarries, blocks of the bed being exceptionally abundant in the tips at this latter quarry. Farther west on Heyshaw Moor, an old quarry(155626) contains blocks of fossiliferous flaggy sandstone which must be either a local fossiliferous phase in the Libishaw Sandstone or the equivalent of the Scot Gate Ash Marine Band, but certainly the lithology is more typical of the former.

The Libishaw Sandstone crops out twice in Fosse Gill, once lower downstream as described above and then upstream on Heyshaw Moor. Only 6 feet of medium grained sandstone are exposed in the stream, but in the crags on the western bank, more than 20 feet of medium grained quartzitic sandstone are seen, folded into a shallow anticline.

On the eastern side of Nidderdale the Libishaw Sandstone is rapidly transgressed by the First Brimham Grit, but reappears locally in the vicinity of Fell Beck. 10 feet of medium grained subgreywacke immediately underlie the First Brimham Grit in Fell Beck(194665) whilst near North Pasture Farm(207657) the sandstone has been quarried for roofing slates in time past. Nothing further is seen of the formation until Bishop Thornton where a few feet of flaggy sandstone can be seen overlying the Libishaw Shales in the stream by Hardgate Farm(267632). The only other exposure occurs much farther north in Gill Beck(251689) where approximately 35 feet of flaggy medium grained sandstone with some more massive bands and thin shale partings crops out in the stream.

The Bewerley Shales

North of Pateley Bridge the Capelshaw Shales are never seen at the surface except for fragments of hard blue siltstone below Sigsworth Crags (141700). The control offered by the Libishaw Sandstone and the First Brimham Grit however suggest a thickness of 55 feet for the division near Lofthouse decreasing to 30 feet near Pateley Bridge. In the Scot Gate Ash Quarries, the upper bed of grey micaceous shale is referred to this horizon, thus including the Scot Gate Ash Marine Band near the middle. This latter bed is 4 feet 4 inches thick and consists of grey/black platy siltstone in which fossils are relatively abundant.

South of Pateley Bridge the Capelshaw Shales can be traced as a thin band west of Nidderdale, first seen in Middle Tongue Dike where the following section was measured:

First Brimham Grit

2' 5" black shale - 1 Lingula found
2' 5" grey micaceous shale
5' 7" sandy siltstone with fossils - Scot Gate Ash Marine Band
5' 10" dark grey shale - 1 lamellibranch found

Libishaw Sandstone

Farther south in Guisecliff Quarries(169633) only 2 feet 5 inches of micaceous shale separate the First Brimham Grit from medium grained sandstone of Libishaw type, whilst at Heyshaw Moor Quarries(168629) the thickness of shale has increased to 6 feet 8½ inches.

East of Nidderdale the Capelshaw Shales are completely cut out by the unconformity at the base of the First Brimham Grit except near Risplithh where they are approximately 40 feet thick and consist of dark grey pyritic shale becoming more sandy towards the top. The only exposures are in Gill Beck(250689), Hook Gill(260689) and the road cutting on Lodge Bank(249692).

Palaeontology

Cayton Gill Shell Bed

The fauna of the Cayton Gill Shell Bed has received considerable attention from former workers in this area, notably from Hind(1907, 1914) following the earlier work of Tute(1868, 1886). More recently George(1932) and Wilson(1957) have made valuable contributions and extended still further the comprehensive lists of the earlier authors. The present study has largely duplicated the fossil lists of earlier workers, but in addition several forms new to this horizon have been found. Easily the most important of these is the goniatite Reticuloceras circumplicatile group, the first goniatite ever to be recorded from this horizon. It is accompanied by a new species of Spiriferellina, Grammatadon squamifer, Coleolus reticulatus and Pseudometacoceras sp.

The fauna comprises a well balanced assemblage of brachiopods, lamellibranchs and cephalopods together with a subordinate representation of gasteropods and stick bryozoa. Plant remains and crinoid ossicles are abundant throughout the division, the latter being particularly so towards the top. Re-working of the sediment by annelids is also common as witnessed by the disturbed bedding laminae and mottling of the chert matrix, reaching its most advanced stage near Sawley, where the only structure visible in the rock is the mass of burrows of which it is composed.

Brachiopods constitute the most common phylum, but this is with reference to the abundance of individuals rather than species. Of this phylum Productids and Orthids make up the bulk of the genera and are accompanied by a lesser number of Chonetids, Spiriferids and Lingulids. Productus carbonarius is the most common form, closely seconded by Schizophoria hudsoni and Derbyia gigantea. Dictyoclostus hindi is also relatively abundant, but more noteworthy for the delicate preservation of the internal muscle ornament in dorsal valves than its numerical proportion. The genus Schizophoria shows a wide variation in dimensions as noted by George(1932) and whilst most are referred to S. hudsoni some are larger, approaching S. resupinata in shape but lacking the broadly sulcate anterior margin characteristic of that species; others are gibbose approaching S. connivens in shape, but again lack the sulcate anterior margin. Another form well known from this horizon is Derbyia gigantea, found in most of the localities occasionally associated with Derbyia hindi.

A number of spiriferids with a lamellose surface ornament have been collected from the Cayton Gill Shell Bed, most of which have been assigned to a known species without difficulty. One form however, of which 7 specimens have been collected does not fit hitherto described species and is therefore considered to be new. Only pedicle valves have been collected and of these several are fragmentary so the description is necessarily incomplete, but the following is given as a brief outline of the main features:

Spiriferellina sp. nov. - shell spiriferid in shape about twice as wide as long, greatest width along the hinge line, cardinal extremities nearly a right angle. The size is variable, but the average dimensions are: width along the hinge line 20 mm.; length 10 mm.. Surface ornamented with irregularly spaced concentric laminae, closely crowded anteriorly. Shell punctate. Mesian sinus angular about the width of four of the adjacent costae together with their separating furrows. Eash lateral slope bears 6 to 7 simple angular costae separated by angular furrows and crossed by concentric lamellar ornament.

The Chonetids have proved to be a difficult group for identification purposes largely owing to the incomplete revision of the group and it is recognised that species other than those identified by Dr. Ramsbottom may be present.

Unlike the brachiopods, the lamellibranchs are characterised by a profusion of species and a paucity of individuals. Edmondia and Aviculopecten are the commonest genera whilst Limipecten dissimilis is the most abundant individual.

The gastropods are generally of local occurrence only, most of the records coming from one or two localities, as in the case of Upper Nidderdale where Wilson(1957) has related the localisation to environmental conditions.

The cephalopods are relatively abundant, but most are badly preserved making identification rarely possible. Nautiloids are the most abundant sub-class, but easily the most important individual is the goniatite Reticuloceras circumplicatile group the first goniatite ever to be recorded from this horizon. This with several other of the Cayton Gill Shell Bed fossils collected by the author is now preserved in the collections of the Geological Survey in London.

Libishaw Shales

The Libishaw Shales have yielded a fauna hitherto unknown in this area, but familiar in the succession on Rombalds Moor farther south(Stephens et al. 1942). The fauna is a goniatite/lamellibranch one characterised by Reticuloceras aff. pulchellum and two species of Anthracoceras. The former goniatite is similar in form to one collected from the shales below the Aqueduct Grit in North Wales and referred to an early R 1 horizon(Bisat - personal communication). It ranges in size up to 35 mm. diameter and is characterised by an ornament consisting of thin radial transverse striae which average 4/mm. at all diameters, and are notable for the late appearance of the relatively shallow lingua.

The Scot Gate Ash Marine Band

The fauna of this horizon is a comparatively small one characterised by an abundance of brachiopods and nautiloids. Chonetes is the most abundant genus, the remainder of the fossils being predominantly individual records only. A trilobite pygidium from this horizon closely resembles a specimen of Brachymetopus sp. nov. Da 2680 from the Otley Shell Bed, now preserved in the collection of the Geological Survey, London. It will be seen by comparison of the fossil lists that the fauna of the Scot Gate Ash Marine Band is not unlike the Cayton Gill Shell Bed though much less fossiliferous and conspicuously deficient in some of the brachiopods such as Derbyia gigantea and Schizophoria hudsoni which are a feature of that horizon. The band is not known farther north and must represent the transient return of the marine conditions that gave rise to the Cayton Gill Shell Bed though on a much reduced scale because it is thinner and of more restricted areal outcrop.

Zonal succession

The zonal position of the beds described in this chapter was first considered by Bisat(1924) following his earlier discovery of *Glyphioceras* sp. in the Cayton Gill Beds(1914). The specimens collected by this author were badly preserved but tentatively referred to either *G. striolatum* of *G. glabrum*, an identification which did not greatly assist the interpretation of the zonal succession. These specimens have now unfortunately been mislaid and the exact location of the well sinking from which they came has also been forgotten(Bisat - personal communication) so that the records are of historical interest only. Nevertheless the R 1 horizon suggested by Bisat was confirmed by Hudson's(1939) re-survey of the Simonseat anticline, *Reticuloceras reticulatum* var. being found in the Cayton Gill Shales and *Reticuloceras reticulatum* in the Capelshaw Shales. Subsequent revision by these two authors combined(1942), resulted in a detailed sub-division of the R 1 Stage and the following succession being adopted for the beds at this level in Knaresborough Forest.

	Upper Plumpton Grit
	(Shales with *R. reticulatum* s.l.(Killinghall Brick Pit)
R. reticulatum zone	(Lower Plumpton Grit
	(Shales with *Reticuloceras* sp.(Capelshaw Beck)
	Addlethorpe Grit
R. dubium zone	(Shales with *R. dubium* (Bottom Beck, Spofforth Haggs)
	(Cayton Gill Beds
R. inconstans zone	(Shales with *R. inconstans* group (Redlish Gill)
	(Upper Follifoot Grit
	Follifoot Shales with *H. smithi* and *H. undulatum*

From this it will be seen that the three original zones of the Lower *Reticuloceras* Stage were recognised, viz. *R. inconstans*, *R. eoreticulatum*, *R. reticulatum*, but the more detailed sub-division could not be applied because of the incompleteness of the marine sequence in this area. Farther south on Rombalds Moor Bisat and Hudson(op. cit) claimed that they could apply their six-fold division to the Lower *Reticuloceras* Stage but this was not confirmed by the officers of The Geological Survey(Bradford and Leeds Memoirs), who experienced difficulty in distinguishing species in the middle portions of the stage. The threefold division has therefore been reverted to, though in the Leeds district only the lower and upper zones have been traced. There, the marine shales between the Cayton Gill Shell Bed and the Addlethorpe Grit have been referred entirely to the R. inconstans zone and not to the R. eoreticulatum zone as in Bisat and Hudson's paper, whilst the shales above the Caley Crags Grit have yielded R. reticulatum. The Otley Shell Bed, known only from the Bradford district to the west has been tentatively taken as the base of the R. reticulatum zone which extends to the shales above the Caley Crags Grit.

In Nidderdale goniatites have been found at two levels in the sequence, namely the Cayton Gill Shell Bed and the Libishaw Shales. The forms recorded include R. circumplicatile group from the former and R. umbilicatum and R. aff. pulchellum from the latter, all forms characteristic of the R. inconstans zone. This zone therefore is the only one definitely traced in Nidderdale, though on the basis of the correlation of the Scot Gate Ash Marine Band with the Otley Shell Bed the R. reticulatum zone is also considered to be present. Like the Leeds district (Leeds Memoir) the R. eoreticulatum is not known but is probably represented by the major part of the Libishaw Sandstone. The zonal succession in Nidderdale is therefore as follows:

R. reticulatum zone	(First Brimham Grit
-	(Bewerley Shales containing Scot Gate Ash Marine Band
R.eoreticulatum zone -	(Libishaw Sandstone
	(Libishaw Shales
R. inconstans zone	(Agill Sandstone
	(Cayton Gill Shell Bed
	(Cayton Gill Shales
-	(Upper Follifoot Grit
	Follifoot Shale

Faunal Lists

Cayton Gill Shell Bed

Plant remains, 2, 5, 7, 11

Fucoid markings, 3

Sponge spicules, 3, 11

Crinoid ossicles up to 7 mm. diameter, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17

Fenestella sp., 2, 3, 5, 9, 11, 14
Rhabdomeson sp., 3

Chonetes sp., 3, 4, 5, 7, 8, 9, 11
——— (Plicochonetes) sp., 14, 17
——— (Rugosochonetes) sp., 14, 15

Derbyia gigantea Thomas, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 15, 17
------- hindi Thomas, 3, 9, 15, 16, 17
------- sp., 2, 3
Orbiculoidea nitida (Phillips), 2, 3, 7, 14
----------- ------ var. ingens Demanet, 2, 7, 14
Productus (Buxtonia) scrabiculus (Martin), 15
--------- (Dictyoclostus) hindi Muir Wood, 2, 3, 4, 5, 6, 7, 12, 14, 15, 17
--------- ------------ cf. pugilis Phillips, 17
--------- (Eomarganifera) sp. 7, 15
--------- (Productus) carbonarius de Koninck, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11
12, 14, 15, 17
--------- --------- productus (Martin), 2, 3, 5, 7, 8, 10, 11
--------- --------- sp., 1, 4, 16
Productid spines
Rhipidomella michelini (Leveille), 3, 5, 9
Schizophoria hudsoni George, 1, 3, 4, 5, 7, 8, 9, 10, 11, 12, 14, 15, 17
------------ resupinata (Martin), 3, 15
------------ sp., 1, 2, 7, 15
Spirifer bisulcatus J. de C. Sowerby, 3, 15
-------- sp., 3, 15
Spiriferellina octoplicata (J. de C. Sowerby), 3, 8, 10, 16
-------------- sp. nov., 15, 17
Striatifera striatus (Fischer), 15
Tylothyris laminosa (McCoy), 7, 10

Amusium concentricum Hind, 13
Aviculopecten interstitialis (Phillips), 2, 3, 4
------------- -------------- Hind non Phillips, 2
------------- murchisoni (McCoy), 11, 14, 15
------------- cf. semicostatus (Portlock), 1
------------- stellaris (Phillips), 3, 5
------------- sp., 2, 3, 7
Dunbarella tesselatus (Phillips), 2, 3, 6
Edmondia maccoyi Hind, 2, 11
-------- rudis McCoy, 2, 7
-------- sulcata (Phillips), 5, 7, 10, 14
-------- sp., 2, 3, 7

Grammatadon cancellatus (Martin), 3, 8, 15
----------- regularis Hind, 11
----------- squamifer (Phillips), 11
----------- sp., 3, 5, 15
Leda attenuata (Fleming), 3
Leiopteria laminosa (Phillips), 3
Limatulina sp., 3
Limipecten dissimilis (Fleming), 15, 16
Modiola sp., 5
Myalina sp., 14, 15
Nuculopsis gibbosa (Fleming), 11
Pinna mutica McCoy, 13
Posidoniella elongata (Phillips), 3
------------ laevis (Brown), 3, 7
------------ cf. pyriformis Hind, 3
Protoschizodus axiniformis (Portlock), 9

Pseudamusium sp., 5
Sanguinolites plicatus (Portlock), 5
------------- tricostatus (Portlock)
------------- V scriptus Hind, 3
Scaldia benedeniana de Ryckholt, 11
------- fragilis de Koninck, 11

Bellerophon sp., 3, 7, 8
Coleolus reticulatus Demanet, 11
Loxonema sp., 7, 8, 9, 11
Macrocheilina sp., 9
Murchisonia sp., 15

Reticuloceras circumplicatile group (Floord), 15
Pseudometacoceras sp., 2
Stroboceras sp., 3
Temnocheilus sp., 2, 3
Orthoconic nautiloid indet., 8

Fish scales and teeth.

Index of localities for the above

1.	Lul Beck	136731
2.	Ramsgill Beck	071691
3.	Sigsworth Grange Quarry	151687
4.	Fosse Gill, Bewerley	157644
5.	Gravel Pit, Sawley	264678
6.	Righouse Gill	197654
7.	Whitehouses Quarry	192650
8.	Hazel Hill Quarry	233685
9.	Spa Gill, east of Hind House	258685
10.	Banks of River Skell, Fountains Abbey	267680
11.	Old Quarry, Brimham Rocks	217651
12.	Old Quarry, Cayton Gill	277633
13.	Old Quarry, Cayton Gill Farm	289625
14.	Baal Ridge Quarry	165623
15.	Prospect Farm Quarry, Hartwith	213615
16.	Low Wood Quarry	201653
17.	Maud's Farm Quarry	207639

Libishaw Shales

Plant remains, 1, 2, 3

Lingula mytiloides J. Sowerby, 2

Dunbarella rhythmica (Jackson), 2
Posidonia sp., 2
Posidoniella variabilis Hind, 2, 3
------------ sp.,

Anthracoceras cf. paucilobum (Phillips), 2, 3
------------- vanderbeckei group, 2, 3
Metacoceras sp., 1

Orthoconic nautiloid indet., 2
Reticuloceras aff. *pulchellum* (Foord), 1, 2, 3
------------- *umbilicatum* Bisat and Hudson, 1

Fish scales and teeth, 1, 3

Index of localitites for the above

1.	Pencil Dike, Fell Beck	205659
2.	Lurk Beck	236625
3.	Stream by Hardgate Farm, Bishop Thornton	267629

Scot Gate Ash Marine Band

Plant remains, 1

Annelid trails, 1

Crinoid ossicles up to 4 mm. diameter, 1, 2

Fenestella sp., 1

Chonetes sp., 1
-------- (*Plicochonetes*) sp., 1
-------- (*Rugosochonetes*) sp., 1
Productus (*Dictyoclostus*) *hindi* Muir Wood, 1, 2
--------- (*Eomarganifera*) sp., 1
--------- (*Productus*) *carbonarius* de Koninck, 1, 2
--------- ---------- *productus* (Martin), 1
Spirifer sp., 2

Edmondia sp., 1
Limatulina sp., 1
Protoschizodua sp., 1

Bellerophon sp., 2

Ammonellipsites sp., 1
Discoceras sp., 1
Stroboceras sp., 1
Orthoconic nautiloid indet., 2

Brachymetopus sp. nov. 2

Index of localities for the above

1.	Scot Gate Ash - Drayman's Field Quarries	167660
2.	Middle Tongue Valley	148641

CHAPTER X
THE BRIMHAM GRITS

The term "Brimham Grits" was introduced to geological literature by Phillips(1836) in his painstaking account of the Pennine rocks. Originally designed as a group term it appears to have covered all the Carboniferous strata in this area above the Lower Follifoot Grit, though the trend of evidence unquestionably connects the term with the extensive outcrop of coarse sandstone at Brimham Rocks. The Geological Survey modified this group definition and included only those beds above the Libishaw Sandstone, thus excluding the Follifoot Grits and the Cayton Gill Shell Bed, though nevertheless still retaining no less than 8 beds of sandstone. Succeeding authors have tended to follow the Survey's lead and maintain a group name, at the same time introducing local names for individual beds. Thus Hudson(1939) designated the highest bed of coarse felspathic sandstone at Simonseat, the Comb Hill Grit and this term was retained by Jones(1943) and Dunham and Stubblefield(1945), working in adjoining areas. Wilson(1957) however, reverted to the original term"Brimham Grits" and proposed a sub-division on the basis of appended numerals, ie the First and Second Brimham Grits. His terminology is adhered to in this account for the lowest two beds of coarse sandstone, but higher beds in the succession having no connection with Brimham Rocks are not included in the classification, and therefore given local place names.

The age of the rocks at this level was for some time in doubt owing to a mistaken correlation by the officers of The Geological Survey, recorded by Dakyns(1890). They considered the Kinderscout Grit of Yorkshire to be represented by all the beds between the base of the Grassington Grit Group and the top of the Red Scar Grit, whilst the First Brimham Grit was equated with the 3rd. Grit of Lancashire. Zonal sub-division on the basis of goniatites, suggested first by Wheelton Hind and later elaborated by Bisat(1924) quickly corrected this impression and showed that the Brimham Grits belonged to the Lower Reticuloceras Stage of the Namurian, ie. were equivalent to the Kinderscout Grit. Further work(Bisat & Hudson, 1942) has now improved the classification and indicated a position in the R. reticulatum zone for the First and Second Brimham Grits.

The relation of the First Brimham Grit to the underlying rocks.

The primary geological mapping of this area was conducted by The Geological Survey and on their published maps no evidence is forthcoming to suggest in any way that they considered the First Brimham Grit to be other than conformable on the underlying rocks throughout the district. Nor indeed was this position questioned by succeeding workers in the area, until Walker (1952) drew attention to the unconformable relations at the base of the First Brimham Grit discernible in the vicinity of Pateley Bridge. This author maintained that at Pateley Bridge several hundred feet of strata separated the Cayton Gill Shell Bed and the First Brimham Grit, whilst less than 3 miles to the east at Brimham Rocks only 10 feet separated the two horizons. This change he held to indicate not rapid southerly thinning, but an unconformity which he was further able to trace at Simonseat and also in Wharfedale, obviously therefore of more than local effect.

The present study has not only amplified the conclusions of Walker in Nidderdale, but in addition it has shown that the unconformity extends some distance to the east also, and can be related to a change that takes place at the line of the North Craven Fault. Fig.13 is an isopachyte map of the beds between the Cayton Gill Shell Bed and the First Brimham Grit and attempts to depict the nature of the sub-First Brimham Grit surface east of Nidderdale. In this however it is not completely accurate because of local variations in the thickness of the strata and therefore an overlay has been incorporated, indicating the disposition of the major stratigraphical divisions. From this it will be seen that a complete succession of the beds between the Cayton Gill Shell Bed and the First Brimham Grit occurs at Pateley Bridge and Skell Banks, near Fountains Abbey, inter-divisional relations in both cases being conformable throughout. South of that Pateley Bridge - Fountains Abbey line however, a marked and rapid cutting out of the underlying strata takes place at the base of the First Brimham Grit, perhaps most easily demonstrated in Nidderdale. At Pateley Bridge for example, 240 feet of sediments separate the Cayton Gill Shell Bed and the First Brimham Grit, at Raikes the thickness is only 60 feet, at Low Laithe 15 feet, whilst at Maud's Farm, Brimham Rocks it is just over 10 feet. Thus in a distance of less than 3 miles, 230 feet of strata have been cut out by the First Brimham Grit.

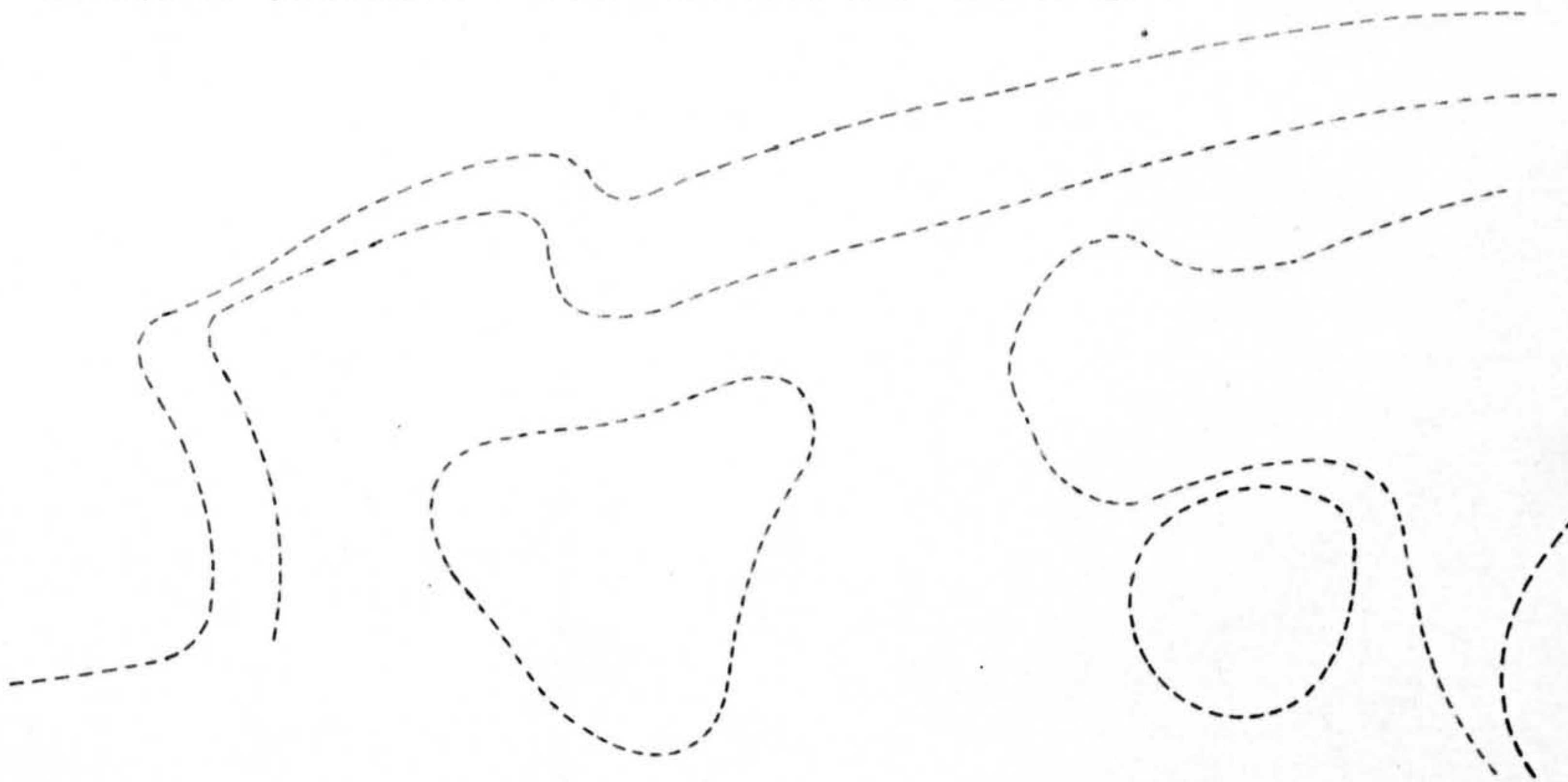
In addition to this cut out of underlying sediments, evidence is also forthcoming to indicate that locally the First Brimham Grit rests on

-------- Interpreted junction of First Brimham Grit with base of Bewerley Shales.

-------- Interpreted junction of First Brimham Grit with base of Libishaw Sandstone.

-------- Interpreted junction of First Brimham Grit with base of Libishaw Shales.

-------- Interpreted junction of First Brimham Grit with base of Agill Sandstone.



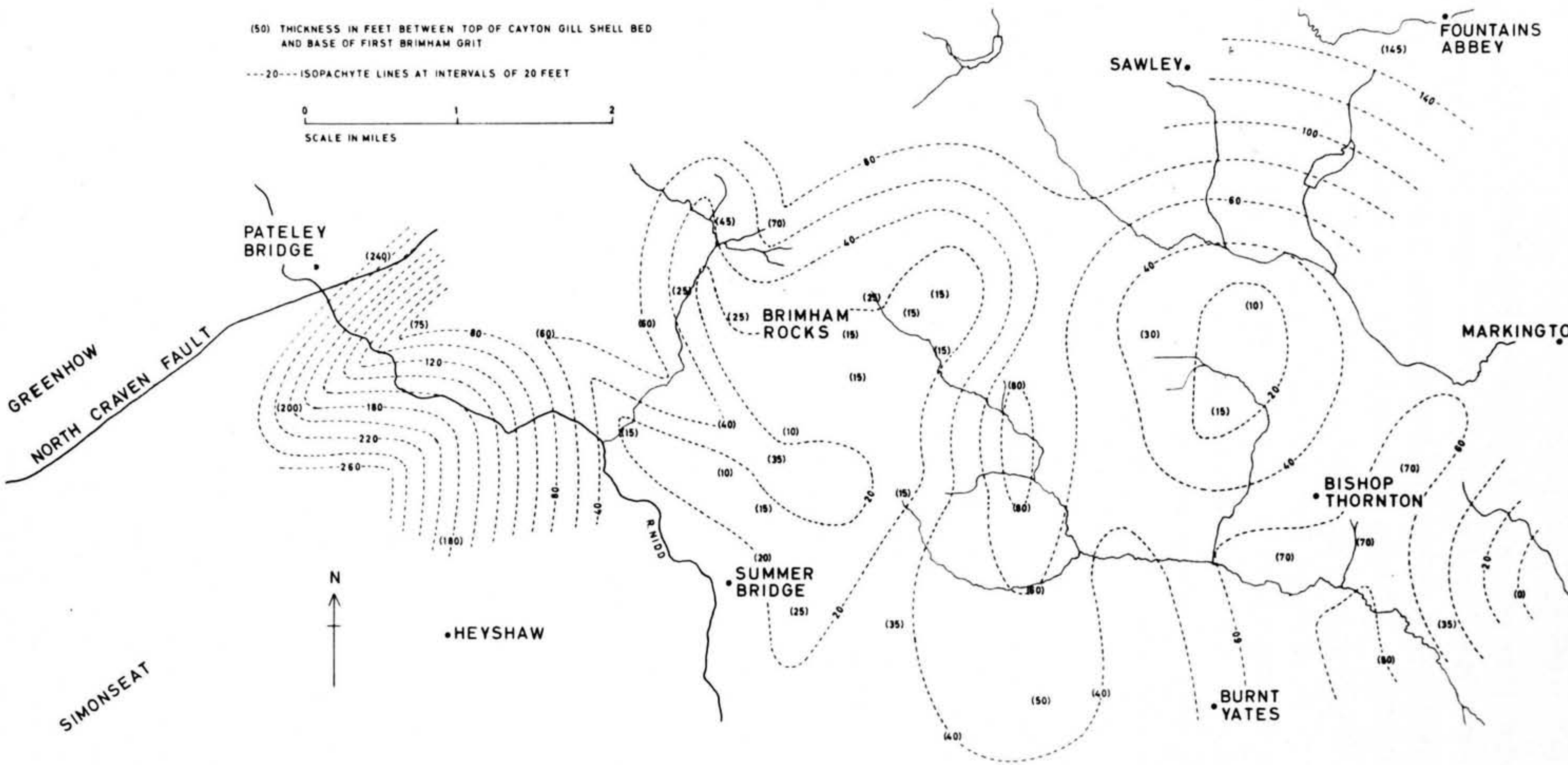


Figure 13. Isopachyte map of the beds between the top of the Cayton Gill Shell Bed and the base of the First Brimham Grit illustrating the topography of the pre-First Brimham Grit land surface.

folded strata. For instance, east of Bishop Thornton on the western side of Cayton Gill, the First Brimham Grit can be seen to transgress from the Libishaw Sandstone to the Cayton Gill Shell Bed in just over a mile and although both the First Brimham Grit and the underlying sediments are folded on synclinal axes, features and stratal dips indicate that the fold axes are not coincident and must therefore represent differing periods of deformation. The same conclusion is also suggested by the closed synclinal structure between Brimham Rocks and Bishop Thornton on Fig.13, for whilst on a reconstructed topographic map of this kind, what appear to be domes may represent hills and apparent synclines may be valleys, elongated closed basins, unless the product of subsequent tilting, must be due to folding, because in the present setting they are not possible topographic forms. The inference is therefore, that not only does the First Brimham Grit rest on an irregular surface, but that the underlying rocks were folded prior to its deposition.

These unconformable relations can be explained in at least two ways:- i) simultaneous deposition and deformation producing areas of negative deposition, or ii) deposition succeeding uplift and erosion, both possibly accompanied by a certain amount of erosive channelling at the base. Unfortunately however, no critical evidence is available to interpret satisfactorily the geological history and all that can be said is that south of the North Craven Fault the First Brimham Grit rests with unconformity on the underlying sediments. Nevertheless it is significant that north of the North Craven Fault no transgressive relations at the base of the First Brimham Grit occur, other than those tentatively hinted at by Wilson(1957) near High Ellington. South of the fault however they become apparent and can be detected in Nidderdale, Wharfedale, Simonseat and Clapham(Walker,1952). A precise knowledge of the history of that fault is therefore of supreme importance to the problem. This is really more appropriate to Chapter XIII, suffice it to say that in this area valuable new evidence is forthcoming to indicate movement of the fault during R I times. It is known for instance that in Nidderdale a marked thickening of the First Brimham Grit from 30 feet to 400 feet takes place at the line of the North Craven Fault, implying contemperaneous movement along the fault during the deposition of that bed. Unfortunately exposures of the beds below the First Brimham Grit are not sufficiently good to say whether thickening takes place in them also, but the available evidence on Knott Side and Fosse Gill, both half a mile from the fault, does not favour such a suggestion. Moreover, no comparable thickening at this level was noted by Dunham and Stubblefield(1945) in the adjoining ground of Greenhow so that it seems reasonable to conclude that it is confined to the First Brimham Grit only. In this connection, a borehole at Pateley Cemetrey(Appendix), 100 yards south of the fault, passed through 250 feet of beds, which from the log appear to be of post-Follifoot Grit lithology. The increased dip of the beds adjacent to the fault however, makes interpretation of the borehole log open to considerable innaccuracies and in the absence of cores, the record is discounted. If therefore this thickening is confined to the First Brimham Grit, it means that one period of movement of the North Craven Fault commenced shortly after the opening stages of deposition of that bed and continued until the end of the deposition of that formation, the terminating date being suggested by the fact that the basal feature of the Second Brimham Grit passes uninterruptedly over the projected line of the fault and features at a lower level in the Brimham Shales also appear to do the same. Prior to this however, earth movements took place south of the fault producing unconformable relations at the base of the First Brimham Grit, the fault presumably acting as a "hinge line".

Stratigraphy

The Brimham Grits are a stratigraphical division with a wide areal outcrop in this district, most of which occurs east of Nidderdale. Throughout, they are divisible into three major units, the First Brimham Grit, the Brimham Shales and the Second Brimham Grit, whilst locally the First Brimham Grit is further sub-divided by a shale parting near the top. For convenience and clarity therefore they will be described in their major units, here placed in ascending order.

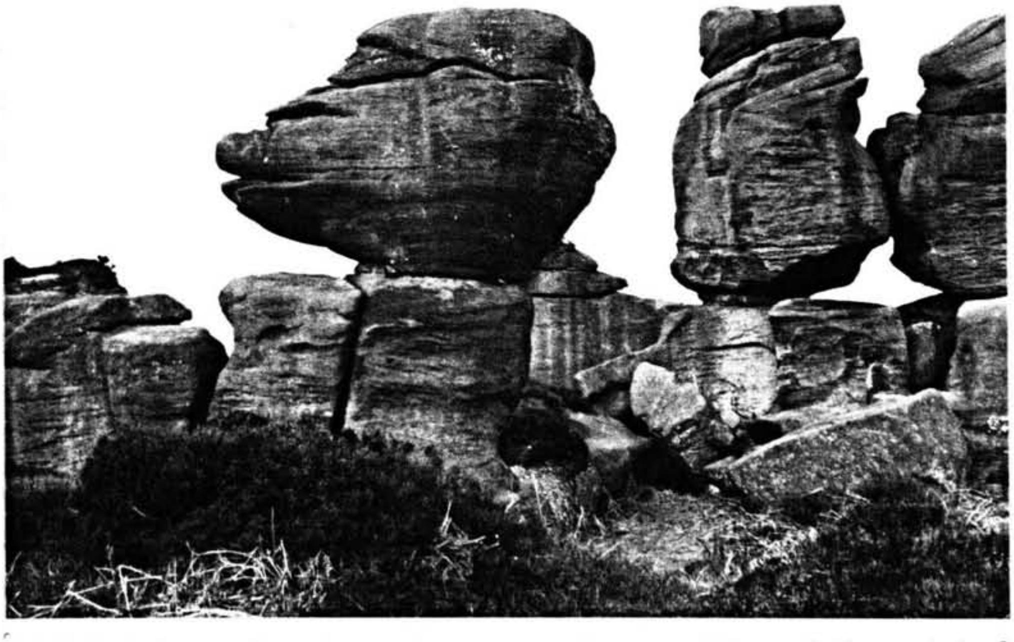
First Brimham Grit

The First Brimham Grit is persistent throughout the area, ranging from 30 feet to 400 feet in thickness and composed largely of coarse felspathic sandstone. It can be traced as a thin band down the eastern flank of Nidderdale to Pateley Bridge averaging 35 feet in thickness with the exception of a local thickening to 80 feet on Sigsworth Moor. To the east it passes underground, reappearing in the valleys of the Laver and Skell where it seems to have thickened to approximately 100 feet and developed an impersistent shale parting 15 feet thick near the top. At Pateley Bridge in Nidderdale the bed is displaced by the North Craven Fault and there undergoes a remarkable and

A

Brimham Rocks from the south. The locality is famous for the bizarre forms assumed by this extensive outcrop of the 1st. Brimham Grit. The origin of these forms is thought to be closely associated with weathering under glacial conditions.

B



The Baboon's Head, Brimham Rocks. The false bedding of the original rock has been exploited by weathering processes to produce these life like images in stone.

unprecedented increase in thickness from 30 feet to 400 feet, indicating that the fault was in action during the deposition of the bed. Southwards this prodigious thickness decreases rapidly and in the south east 100 feet is an average figure, but this decreases still further to 45 feet towards Ripley where the formation passes out of the area.

The rock is dominantly a coarse, pebbly felspathic sandstone, locally a granular conglomerate made up of pebbles of quartz and felspar. In the pebbly sandstones, quartz is overwhelmingly the most abundant type of pebble, but felspar is also important and granite and chert pebbles are known. Generally they average half an inch in diameter, none as large as those described by Gilligan(1919) from the Middle Grits of the Aire valley ever having been seen. The composition of the rock varies considerably, an average calculation being:- Quartz 81·02%, Microcline and orthoclase 12·80%, Plagioclase 1·13%, White mica 1·54%, Biotite 2.45%, Clay minerals 1·03%. Of the felspars microcline is easily the most important and may locally constitute as much as 21% of the rock; the other felspars are much less impressive numerically and the rock is according to Pettijohn(1949) a felspathic sandstone, not an arkose.

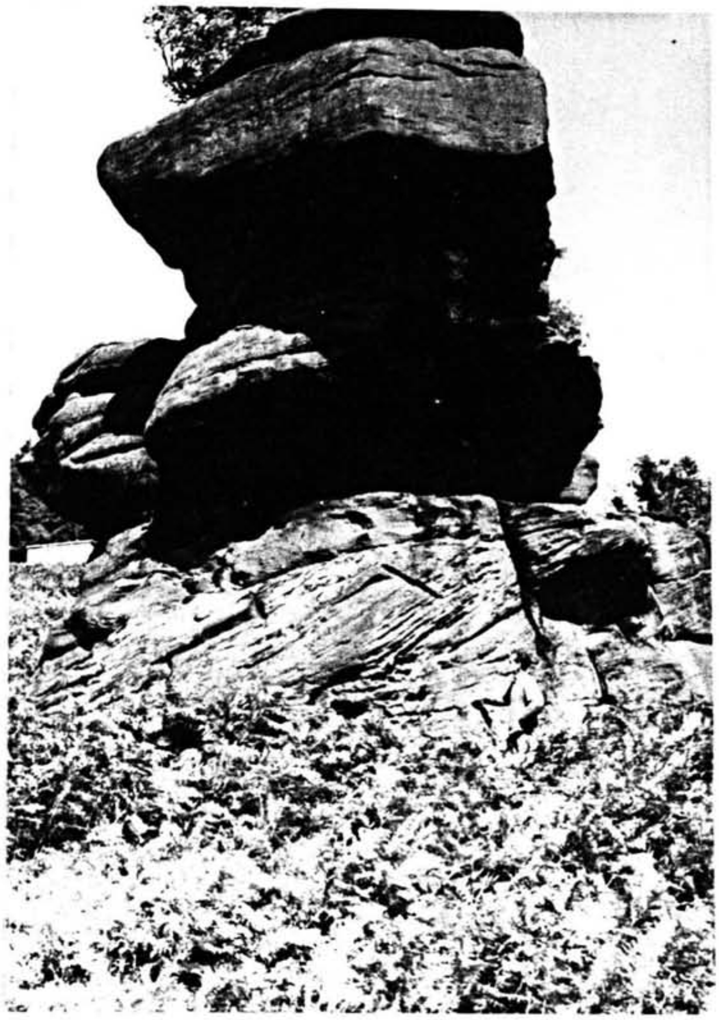
Upwards the lithology changes and in places about 40 feet above the base, the bed becomes a medium grained quartzitic sandstone, occasionally ganisteroid and rich in plant remains. In two localities this bed contains worn fragments of lamellibranchs near the top, which, as will be seen later are of importance in establishing the line of the North Craven Fault. It is of variable thickness, as far as can be estimated never exceeding 30 feet in thickness and is overlain by a thin impersistent shale parting, 15 feet thick which contains chalybite nodules and thin sandstone lenses. This bed passes upwards into coarse felspathic sandstone again, but it must be emphasised that in parts of the ground, eg. Brimham Rocks, neither the shale parting nor the underlying sandstone appear to be present, the First Brimham Grit there consisting almost entirely of coarse felspathic sandstone.

A notable characteristic of the horizon is the persistent occurrence of a bold basal feature, frequently accompanied by open scars of coarse sandstone near the base. Upwards, the durable nature of the sandstone is responsible for its tendency to form extensive areas of exposed crags, the most famous of which is Brimham Rocks (Plate XV). Here, the excellent foreset bedding and graded bedding have been exploited by weathering agencies to produce bizarre and grotesque forms sculptured in coarse sandstone. A further development in the weathering process is the differential removal of some of the crags, leaving isolated stacks such as London Crag (Plate XVI) which rises 30 feet above the surrounding ground. The weathering agency responsible for this penetrating erosion is now considered to be Pleistocene wind action, effectual after the Main Dales glaciation when the inter-stream areas were free of ice(Hudson & others, 1938). A recent excursion conducted by the Yorkshire Geological Society(Y.G.S. Pamphlet 160) set out to examine the weight of support favouring wind erosion alone, but unfortunately the author was not present on this occasion and the findings of the excursion were not published. However it is interesting to note that today no credence is given to the explanation proposed by Tute(1868) and reproduced by Davis and Lees(1878) that the Rocks represent old sea stacks in close proximity to a former shore line, if for no other reason than that the supporting evidence for marine erosion is completely absent. Another interesting feature of the First Brimham Grit seen on weathered surfaces is fluting, due to the differential hardness of individual bands. Very often this can be related to mineralogically distinct bands, eg. those with a higher quartz content, or to grading and sorting, producing bands of differing grain sizes. "Knot structure" or the formation of rounded hollows on the surface is also common and appears to be due to patchy silica cementation of the original rock.

The First Brimham Grit has been extensively quarried for millstones in this area, notably in the neighbourhood of Pateley Bridge where the impressive quarries of Guisecliff overlook the town. However, this industry is now completely defunct, as is also the use of the bed as a building stone, for which it was renowned as a result of its use in the construction of Fountains Abbey. Many of the quarry faces (Plate XVII) rise sheer and illustrate another characteristic of the formation, namely the absence of regular bedding planes and the presence of well developed joints.

Brimham Shales

The Brimham Shales are on the whole a very poorly exposed horizon. Indeed, north of Pateley Bridge they are nowhere seen at the surface in Nidderdale, though marshy slacks and the good basal feature of the Second Brimham Grit provide some control over thickness variations. In the extreme north the bed is 80 feet thick, but thins rapidly to 50 feet just south of Lulbeck Crags. Thereafter in a southerly direction, thickening to 90 feet



London Crag, Warsill(228651). This large, isolated crag of the 1st. Brimham Grit, nearly 30' high shows the differential resistance of individual beds to weathering processes.

takes place, but this is only local because on Light Hill the bed is 30 feet thick and retains this average thickness to Pateley Bridge.

The Brimham Shales do not appear to be affected by the North Craven Fault, passing uninterruptedly over the line of dislocation without change in thickness. They are exposed in several quarries east of Pateley Bridge and occur in the form of two outliers near Sawley. Northwards they are present as sinuous inliers in the valleys of the Skell and Laver whilst in the extreme south east they crop out again on the western flank of Cayton Gill. Throughout this area they average 30 feet in thickness, but in Skell Gill they thin to their minimum thickness of 15 feet.

The lithology ranges from grey sandy shale to grey mudstone with thin intercalated beds of flaggy sandstone, in one instance forming a series of interbedded sandstones and shales. No trace of the marine horizon known farther south of Rombalds Moor at this level (Stephens and others, 1942) has been found, or of the Lingula horizon present to the north(Wilson, 1957), but this may well be the result of incomplete exposure rather than non-occurrence of the horizon.

Second Brimham Grit

In many respects the Second Brimham Grit bears such close resemblance to the First Brimham Grit that to describe it in detail would be to incur needless repetition. It is composed predominantly of coarse sandstone, which over the whole of the area shows a ready division into a lower part of pebbly felspathic sandstone, indistinguishable from the bulk of the First Brimham Grit in lithology and an upper part of quartzitic sandstone. The lower part, like the First Brimham Grit forms a good basal feature accompanied by a line of prominent crags, and tends to form large areas of exposed crags, eg. Huller Stones on Eavestone Moor. These crags weather in a manner closely comparable to that of the First Brimham Grit, though not quite so impressively and show similar sedimentary structures also.

Above this lower part, which may be up to 50 feet in thickness, a shale parting is locally present and serves to separate the upper part of quartzitic sandstone from the lower part of felspathic sandstone. This upper part is similar to the Follifoot Grits in its high quartz content and like those formations tends to be ganisteroid in parts, notably so towards the top. Its main occurrence is as pavement crags and scattered blocks in the moor surface, many of which are present on Dallow Moor.

The formation is only known east of Nidderdale, where it forms an extensive dip slope on the high ground stretching from Fountains Earth Moor to Eavestone Moor. The beds are downfaulted to the east, and are next seen in the valley of the Laver, where they dip gently to the east and eventually pass underground near Laverton. They reappear at the surface farther east however on the eastern limb of a syncline and are exposed in Spa Gill Wood. Two other areas of outcrop also occur, both faulted outliers, one near Smelthouses and the other north west of Ripley. The division averages 70 feet in thickness in the north on Fountains Earth Moor, thinning to 40 feet on Dallow Moor, but this is only local, for elsewhere in the area it is of the order of 70 feet thick.

Details

First Brimham Grit

Nidderdale, north of Pateley Bridge - The most northerly exposure of the First Brimham Grit occurs on Fountains Earth Moor just south of Sypeland Crags, where a bold feature coincides with its base and the rock outcrops in Lul Beck Crags (139726). The crags are nearly 25 feet high and composed of massive, pebbly felspathic current bedded sandstone. The bed averages 35 feet in thickness in this vicinity and can be traced southwards by a good basal feature to Sigsworth Moor, gradually thickening to 80 feet. This is only a local area of subsidence however, because it thins quickly to 35 feet farther to the south. Blocks of pebbly felspathic sandstone are common along the outcrop here and on Sigsworth Moor the sandstone crops out at the surface in the form of crags. Sigsworth Crags (143698) a short distance to the south are a prominent landmark in this neighbourhood and made up of coarse pebbly sandstone current bedded on a large scale. The crags crop out intermittently for more than half a mile and illustrate well the differential weathering that takes place in these beds producing a fluted effect.

Near Dauber Gill the beds are displaced by a fault and continue to the south forming a series of basal crags composed of coarse felspathic sandstone. The rock here also, has a fluted appearance and shows wavy bedding and "knot structure". Southwards below Howson Ridge a good basal feature runs to Yeadon Farm and is there displaced by a fault throwing to the south. Crags of coarse felspathic sandstone occur on High Bishopside (158673), whilst farther south above Scot Gate Ash Quarries, the bed has been quarried in several localities. In this neighbourhood the division is about 40 feet thick, but at the line of the North Craven Fault it undergoes a remarkable thickening to 400 feet. The basal feature is well developed here and can be seen to be displaced about 400 feet to Panorama Walk(161655) whence it rises rapidly towards Blazefield accompanied by a line of crags. Exposures here are unfortunately far from complete but an Old Quarry above St. Mary's Church (165656) reveals steeply dipping (25°) coarse felspathic sandstone and a short distance to the east blocks of massive ganisteroid quartzitic sandstone lie scattered about on the hillside. The exact interpretation of the remainder of the succession is very much bound up with the location of the North Craven Fault and as discovered by earlier workers this is far from plainly straightforward. The fault can be traced from the House of Rest(150651) on the Greenhow Road across the valley of the Nidd to an Old Quarry above St. Mary's Church(165656). Thereafter its course is dependent on the interpretation placed on blocks of medium grained quartzitic sandstone found in the Old Quarry, north east of Knott village(170656). These blocks, not unlike the Libishaw Sandstone in lithology contain occasional fossils of the Aviculopecten type suggesting prima facie that they are indeed the upper beds of the Libishaw Sandstone. However, beds of an identical lithology and fauna occur in a small quarry west of Fosse Gill(150634) in the midst of an incontrovertible outcrop of the First Brimham Grit, indicating that upwards the First Brimham Grit becomes a medium grained quartzitic sandstone in which occasional fossils occur (the alternative explanation of the beds west of Fosse Gill is a triangular faulted inlier - an explanation not only without supporting field evidence, but an unlikely geological condition on this scale). If this interpretation is accepted, ie. that the beds in the Old Quarry north east of Knott are in fact First Brimham Grit, it means that the line of the North Craven Fault lies between Drayman's Field Quarry and the Old Quarry, running in a north easterly direction. A further change that takes place across the North Craven Fault is the incoming of a thin bed of shale near the middle of the formation. The evidence for this is only indirect, but the combination of a feature and line of springs suggest the probability of such an horizon being present.

The First Brimham Grit is extensively quarried between Pateley Bridge and Blazefield, the upper beds in Prospect Quarry(175657) and the lower beds near Blazefield. In the former quarry a Corporation rubbish tip is rapidly obscuring the old face, but the following section was measured here:

10' 1" grey micaceous shale

28' 10" coarse massive felspathic sandstone - slickensided along joint faces.

In the Old Quarry, Blazefield(177653) approximately 25 feet of coarse, massive felspathic sandstone are exposed and another quarry 560 yards to the E.S.E. reveals 18 feet of coarse massive pebbly felspathic sandstone. A characteristic of the First Brimham Grit is the persistent development of a good basal feature and this can be seen at Crag House(179651), continuing uninterrupted for nearly a mile to the east. The formation undergoes a notable thinning in this direction, from 400 feet near Pateley Bridge to 200 feet near Wilsill and still further to 120 feet near Fell Beck. Just north of Whitehouses Farm(193653) an E - W fault displaces the beds to the north, the lower strata cropping out as blocks by Fell Beck House(195654). The beds also form crags 20 feet high in Fell Beck itself and above the stream(Knoxstone Crags) revealing the current bedded, pebbly nature of the sandstone. Another quarry by the side of the Ripon Road, below Knoll Top Farm(198660) is distinctive because here the rock is more of a quartzitic sandstone than a felspathic one, indicating a decreasing felspar content in the bed about 40 feet above the base. This is also borne out by the large pavement crags that crop out 700 yards N.W. of this farm and which consist of pebbly quartzitic sandstone. East of these crags in Fell Beck itself(196665) the coarse felspathic sandstone so characteristic of the First Brimham Grit can be seen resting on the Libishaw Sandstone, indicating transgressive relations at the base of the formation. This coarse sandstone also crops out farther upstream in the bed of the stream and as crags on the side.

West of Fell Beck the shale parting in the middle of the formation spreads out as a thick band, mainly due to the dip slope nature of the outcrop. Above this parting, a higher bed of coarse felspathic sandstone crops out at the surface in the form of crags. Farther north near South Oaks Farm stratigraphical interpretation is very difficult because of the incompleteness of the exposure, but proceeding on the assumption that Midwife Stones(180673) is the Second Brimham Grit, the Old Quarries 200 yards to the S.E. reveal the upper beds of the First Brimham Grit. The lithology is a medium grained thinly bedded sandstone, seen again in Far Beck to the north, here underlain by a parting of shale, also exposed in Near Beck.

East of Fell Beck the beds are displaced by a fault and occur in the form of a faulted inlier. The First Brimham Grit caps Bale Hill(210663) and is again characterised by a prominent basal feature and numerous blocks of coarse sandstone on the surface. The formation was formerly quarried by Crossgates(212669), but these quarries are now completely overgrown and only scattered blocks of coarse felspathic sandstone remain in the tip.

South of this point the bed is next seen at Brimham Rocks, perhaps the most famous outcrop of this formation. The Rocks cover an area of more than 50 acres and provide an excellent opportunity for a study of the local variations in the succession. Coarse felspathic sandstone is the consistent lithological type, but throughout variations in grain size and current bedding have been exploited by weathering agencies to produce the many bizarre forms for which this locality is renowned. The exact origin of the Rocks has for long been uncertain, but today little support is given to the thesis propounded by Tute(1868) that the Rocks represent old sea stacks, in close proximity to a former shoreline. In fact the visit of the Geologists Association field excursion in 1938 (Hudson & others, 1938) evoked no comment on this explanation, but rather favoured Pleistocene wind action as the sculpturing force, if for no other reason than that the supporting evidence for marine erosion is completely absent. This proposal is that most current today, the time of the wind action being taken to post-date the Main Dales Glaciation, ie. when the inter-stream areas had lost their ice cover.

Considerable faulting has taken place in this vicinity and the First Brimham Grit is displaced several times, first to the south by High Wood Farm(208644). From there a good basal feature runs southward past Maud's Farm and round the southern end of Graffa Plain, the bed here resting on the Agill Sandstone. To the west the formation is displaced three times, in each case a good basal feature accompanied by crags being evident. The first fault is 300 yards west of Maud's Farm, the next 730 yards west of the Farm. The small outcrop west of this latter fault has been quarried for millstones and in the face, 25 feet of coarse felspathic sandstone can still be seen. Farther west still, above Low Laithe the third fault brings in the First Brimham Grit in Knox Wood. The bed is about 150 feet thick here and again overlies the Agill Sandstones. It consists mainly of coarse felspathic sandstone, blocks of which crop out at the surface due east of the Little Mill and crags of which occur higher up in the wood. These crags(192639) stand immediately above a small stream trench incised in grey shale, indicating the persistence of the shale horizon to the south.

On Hartwith Moor the surface rock is almost entirely First Brimham Grit, the base forming a good feature on the hillside above Summer Bridge disposed in synclinal form. Above this blocks of coarse felspathic sandstone are fairly common in the fields whilst Hartwith Crags are a prominent landmark composed of the same lithology. Near Prospect House Farm(215632) a small quarry indicates that there the First Brimham Grit consists of medium grained felspathic sandstone with carbonaceous flecks. 500 yards E.N.E. of this point by the side of the Burnt Yates road the normal lithology of coarse felspathic sandstone is again evident in a disused quarry. This latter quarry is separated by a fault from Burtree Hill to the north, a small outlier of the First Brimham Grit resting on the Agill Sandstone.

Farther north another outlier occurs at Riva Hill, a good basal feature being developed here as well as numerous blocks of coarse felspathic sandstone on the surface. Due north of this are the Klondyke Quarries(222659), originally commenced for the production of millstones. That part of the quarry south of the Warsill road reveals a consistent lithology of coarse felspathic sandstone throughout the face, 33 feet 6 inches in height. In the quarry north of the road, higher beds in the succession are seen and here the following succession was measured:

1' 11"	shale
6½"	medium grained felspathic sandstone
7' 3"	shale
23' 8"	coarse felspathic sandstone

The outcrop of the formation spreads out north of this quarry and forms much of High Moor. Crags and blocks of coarse felspathic sandstone are fairly common in the old forest, and a number of old quarries also exist, confirming the consistency of the lithology throughout the area.

North of the moor Eavestone Lake(Pl.XXIV) is a picturesque beauty spot, originally planned as a reservoir for Grantley Hall. The lake, a former glacial lake drained by a spillway leading into Picking Gill is flanked by bold crags of the First Brimham Grit. The rock is very coarse here, locally a granular conglomerate and shows fluting and "knot structure" besides well developed jointing. It extends as crags 40 feet high some distance down Hungate Gill to the east where it is faulted against the Upper Follifoot Grit, whilst south of the lake(229678) a line of crags rise steeply in Fishponds Wood.

A quarry in this same bed occurs by the mouth of the overflow channel overlooking the lake and other quarries also are situated a short distance to the south, beyond the Ripon road. These quarries, now largely overgrown reveal the pebbly well jointed nature of the sandstone, 20 feet of which are seen here, but more than 100 feet of which were penetrated by a borehole 700 yards to the W.S.W.(Appendix).

Crags of the formation extend down both sides of Picking Gill, well seen just above the Low Fish Pond(237667) where they are composed of finer grained sandstone. This finer grained bed has been quarried below the Fish Pond and passes downwards into the normal coarse sandstone, whilst from the stream descending from the west at Batterton Bridge it can be seen that it passes upwards into coarser sandstone also. Higher up the stream on the moor, two thin shale partings 6 inches and 8 inches thick respectively occur, neither of which can be traced in a north or south direction, though farther south between Jeffrey Crags and Rabbit Hill(233655) the flat nature of the ground suggests the continuation of the shale horizon, but this cannot be proved.

In the neighbourhood of Warsill a number of Crags appear, particularly in the wooded hillside of Warren(227654) and in Jeffrey Crags to the east. These crags, some of which are isolated and rise to 40 feet in height(Plate XVI) extend northwards and link up with the others that occur on High Moor. The rock is again pebbly and felspathic, fluted on weathered surfaces and frequently showing graded bedding. To the south the base of the formation forms a spring line by Middle Farm(227651) and this can be traced southwards to South Farm where a line of crags occur on the side of Shaw Beck, faulted against the Upper Follifoot Grit.

Eastwards the base of the formation can be seen in a stream by Low Farm(235650) and above this Rabbit Hill contains numerous blocks and crags of coarse felspathic sandstone. Pavement crags of this lithology occur farther east also in the rough wooded ground adjacent to Hebden Wood House Farm(244654) where the rock is a medium grained quartzitic sandstone. The basal beds of coarse felspathic sandstone can again be seen in Calf Haugh Wood(243658) to the north, whence they are displaced northwards by a fault.

South of this point, boreholes at Hebden Wood House Farm, Volla Farm, Gill Moor Farm and High Gill Moor Farm all passed through sandstone at the surface which is referred to this horizon. The upper beds in the British Petroleum Company's Sawley borehole(Appendix) also appear from their lithology to belong to this formation, 48 feet of which are present. The lower beds of the First Brimham Grit crop out in Colber Beck(250647) to the east and in the stream just south of Careless House, in each case consisting of coarse felspathic sandstone of the normal Brimham type.

Northwards as noted above, a N.W. - S.E. fault displaces the First Brimham Grit to the north and beyond the fault, the bed is first seen in Hebden Wood(249658) where coarse pebbly felspathic sandstone is exposed in an old Quarry. 8 feet of the same bed can be seen in another quarry 700 yards to the E.S.E. and also lower down the hill in the form of crags by the side of Hebden Beck(259658). North of Hebden Beck, large crags of the formation occur at the Lord's Nab(660247) where more than 30 feet of massive felspathic sandstone are exposed. The basal feature can be traced from here round to Hiddycar Beck where again extensive crags flank the stream. The sandstone is pebbly and felspathic, current bedded on a large scale and weathered into the peculiar shapes so characteristic of this formation. The division has thinned slightly in this neighbourhood, for whilst a borehole at Sawley Hall(Appendix) penetrated 89 feet of coarse sandstone and was still in that lithology when drilling was stopped, features indicate a thickness of only 100 feet for the bed here. In addition to the thickness change, a lateral change in lithology is suggested by the blocks of medium grained quartzitic sandstone that lie on the ground surface below the Sawley Hall Fish Ponds.

Beyond Sawley Hall the First Brimham Grit is next seen in the banks of the River Skell by Fountains Abbey. Here, large quarries operated by the monks were opened up to provide the stone of which the abbey is constructed. These quarries, with faces up to 30 feet in height are in coarse felspathic sandstone and occur north of the Abbey in Rye Bank Wood and south of the Abbey by Galand Bridge, in both cases overlain by the Magnesian Limestone. To the east, crags of coarse felspathic sandstone occur in a small faulted outlier at the top of the banks of the Skell by Hook Gill(257687). The bed can be seen farther east also, first in the Cat Crag Quarry(252694) where 12 feet of coarse felspathic sandstone are overlain and penetrated along joint planes by glacial gravel, and later opposite this on the other bank of the river where 10 feet of coarse slightly felspathic sandstone are exposed. Some 400 yards east of this quarry another Old Quarry contains a good section of coarse sandstone. The bed in this latter exposure is unlike the normal felspathic First Brimham Grit in that it is more of a quartzitic sandstone comparable to the Follifoot

Grits, but the disposition of the beds make it highly unlikely that it is anything other than the First Brimham Grit. This arises from the fact that if it were the Upper Follifoot Grit it would mean that that horizon had undergone a considerable change from the proved Upper Follifoot Grit farther south in Skell Bank, a change sufficient to discount the idea altogether. Further the interpretation would imply that the flaggy sandstone in Gill Beck was the Lower Follifoot Grit, again requiring an unlikely change in lithology. These observations coupled with the character of the bed exposed in Cat Crag Quarry make it highly probable that the bed exposed in the Old Quarry is in fact the First Brimham Grit. In any case the beds in this quarry become coarser upwards and locally felspathic whilst a certain amount of slickensiding along joint planes indicates the proximity of a fault.

Farther north coarse sandstone is next seen in the banks of the River Laver by Galphay Mill(270722), the outcrop extending some distance along the banks of the river in Birkby Nab Wood. Stratigraphical interpretation of the horizon is necessarily tentative in the absence of diagnostic marker beds, but on lithological grounds the rock, a coarse quartzitic sandstone with a more than usual amount of mica bears close similarity to the Agill Sandstone exposed in Skell Banks. By straightforward extrapolation however the bed should be the First Brimham Grit and as no evidence is forthcoming to support the presence of a fault in the vicinity and it is known that quartzitic sandstone does occur at this level elsewhere, the bed is assigned to this division. Approximately 20 feet of the sandstone can be measured in discontinuous outcrops along the banks of the river, in each case the bed being overlain by the Magnesian Limestone.

Due west of this point, again in the banks of the River Laver and its tributary Carlesmoor Beck, the First Brimham Grit is exposed. Firstly in Hell Holme Wood(198719) where up to 30 feet of coarse felspathic sandstone occur as crags and blocks littering the steep sides of the valley. This coarse sandstone extends for more than 2 miles upstream and must be at least 100 feet thick in North Gill though its lithology is not consistent throughout. In fact a quarter of a mile east of Potter Lane House(177721) the sandstone ca. 50 feet below the top is flaggy and micaceous and contains a shale parting 2 feet 6 inches thick. This flaggy sandstone has been quarried for roofing slates here, but it thins to the north, whilst the shale parting thickens and is next seen in Carlesmoor Beck where it crops out 200 yards west of the aqueduct.

Here it is locally ganisteroid and full of plant remains, passing upwards into more massive sandstone of the normal Brimham type. The shale parting is also variable containing chalybite nodules and thin lenses of sandstone. Together with the overlying beds it is folded on a minor scale, probably the result of the fault that traverses Swetton Moor.

These beds dip to the east and were penetrated by the Leeds Corporation boreholes sunk in connection with the two projected reservoirs at Carlesmoor and Laverton respectively. Coring was more or less complete in all these boreholes and it is therefore a pity that the cores have now become disarranged in order, thus making them valueless in interpreting the local stratigraphical succession. From the drilling logs(Appendix) and the diagram (Fig.24) however, it is possible to see the considerable lithological variation that takes place in short distances though the clear division into stratigraphical groups is difficult without the supporting evidence from cores. This arises chiefly from the subjective driller's terms for rock descriptions which are really only understood when the cores are available for comparison so that the damage done is irreparable.

South of this point another inlier of the First Brimham Grit occurs in the valley of the Skell, extending for 2 miles downstream from Skell Gill Bank. The following section was measured at Great Scar(192685) at the western end of the inlier:

		Second Brimham Grit
15'	7½"	interbedded flaggy sandstone and shale.
	10 "	thinly bedded flaggy sandstone.
7'	4 "	shale
6'	2 "	thinly bedded flaggy sandstone.
20'	0 "	obscured
3'	3 "	grey pyritic shale.

Farther downstream the lower beds are exposed and consist of coarse felspathic sandstone, well seen at Foster Crags where good current bedding is apparent. A spring line runs along Skell Gill Wood coincident with the top of the shale parting, but this dies out locally for in the stream passing through Skell Gill Farm no trace of shale was found in a more or less continuous section of sandstone. The shale parting reappears to the east however and can be seen in an Old Shaft(208693) above the stream, from where it can be traced by feature and fragments to Low Skelding. The massive sandstone below it crops out intermittently in the bed of the Skell, locally flaggy and quartzitic it appears as its normal coarse felspathic type in crags below Low Skelding Farm.

The only other outcrop of this formation is in the south, in the neighbourhood of Hartwith, Bishop Thornton and Burnt Yates. Passing from west to east, the bed is first seen near Brimham Lodge Farm(226634) where crags of coarse felspathic sandstone 8 feet high occur. Above this point on the hillside large blocks of a similar lithology are common and assist in placing the line of the fault that passes nearby. The bed occurs south of Lurk Beck also in the form of blocks of coarse felspathic sandstone in Spring House Wood(225623) and farther uphill in an old quarry. Here the lithology has changed to a medium grained quartzitic sandstone, 8 feet of which are present, but passing over the watershed to the south the normal lithology is quickly resumed and can be seen in an old quarry 200 yards east of Spring House Farm. Another old quarry occurs south of this by Winsleyhurst(225614) and is again in coarse felspathic sandstone, this time right at the base of the division. The formation is displaced to the east by a N-S fault resulting in its occurrence on the southern bank of Lurk Beck. To the east it is next seen in Trustee Wood (246624) where it was formerly quarried, but the quarries are now overgrown completely except for scattered blocks at the entrance. In each of these exposures the rock is a coarse felspathic sandstone, but to the south by Hollin Wood(246618) crags of medium grained quartzitic sandstone occur, confirming the upward change of lithology already observed farther west. This is apparent north of Thornton Beck also where in Fox Wood large pavement crags of quartzitic sandstone occur, and can be seen half a mile to the north as well.

An E-W fold axis passes through Shaw Mills so that the formation appears in the north by Bishop Thornton where two old quarries(260634) in coarse felspathic sandstone occur and in the south in Pye Lane(257622) also where there is another quarry in the same lithology. East of this latter quarry blocks of coarse felspathic sandstone are common on the hillside, indicating the presence of the First Brimham Grit, 42 feet of which was penetrated by a borehole at Hill Top Farm. Boreholes at Winsley Hall Farm, the Bay Horse Inn and the New Inn, Burnt Yates also passed through this formation at the surface(see Appendix). Farther east near Bedlam(265615) blocks of coarse felspathic sandstone and white quartzitic sandstone lie scattered about the surface in the area of outcrop of this division and a short distance to the north of this point an old quarry by Spinner Lane reveals 3 feet of fine grained quartzitic sandstone.

East of Thornton Beck again, the formation shows signs of noticeable

A

Heyshaw Moor Quarry(170630). The quarry face is over 40' high and consists of coarse,massive, felspathic sandstone(1st. Brimham Grit).

B

High Crag Ridge, Heyshaw Moor. Large blocks of the 1st. Brimham Grit weather out at the surface and lie in a jumbled mass on the moor.

thinning for it is only about 45 feet thick here. It can be seen by High Kettle Spring Farm (268625) where an old quarry reveals 30 feet of well jointed coarse felspathic sandstone and in another old quarry on Scarah Bank (277622) maintaining the same lithology. A good basal feature is apparent in this vicinity running from High Kettle Spring Farm to the main Scarah Quarry where 17 feet 6 inches of pebbly felspathic sandstone are overlain by the Brimham Shales. Further exposures are mainly fragmentary, but a quarry by Newton Hall(289616) reveals 6 feet 3 inches of medium grained felspathic sandstone and north of this, three quarries on the eastern flank of Cayton Gill, one by Cayton Grange and the others in Crag Wood were all worked in coarse felspathic sandstone.

A fairly extensive outcrop of the First Brimham Grit also occurs west of Nidderdale on Heyshaw Moor, connecting up with those already described from Greenhow(Dunham and Stubblefield, 1945) and Simonseat (Hudson, 1939). In the north west the bed is first seen on the southern limb of the North Craven Fault in Hindmes Wood where large crags of coarse felspathic sandstone crop out and the bed is quarried in the vicinity. This same bed has been excavated in connection with the construction of the Greenhow road and is exposed in a road cutting just below the House of Rest. Lower down the hill crags of coarse sandstone occur on the side of the stream descending from Eagle Level and from here, just above Bewerley Park, no further exposures occur to the south until Fishpond Wood. In this wood overlooking Middle Tongue valley, impressive crags of coarse sandstone occur discontinuously all the way up the valley to Middle Tongue Bank, more than half a mile away and retain a consistent lithology throughout, except for a parting of shale and overlying ganisteroid sandstone 3 feet thick in the stream below Hover Garth Farm (149644). On the southern bank of Middle Tongue valley, crags of felspathic sandstone 15 feet high adjoin the Greenhow area(145639) and 100 yards east of these the extensive Middle Tongue Quarry occurs revealing a quarry face more than 60 feet in height, composed of coarse felspathic sandstone. South of this quarry, large crags flank Fosse Gill and are again made up of pebbly felspathic sandstone, of the normal Brimham type. An old quarry occurs west of the gill(150634) and is distinctive because the beds here are medium grained sandstones of the Libishaw type in which scattered fossils are occasionally preserved. Blocks of a similar lithology lie scattered on the moor surface north of the quarry, above Fox Crags, indicating that the outcrop is not confined to one quarry.

As coarse felspathic sandstone of the normal Brimham type surrounds this outcrop it must represent an upward change in lithology, which as noted above is highly significant east of Nidderdale in determining the line of the North Craven Fault.

East of Fosse Gill the basal crags turn abruptly east from the gill and can be traced via Rowantree Crags and High Crag Ridge to the large Heyshaw Moor Quarries(Plate XVII). The crags and the quarries are notable for the consistency of their lithology throughout 50 feet of strata and this also obtains for Guisecliff Quarries which extend for nearly a mile above the dale. Good false bedding(Plate XXI) and graded bedding are apparent and have been exploited by weathering agencies to produce forms similar to Brimham Rocks, though in the quarries themselves the faces rise sheer and moreover in the case of the latter, descend precipitously through Guisecliff Woods below. In this vicinity the beds have been folded along 2 axes, one a N.E.-S.W. synclinal continuation of the Redlish syncline and the other a N.-S. anticlinal axis more or less coincident with the Pateley-Heyshaw road.

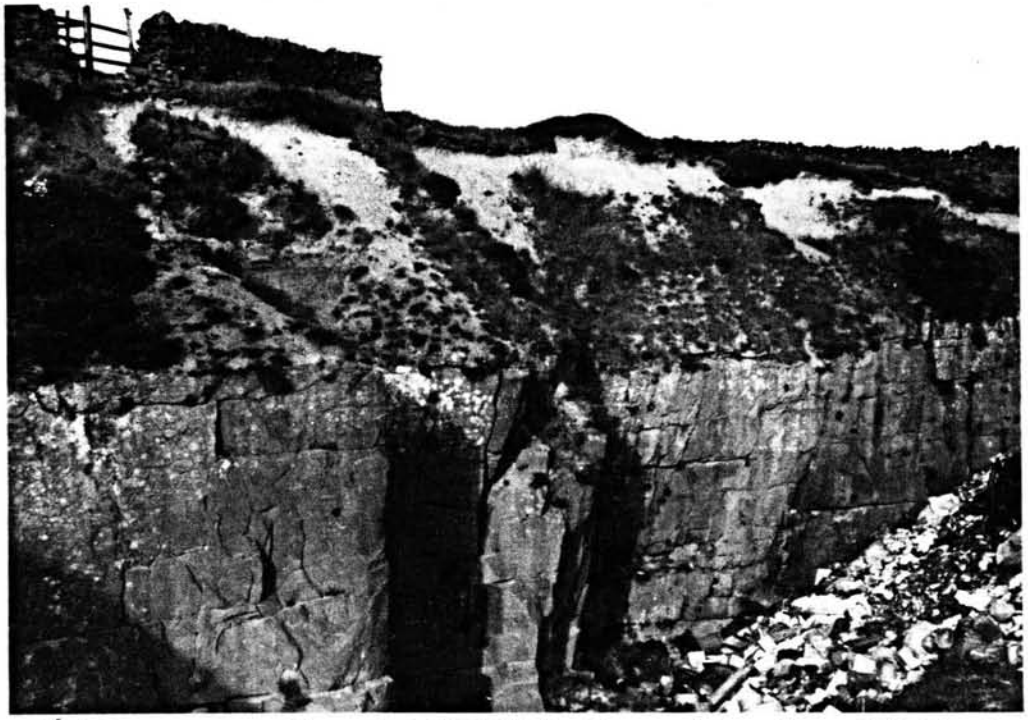
Brimham Shales

The Brimham Shales are on the whole a very poorly exposed group. Indeed, north of Pateley Bridge they are nowhere seen at the surface in Nidderdale, though marshy slacks and the good basal feature of the Second Brimham Grit provide some control over thickness variations. In the extreme north the bed is 80 feet thick, but thins rapidly to 50 feet just south of Lulbeck Crags. Thereafter in a southerly direction, thickening to 90 feet takes place, but this is only local because on Light Hill the beds are 30 feet thick and retain this average thickness to Pateley Bridge.

The Brimham Shales do not appear to be affected by the North Craven Fault, passing uninterruptedly over the line of dislocation and are first seen to the south in Prospect Quarry(175657). There, 10 feet 1 inch of grey sandy shale overlie the First Brimham Grit, the complete group being estimated from features to be about 30 feet thick. North of this quarry on the other side of the hill, the shales are seen again in Near Beck(175673) where they consist of grey mudstone about 30 feet thick, In Far Beck to the north only the upper beds crop out and these are sandy shales with thin intercalated beds of flaggy sandstone.

The beds are displaced by a fault to the east, nothing being seen

A



Old Quarry near Blazefield(174657). The section shows 10' 1" of grey sandy shale overlying about 15' of the 1st. Brimham Grit.

B

Klondyke Quarry, Warsill(222658). The quarry face is about 15' high and shows well bedded and jointed 1st. Brimham Grit overlain by grey sandy shale.

of the shales below Tarn Ridge, but north of Eavestone Moor they crop out in the banks of the Skell. There, at Great Scar(192685) approximately 24 feet of inter-bedded flaggy sandstone and shale constitute the horizon and can be seen to the east in Grain Beck also, grey shale predominating. A good feature which is also a spring line runs down both sides of the valley, eg. below Muller Stones on the south and indicates the top of the division. 18 feet 3 inches of sandy micaceous shale were measured in a small stream descending from Eavestone Moor(208688) to the east and farther east still in Smaden Head Dike, discontinuous sections in grey sandy shale with thin beds of flaggy sandstone occur. On the north side of the Skell in a small stream below High Skelding Farm(218695) the Brimham Shales are partially exposed and consist of grey shale with intercalated beds of flaggy sandstone, but the division appears to have thinned to 15 feet here and nothing further is seen of it locally.

To the north, occasional exposures of the Brimham Shales are observed in the valley inliers of the Brimham Grits. Firstly in North Gill Beck(165728) where the following section was measured :

Second Brimham Grit

11'	2 "	thinly bedded sandstone with shale partings
6'	8 "	shale
2'	7½"	thinly bedded flaggy sandstone
1'	10½"	shale
1'	6 "	flaggy sandstone

First Brimham Grit

The shale parting can be traced by occasional fragments eastwards and is seen again in South Gill Beck(185708) where the following section was measured :-

Second Brimham Grit

8'	2 "	grey pyritic shale
1'	0 "	flaggy sandstone
3'	11 "	dark grey shale
		obscured

On the southern bank of the stream no further surface exposures occur, but to the north the bed swings round Swetton Moor and reappears in Carlesmoor Beck(179735) where 6 feet of micaceous shale are exposed in a small cutting.

The bed passes underground to the east and is next seen in Spa Gill Wood(243702), having been brought to the surface on the eastern limb of syncline. There, the exposed succession comprises the following strata :

of the shales below Tarn Ridge, but north of Eavestone Moor they crop out in the banks of the Skell. There, at Great Scar(192685) approximately 24 feet of inter-bedded flaggy sandstone and shale constitute the horizon and can be seen to the east in Grain Beck also, grey shale predominating. A good feature which is also a spring line runs down both sides of the valley, eg. below Huller Stones on the south and indicates the top of the division. 18 feet 3 inches of sandy micaceous shale were measured in a small stream descending from Eavestone Moor(208688) to the east and farther east still in Smaden Head Dike, discontinuous sections in grey sandy shale with thin beds of flaggy sandstone occur. On the north side of the Skell in a small stream below High Skelding Farm(218695) the Brimham Shales are partially exposed and consist of grey shale with intercalated beds of flaggy sandstone, but the division appears to have thinned to 15 feet here and nothing further is seen of it locally.

To the north, occasional exposures of the Brimham Shales are observed in the valley inliers of the Brimham Grits. Firstly in North Gill Beck(165728) where the following section was measured :

Second Brimham Grit

11'	2 "	thinly bedded sandstone with shale partings
6'	8 "	shale
2'	7½"	thinly bedded flaggy sandstone
1'	10½"	shale
1'	6 "	flaggy sandstone

First Brimham Grit

The shale parting can be traced by occasional fragments eastwards and is seen again in South Gill Beck(185708) where the following section was measured :-

Second Brimham Grit

8'	2 "	grey pyritic shale
1'	0 "	flaggy sandstone
3'	11 "	dark grey shale
		obscured

On the southern bank of the stream no further surface exposures occur, but to the north the bed swings round Swetton Moor and reappears in Carlesmoor Beck(179735) where 6 feet of micaceous shale are exposed in a small cutting.

The bed passes underground to the east and is next seen in Spa Gill Wood(243702), having been brought to the surface on the eastern limb of a syncline. There, the exposed succession comprises the following strata :

Second Brimham Grit

5' 4 " shale
1' 6½" flaggy sandstone
11' 3 " micaceous siltstone

The remaining exposures of the bed are all fragmentary and will therefore be detailed in order. Firstly, a small faulted outlier is preserved near Warsill and can be seen in Klondyke quarry north of the Warsill road (222658) where the following succession was measured :

1' 11 " grey shale
6½" flaggy sandstone
7' 3 " grey sandy shale

First Brimham Grit

North east of this quarry on Sawley Moor, a borehole at Moor Land Farm(244677) passed through 43 feet of grey shale. This thickness is greatly accentuated by the increased dip arising from proximity to a fault (the true thickness is probably of the order of 25 feet), but the borehole is important because of the indication it gives of the presence of two outliers of shale in the vicinity of Sawley.

The remaining outcrop of the Brimham Shales occurs on Scarah Moor in the extreme south east of the area, the bed being exposed in Scarah Quarry (278616) where 13' 5" of grey sandy shale with intercalated bands of micaceous sandstone are seen above the First Brimham Grit.

Second Brimham Grit

The Second Brimham Grit is first seen in the north of the area on Fountain's Earth Moor where it averages 70 feet in thickness and forms a good basal feature. A point of interest in this vicinity is the number of discontinuous features that occur in the outcrop, suggesting bands of differing hardness, but only blocks of coarse quartzitic sandstone occur on the surface. The bed swings down Covill House Moor towards Sigsworth Moor, the good basal feature persisting accompanied by another persistent feature 25 feet above it. Once again surface crags and blocks of medium - coarse grained white quartzitic sandstone, locally ganisteroid are abundant on the moor surface, notably so at Jordan Crags(149706). The bed thins to about 40 feet below High Hill and maintains this thickness for some distance to the south, thickening slightly towards Pateley Bridge. Prominent crags commence on Howson Ridge and are known as Cow Close Crags and Yeadon Crags, both with a spring line at their base. The rock that forms the crags is a coarse pebbly felspathic sandstone, closely resembling the typical First Brimham Grit in lithology and this passes upwards into a white quartzitic sandstone. The crags extend for a considerable distance to the south, being demonstrably displaced by a fault above Yeadon Farm(160678), whilst farther south they pass quite uninterrupted over the line of the North Craven Fault. A number of quarries on Low Bishopside have worked the beds just above the basal crags and all are in coarse felspathic sandstone. Above another set of crags is evident on Madge Hill (182660), the same bed being exposed in a quarry to the west, where it is exceptionally rich in plant remains and passes upwards into flaggy micaceous sandstone.

The Second Brimham Grit forms the highest ground here so that the lower beds occur the other side of the hill on Thistle Hill. There the lower beds form crags composed of coarse felspathic sandstone as at Midwife Stones, whilst the higher beds are as usual ganisteroid quartzitic sandstone, abundant as blocks on the moor. A fault displaces the strata to the N.E. whence they spread out to form a wide dip slope outcrop on Eavestone Moor. The basal crags are again prominently displayed at Green Brackens and Russell's Plantation in the south(194673) and at High and Low Huller Stones in the north, overlooking Skell Gill. About 60 feet above this basal feature, another persistent feature with a spring line at its base runs around the moor, suggesting the presence of a thin shale horizon in the succession, but this cannot be proved. The higher beds are well represented on the moor, both as crags and blocks and maintain a consistent lithology of white quartzitic sandstone.

North of Skell Gill the Second Brimham Grit forms another extensive dip slope outcrop on Dallow Gill Moor. Descending in the succession, the higher beds are composed of medium to coarse grained ganisteroid sandstone, common as blocks and pavement crags on High Ruckle Hill and Iron Well Hill (166706). These pass downwards into a coarse quartzitic sandstone which forms Lund Stones(174714) in the north, and numerous blocks on Edge Hill to the south. Below this come the normal coarse felspathic sandstones, well displayed on the northern bank of Skell Gill where they form Canary Crags (196688) and other crags farther downstream.

The beds are displaced by a long fault to the N.E. so that they occur on Swetton Moor in the north and farther east also near Winksley, there brought to the surface by a synclinal fold. They can be seen in North Gill Beck(163729) where they consist of coarse felspathic sandstone with thin pockets of coal at the base, passing upwards into coarse quartzitic sandstone. Farther east the basal beds of coarse felspathic sandstone form Whin Crags and Gate House Crags above South Gill Beck, the upper beds of quartzitic sandstone being common as blocks on the moor.

North of North Gill Beck exposures are very infrequent and really confined to the upper reaches of Carlesmoor Beck and Hawset Riggs south of it. South of South Gill Beck however they are quite common, commencing at Cow Close Crags(189711) composed of coarse felspathic sandstone overlain by quartzitic sandstone, passing on to Cow Hill Crags made of quartzitic sandstone. Beyond this the bed passes underground by Laverton and is not seen again until Spa Gill Wood near Winksley(244704) where an old quarry reveals more than 30 feet of pebbly felspathic sandstone near the base of the division. This sandstone can be traced up the side of Sun Wood to the south and is notable for its rich content of plant remains. As elsewhere it passes upwards into quartzitic sandstone, which crops out in the banks of the River Laver to the north, forming good cliff sections in that lithology.

The only other place where the Second Brimham Grit occurs in this area is in the extreme south east on Scarah Moor. There, the division forms a persistent basal feature accompanied by a line of crags of coarse felspathic sandstone, and has been quarried at two localities. The first of these is at Scarah Moor Farm(279623) where 14 feet 6 inches of coarse pebbly felspathic sandstone are exposed and the other by Newton Hall(288616) where 6 feet 3 inches of medium grained felspathic sandstone constitute the face.

CHAPTER XI

THE BEDS ABOVE THE FIRST BRIMHAM GRIT

The Second Brimham Grit is succeeded by a group of beds consisting of two members of sandstone and two of shale. They were originally included by Phillips(1836) in his major group "The Brimham Grits" and subsequent authors have tended to follow this lead, giving no precise definition to the number or type of beds. In this account the term "Brimham Grits" is taken to refer only to those beds having a direct connection with Brimham Rocks, ie. the First and Second Brimham Grits, higher beds in the sequence being given local place names as shown in Fig.14.

These beds are of interest, chiefly because of the discovery of marine shale containing a Gastrioceras cumbriense fauna in the Laverton Shales, thus emphasising the absence of goniatites of the R 2 Stage in this area. Comparing the sequence with that of Rombalds Moor(Stephens and others, 1942) to the south, it is apparent that the sandstone overlying the Laverton Shales, ie. the Laverton Sandstone is equivalent to the Rough Rock, whilst higher beds represent the lowermost Coal Measures, hitherto unknown in this area. Even though therefore, a major stratigraphic boundary comes within the group, for convenience they will be described together, as no break or change is discernible in the field. They occur only in the north eastern part of the district, where they have an extensive outcrop in the parishes of Laverton, Skelding and Winksley, and in addition form a series of outliers on the highest ground east of Nidderdale.

The group commences with the Laverton Shales and includes altogether one newly discovered goniatite/pelecypod horizon and three Lingula bands. The lower marine horizon occurs just over 20 feet above the base and contains as its basal member a Lingula band 1 inch thick. This is in turn succeeded by 4 feet 3 inches of grey sparsely fossiliferous shale containing a goniatite lamellibranch fauna, which passes up into a band of black, carbonaceous shale $2\frac{1}{2}$ inches thick. This band is fossiliferous and together with the bed below has yielded the following fauna :-

Plant remains

Productus sp.
Productid spines

Aviculopecten sp.

Dunbarella sp.
Posidoniella rugata Jackson
Gastrioceras sp.

Several specimens of Gastrioceras were collected, most of which revealed an ornament containing either no lingua or a degenerate one, suggesting a position high in the goniatite zonal sequence. Subsequent examination by Mr. Bisat and Dr. Ramsbottom confirmed this high position and declared the fauna to most closely resemble that obtained from the G. cumbriense band on Rombalds Moor(Stephens and others, op. cit.)

20 feet above this marine band a further Lingula band occurs, only exposed in Hambleton Dike to the east, where it is 5 feet 7 inches thick and consists of thinly bedded black shales crowded with single valves of Lingula mytiloides.

The Laverton Shales are overlain by a thick bed of sandstone, approximately 120 feet thick which consists predominantly of medium to coarse grained quartzitic sandstone, locally ganisteroid and elsewhere slightly felspathic. It forms the surface rock of much of Skelding Moor where it contains a thin shale parting with a coal 90 feet above the base. This coal has been exploited on a small scale near Harper Hill Farm(200707) whilst to the east the sandstone above and below it, have been extensively quarried for building stone.

The overlying Winksley Shales occur only in the neighbourhood of Grantley and Azerley where they form two outliers capped by Winksley Sandstone. The southern most of these outliers contains no exposures, whilst in the northern one, apart from a 9 feet section in grey silty shale by High Missies Farm(232725), exposures are confined to Winksley Banks in the River Laver. There, the section illustrated in Fig. 14 was compiled. No trace of the Gastrioceras subcrenatum band has been found and it is concluded that it has died out northwards. The underlying Pot Clay Coal horizon may however be represented by the basal bed of micaceous siltstone rich in plant remains.

Like the Winksley Shales, the Winksley Sandstone is badly exposed, exposures being confined to a quarry by Woodhouse Farm(240716), where 15 feet of coarse quartzitic sandstone are visible and a series of crags on West Hill Plantation(231715), again composed of coarse quartzitic sandstone.

Details

Laverton Shales

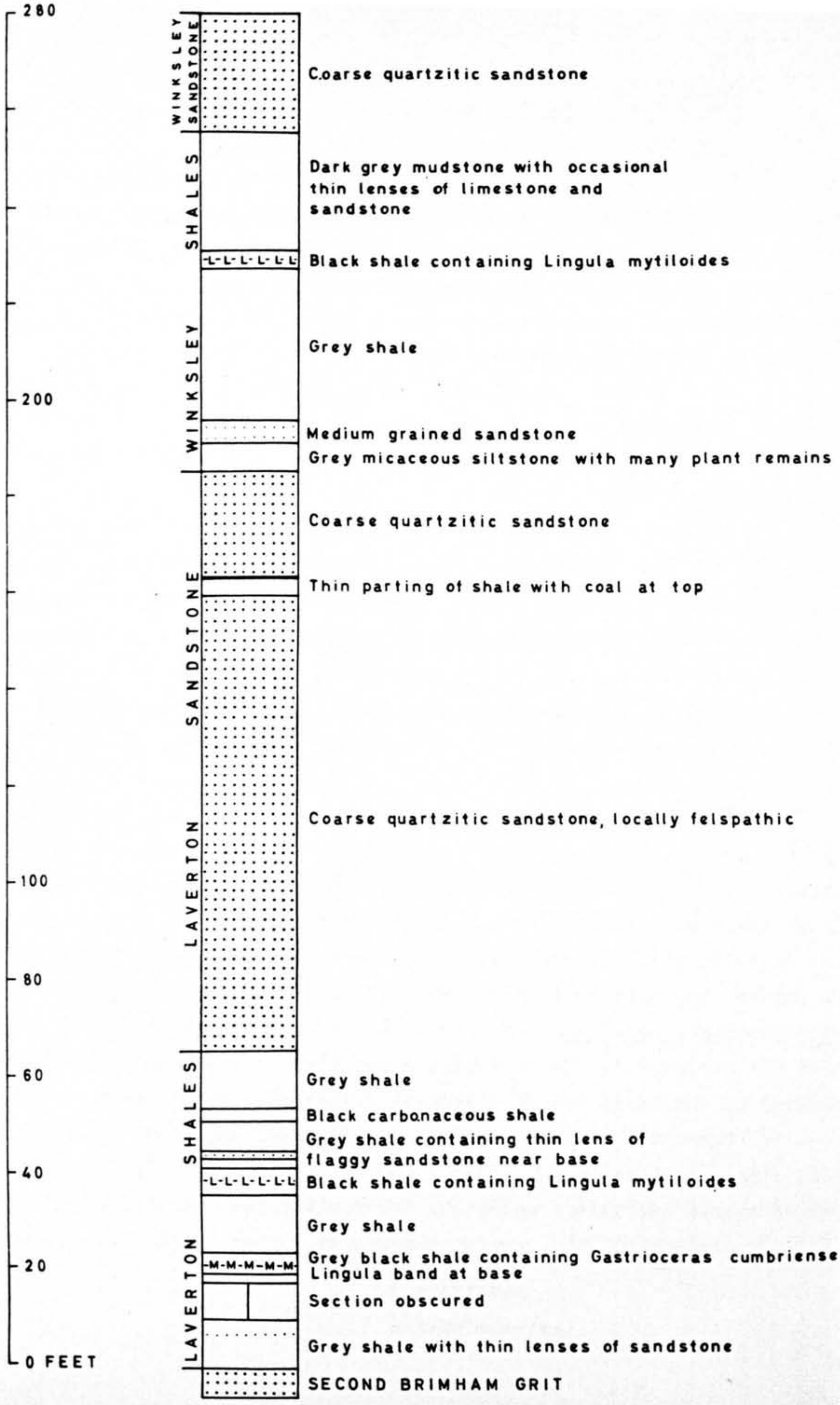

280
200
100
80
60
40
20
0 FEET
WINKSLEY SANDSTONE
WINKSLEY SHALES
LAVERTON SANDSTONE
LAVERTON SHALES
Coarse quartzitic sandstone
Dark grey mudstone with occasional thin lenses of limestone and sandstone
Black shale containing Lingula mytiloides
Grey shale
Medium grained sandstone
Grey micaceous siltstone with many plant remains
Coarse quartzitic sandstone
Thin parting of shale with coal at top
Coarse quartzitic sandstone, locally felspathic
Grey shale
Black carbonaceous shale
Grey shale containing thin lens of flaggy sandstone near base
Black shale containing Lingula mytiloides
Grey shale
Grey black shale containing Gastrioceras cumbriense
Lingula band at base
Section obscured
Grey shale with thin lenses of sandstone
SECOND BRIMHAM GRIT

Figure 14. Composite section of the beds above the Second Brimham Grit.

Exposures of the Laverton Shales are in the main confined to the east of the area, all situated east of Nidderdale. On Dallow Gill and Bishop's Moor the bed occurs in the form of three outliers capped by the Laverton Sandstone. The northernmost of these is Hambleton Hill(149732), where the top of the division is indicated by a prominent feature, below which some shale fragments occur. This prominent feature can also be traced round Kettlestang Hill to the southeast where it forms a spring line. Below it on Green Banks (159722) a small scar in micaceous shale is the only exposure of the bed, but on this outlier and the one south of it on Bishop's Moor much of the ground formed by the shale is marshy.

North east of Kettlestang Hill the bed is downthrown by a fault and reappears in Hambleton Dike. Here as in the outliers to the west it is about 50 feet thick and exposed near the base and top of the division. Near the base it consists of micaceous shale, exposed just above the Dallowgill/ Ramsgill road, whilst towards the top a Lingula band is observed, the section comprising the following strata at 152733.

Laverton Sandstone

12'	0"	grey shale
2'	9½"	black carbonaceous shale
6'	3"	grey shale
1'	10"	flaggy micaceous sandstone
2'	0"	grey shale
5'	7"	black shale containing Lingula mytiloides

The strata dip to the east and run down towards Swetton Moor, there encircling Greygarth Hill. Marshy ground is the chief indicator of the bed here, but on Near Toady Bank(175728) and west of Greygarth Hill(183725) small scars in black micaceous shale also occur.

South of this, on the southern side of the River Laver the basal beds are exposed in an Old Quarry on Wake Hill(189707) and consist of black carbonaceous shale. Between here and Laverton they are nowhere exposed at the surface, but on Lumley Moor, Tute(1887) records the occurrence of Lingula mytiloides in shales penetrated in connection with the construction of the Lumley reservoir.

The only other exposure of the Laverton Shales occurs east of the reservoir, in the banks of the River Laver near Winksley(246709). There the following section was measured :

Laverton Sandstone

39'	0 "	obscured
3'	0 "	grey unfossiliferous shale
	$2\frac{1}{2}$"	black carbonaceous shale - goniatite/lamellibranch fauna
2'	9 "	grey shale with occasional lamellibranchs
1'	6 "	grey soapy shale - sparsely fossiliferous, more fossiliferous in top 3 inches - goniatites and lamellibranchs.
	1 "	carbonaceous micaceous shale - Lingula band at top
2'	$1\frac{1}{2}$"	ganisteroid sandstone with 5 inch lenticular coal at base
		grey shale in bed of stream.

Southwards however, the bed is seen in a small stream cutting in the River Skell(229692) where 15 feet of blue/grey micaceous shale are folded into a syncline, suggestive of the close proximity of a fault.

Laverton Sandstone

The Laverton Sandstone is known only in the north eastern part of the area, it forming four outliers on the watershed between Nidderdale and Vale of York and a large outcrop on Skelding Moor, extending eastwards to Galphay and northwards to Kirkby Malzeard Moor.

The northernmost of the four outliers is Hambleton Hill(149732), composed of a capping of Laverton Sandstone on Laverton Shales. The sandstone forms a good basal feature which is also prominent on Kettlestang Hill to the south east, where it is overlain by numerous blocks of white ganisteroid quartzitic sandstone. These blocks litter the surface of this pear-shaped hill and are the only indication of the sandstone below, here approximately 50 feet thick. Southwards, two more outliers of Laverton Sandstone, High Hill and High Ruckles respectively, are both covered with numerous blocks of medium to coarse grained ganisteroid sandstone, the bed actually having been quarried on High Hill. The basal feature is not present here, but on High Ruckles it is, and there forms a spring line.

The strata are displaced by a fault to the north east and are next seen on Sandstone Ridge, north of the River Laver. In this northern outcrop, Hambleton Crags(152735) is the most westerly exposure, composed of coarse quartzitic sandstone. The beds dip to the east forming a tongue-shaped outcrop, on the surface of which blocks of quartzitic sandstone abound, notably so on Sandstone Ridge. This tongue thins out to the east and is separated by just under 400 yards from the fault traversed outlier of Greygarth Hill(185725). In this latter outlier old quarries and crags confirm the persistence of the coarse quartzitic sandstone lithology.

South of the River Laver, the Laverton Sandstone forms an extensive outcrop, much of it rough moorland covered by blocks of quartzitic sandstone. The basal beds are exposed in quarries near High Ray Carr Farm (208721) and Laverton, a mile to the east, where they consist of well jointed irregularly bedded, massive quartzitic sandstone. About 80 feet above the base of the division, quarries have again been worked in coarse quartzitic sandstone at Coal Hill(201709), the beds being succeeded by a thin shale parting containing a coal, exposed in several trial shafts in the vicinity. The upper beds are again composed of coarse quartzitic sandstone, extensively quarried on Skelding Moor, near High Grey Stones(205705), Jenny Cross Plantation (221722) and Gate Bridge Mill(240724), the complete division averaging 120 feet in thickness.

South of Galphay Moor exposures are less abundant, and are in fact confined to a discontinuous section of coarse quartzitic sandstone in the upper reaches of Holborn Beck below the Lumley reservoir and a few quarries on Lumley Moor. Eastwards however, the bed is well displayed in the banks of the River Laver by Winksley Bridge(247711), cliffs of coarse - medium grained quartzitic sandstone occurring on both sides of the stream. The sandstone is locally felspathic and current bedded on a large scale, whilst on some bedding planes ripple-marks and a wealth of plant remains can be seen. On the eastern bank it is overlain and penetrated along joint planes by glacial gravel, the sandstone dipping to the north and eventually appearing in the bed of the stream by Winksley Bridge.

CHAPTER XII

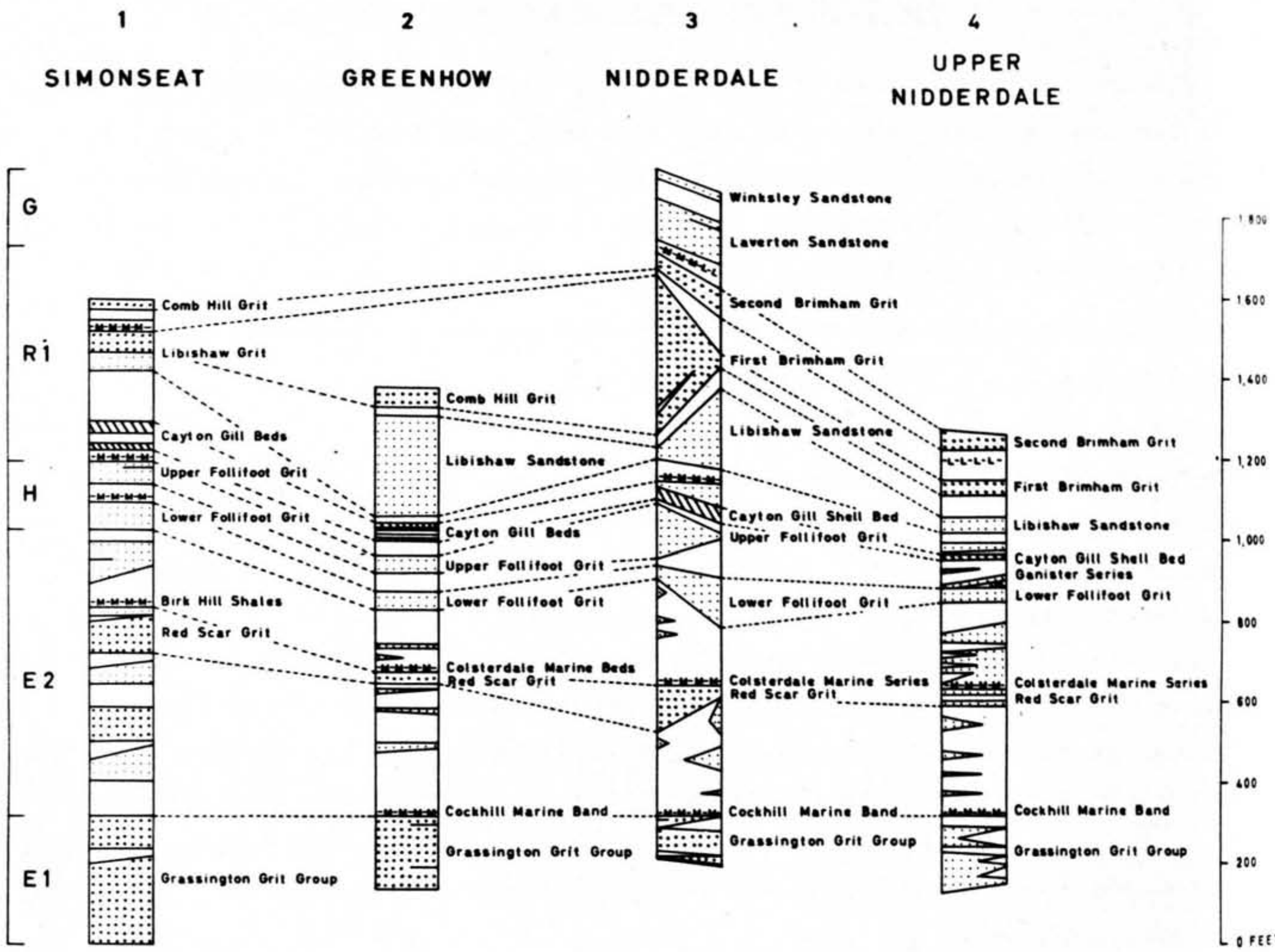
CORRELATION WITH SURROUNDING AREAS

The precise correlation of the Millstone Grit of Nidderdale with comparable sediments elsewhere has long been made difficult by the absence of marker horizons persistent throughout the Pennine Uplands. In addition to this conspicuous deficiency the position is further complicated by the diachronism and lateral change in facies known to take place, so that it is hardly surprising that some of the earlier attempts at correlation, based on considerably less detailed knowledge than is available today, should contain a number of inaccuracies.

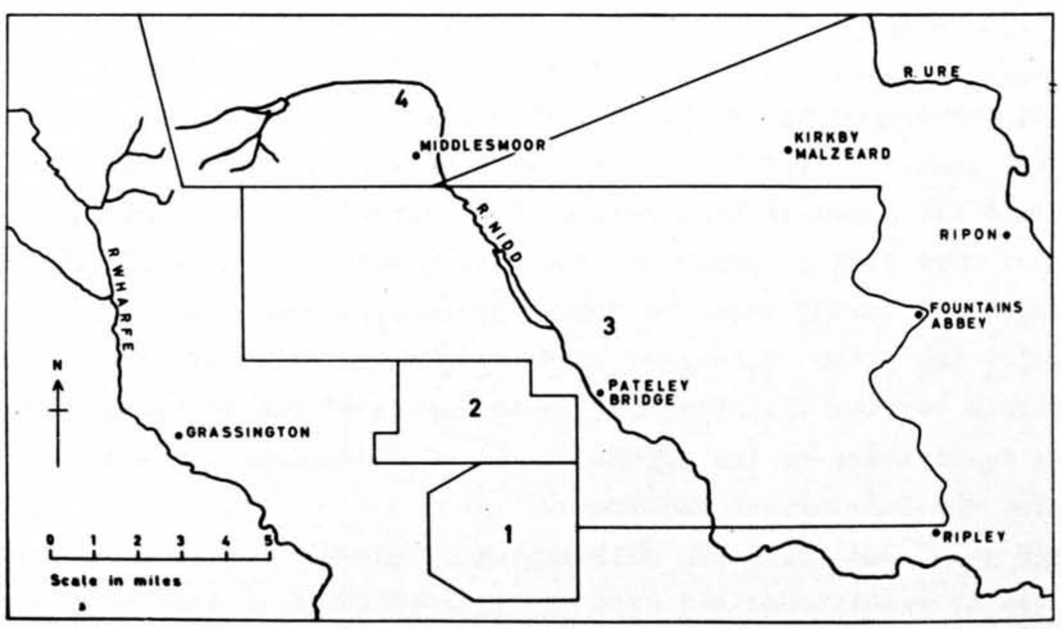
The first of these was that made by Phillips (1836 p.71), based on the lateral persistence of coal seams. At first sight such a basis of correlation would appear to have considerable merit, because the conditions conducive to the formation of coal are likely to be effective over a wide area at any one time, as indeed they were in the Eastern Interior Region of the United States, where the Herrin and Harrisburg coals extend throughout much of Illinois and Indiana (Wanless and Weller, 1939). In the Pennines, however, the Millstone Grit coals are thin and impersistent most of them being of only restricted lateral extent, so that their usefulness as marker horizons is limited, and over a wide area are virtually valueless.

Following Phillip's work, another attempt at correlation was made by Dakyns (1890), who suggested on the basis of the primary survey just concluded throughout the north of England, that the Kinderscout Grits of Derbyshire passed laterally into the beds between the Grassington Grit and Colsterdale Limestone in Nidderdale. This correlation remained uncontested for more than 30 years and was only corrected by the advent of stratigraphical zoning based on goniatite successions. Initiated by Hind (1918) and later elaborated by Bisat (1924), this palaeontological work quickly revealed that the Kinderscout Grits of Derbyshire were in fact the equivalents of the Brimham Grits of Nidderdale and not of the beds below the Colsterdale Limestone.

In the year succeeding the publication of Bisat's paper, Chubb and Hudson (1925) established (i) that the base of the Millstone Grit is transgressive, thus confirming a conclusion previously reached by



1
SIMONSEAT
2
GREENHOW
3
NIDDERDALE
4
UPPER NIDDERDALE
G
R1
H
E2
E1
Comb Hill Grit
Libishaw Grit
Cayton Gill Beds
Upper Follifoot Grit
Lower Follifoot Grit
Birk Hill Shales
Red Scar Grit
Grassington Grit Group
Comb Hill Grit
Libishaw Sandstone
Cayton Gill Beds
Upper Follifoot Grit
Lower Follifoot Grit
Colsterdale Marine Beds
Red Scar Grit
Cockhill Marine Band
Grassington Grit Group
Winksley Sandstone
Laverton Sandstone
Second Brimham Grit
First Brimham Grit
Libishaw Sandstone
Cayton Gill Shell Bed
Upper Follifoot Grit
Lower Follifoot Grit
Colsterdale Marine Series
Red Scar Grit
Cockhill Marine Band
Grassington Grit Group
Second Brimham Grit
First Brimham Grit
Libishaw Sandstone
Cayton Gill Shell Bed
Ganister Series
Lower Follifoot Grit
Colsterdale Marine Series
Red Scar Grit
Cockhill Marine Band
Grassington Grit Group
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0 FEET



R. URE
4
MIDDLESMOOR
KIRKBY MALZEARD
R. NIDD
RIPON
R WHARFE
FOUNTAINS ABBEY
3
N
PATELEY BRIDGE
2
GRASSINGTON
1
RIPLEY
0 1 2 3 4 5
Scale in miles

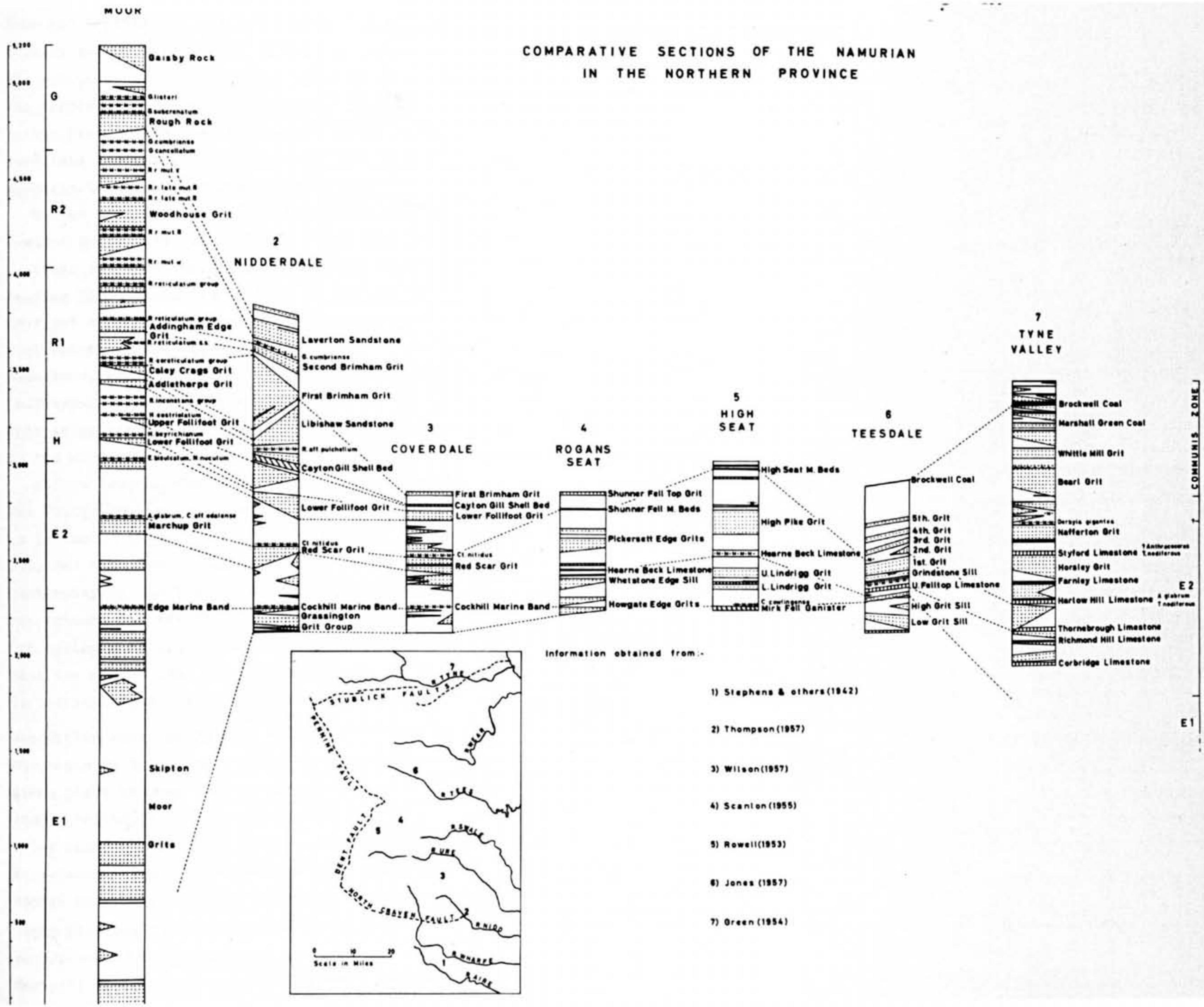
Figure 15. Comparative sections of the Millstone Grit and Lower Coal Measures of Nidderdale and adjacent areas. The boundaries on the sketch-map indicate the positions of the described areas. Simonseat(Hudson, 1939); Greenhow (Dunham & Stubblefield, 1945); Upper Nidderdale(Wilson, 1957)

Dakyns (op.cit.p.258); (ii) that the unconformity is of the nature of a northerly overlap, the Pinlow Pike Grit (equals Priest's Tarn Grit) being equivalent to the Lower Howgate Edge Grit of Shunner Fell; (iii) that if the latter correlation is correct, then the Colsterdale Limestone is probably equivalent to the Hearne Beck Limestone and the Cayton Gill Beds to the Shunner Fell Marine Beds, the faunal differences merely reflecting a progressive change to shallower water conditions in the north.

Hudson (1939) himself provided the first evidence to refute this correlation following his survey of the Simonseat anticline. There the discovery of a Reticuloceras fauna in the shales below the Cayton Gill Shell Bed immediately invalidated his equation of the Cayton Gill Beds with the Shunner Fell Beds, because the latter were already known to contain Anthracoceras making them of E2 age (Chubb and Hudson, 1925 p.262). Instead it seemed more likely that the Shunner Fell Beds were equivalent to part of the Birk Gill Shales (equals Colsterdale Marine Series), and the Hearne Beck Limestone to the Gate-up Limestone (equals Cockhill Marine Band) of Nidderdale. Hudson's later discovery (1941) of Cravenoceras cowlingense in the Mirk Fell altered this correlation because it indicated that the Hearne Beck Limestone is higher in the sequence than the Gate-up Limestone and most likely equivalent to a shale horizon above the Pinlow Pike Grit. The importance of Hudson's find however, was not that it proved his earlier correlations wrong, so much as that he was able to demonstrate for the first time that sediments of Millstone Grit facies passed laterally into sediments of Yoredale facies.

Cravenoceras cowlingense has now been found in a number of widely scattered localities, enabling the Mirk Fell Ironstones to be correlated directly with other marine bands in the south. Dunham and Stubblefields (1945) discovered it in the Cockhill Marine Band at Greenhow, and Wilson (1957) and the present author have subsequently confirmed its presence at several localities in the same band farther north. It has been found in the Lancaster Fells by Moseley (1953), there as at Greenhow associated with Eumorphoceras bisulcatum. Nothing peculiar was noted about the specimens of this latter goniatite from the Lancaster Fells, but at Greenhow Eumorphoceras bisulcatum mut. grassingtonensis (Stubblefield, 1945) was seen to possess features apparent in specimens

COMPARATIVE SECTIONS OF THE NAMURIAN IN THE NORTHERN PROVINCE



from the Edge Marine Band of Rombalds Moor (Stephens et.al.1942), giving support to the correlation of the two horizons. The "early" aspect of the specimens of Eumorphoceras from the latter band however, coupled with the discovery of Cravenoceras near to malhamense in its equivalent the Warley Wise Marine Band, led Dunham and Stubblefield (op.cit. p.238) to postulate a slightly later date for the Cockhill Marine Band. This approximate correlation is followed here.

To the north the Mirk Fell Ironstones have been correlated with the Knucton Shell Beds (Carruthers, 1938), and the Rookhope Shell Beds together with the overlying Lower Felltop Limestone (Hudson, 1941). Reading (1954) however, working on the correlation problems across Stainmore does not support either suggestion, and in fact has demonstrated the lateral equivalence of the Upper Stonesdale Limestone to the Lower Felltop Limestone, concluding that the Mirk Fell Ironstones are not represented in Teesdale where they seem to have been cut out by the Transgression Beds. This interpretation is also favoured by Jones (1957) working in the area to the north so it is followed in Fig.16.

Before leaving the Cockhill Marine Band and its equivalents elsewhere, two things remain for comment. The first is that the band was not found at Simonseat (Hudson, 1939) or at Keasden (Moseley, 1956), nor was it recorded from the Sawley borehole. In the case of the latter, the discontinuity of the limestone already noted near Grassington (Chapter III) may account for its failure to be recorded in the drilling mud fragments (no coring took place), but its absence in the other two areas suggests that the marine band was not everywhere deposited. In this connection it is interesting to observe that Scanlon (1955) considered the area of deposition surrounding Mirk Fell Gill to have no direct connection with the basin to the south, though it is obvious that some migration must have taken place between the two though more recently, Wilson (personal communication) has discovered fossiliferous strata at this level seven miles south of Mirk Fell Gill so that some modification to Scanlon's conclusion may now be necessary. The second is that whilst some faunal change is apparent in the Cockhill Marine Band in a northerly direction in Upper Nidderdale, as witnessed by the incoming of brachiopods, apart from the occurrence of C. cowlingense no general faunal similarity exists between the Cockhill Marine Band and the Mirk Fell Ironstones. This is interpreted by

Wilson (1957) as being due to shallower water conditions of deposition in the north.

Assuming the correcteness of the correlation of the Cockhill Marine Band with the other marine bands shown in Figs. 15 and 16, it is now possible to say something about the changes that take place in the Millstone Grit beds below. These have been dealt with in detail in Chapter II where it has been noted that the Grassington Grit Group thickens rapidly to the south, attaining the prodigious figure of 2,400 feet on Skipton Moor (Bradford Memoir). To the north the group thins markedly, changing from a series of coarse sandstones in Nidderdale to a predominantly shaly sequence in Coverdale (Wilson, 1957); farther north still in the Shunner Fell area, Scanlon (1955) has shown that the Mirk Fell Ganister which underlies the Ironstones containing C. cowlingense, maps laterally into the Lower Howgate Edge Grit, making it likely that the northerly thinning persists to that area also.

The next horizon which can be successfully correlated is the Colsterdale Marine Series, a group of fossiliferous shales with a thin limestone near the middle, characterised by Cravenoceratoides nitidus. This goniatite has been recorded from Upper Nidderdale (Tonks, 1925; Wilson, 1957), Simonseat (Hudson, 1939), Greenhow (Dunham and Stubblefield, 1945), Keasden (Moseley, 1956) and the Lancaster Fells (Slinger, 1936; Moseley, 1953), in each case occurring in a limestone nearly constant in fauna, thickness and lithology, suggesting its probable simultaneous deposition over a wide area. In the Bradford-Skipton area (Bradford Memoir), Leeds area (Leeds Memoir) and the Beamsley anticline (Jones, 1943) however, Ct. nitidus has not been found, but Cravenoceras subplicatum has, a form known from the Alport borehole (Hudson and Cotton, 1943) to underlie Ct. nitidus in the goniatite sequence. It is therefore concluded that the Colsterdale Marine Series are in part the equivalent of the Marchup Marine Beds of Rombalds Moor (Stephens et.al. 1942), though as in the case of the Cockhill Marine Band, marine deposition commenced later in Nidderdale than in the ground to the south.

From Nidderdale the Colsterdale Marine Series undergo a marked change in thickness when traced into adjoining areas. This is observed to the south (Simonseat), west (Keasden and Lancaster Dells) and north (Upper Nidderdale), in each case the change appearing to be most noticeable in the shales below the Colsterdale Limestone. To the north the thickening is accompanied by the incoming of a nuculid/gastropod phase at the base of the marine sequence (Wilson, 1957), which as in the instance of the Mirk Fell Ironstones, Wilson has interpreted as an indication of shallower water conditions northwards. Farther north still at Shunner Fell (Scanlon, 1955) no nuculid/gastropod phase is evident, but on the basis of the occurrence of Anthracoceras cf. paucilobum and Tylonautilus nodiferus, Scanlon has equated the Shunner Fell Marine Beds with the Colsterdale Marine Series and this correlation is followed here, if anything strengthened by the discovery of Tylonautilus nodiferus in the shales below the Colsterdale Limestone in Backohean Gill, Nidderdale. Beyond Swaledale, Reading (1954) has correlated the Botany Limestone with the Shunner Fell Marine Beds and their equivalent the High Seat Marine Beds. In addition, these horizons have been considered to be equivalent to the Harlow Hill Limestone of Northumberland by Hedley (1931) and Green (1954) on the grounds of the occurrence of Anthracoceras glabrum and T. nodiferus. Neither of these fossils are diagnostic of anything but the E2 stage so that the correlation cannot be said to have a firm foundation; in particular the value of T. nodiferus s.l. as a guide fossil must be limited because it ranges from the Corbridge Limestone to the Styford Limestone in Northumberland, a vertical distance of more than 600 feet.

The correlations mentioned above are set out in Fig. 16, whence it will be apparent that the Arnsbergian thickens noticeably to the north, thinning slightly in Teesdale; Beyond Swaledale another marine band comes in, the Hearne Beck Limestone which has been correlated by Reading (1954) with the Upper Felltop Limestone of Alston and by Green (1954) with the Thornborough Limestone of Northumberland.

No higher beds in the sequence occur between Wensleydale and Teesdale, but farther north they come in, and there, being deficient in marine horizons they provide considerable difficulty in correlation. To the south, however, where they also occur, the correlation is quite straightforward and this is illustrated in Figs. 15 and 16. From the diagrams it will be apparent that the Lower Follifoot Grit persists from Colsterdale to Rombalds Moor, dying out in the Bradford-Skipton area. Likewise the Upper Follifoot Grit also dies out in that area, but can be traced northwards to Nidderdale, passing laterally into the Ganister Series in Upper Nidderdale. This correlation has only recently been put forward and as observed by Wilson (1957) was only made possible by the discovery of a marine band containing Homoceras beyrichianum in the shales above the Lower Follifoot Grit in Upper Nidderdale, the equivalent horizon being already known from Rombalds Moor (Stephens et.al., 1942), Simonseat (Hudson, 1939), Keasden (Moseley, 1956) and the Lancaster Fells (Moseley, 1953), though not at Greenhow (Dunham and Stubblefield, 1945), the Leeds district (Leeds Memoir) or the present area. On the basis of this marine horizon, Moseley (1956) has correlated the Follifoot Grits with the Silver Hills and Clintsfield's Grits of the Keasden area to the west.

Below the Follifoot Grits the beds are dominantly shales with impersistent sandstones, a lithology apparently maintained over a wide area to the south. At Rombalds Moor (Stephens et.al., 1942) a marine band characterised by the goniatite Nuculoceras nuculum occurs near the top of the sequence, but this is not known in the present area or at Simonseat (Hudson, 1939). Greenhow (Dunham and Stubblefield, 1945) and Upper Nidderdale (Wilson, 1957).

Above the Follifoot Grits, the distinctive Cayton Gill Beds come in, a group of marine sediments confined to a relatively small area in the mid and north Pennines. The succession consists of the Cayton Gill Shales below, a series of shales partially marine at Greenhow (Dunham and Stubblefield, 1945) and Simonseat (Hudson, 1939), and the Cayton Gill Shell Bed above, a group of shelly siltstones characterised by a brachiopod/lamellibranch fauna. This latter horizon was originally equated with the Otley Shell Bed of Rombalds Moor (Edwards, 1936, p.139), but later work (Stephens et.al., 1942) has proved this correlation to be incorrect, the Otley Shell Bed actually being much higher in the sequence. Similarly, the correlation of the Upper Hard Bed of Simonseat (Hudson, 1939) with the upper Shell Bed of Upper Nidderdale is now no longer supported, Wilson (1957) having shown that the latter bed passes laterally into the Libishaw Sandstone of the present area. The Cayton Gill Shell Bed is however correlated with the Hard Beds of Simonseat and Greenhow (Dunham and Stubblefield, 1945), the Cayton Gill Beds of Beamsley (Jones, 1943) and the Leeds district (Leeds Memoir) and the bed of similar title in Upper Nidderdale (Wilson, 1957), in each case the fauna being closely comparable. Bands containing brachiopods occur at this approximate level in the Keasden area (Moseley, 1956), but the general lack of identity between the two successions makes positive correlation of any of the Keasden shell beds with similar beds in Nidderdale most difficult.

The next bed in the succession is the Agill Sandstone, and this is directly overlain by the Libishaw Shales. Both these beds can be traced laterally into Upper Nidderdale (Wilson, 1957), the latter being known at Simonseat (Hudson, 1939) and Greenhow (Dunham and Stubblefield, 1945) as well, though it dies out near Greenhow. In the Leeds district (Leeds Memoir), the Libishaw Shales include a marine band (the Addlethorpe Marine Band) near their base which contains the goniatite Reticuloceras aff. pulchellum (bed W in the railway cutting at Storris House). This form is now known to characterise the marine band in the Libishaw Shales of this area, a fact which coupled with the band's stratigraphical position supports the correlation of the two horizons, It is perhaps appropriate to mention here also that R. circumplicatile group, the only goniatite ever recorded from the Cayton Gill Shell Bed also occurs in bed X of the same section at Storris House.

The Libishaw Shales are suceeded by the Libishaw Sandstone, a bed of uniform lithology over a wide area. It is correlated on the grounds of stratigraphical position with the Libishaw Sandstone of Upper Nidderdale (Wilson, 1957) and Greenhow (Dunham and Stubblefield, 1945), and the Addlethorpe Grit of Rombalds Moor (Stephens et.al., 1942). The bed appears to thicken in a southerly direction, attain itsmaximum at Greenhow and then thin to the south, eventually dying out near Harewood (Bradford Memoir). The Libishaw Sandstone is not however correlated with the whole of the Libishaw Sandstone of Simonseat (Hudson, 1939), the reasons for this having already been stated in Chapter IX. It seems that in the north of Simonseat, Hudson's interpretation is correct, the Comb Hill Grit of Redlish Moor passing laterally into the Comb Hill Grit of Greenhow (Dunham and Stubblefield, 1945) and the First Brimham Grit of Heyshaw Moor; farther south however, in Capelshaw Beck, the upper part of the "Libishaw Sandstone" is a coarse felspathic sandstone of undoubted First Brimham Grit type and there it is overlain by a marine sequence which includes the goniatites Homoceras striolatum and Reticuloceras reticulatum. As these forms also occur in a marine band overlying the Lower Plumpton Grit at Killinghall (Bisat and Hudson, 1943) and the Caley Crags Grit at Rombalds

Moor (Bradford Memoir), it is concluded that the upper part of the Libishaw Sandstone of Capelshaw Beck is in fact the equivalent of the First Brimham Grit. It is about 50 feet thick there and overlies a medium grained quartzitic sandstone, almost identical in the flaggy nature of its beds and the occasional shale lenses to the Libishaw Sandstone of Nidderdale, with which it is therefore partially correlated.

This interpretation necessarily implies the absence of the Bewerley Shales from the southern part of Simonseat, but they are known at Greenhow (Dunham and Stubblefield, 1945), Beamsley (Jones, 1943), Upper Nidderdale (Wilson, 1957) and Rombalds Moor (Bradford Memoir), in the latter area, characterised by a marine band, the Otley Shell Bed near the top. The position, lithology and fauna of this band closely resemble that of the Scot Gate Ash Marine Band, thus supporting the correlation of the two horizons, a view already advanced by Walker (1952).

The succeeding beds in the sequence are the Brimham Grits, coarse felspathic sandstones which map laterally into the First and Second Brimham Grit of Upper Nidderdale (Wilson, 1957), the Comb Hill Grit of Greenhow (First Brimham Grit only) and the northern part of Simonseat, and the upper part of the Libishaw Sandstone and Comb Hill Grit of the southern part of Simonseat (Hudson, 1939). On the grounds of stratigraphical position and lithology, these beds are equated with the Plumpton Grits of the Leeds district (Leeds Memoir) and the Caley Crags Grit and Bramhope Grit of the Bradford-Skipton district (Bradford Memoir). The marine band containing H. striolatum and R. reticulatum which occurs in the shales between the Plumpton Grits in the Leeds area has not however been found in this area, nor is it recorded from Greenhow (Dunham and Stubblefield, 1945) or Upper Nidderdale (Wilson, 1957).

The Brimham Grits are overlain by the Laverton Shales, a group distinguished by the Marine band that occurs near the middle of them, which is considered to be equivalent to the Gastrioceras cumbriense band on Rombalds Moor (see Chapter XI). This faunal equivalence implies the complete absence from this area of the Middle Grit Group of Rombalds Moor, a series of sandstones and shales which average 525 feet in that district. Such a hiatus was not entirely unexpected in view of the failure of several authors (Dunham, 1948, Green, 1954 and Currie, 1954) to detect the H, R and G_1

zones on the Alston Block or in Scotland but the accurate location or description of the break does not appear to be possible. It is almost certain that in the present area it occurs in the 20 feet of shale between the Second Brimham Grit and the G. cumbriense band, correlation of the beds up the Second Brimham Grit with Rombalds Moor being quite satisfactory. To say more than this would be mere speculation because the break may have the nature of (i) a non-sequence, (ii) a condensed sequence, (iii) an unconformity, or (iv) a succession of unconformities, but no critical evidence is at present available to resolve the problem.

Above the Laverton Shales lies the Laverton Sandstone, a bed now equated withethe Rough Rock of Rombalds Moor (Stephens et.al., 1942) on the basis of the faunal equivalence noted above. This correlation finds some support on the grounds of similar thickness, both beds being approximately 120 feet thick, but not lithology, for whereas the Laverton Sandstone is predominantly massive and quartzitic, the Rough Rock is divided into a lower flaggy portion and an upper portion of coarse felspathic sandstone. A shale parting is locally known between the Rough Rock Flags and the overlying Rough Rock, but this does not carry a coal as in the present area. Additional evidence for the correlation is however found in the Lingula band recorded from the upper part of the Laverton Shales, a similar band having been found in the area to thesouth by Hudson and Dunnington (1939 p.134), Gilligan (1921) and Slinger (1936a).

The remaining beds in the sequence are the Winksley Beds, shales below and sandstone above. On Rombalds Moor (Stephens et.al., 1942) the equivalents of these beds are referred to the Coal Measures, the base of that division being drawn at the base of the Gastrioceras subcrenatum band, or for practical purposes at the top of the Rough Rock. The G. subcrenatum band has not been found in this area, but a short distance above the base of the Winksley Shales a Lingula Band occurs, which is possibly the northern representative of the Lingula Band overlying the Middle Bed Coal in the Leeds District (Leeds Memoir). If this correlation is correct then the Winksley Sandstone is most likely the equivalent of the Stanningley Rock of Rombalds Moor (Bradford Memoir), but in support of this, no trace the G. listeri marine band has yet been found in this area.

Zonal Succession

The sub-division of the Namurian on the basis of goniatite zones was first attempted by Bisat (1924) following an earlier proposal by Hind (1918). Names for the divisions were not then incorporated, but Bisat (1928) later introduced them and these were subsequently re-defined by Hudson and Cotton (1943). Further revision by Hudson (1945) delineated the zones with greater precision and for the first time raised the status of each former "genus zone" to an age.

Hudson's zonal system extended from the Pendleian to the Yeadonian,ie. from the E_1 Stage to the G_1 Stage. Of these zonal divisions all were considered to be present on Rombalds Moor, though not in every case was it possible to recognise individual sub-zones. Farther north however, a number of these zones appeared to be unrepresented and it was concluded that the succession, unless incomplete, was considerably attenuated.

In the areas adjoining this district, ie. Simonseat (Hudson, 1939), Greenhow (Dunham and Stubblefield 1945) and Upper Nidderdale (Wilson, 1957) the zonal divisions from the E_1 Stage to the R_1 Stage can be discerned. The E_1 Stage is represented by the Grassington Grit Group, bounded at the base by an unconformity and at the top by the base of the Cockhill Marine Band. This latter boundary appears to be somewhat subjective because Hudson (1945) and Trotter (1952) place the marine horizon overlying the Grassington Grit Group and its equivalents elsewhere in the E_1 Stage, whereas Dunham and Stubblefield (1945), the authors of the Bradford Memoir and Dunham (1948) place it in the E_2 Stage. The Arnsbergian therefore extends either from the base of the Cockhill Marine Band to the base of the Lower Follifoot Grit or from the top of the Cockhill Marine Band to the base of the Lower Follifoot Grit, depending on which author is supported. The conclusions of Dunham and Stubblefield (1945) are favoured in this account, so the E_1:E_2 junction is drawn at the base of the Cockhill Marine Band.

In addition to differences of opinion about the lower limit of the Arnsbergian, the upper limit is also subject to personal preference. On Rombalds Moor it is drawn at the top of the marine band containing Cravenoceras fragilis and Nuculoceras nuclum by Hudson (1945) and at the base of that band by Bisat (1928) and the authors of the Bradford Memoir. As that marine band does not occur in this area, the E_2:H boundary is generally taken as the base of the Lower Follifoot Grit, following the correlations of Hudson (1939, p.337). This procedure is maintained here.

The position of the succeeding major zonal junction, that of the Sabdenian:Kinderscoutian is now fairly certain. In 1939, Hudson discovered a Reticuloceras fauna in the shales overlying the Upper Follifoot Grit, thus proving that the Cayton Gill Beds belonged to the R_1 Stage. Below this the nearest marine band was that containing Homoceras beyrichianum in the shales above the Lower Follifoot Grit. The $H:R_1$ boundary therefore lay somewhere between these two marine horizons. A comparison of the succession at Simonseat with that of Bowland Forest to the west, suggested to Hudson (1939, p.337) that the boundary lay below the Upper Follifoot Grit because an R. inconstans fauna was thought to underlie the equivalent of the Upper Follifoot Grit in the latter area. More recent work from Rombalds Moor (Bradford Memoir) however, does not support this suggestion, an H zone fauna (H. aff. eostriolatum) having been found in the shales above the Brocka Bank Grit (equivalent of the Upper Follifoot Grit) in the Bradford-Skipton area, indicating that the $H:R_1$ boundary lies above the Upper Follifoot Grit. This would place it somewhere in the Cayton Gill Shales, from which Hudson (1939) earlier collected a Reticuloceras fauna, so that the junction must occur towards the base of the shales.

Above the Cayton Gill Shales lie the Cayton Gill Beds and the Brimham Grits. Of these, the Cayton Gill Shell Bed and Libishaw Shales belong to the R. inconstans zone on the basis of the occurrence of R. circumplicatile group and R. aff. pulchellum respectively. Above them lies the Scot Gate Ash Marine Band, the northern equivalent of the Otley Shell Bed, which on Rombalds Moor (Bradford Memoir) is considered to form the base of the R. reticulatum zone. The overlying Brimham Grits are thought to be equivalent to the PlumptonGrits of the Leeds District (Leeds Memoir) and the Caley Crags and Bramhope Grits of the Bradford-Skipton area (Bradford Memoir) on the basis of stratigraphical position and lithological identity. These latter beds contain a marine band of R_1 age between them and it is likely on the correlations presented above that all the strata between the upper part of the Cayton Gill Shales and the top of the Second Brimham Grit belong to that Stage of the Namurian also.

A short distance above the top of the Second Brimham Grit, a Gastrioceras cumbriense fauna occurs. This implies the complete absence from this area of the R_2 Stage. As has been mentioned above, this hiatus was not unexpected in view of the failure of several authors (Dunham, 1948; Green, 1954; Currie, 1954) to detect all the higher zones in the region to the north. On the Alston Block for instance, Dunham (1948) has summarised the zonal sequence and stated that whilst beds of E_2 age can be recognised, e.g. some of the limestones in the Upper Limestone Group, no evidence is forthcoming to support the occurrence of zones H, R and G. "In any case", he continues, "the thickness of strata that could be assigned to these zones is in no way comparable to that developed in the mid-Pennines". Beyond the Alston Block (Green, 1954) has recently described the Upper Carboniferous succession in the Tyne valley and adduced evidence to support Dunham's conclusions. There, the Harlow Hill Limestone and Styford Limestone have been referred to the E_2 Stage on the grounds of the occurrence of Anthracoceras sp. and Tylonautilus nodiferus. The beds above have yielded no critical faunal information, but 500 feet below the Brockwell Seam the strata still appear to have close affinity to the Coal Measures (considered to be communis zone), thus leaving only 300 feet in which the lenisulcata, G_1, R and H zones if present, could occur. Whether they do is very questionable and the hiatus which Green (p.299) envisages is situated either a short distance above, or a short distance below the Nafferton Grit.

The position therefore, is of a probable failure of the H, R and G_1 zones in a northerly direction. Into this picture the recent evidence from Nidderdale comes with considerable interest, because a stage in the process is now evident. On Rombalds Moor (Bradford Memoir) a complete succession from the E_1 Stage to the G_1 Stage can be detected. In the present area the succession is complete except for the whole of the R_2 Stage. In Upper Nidderdale (Wilson, 1957), the highest beds described are of R_1 age, whilst farther north on the Alston Block (Dunham, 1948) zones H, R and G are possibly missing. The area in which the upper zones seem to disappear is therefore between Upper Nidderdale and Teesdale.

One explanation of this contingent dying out of zones is a tilting of the "rigid block", the process commencing after the deposition of the E_2 Stage. This would produce progressive overlapping relations in a northerly direction and a southerly migration of the northern limit of each zone. In this area the effects of the tilt would not have become sufficiently marked to incur the absence of a zone until after the deposition of the R_1 Stage, but a thinning of the H and R zones would and this is observed in practice. Following the downward tilt of the "rigid block" to the south in H and R times the process would seem to have been reversed at the commencement of G times, because the G zone is present in this district. Clearly this explanation is very tentative and cannot be given reasonable credence until several more stratigraphic facts are known. Amongst these are the precise areal limits of each zone, the direction from which the marine invasions came, the source and direction of deposition of the deltaic deposits and the possible occurrence of separate basins of marine deposition as hinted at by Scanlon(1955). Some of these may never be known because of insuperable factors such as poor exposure and change in marine facies, but the increasing output of more detailed work should help to exclude certain possibilities and strengthen the likelihood of others.

CHAPTER XIII

STRUCTURE

The broad structural pattern of the Carboniferous rocks of this area may reasonably be asserted to have been established well before the close of the 19th. Century. The Craven Fault, that important tectonic line, had been recognised first by Sedgwick in 1835 and again the following year by Phillips (1836). Then it had been shown to consist of two members, a northern and southern. The northern one, termed the North Craven Fault by Phillips, appeared to be especially distinctive, in that throughout the length of its course between Ingleton and Pateley Bridge it separated an area of gently dipping sediments from one in which the strata had undergone profound disturbance. This alone was noteworthy, but in addition, it was observed that the N.E.-S.W. flexures (the Ribblesdale folds) which formed the main element of the structures south of the fault, veered to an E-W direction (approximating to the line of the fault) in the northern part of the folded region, suggesting a similar if not equivalent age of the folds and the fault.

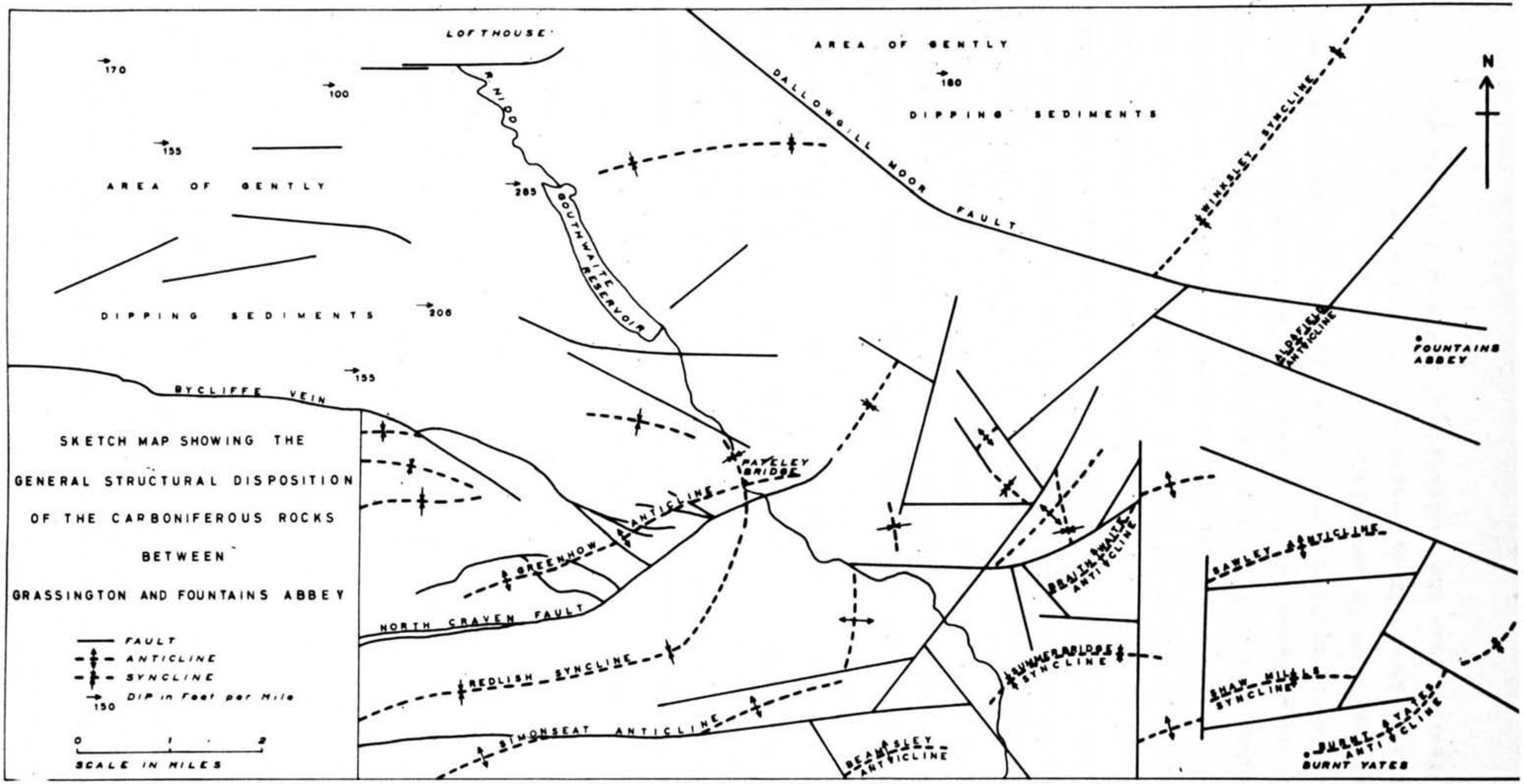
Following Phillip's work, little of importance was added prior to the publication of the results of the primary geological survey. It is true that Hull (1868) and Miall (1869) expanded the detail of the Ribblesdale structures, but this was chiefly with reference to the folds in the west of the region and not those occurring in the vicinity of Nidderdale. The work of the Geological Survey covered the whole of the north of England, the present district being surveyed mainly by John Lucas. To the west, a large part of the ground was examined by Tiddeman and Dakyns and it is to these officers that the bulk of the structural information that appeared about this time is due. The first paper came from the pen of Tiddeman (1890) and dealt with the course of the Craven Faults, a third member by now having been established. In addition to outlining their course, reference was made to the marked change in thickness and facies that takes place at the line of the North Craven Fault, the Carboniferous appearing to be divisible into two series, whose boundary is the fault. This was corroborated by Dakyns (1890) later in the year, the stratigraphical changes taking place being described in greater detail. Two further papers by the same author (1892, 1895) also touched on matters of stratigraphical change, but a section in the later one contains a reference to the position of the main fold axes in the vicinity of Nidderdale as well.

From the above it will be clear that many of the major structural features of this area were established relatively early in the history of Carboniferous geology, but the expansion of the detail and the relation of it to causal tectonic forces was yet to come. This may be said to have commenced with Marr (1910), who after emphasising the structural change that takes place at the line of the North Craven fault in an earlier paper (1890), considered the northern Pennines to constitute a fault bounded block, tilted in an easterly direction. The fault bounded block was discussed by Kendall (1911) a year later and thought to have greater structural implications, in view of new evidence that was forthcoming, to indicate a simultaneous and unified operation of the bounding faults. In 1921 all the known evidence relating to this stable massif was reviewed by Marr (1921) and as a result, the region bounded by the Stublick, Pennine, Dent and Craven Faults was designated a "rigid block", distinguished from the surrounding areas by its relative thinness of sediments and simplicity of structure. Aspects of the block were further discussed by Versey (1927) and Trotter and Hollingworth (1928), the northern part being named the Alston Block by the latter authors. Similarly, the southern half, separated from its northern counterpart by the Stainmore Syncline, was termed the Askrigg Block by Hudson (1938, p.300) and the whole "block" stated to be the result of compaction of Lower Carboniferous and earlier sediments by the Caledonian orogeny - a stable massif therefore, since early if not preCarboniferous times. Its tectonic simplicity has been upheld by later workers (Dunham and Stubblefield, 1945; Rowell, 1953; Scanlon, 1955; Wilson, 1957), though Dunham and Stubblefield (1945, p.243) have stressed that this is relative only, folds being apparent on the "block". To the south, lies the folded region of the Craven Basin, part of which has been discussed by Anderson (1928), Hudson and Mitchell (1937), Jones (1943) and Hudson (1938, 1939), whilst the separating fault (the North Craven Fault) has been the subject of investigation by Wager (1931), Dunham and Stubblefield (1945), Black (1950) and Rayner (1953).

It will be seen from the Fig. 1 that The area described in this account is situated at the south eastern corner of the Askrigg Block and extends southwards into the Craven Basin of sedimentation. Its structural disposition is depicted in Fig. 17, the diagram showing contours relative to O.D. of the base of the Cayton Gill Shell Bed. The possibility of error in the diagram due to variations in thickness of individual beds is recognised, but these have been minimised wherever possible, by using only well established stratigraphical planes. These are: base of Cockhill Marine Band, base of Red Scar Grit, base of Colsterdale Marine Series, base of Lower Follifoot Grit, base of Upper Follifoot Grit, base Cayton Gill Shell Bed, base of Libishaw Sandstone and base of the two Brimham Grits, north of the North Craven Fault. South of the North Craven Fault where the First Brimham Grit is transgressive and in the north-west of the area, where thickness variations in the Brimham Grits are most likely to occur, the chances of error are greatest, but even allowing for their occurrence it is not thought that the interpretation of the diagram will be radically affected. Elsewhere the possible error should be well within 100 feet and in many places considerably less than this.

The diagram reveals a ready division of the district into two sections: (i) a northern region of gently dipping sediments and (ii) a southern region of structural complexity. In the north the strata dip gently to the east at an average figure of 180 feet per mile or just under 2°. This resembles closely the average dip in Upper Nidderdale (Wilson, 1957), but unlike that area a general steepening of dip to the east cannot be discerned. Local variations within the district are however abundant, and can often be related to the proximity of fault lines. Some of the variations are recorded in Fig.18 and will be seen from the diagram to range from 100 feet to 285 feet per mile, the dips being calculated over distances of more than half a mile. A feature not given prominence in the diagram however, is the general steepening of dip across the valley of the Nidd, the actual reason for which is far from certain but possibly related to a large scale solifluction effect . To the east the gentle easterly dip is reversed, and beyond Laverton the strata are flexured into an asymmetric syncline, whose trend is N.E.-S.W. The eastern limb of this syncline is much steeper than the western and is partially repeated by a fault near Aldfield, the dip appearing to moderate beyond that structure. Farther east, the Carboniferous strata are obscured under the later sediments of the Vale of York so that it is not possible to say whether this fold is just a local flexure on the "rigid block" or whether the gently dipping strata pass eastwards into a region of N.E.-S.W. folds.

To the south, the gentle easterly dip is lost and the area of structural



The information for the Greenhow and Simonseat areas in the bottom left hand quadrant of the diagram is obtained from Dunham and Stubblefield(1945) and Hudson(1939) respectively.

simplicity gives way to an area of structural complexity. In the west of the district, this change is quite abrupt and can be identified with the Bycliffe Vein, the strata to the north dipping gently to the east, whilst to the south they are folded on approximately east-west axes. This is readily apparent from Fig.17, the inset of the Greenhow area (Dunham and Stubblefield, 1945) being included to illustrate the point. Farther east, however, this change cannot be localised or identified with any lone line, though it appears to be more or less coincident with the extension of the North Craven Fault Line.

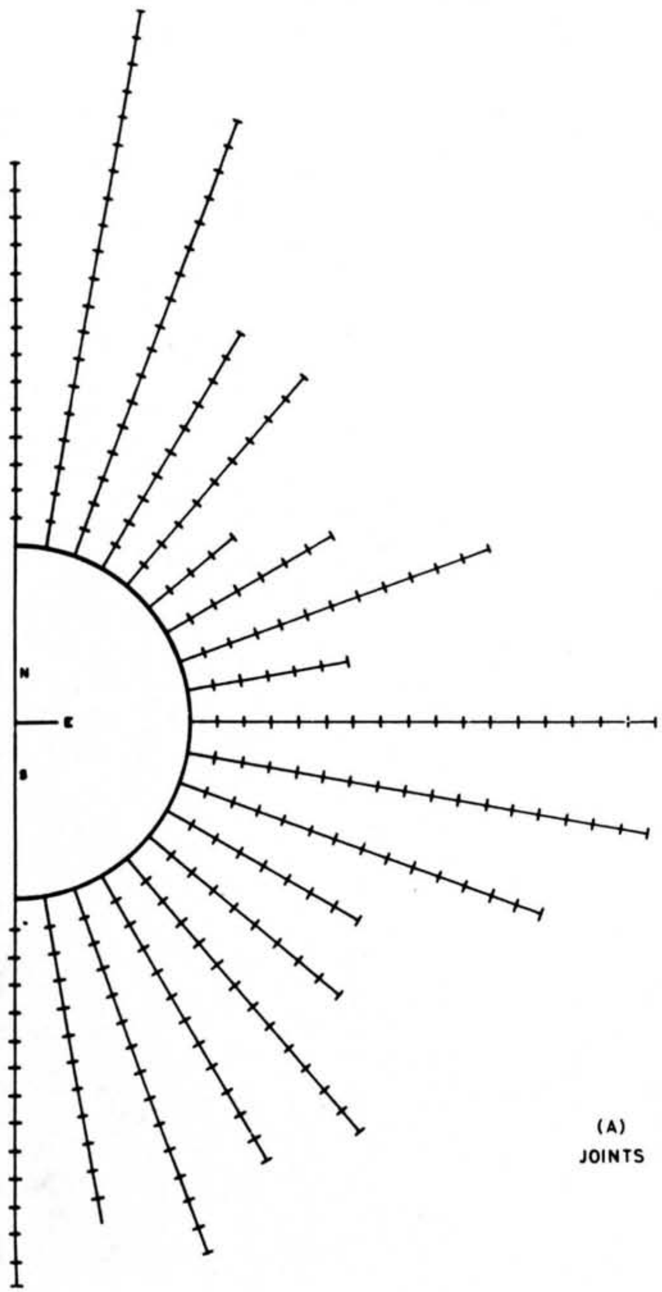
Before passing on to a description of the general pattern of faults and folds, one further comment remains. This concerns the gentle fold east of Ramsgill, in the middle of the structurally simple area. Its presence there illustrates Dunham and Stubblefield's (1945) contention that folds do occur on the "rigid block", though in this case, the flexure is of very restricted importance.

Faults

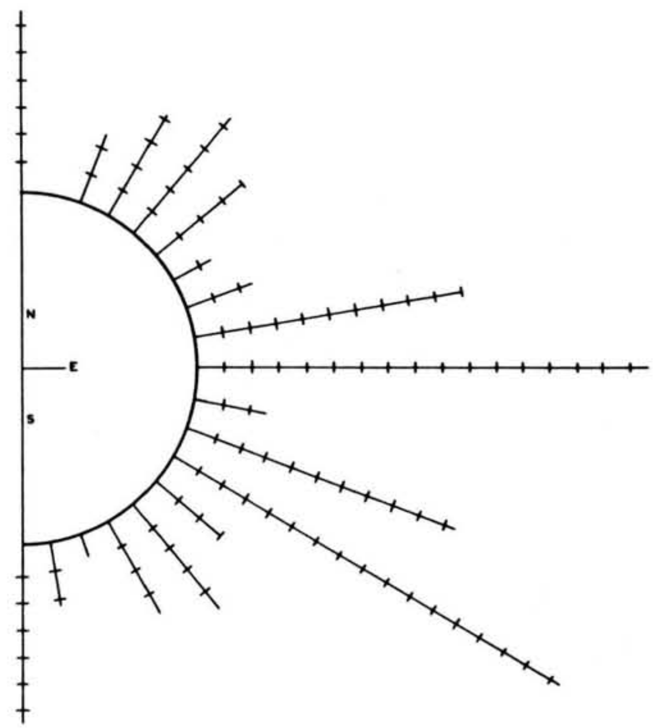
A quick glance at the Structure Contour Map, Fig. 17 will reveal that the area described in this account is traversed by a large number of faults. Several of these were not mapped by the Geological Survey and in other cases it has been found that supporting evidence for some of the Survey's faults could not be maintained. On the whole however, considerable similarity between the two maps is apparent.

The majority of the faults occur in the south-east quadrant of the area, where their disposition appears to follow no regular pattern. Elsewhere, the importance of the E-W and W.N.W.-E.S.E. directions can be discerned and as these are significant directions in Upper Nidderdale (Wilson, 1957), they may be taken as characteristic of the south-eastern corner of the Askrigg Block. The trend of all the faults is analysed in Fig. 19 B; from the diagram it will be seen that two prominent directions occur within the district as a whole: one at 90° E. of N. and the other at 130° E. of N. In addition to these, a direction of subordinate importance is the N-S one, a direction which Wilson (1957) has observed to be conspicuously absent in Upper Nidderdale. Those faults of this direction occurring here however, are confined to the southern part of the district and hence are some distance from the Askrigg Block to the north.

So far as can be ascertained, nearly all the faults encountered in this district are normal faults, only one indication of the tear faulting described from



(A)
JOINTS



(B)
FAULTS

Figure 19. Statistical analysis of Structural trends.

A. Joints. Each division represents one joint direction.

B. Faults. Each division represents one mile of fault in the direction indicated.

Simonseat (Hudson, 1939, p.342) being evident here. Most are of small throw, the average being less than 50 feet, but a few exceed this and locally have a throw of as much as 400 feet. As nearly all of them have been mentioned in the section dealing with Stratigraphy, only the more salient features will be touched upon here.

In the extreme N.W. of the district a small group of faults occurs in the ground between Riggs Moor and Stean Moor. All these faults are normal faults with a variable throw to the south and north. Some are sharply defined fractures with a steep hade (Pl. XX A); others are shallower and in addition to zones of fault breccia reveal noticeable terminal bending. Their point of interest, however, lies in the fact that they come to a focus at the confluence of West Gill and Green Grooves Gill, and hence have a collective fan shape.

To the east of them lies the two Lofthouse Faults, both of which have an E-W trend and are exposed in Blayshaw Gill. The northern one is the longer and has the greater throw (ca. 60 feet), this being well displayed on the hillside east of Sikes Grange (118729), but the southern one is distinctive because of the sharpness of the fracture and the local mineralisation that has taken place along it.

Farther east still is the Dallowgill Moor Fault, a fracture that continues the trend initiated by the Lofthouse Moor Fault (Wilson, 1957), though its throw is in the reverse direction. This fault is the longest in the area and has a steadily increasing throw (to the N.E.) in an easterly direction, ranging from 60 feet in the west to more than 200 feet in the east. At its easterly extremity it forms the northern member of a small fault complex, the whole of which contains the Aldfield anticline. The southern member of this complex has a trend similar to the Dallowgill Moor Fault and like that fault has a throw of more than 200 feet. South of How Hill it passes underneath the outcrop of the Magnesian Limestone, but at 285665 there is a suggestion that the basal feature of that formation is slightly displaced. The displacement is nowhere near the throw of the fault farther west, but if real it provides the only evidence in this district for post-Permian faulting.

Returning to the west of the area, it will be seen from Fig. 17 that the Bycliffe Vein forms the southern boundary of the district in the west. This fault has an uncertain course on Grassington Moor, the original evidence for its placing being obtained wholly from mines which are now disused. It can be accurately sited in Deep Cut however, and thence its course to the east is exposed by the former quarrying operations conducted on the thin tongue of Grassington Grit caught up on its northern side. In Gate-up Gill the fault can be placed with relative accuracy, and this obtains for Sikes Dike farther east also, so that throughout its course no real difficulty has been encountered in locating the fault. To the east it passes into the Greenhow district where like this area, it maintains a more or less consistent throw of 200 feet to the south. At its eastern end at Greenhow, however, it breaks up into a number of smaller fractures of lesser throw (Dunham and Stubblefield, 1945).

North of the Bycliffe Vein a series of faults occur whose discontinuous trend is roughly parallel with that fault. Not only is their trend similar however, but like the Bycliffe Vein they all throw to the south, suggesting that they are related to each other and probably also to some marginal change that takes place at the edge of the Askrigg Block. A feature of interest connected with two of them on Ramsgill Moor, is the considerable amount of minor folding visible in Ramsgill Beck, which is thought to be due to differential movement between the two faults north and south of the stream.

The next important, probably the most important fault in this area is the North Craven Fault, a fracture already known to extend from Ingleton via Feizor and Stainforth in the Ribble valley, Malham Tarn and Treshfield to Pateley Bridge (Tiddeman, 1890). Its history of discovery has been partially alluded to above, commencing with its original recognition by Sedgwick (1835) and subsequent description by Phillips (1836), Tiddeman (1890) and Dakyns (1890). Since this pioneer work, much more detailed research has been conducted on its course and effects, enabling a sounder picture of the history of the fault to be established. The differing interpretations up to 1931 were summarised by Wager (1931, p.408):

"Most of the faults of the Craven system are regarded as normal faults, but J.E.Marr (1899, pp.351-4) considered that in places they are thrust faults with small inclination to the horizontal. The faults separate an area to the north, in which the superficial rocks are lying horizontally, from an area to the south, where they are folded into sharp anticlines and synclines. Because of this, Marr (1910, p.652) has considered that the Craven Fault system must have been in part contemporaneous with the folding of South Craven. For the same reason, and also because the fault system coincides roughly with so remarkable a change in facies of the Carboniferous sediments, E.J.Garwood and E.Goodyear (1924, p.257-8) have tentatively suggested that in some places the Craven Faults must have acted as tear faults. The abrupt change of facies suggested to Tiddeman (1890, pp.600-3) that some of the faulting was contemporaneous with the deposition of the Carboniferous.rocks. Finally, the small patch of Permian near Ingleton shows that the outer fault (South Craven Fault) must have undergone movement in post-Permian time. Thus it is probable that disturbances along the line of the Craven Faults were taking place throughout a long period; and the nature of the movements may have varied at different times as well as at different parts of the fault system".

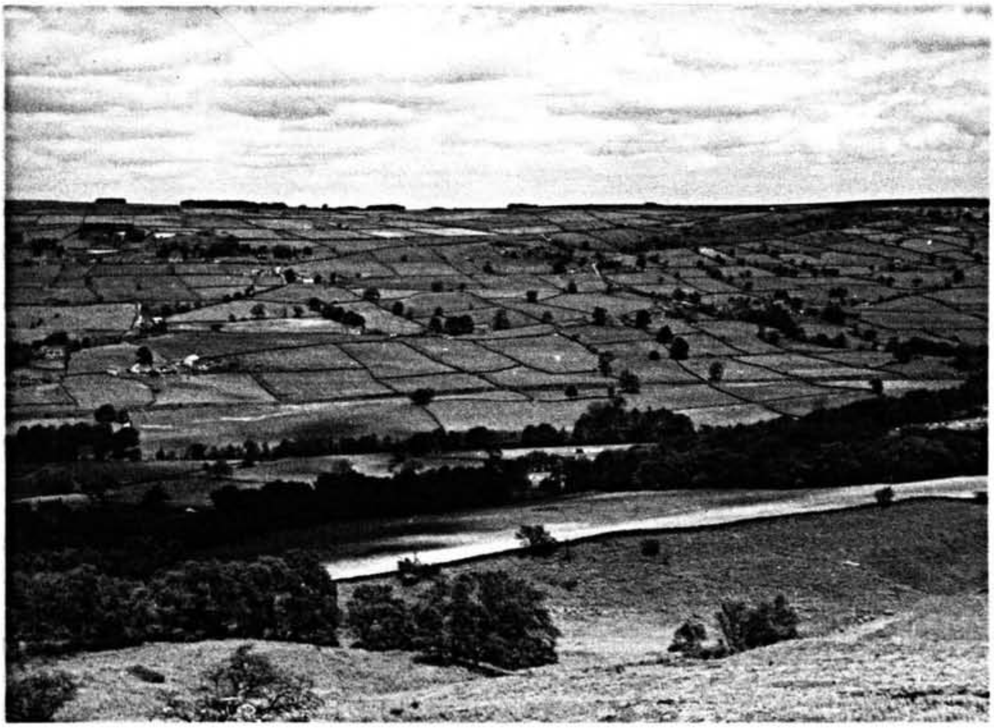
In addition to these comments, further ones have been added by later workers. Wager (1931) had adduced convincing evidence from the change in direction of the joints to confirm Garwood and Goodyear's (1924) conclusions about lateral movement along the fault, the lateral movement being shown to die out near Greenhow. He interprets it as dextral movement however, the country north of the fault moving in a N.W. direction relative to the country south of the fault (Garwood and Goodyear thought the movement was sinistral). A later paper by Black (1950) has shown that in the vicinity of the Wharfe, the North Craven Fault consists of three major fractures, the two outer ones of which throw to the south, whilst the middle one throws to the north; their overall effect on the base of the Grassington Grit however, is relatively small (Rayner, 1953, p.238). East of Hebden Beck the southernmost of these dies out (Anderson, 1928) and the remaining two continue as a trough fault into the Greenhow area (Dunham and Stubblefield, 1945, p.246-7), where their combined downthrow to the south is approximately 800 feet. These two fractures are 350 feet apart in the Bradford Corporation aqueduct tunnel, but eastwards they join up into one fault, which changes course to a N.E. direction and degenerates into a comparatively small strike fault (Dunham and Stubblefield, 1945).

The North Craven Fault enters the present area from the eastern extremity of the Greenhow district, and the author is able to confirm the single component nature of the fault in this part of its course. Its N.E. trend changes to an E.N.E. one by the House of Rest and continues as such across the valley of the Nidd, the throw increasing progressively from Greenhow to Pateley Bridge, and reaching a maximum of 400 feet there. Beyond Pateley Bridge the exact course of the fault is uncertain owing to inadequate exposure, but as stated in Chapter X it is thought to pass just south of Drayman's Field Quarry and resume

A

A view across Nidderdale showing the hillside above Pateley Bridge. The red dotted line indicates the course of the North Craven fault, whilst the black dotted line represents the base of the 1st. Brimham Grit, here displaced 400'. The 2nd. Brimham Grit forms the sky line and is unaffected by the fault.

B



The prominent feature formed by the base of the 1st. Brimham Grit reveals the shallow Wilsill syncline. This fold passes northwards into a normal fault which downthrows to the west. The two villages in the centre of the picture are Glasshouses and Raikes.

its N. E. trend there. The evidence for this is largely stratigraphical and centres around the exact horizon assigned to blocks of medium-grained quartzitic sandstone in the Old Quarry, N.E. of Knott village(170656). These blocks, not unlike the Libishaw Sandstone in lithology contain occasional fossils of the <u>Aviculopecten</u> type suggesting <u>prima facie</u> that they are indeed the upper beds of the Libishaw Sandstone. Against this however, beds of identical lithology and fauna occur in a small quarry west of Fosse Gill(150634) in the midst of an incontrovertible outcrop of the First Brimham Grit and are seen as blocks on the surface of the moor north of the quarry as well. This suggests that upwards the First Brimham Grit becomes a medium-grained quartzitic sandstone in which occasional fossils occur, and that the blocks of sandstone in the Old Quarry, N.E. of Knott village belong to that formation. Such an interpretation is adhered to in this account, and in placing the position of the North Craven Fault north of the quarry' implies that the First Brimham Grit is considerably thicker on the southern side of the fault than the northern. Not only is this so, but farther east it is observed that the prominent basal feature of the Second Brimham Grit passes uninterruptedly over the extrapolated line of the fault, attesting to the complete cessation of movement along the the fault, prior to the deposition of that bed. In the vicinity of Pateley Bridge therefore, it would seem that the North Craven Fault was in action during the deposition of the First Brimham Grit and that this movement had ceased entirely before the commencement of Second Brimham Grit times. The movement can be even more closely defined however, because no comparable thickening across the fault is discernible in the beds below the First Brimham Grit, either in Nidderdale or Greenhow(Dunham and Stubblefield, 1945), which means that movement along the fault did not commence until after the opening stages of deposition of the First Brimham Grit(it is recognised that pre-Millstone Grit movement may have taken place, though Dunham and Stubblefield (1945, p.249) found no evidence for this at Greenhow). Furthermore, although the First Brimham Grit is a transgressive horizon south of the North Craven Fault, there is no indication that the movement along the fault was sudden, leaving a fault scarp 400 feet high, against which the later sediments of the First Brimham Grit were banked, but rather that the movement was contemperaneous with the deposition, because the few exposures of the First Brimham Grit in proximity to the fault reveal relatively high(25°) dips.

The eastward extension of the fault is still a problem. Kendall (1911, p.58) considered the Coxwold-Gilling trough faults to be the lateral prolongation of the North Craven Fault on the basis of his belief in the deep-seated origin of the North Craven Fault. To a certain extent this proposal received confirmation from the Isogam and Structural Map of White(1949, Pl. XVIII), which showed that some deep-seated structural effect continued along the line of the fault to about Ripon, but no farther. As there is no indication on White's diagram of the evidence upon which his Isogam lines are based, his conclusions have had to be discounted. The field evidence is unfortunately very limited, no sign being apparent of a dislocation on Pateley Moor, where it would be expected if the trend of the fault was maintained. It is therefore concluded that the fault has died out eastwards, passing laterally into a shallow syncline.

From the above, it will be evident that most of the deductions concerning the history of the fault in this area, are dependent on the correctness of the fault's course. In view of the other post-Carboniferous earth-movements within the district, it is tempting to question the validity of this course, because an intra-Carboniferous movement only, is allowed for in the interpretation offered here. Until however, the age of the beds in the Old Quarry, N.E. of Knott village can be satisfactorily explained in terms other than of their membership of the First Brimham Grit, this interpretation must be maintained. Should those beds be proved to be equivalent to the Libishaw Sandstone then the fault would pass south of the quarry at 170656, having assumed an approximate E-W trend at the Old Quarry(165656) east of St. Mary's church, and would then presumably continue to the fault running N.N.E. from Raikes village. The features do not favour this possibility however(see Pl. XIX A), nor indeed do the disposition of the beds in Prospect Quarry(175656) which have a gentle dip of 2½ degrees. In either case however, the First Brimham Grit is much thicker south of the fault than north of it, so the fault must have been active during R_1 times, which therefore invalidates Rayner's(1953, p.253) contention that the North Craven Fault is entirely a post-Carboniferous structure; in fact on the evidence here put forward the fault would be entirely intra-Carboniferous in this area.

South of Pateley Bridge, on Heyshaw Moor, two other faults maintain a roughly parallel trend with the North Craven Fault. Both throw to the north and both appear to be relatively important. The northern one was not mapped by the Geological Survey or by Hudson(1939), the Cayton Gill Shell Bed being considered by them to run as an uninterrupted band from Loftshaw Gill to Nanny Black Hill. In the field, however, this view cannot be sustained and it has been necessary to invoke a normal fault of considerable throw(200') to explain the observed outcrops. The southern fault is the eastern extremity of the Nar

A

One of the several faults passing through Backstean Gill(054711), throws a lenticular sandstone in the Nidderdale Shales against older shales in the same group.

B

A fault exposed in Ramsgill Beck(091700) shows the terminally bended Nar Hill Beds in contact with the Red Scar Grit.

Hill Fault, a fracture which at Simonseat, Hudson(1939, p.342) considered to be a reverse fault with a tear component. The tear component seems to extend into this area also, thus accounting for the displaced outcrop of the Cayton Gill Shell Bed from Dacre Banks to Dodd Hill, but the fault is not regarded as a reverse one with a tear component, but rather a normal one with a tear component. Its exact movement is necessarily closely associated with the correct identification of the coarse sandstone at Woodmanwray, which as stated in Chapter V is tentatively accepted as Red Scar Grit, but in the absence of a diagnostic marker horizon this might just as well be the Upper Follifoot Grit. Whichever it is, the movement increases to the west and is accompanied by a tear component which shifts the country south of the fault in a westerly direction.

The other faults in this area are concentrated into two groups, one in the vicinity of Brimham Rocks and the other near Shaw Mills. In neither case is there any distinctive pattern or obvious relationship between trend and age, but four directions can be discerned: approx. E-W; N.E.-S.W.; N-S; N.W.-S.E.. All appear to be normal faults; in one instance near Smelthouses two of these are shown crossing each other without displacement, but the exposure is so bad here that this interpretation must be considered as tentative only. Many of the faults are clearly demonstrable in the field and in the case of the Brimham Rocks complex, several of these can be easily picked out from Guisecliff, above Pateley Bridge. The reason for their grouping is uncertain, but as the change from undisturbed sediments in the north to complexly fractured ones in the south is so sudden, the cause must be a deep-seated one, probably connected with the edge of the Askrigg Block and the easterly termination of the North Craven Fault.

Folds

The present survey has established the presence of a considerable number of folds in this area, south of a line joining Fountains Abbey to Wath. The discovery of these folds is not new however, because they were known to Phillips(1836) and termed the Ribblesdale folds by him(p.106). The folds are part of a system of N.E.-S.W. flexures whose en echelon arrangement characterises the country between the North Craven Fault and a line joining Burnley to Harrogate(Hudson, 1938, p.303). Several of them have been described in detail by later authors, eg. Greenhow(Dunham and Stubblefield, 1945), Simonseat (Hudson, 1939), Beamsley(Jones, 1943) and Skyreholme(Anderson, 1928), and their precise position, trend and character indicated on published maps and sections. Those occurring in this district received passing attention from Dakyns(1893, p.298-9), their course being briefly outlined by him. Subsequently this information was reproduced by Hudson(1939) on a small sketch-map. The pattern of folds outlined by Dakyns however, does differ in many important details from that proposed by the present author, chiefly with respect to length, the Aldfield anticline for instance, being stated by Dakyns to be continuous with the Beamsley anticline, an interpretation that cannot be sustained by field examination.

The main system of folds discerned by the author is depicted in Fig.18, it being apparent from the diagram that most of the folds are less than 2 miles long and that they are disposed in more than one direction. East of Pateley Bridge, the prominent trend is N.E.-S.W., but southwards this veers to an E.N.E.-W.S.W. trend, approximating to the trend of the folds west of Pateley Bridge. In several places these E.N.E.-W.S.W. folds are crossed by another set of N-S trend, a set hitherto unknown in this area and hence not invoked to explain the formation of subsidiary domes and basins along the Greenhow anticline(Dunham and Stubblefield, 1945, p.246). The exact relationship between this set and the others is not certain, but as this set is the less prominent, it may well be the older. It is certainly the tighter, individual limbs having dips of up to 22° compared with 12° for the folds in the other directions. One or two folds fit neither of these dominant trends, eg. one near Fell Beck, but in each case these can be shown to be the lateral prolongation of fault lines.

The E.N.E.-W.S.W. folds all pitch to the east under the influence of the Pennine tilt. In some cases this pitch is sufficiently great to indicate that westerly closure of the fold would not be effected by subtracting the average easterly dip of the Pennines, so an easterly pitch must have been in evidence before the Tertiary movements. In addition to this easterly pitch most of the folds are asymmetrical, with a steeper northern limb, a feature already recorded from Greenhow(Dunham and Stubblefield, 1945), Simonseat (Hudson, 1939) and Harrogate(Fox Strangways, 1874), suggesting that it is a characteristic of the whole of the eastern part of the Ribblesdale folds.

The most easterly fold in this district is the Greenhow anticline, a structure which has been described in detail by Dunham and Stubblefield(1945). It will be seen from Fig.17 that this fold is contained almost entirely between two powerful faults, the Bycliffe Vein and the North Craven Fault, and is crossed by a number of epi-anticlinal faults. It pitches steeply to the east, dying out rapidly in an easterly direction. In this area its easterly extremity only is known and can be detected in the Scot Gate Ash Quarries(Fig.11) above Pateley Bridge, where shallow dips of 4° and 7° reflect its northern and southern limbs respectively. It passes northwards into a series of three smaller folds on Hardcastle Moor(Dunham and Stubblefield, 1945) and on the eastern flank of Nidderdale also, but west of the dale in this area, only one complementary syncline can be discerned.

On its southern margin it passes laterally into the Redlish syncline and later into the Simonseat anticline(Hudson, 1939). The Redlish structure enters this area with an E.N.E.-W.S.W. trend, but changes course abruptly on Heyshaw Moor, passing northwards into a fold whose axis is more or less coincident with the valley of the Nidd. This synclinal structure is the tightest fold in the district, with dips of up to 22°, and appears to pass without displacement over the North Craven Fault near Pateley Bridge.

To the south is the Simonseat anticline, a structure that dies out just north of Heyshaw, between two faults. At its eastern extremity it gives place to another fold of N-S trend, which runs northwards to Glasshouses and passes eastwards into a complementary syncline near Wilsill. South of the Simonseat anticline and separated from it by the Nar Hill Fault, is the Beamsley anticline, a flexure whose trend swings from N.E.-S.W. to E-W before it dies out near Dacre.

East of it, on the other side of Nidderdale, is the main group of E.N.E.-W.S.W. folds, whose presence can be traced as far north as Fountains Abbey. The southernmost of these is the Summerbridge syncline, a gentle fold which is easily picked out on the eastern flank of Nidderdale above Summerbridge, from Heyshaw. It is succeeded to the north by the Braithwaite anticline, so named by Palmer and Versey(1953). This fold is relatively sharp and pitches to the N.E., suggesting later modification by faulting. Immediately north of it is the Brimham Rocks anticline, another structure which is contained between two faults and which is crossed by a N-S trending fold near its centre. This fold cannot be detected on High Moor to the north-east, so there would appear to be no evidence to support its connection with the Aldfield anticline farther north. In fact, the latter structure seems to be bounded sharply on the north and south by powerful faults, and is itself more or less coincident with a fault trending along its axis.

The only other folds in the district are the very shallow, easterly pitching flexures of Sawley, Shaw Mills and Burnt Yates. The latter continues eastwards into a fold which is readily picked out in Cayton Gill, a fold that has already been mentioned in Chapter X in connection with the establishment of two similar axes, one of which appears to be of pre-First Brimham Grit age. Otherwise all the flexures are of post-Carboniferous age and as the Magnesian Limestone transgresses their outcrop in the east, they are of pre-Permian age also.

Joints

The recording of joints in the rocks of this region dates back to the time of John Phillips(1836), 89 pairs being measured by that author, the majority of which came from the Askrigg Block. These joint readings were plotted on a rose diagram by Phillips and indicated a dominant N.N.W. direction, with subsidiary maxima at N-S, N.W.-S.E., E.N.E.-W.S.W. and E-W. Since the time of Phillips, considerable advances have been made in the study of joints by later authors, both in the establishment of dominant directions in the Pennines and the relation of these directions to causal tectonic forces. Thus Wager(1931) has demonstrated the occurrence of maxima at 55° and 135° at Proctor High Mark, and at 75°, 155° and 170° at Littondale, both west of the present area. These joints he interpreted as shear fractures resulting from compression in a N.W.-S.E. direction, and probably produced in the interval between the Coal Measures and the Permian. A later paper by Dunham(1933) supported Wager's interpretation of the joints as shearing fractures, but in Weardale on the Alston Block, the results of more than 1,000 readings on the Great Limestone suggested compression in a N.N.E-S.S.W. direction.

South of Weardale, in the Stainmore syncline, Reading(1954) has observed the tendency of joint readings to "box the compass". In general however, he is able to detect a broad maximum at 45° and a slight double maximum at 130-135° and 160-165°. Similar readings were also obtained by Wells(1955) in the Middleton Tyas anticline farther south, though the major maximum was at 55-60°. The double maximum Wells considered, following the work of Parker(1942), to reflect a period of tension in a N.E.-S.W. direction subsequent to a period of compression at right angles to it.

More recently, Wilson(1957) has examined the rocks in the adjoining ground of Upper Nidderdale and detected a clear maximum in two directions, one at 75° and the other at 155°, the latter containing a hint of a double maximum at 150° and 160°. These, he did not categorically interpret, but suggested that if the conclusions of Parker(1942) were correct, then the compression was in a N.N.W.-S.S.E. direction, but if Wager's hypothesis was right, then the pressure came from a S.S.W. direction.

In this area, 103 pairs of joints have been measured, all of which are incorporated in a rose diagram, Fig. 19 A. These readings, taken predominantly from sandstones in the Namurian succession, reveal no dominant trends and like the Stainmore area have a tendency to "box the compass". The situation is worse than Stainmore however, in that no hint of a dominant direction can be discerned, and it is felt that no reasonable conclusion as to direction of compression can be drawn from them.

To a certain extent this is compensated for by the persistent trend of the Ribblesdale folds, which were stated by Hudson(1938, p.303) to indicate compression of the strata in a N.W.-S.E. direction against the Askrigg Block. The trend of the folds here however, is not N.E.-S.W. as implied by Hudson's interpretation, but E.N.E.-W.S.W., which bespeaks pressure from a S.S.E. direction against the "rigid block" in the north. This interpretation would harmonise well with the conclusions of Wilson(1957) in Upper Nidderdale, based on the work of Parker(1942), and would at the same time receive some support from the epi-anticlinal faults at Greenhow, which are usually considered to result from reduction in pressure laterally, ie. they are tension fractures parallel to the direction of major stress(Nevin, 1942, p.95). It is nevertheless important to consider also the folds in a N-S direction. The subject of "cross" and "oblique" folds has recently been discussed by Rast and Platt(1957) and it has been stated in their paper that these are interpreted either as (i) the product of differing periods of earth-movements, or (ii) the product of the same period of earth-movement. In the case of the latter, the two sets are generally at right-angles to each other, which is a phenomenon not observed here. Yet no evidence from the remainder of the mid-Pennines is forthcoming to support the occurrence of a period of compression in an E-W direction, either before or after the main period of N.W.-S.E. compression, though this has been invoked in the Northumbrian trough(Westoll, Robson and Green, 1955, p.90). It is therefore concluded that whilst the E.N.E. flexures are best interpreted as resulting from compression in an N.N.W.-S.S.E. direction, the evidence is insufficiently critical to interpret the origin of the N-S folds.

It now remains to summarise the grounds for establishing a boundary to the Askrigg Block in the south-east, and also to recount the differing periods of earth-movements within the area. The Askrigg Block has been stated by Hudson (1938) to be the southern half of the Northumbrian Fault Block, and hence to be bounded on the north by the Stainmore syncline, on the west by the Dent Fault, on the south by the North Craven Fault and on the east by a boundary hidden under the later sediments of the Vale of York. Whilst the boundaries of the Block on two sides have been considered to be faults however, their real distinguishing features are the changes in facies, thickness and tectonic character of the sediments outwards, and these in no case precisely coincide with the lines of the faults. In the Craven district for instance, the change in facies from "block" type to "basin" type in the Lower Carboniferous, is represented by the change from the Great Scar Limestone and its overlying Yoredale Series to the Bowland Shales. East of the Wharfe, this change takes place south of the stated boundary of the Block, ie the North Craven Fault, Carboniferous Limestone of "block" facies being found in the Skyreholme area(Garwood and Goodyear, 1924; Anderson, 1928). This fact has been noted by Rayner(1953, p.253), who after a complete review of the region concludes that the change is more in the nature of a transition, it taking place in a belt whose position altered slightly throughout Lower Carboniferous times and was in fact more or less independent of the North Craven Fault.

The change in tectonic character, from gently dipping sediments to regularly folded ones, is similarly not coincident with the North Craven Fault in this area, it commencing quite unobtrusively near Wath, north of the fault. If therefore the southern edge of the Askrigg Block is taken as the North Craven Fault, and as has been shown, the position of the fault does not coincide with the change in tectonic character and facies of the sediments(or thickness, cf. Chapter II), then it becomes extremely difficult to recognise a boundary to the Block east of Pateley Bridge, where the North Craven Fault can no longer be located. From Fig. 17 it will be seen that east of Pateley Bridge a change from gently dipping sediments to folded ones does take place, and can be followed to a point 2½ miles west of Fountains Abbey, ie. near Risplith. Beyond the Dallowgill fault however, the gently dipping sediments pass laterally into the Winksley syncline, prior to passing under the Magnesian Limestone, so that no abrupt marginal change can be discerned there. A line of tectonic change nevertheless, can be traced as far as Risplith. This line unfortunately does not coincide with the line of stratigraphical change, Carboniferous Limestone of "block" facies being found in the boreholes at Aldfield and Sawley(Appendix), some distance to the south. It has already been noted however, that farther west in the Skyreholme area the same position obtains, "block" facies passing into "basin" facies south of the line of tectonic change, so this lack of coincidence is not necessarily very significant. In fact, it suggests that the line of tectonic change east of Pateley Bridge most closely represents the edge of the Askrigg Block, which is therefore proposed here, though on this basis nothing can be said about its eastern extremity beyond the Dallowgill fault.

The eastern boundary of the Askrigg Block is as yet unknown, the actual junction being obscured under the later sediments of the Vale of York. Passing comments by Hudson(1949, p.41) have indicated that a borehole at Boroughbridge passed through a thick series of "basin" facies from the upper Visean down to the Clitheroe Limestone, no Millstone Grit or Coal Measures being encountered, which suggests that boundary lies somewhere between the boreholes at Aldfield and Sawley(Appendix) and the borehole at Boroughbridge, but precisely where is not known.

Summary of the earth-movements in this area

1) Uplift in mid-E_1 times, indicated by the unconformity at the base of the Grassington Grit Group. This is thought by Hudson and Turner(1933) to be representative of the late Sudetic movements of western Europe.
2) Uplift and some folding south of the North Craven Fault in early R_1 times, suggested by the unconformity at the base of the First Brimham Grit in the southern part of the area.
3) Movement along the North Craven Fault in early R_1 times, indicated by the considerable difference in thickness of the First Brimham Grit north and south of the North Craven Fault.
4) Regional uplift in late R_1 times, accounting for the absence of the R_2 Stage in this area.
5) Regional subsidence in late R_2 or early G_1 times accounting for the non-sequence at the base of the Laverton Shales.

   On the basis of Hudson and Turner's(1933) comparison, movements 2 - 5 would be manifestations of the Erzgebirgian phase of the Variscan orogeny of western Europe.
6) Regional uplift in post-Carboniferous - pre-Permian times, followed by:
   (i) Formation of a system of joints.
   (ii) Formation of folds in E.N.E.-W.S.W. direction, possibly preceded, accompanied or succeeded by formation of folds in N-S direction.
   (iii) Formation of main system of faults.

   The pre-Permian age of these movements is indicated by the unconformable relations at the base of the main outcrop of the Magnesian Limestone, and the occurrence of transgressive outliers of Magnesian Limestone, east of Cayton Gill near Markington. The movements have been considered by Wager(1931) and Hudson(1938) to have taken place in the interval between the deposition of the Coal Measures and the deposition of the Permian, and therefore to be part of the late-Variscan changes of western Europe. They were followed by:

7) Regional subsidence and the deposition of the Permo-Triassic rocks. Post-Permian movement along one of the faults has been mentioned above, though it has been stated that this is only tentatively invoked. Comparable movements are however relatively common in the Wakefield district(Stephens et. al., 1940, p.145) where they are considered to be part of the:

8) Uplift of the whole region in Tertiary times, with the production of an easterly tilt to the Pennines and renewed movement along some of the earlier fault lines.

CHAPTER XIV
PETROGRAPHY

The earliest petrographical study of the Millstone Grit was that conducted by Sorby(1859), in the course of which the coarse pebbly nature of many of the sandstones was recognised. Current bedding directions were also observed by him and combined with the granitic nature of some of the pebbles they suggested a derivation of the sediments from the primary rocks of Scandinavia. A similar conclusion was arrived at by Gilligan(1919), after a detailed description of the rock types and their sedimentary structures. In addition to normal microscopic examination, the heavy mineral concentrates were studied by him and showed a predominance of garnet with subordinate monazite, rutile, zircon, tourmaline and iron oxides. More detailed work on these minor constituents has subsequently been done by Butterfield(1934, 1936, 1937, 1939), but thus far it has proved to have no critical value for correlation of individual beds.

More recently, Walker(1952) has evolved a classification of the rock types according to their environment of deposition, the coarse pebbly sandstones being deemed to be comparable to the Citronelle gravels of the Colorado delta and the finer grained sandstones to the channel, levee and inter-distributary trough sediments of the Mississipi delta. The conclusions of this comparison are not wholly supported by Wilson(1957) however, nor can it be said that the present author gives unconditional assent to all of them. The thesis nevertheless, contains a great deal of valuable information. Amongst this is a description of the rock types met with in the R_1 Stage of the Namurian and an analysis of their current bedding directions. A comment on their origin is also made(p. 285), the overwhelming predominance of quartz among the pebbles, suggesting that the sediments have come from a region of low grade metamorphic rocks, rich in quartz veins.

In this area, the Millstone Grit comprises a sequence of sandstones and shales ranging from the E_1 Stage to the G_1 Stage of the Namurian. It includes a sequence from coarse granular conglomerates to dark, compact marine shales, with occasional calcareous bands and a complete suite of transitional members between. Only the arenaceous and calcareous members have been sectioned however and it is these which are described below. The coarse sandstones are nearly all known by the group term "grit", a term that has also been used by earlier workers to denote various types of sandstones, such as indurated sandstone, angular-grained sandstone or coarse-grained

A

False bedding in the 1st. Brimham Grit, Guisecliff.

B

Wavy bedding in a boulder of the 1st. Brimham Grit, High Moor, Warsill.

sandstone(Bradford Memoir, p.16). Because of these differing connotations and the curious anomaly that the coarser-grained beds of the Millstone Grit are generally composed of rounded grains, the term"grit" is no longer considered to be of value in petrographic description and following the author of the petrographic section of the Bradford Memoir(p.111) its use has therefore been discontinued.

As noted above, the sandstones differ widely in their mineral composition, each variety tending to grade into the next. Those of nearly pure quartz content, ie. 95% or more, come within the definition of the term "quartzitic sandstone" or "orthoquartzite"(Pettijohn, 1942); with increasing felspar content they enter the category of "felspathic sandstone", a term taken to cover those arenites with less than 95% quartz and up to 25% felspar; when the proportion of rock fragments, clay minerals and micas exceeds that of felspar in the latter group, then the term "subgreywacke" is considered appropriate. These last mentioned sandstones are most common in the thick shales groups such as the Nidderdale Shales and Nar Hill Beds, and generally contain between 60 and 75% quartz, rarely more than 10% felspar and the remainder composed of micas, clay minerals and rock fragments, all heavily stained with limonite.

The average grain size terms used in this account are those proposed by Wentworth(1922), the relevant part of the table being:

Average grain size in millimetres.		Description of individual grain or sandstone
64	....	Pebbles
4	....	Granules
2	....	Very coarse
1	....	Coarse
$\frac{1}{2}$	....	Medium
$\frac{1}{4}$	....	Fine
$\frac{1}{8}$	....	Very fine

The petrography of each stratigraphical group has been studied separately and therefore will be presented as such, following an ascending sequence.

Sandstones of the Grassington Grit Group - The sandstones at this level vary considerably in lithology, from coarse felspathic sandstones to fine-grained flaggy subgreywackes, but the coarser beds predominate. They are frequently pebbly, most of the pebbles being quartz, but occasional felspar pebbles have been observed. The average composition of the sandstones is indicated in

Table 1.

Table 1. - Sandstones of the Grassington Grit Group.

Sample number	G.1	G.3A	G.4A	G.5	G.6	G.7	G.8	G.9
Quartz	90·7	84·3	86·7	85·4	85·1	85·7	89·2	92·4
Plagioclase	1·5	0·3	-	0·9	0·7	0·4	1·0	2·3
Orthoclase	3·2	8·0	6·0	2·2	8·3	-	3·0	3·7
Hydrobiotite	-	0·1	-	6·9	-	-	5·2	0·3
Muscovite	-	3·6	5·5	-	1·0	2·9	-	0·5
Calcite	1·8	-	-	-	2·6	-	-	-
Heavy minerals	0·3	0·1	0·2	0·2	0·1	0·3	0·5	-
Clay minerals	2·5	3·6	1·6	4·4	2·2	10·7	1·1	0·8

In thin section, one of them G.1 is seen to consist of quartz, felspar, calcite and iron oxides, the latter giving the specimen a yellowish-brown colouration on weathered surfaces. The grains are porrly sorted and show a wide variation in grain size, the largest being 2·5 mm. in diameter, but over the whole section an average figure would be 0·5 mm., Quartz is easily the most abundant mineral, the rock being largely a sutured mosaic of that material. The grains of it vary from angular to rounded, some preserving well developed crystal form, whilst others are irregularly shaped; many of them are fractured and show evidence of considerable pounding yet still have an angular shape. Undulose extinction is a common phenomenon amongst the quartz grains and may be said to be characteristic of nearly 80% pf them. Inclusions are almost ubiquitous and are composed of zircon, rutile, tourmaline, black dust and gas cavities. Considerable variation in the habit of these inclusions is apparent, they ranging from crystals with a number of faces developed to fine acicular crystals, to irregular crystalline aggregates. Often the inclusions are in the form of a trail, but not infrequently no systematic disposition can be discerned.

The felspar is of two types: plagioclase, near to oligoclase in composition and orthoclase. Both show signs of replacement by secondary mica, the orthoclase generally being in the more advanced stages of decomposition. A feature of the orthoclase is that it is usually rounded, whereas the plagioclase is almost without exception elongated and angular. Inclusions in both types are fairly numerous and composed for the most part of zircon and rutile with some quartz blebs.

Calcite is the next most abundant mineral, occurring as irregularly shaped grains whose cleavage planes are accentuated by limonitic replacement along them. It is accompanied in the matrix by a small proportion of clay minerals and occasional grains of magnetite/ilmenite, zircon and rutile.

The Table of average composition, Table 1, indicates that some of the specimens differ in important respects from G.1. In some of them microcline is observed to be present, but more usually this mineral is conspicuously absent from the sandstones of the E Stage. Mica is almost always represented by two types: fresh flakes of muscovite and sheaf-like masses of hydrobiotite. This latter mineral is generally brown in colour, shows little pleochroism and has a high birefringence; with increasing pleochroism it is likely that the mineral is biotite, but no attempt has been made to distinguish the two, because of the predominance of the irregular vermiform masses with wavy laminae. Calcite is more usually absent, but as in G.1 it has been occasionally detected. The heavy minerals have not been studied in detail, but the two samples examined revealed a predominance of zircon, rutile and opaque oxides, with subordinate tourmaline, anatase, glauconite, monazite, brookite and a single grain of garnet. Usually garnet is absent from the sandstones at this level, a feature also observed by Rowell(1953) and Jones(1957) farther north, but unlike Swarth Fell no evidence for inter-stratal solution is discernible here to account for its absence.

<u>Sandstones within the Nidderdale Shales</u> - The variable sandstones at this horizon consist basically of two types: calcareous sandstones and subgreywackes, but to a certain extent there is gradation between the two. The former are composed of sub-rounded grains(av. 0·08 mm.) of quartz and felspar with occasional flakes of mica, all set in a matrix of crystalline calcite. The latter differ in that they are generally free of calcite and have a higher proportion of quartz, but in addition they invariably include a significant amount of hydrobiotite, clay minerals and carbonaceous fragments. The quartz grains resemble those of the Grassington Grit in their abundant content of inclusions, but discord in that only about half of them show undulose extinction. The felspar is also similar to that found in the Grassington Grit, consisting of plagioclase, near to oligoclase, orthoclase and perthite. The mica is again of two types: fresh laths of muscovite and irregular vermiform masses of hydrobiotite, some of which show strain shadows and have a high birefringence, but usually only little pleochroism.

Of the two rocks the subgreywackes are the commonest at this level and in thin section the dirtiest because of their frequent limonitic stain.

The average composition of the sandstones is indicated in Table 2.

Table 2. - Sandstones within the Nidderdale Shales.

Sample number	N.1	N.2	N.3	N.4	N.5	N.6	N.8
Quartz	37·6	62·9	49·5	55·6	72·9	67·3	82·4
Plagioclase	1·3	1·6	0·4	2·2	1·9	4·1	1·6
Orthoclase/perthite	5·9	4·3	1·1	5·0	2·5	4·6	6·7
Muscovite	2·4	0·4	1·1	0·9	2·6	2·0	1·8
Hydrobiotite	-	27·2	-	13·1	16·1	16·6	4·4
Calcite	38·2	-	47·0	21·5	-	-	-
Biotite alteration?	13·4	-	-	-	-	-	-
Clay minerals	1·2	3·6	0·8	-	3·7	5·5	3·1

Red Scar Grit - The sandstones that comprise the Red Scar Grit are on the whole quartzitic sandstones, not infrequently pebbly, but in places they become decidedly felspathic. One of the former S.10 is seen to consist of a sutured mosaic of sub-angular grains of quartz(av.0·13 mm.), with occasional flakes of fresh muscovite, sodic plagioclase and orthoclase, the felspar being noticeably free from secondary replacement. Over the whole section little pockets of clay minerals occur and in parts, large grains of quartz, up to 2 mm. in length have been observed. These are similar to the quartz grains already described from the Grassington Grit in the number, type and disposition of their inclusions as well as in the abundance of undulose extinction.

None of the felspathic rocks were sectioned so the predominant type of felspar is unknown, but from hand specimens it is apparent that the large pink microclines so characteristic of the Brimham Grits do not occur at this level. A mineral conspicuously absent from the Red Scar Grit in this area is calcite, a mineral which achieves significant proportions in the equivalent horizon in Colsterdale(Wilson, 1957), due to the incoming of crinoidal debris.

The average composition of the sandstones section is summarised in Table 3.

Sandstones within the Nar Hill Beds - The sandstone lenses within the Nar Hill Beds are so similar to the sandstones of the Nidderdale Shales, that to describe them in detail would be to incur needless repetition. Two kinds can be recognised: calcareous sandstone and subgreywacke, the latter predominating. One of these, S.H.3 is distinctive because a manifest alignment of the minerals can be discerned, the flakes of mica and grains of felspar all showing parallelism. Otherwise, there is no difference in composition or texture from the Nidderdale Shale sandstones and the micrometric composition of two of them is indicated in Table 4.

Table 3. - The Red Scar Grit.

Sample number	S.7	S.10	S.11	S.S.
Quartz	92·8	89·7	91·5	98·5
Plagioclase	0·5	0·1	-	-
Orthoclase	0·3	0·1	2·3	-
Muscovite	0·7	0·3	-	-
Hydrobiotite	-	0·5	2·6	0·9
Heavy minerals	0 3	-	0·4	0·2
Clay minerals	5·4	9·3	3·2	0·4

Table 4. - Sandstones within the Nar Hill Beds.

Sample number	S.H.2	S.H.3
Quartz	67·8	67·3
Plagioclase	1·2	0·5
Orthoclase	7·3	2·1
Muscovite	0·9	1·3
Hydrobiotite	10·3	9·7
Biotite alteration?	-	12·5
Clay minerals	12·5	3·1
Calcite	-	3·5

Follifoot Grits - The Follifoot Grits are throughout their outcrop predominantly quartzitic sandstones, but towards the south near Heyshaw and Dacre, an increasing felspathic can be discerned, and in the extreme east near Fountains Abbey the subgreywacke lithology becomes important. The quartzitic sandstones themselves are of two types: one like F.3 which consists of well sorted grains of quartz(av. 0 15 mm.) in a sutured mosaic, the quartz full of inclusions and showing a relatively small amount of undulose extinction;

Sedimentary structures in the 1st. Brimham Grit are frequently accentuated by weathering.

and the other like F.2, which consists of larger grains of quartz(av. 0·2 mm.) which are sub-angular and have in between them a mixture of broken up fragments of angular quartz cemented by clay minerals. This latter feature, described by Gilligan(1919,p.260) as mylonised structure, is also seen in some of the sub-greywackes. On the whole the quartzitic sandstones are coarse, even pebbly. In places they are virtually monomineralic, their only accessory minerals being a few flakes of muscovite and interstitial pockets of clay minerals; when they are of such restricted mineral composition they usually show a characteristic "sugary" texture in hand specimen.

Table 5. - The Follifoot Grits.

Sample number	F.1	F.2	F.3	F.6	F.8	F.9	B.4	B.5
Quartz	81·1	96·6	98·9	65·3	66·7	99·5	98·0	98·2
Plagioclase	2·0	-	-	1·4	2·2	-	-	0·2
K Felspar	8·6	-	-	0·9	7·5	-	-	-
Muscovite	0·2	0·1	0·5	0·8	1·4	-	-	0·5
Hydrobiotite	6·9	-	-	1·7	13·7	-	0·2	-
Heavy minerals	-	0·1	0·1	0·1	0·1	-	0·1	-
Clay minerals	1·2	3·2	0·5	29·8	8·4	0·5	1·7	1·1

Table 6. - The Follifoot Grits.

Sample number	B.6	B.8	B.11	B.12	B.13	B.14	B.41
Quartz	84·9	80·1	85·3	63·2	94·2	74·8	92·1
Plagioclase	2·8	2·1	2·4	4·6	-	3·2	0·2
K Felspar	7·4	7·8	3·0	4·3	-	9·4	-
Muscovite	0·9	2·2	0·1	2·1	0·3	0·9	0·4
Hydrobiotite	1·1	2·4	5·6	9·7	0·7	8·4	-
Heavy minerals	0·1	-	0·2	0·2	0·1	-	-
Clay minerals	2·8	5·4	3·4	15·9	4·7	3·3	7·3

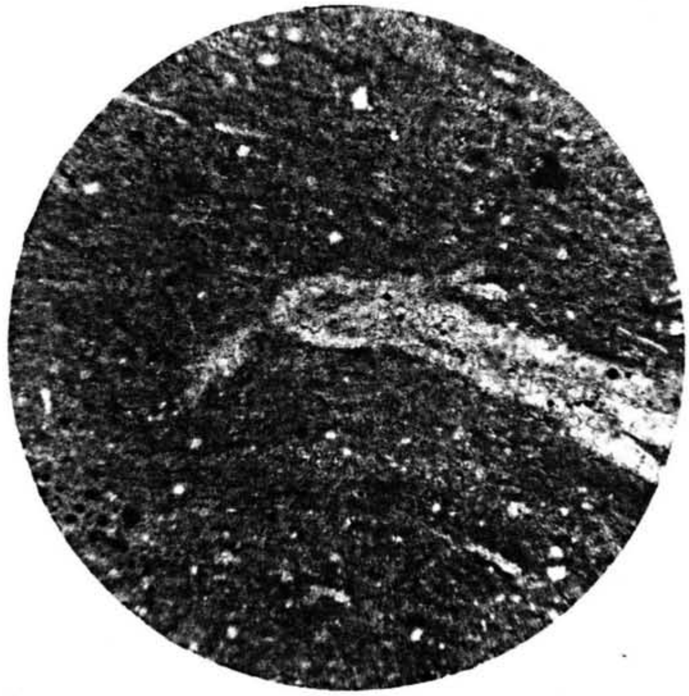
The felspathic sandstones are also generally coarse grained rocks, in thin section the average grain size being 0·5 mm. diameter. They contain about 10% felspar, of which K felspar is three times as abundant as plagioclase, near to oligoclase, and of the former, microcline is easily the most import-

ant mineral. This is significant, because in the ascending sequence of the Namrurian sandstones, it is the first time that microcline (~~that microcline~~) achieves more than accessory proportions. From Table 5 it will be seen that the micas are well represented in the sandstones, particularly in the sub-greywackes, where hydrobiotite may exceed the complete content of felspar. Amongst the heavy minerals, tourmaline and zircon can easily be picked out in this section, both as discrete minerals and as inclusions in quartz.
Cayton Gill Shell Bed - The Cayton Gill Shell Bed appears in general to be a hard, bluish-grey siltstone streaked with occasional black wisps. It is frequently tinged with a greenish colour, stated by Dunham and Stubblefield (1945, p.242) to be due to glauconite, but this mineral has never been seen to occur in crystalline pods flattened parallel to the bedding as at Greenhow and in fact would appear to be of much lesser significance here.

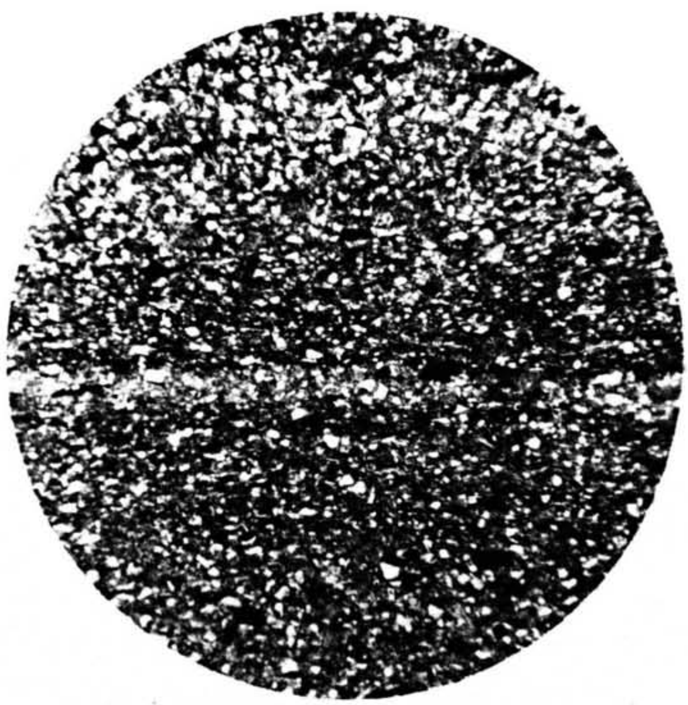
Table 7. - The Cayton Gill Shell Bed.

Sample number	C.G.75	C.G.77	C.G.78
Quartz	41·6	18·5	50·1
Plagioclase	0·2	0·1	-
Muscovite	0·2	2·0	0·2
Hydrobiotite	0·8	-	1·1
Glauconite	0·3	0·1	0·7
Argillaceous matrix	56·9	79·3	47·9

In thin section the rock is seen to consist of a large number of well sorted detrital grains of sub-rounded quartz(av. 0·05 mm.), with subordinate plagioclase, muscovite and glauconite, all set in a streaky argillaceous matrix. In places the proportion of quartz grains increases noticeably and in these areas a vein-like shape of the quartz rich areas is frequently apparent. This is particularly noticeable in the worm-chewed specimens from Sawley, eg. C.G.78 where parts of the rock are composed almost wholly of well sorted sub-rounded grains (av. 0·1 mm.) of quartz set in a sparing argillaceous matrix, and other parts consist almost wholly of argillaceous material. This admixture of the two types is thought to be due to subsequent disturbance of the sediments by worms and is supported by the circular shape of the white sandy "burrows" seen on a black argillaceous background in hand specimens from Sawley. In some of the latter, eg. C.G.78, hydrobiotite is by far the most common mica. The rocks are



Fine grained calcite mudstone(Colsterdale Limestone) with scattered grains of detrital quartz and irregular veinlets of clear crystalline calcite.



Banded calcareous siltstone(Libishaw Shales) consisting of sub-angular grains of quartz and occasional flakes of muscovite, aligned in a matrix of crystalline calcite.

usually described as streaky siltstones, but the proportion of clastic minerals to argillaceous matrix will be seen from Table 7 to indicate that they are more correctly termed sandy mudstones. Towards the top of the Cayton Gill Shell Bed at Sawley, the beds become decidedly calcareous and in thin section(C.G.79) can be seen to be composed predominantly of shell debris(brachiopods, crinoid fragments, foraminifera and bryozoa) in an argillaceous matrix.

Libishaw Sandstone - The Libishaw Sandstone consists primarily of well sorted, sub-rounded grains of quartz(av. 0·1 mm.) as usual full of inclusions, accompanied in minor proportions by felspar, mica and clay minerals. The felspar is mostly fresh, comprising sodic plagioclase, microcline and some orthoclase flecked with secondary mica, whilst of the micas, hydrobiotite is more common than muscovite. In some places the proportion of quartz is sufficiently high to justify the use of the term "quartzitic sandstone", but more usually the rock has the texture and mineral composition of a subgreywacke. A feature of the sandstones at this level is the banding seen in both hand specimen and thin sections. In hand specimen this takes the form of an alternation of light and dark layers, the former being much thicker than the latter, whilst in thin section, a distinct alignment of the minerals is apparent, most strikingly developed in the micas.

The Brimham Grits - The Brimham Grits are perhaps closer to the general conception of the Millstone Grit as a lithology than any other formation in this area. They are massive bedded, coarse felspathic sandstones, frequently graded and false bedded, and distinguished by the manner in which they weather. Considerable variation in grain size is discernible on any exposed face of the bed, and overall and range from coarse granular conglomerates, through pebbly sandstones to medium-grained quartzitic sandstones can be made out.

The pebbles are mostly quartz, accompanied in smaller proportion by flesh-coloured microclines and occasional pebbles of granitic material. In thins section, pebbles of clastic chert and orthoquartzite have also been seen with some of granitic material showing a graphic intergrowth of quartz and felspar. The pebbles usually average half an inch in diameter, but some as large as 1 inch across are known.to occur.

Under the microscope the sandstones are seen to consist of poorly sorted, sub-angular grains of quartz, felspar, mica, clay minerals and rock fragments, the average composition of selected specimens being shown in Table 8.

Easily the most common mineral is quartz, which in some sections constitutes more than 95% of the rock. It occurs in the form of large grains, up to 1·5 mm. in diameter, as usual full of inclusions. Many of the grains are heavily fractured and show the characteristic abundance of undulose extinction. Between some of them, small patches of secondary silica can occasionally be made out, but none of the secondary coating described by Gilligan(1919, p.259) has been observed.

The felspar if of two types: potassic felspar and sodic plagioclase. Of the former, the commonest variety is microcline, characteristically fresh fresh and rounded. It is closely seconded by microcline microperthite, again fairly fresh, but showing some signs of replacement by secondary mica. The plagioclase, near to oligoclase in composition is the most altered felspar, some grains being nearly completely replaced by secondary mica.

Table 8. - The Brimham Grits

Sample number	B.2	B.10	B.15	B.15A	B.17	B.18	B.19	B.20
Quartz	96·3	85·9	91·8	92·2	75·6	80·1	73·7	76·0
Plagioclase	-	1·1	-	-	2·7	0·1	-	0·3
K Felspar	-	2·8	-	-	16·2	16·9	20·5	18·8
Muscovite	0·5	5·6	-	-	0·2	0·3	0·8	0·1
Hydrobiotite	-	3·3	6·1	4·3	1·9	2·0	4·7	2·6
Clay minerals/ rock fragments	3·1	1·3	2·1	3·5	3·4	0·6	0·3	2·2
Heavy minerals	0·1	-	-	-	-	-	-	-

The primary mica differs in no important respect from that found in other coarse sandstones at a lower level. Some of the flakes of muscovite are as long as 1·5 mm., whilst the outstanding features of the hydrobiotite are that some flakes are bent, suggesting subsequent deformation of the rock.

Apart from the occasional grain of zircon, the only other constituents of the sandstones are infrequent slate fragments and small pockets of clay minerals. The mylonised structure mentioned above, in connection with the Follifoot Grits, has also been seen at this level, though much less commonly.

Conclusions - The composition of the sandstones examined from the Namurian of this area provide no evidance to question Gilligan's(1919, p.257) conclusion that the sediments were derived from an area composed predominantly of very acid granitoid gneiss. As noted in the Bradford Memoir, the great variety of sandstones, some being poorly sorted coarse felspathic sandstones, others well sorted quartzitic sandstones, and still others well sorted fine-grained subgreywackes, suggests that conditions of weathering must have altered considerably from time to time. The reason for the absence of microcline and garnet(stated by Gilligan(1919, p.257) to be the most plentiful minerals of their kind in the Millstone Grit) from the sandstones of the E Stage is not known, but it is felt that it cannot be explained by inter-stratal solution. The alternative therefore is non-deposition, which would provide a major point of contrast between the sandstones of the E Stage and those of the R Stage of the Namurian.

CHAPTER XV
ECONOMIC GEOLOGY

Although today the area described in this account is predominantly agricultural, in time past extensive mining and stone quarrying has taken place, attesting to the considerable economic value of the Carboniferous strata. Most of the quarries are now overgrown and the mine tips only occasionally combed for gangue minerals, so that apart from some quarrying for silica and ganister near Smelthouses, any description of the economic geology is essentially a record of former activity. This does not apply to the water reserves however, which are in greater demand than ever before and because of this, the close proximity of upland areas of high rainfall to large industrial centres is most fortunate.

Water Supply

All the geological formations represented on the map contain water-bearing beds, thus ensuring that virtually the whole of the domestic and industrial requirements of this district are met from indigenous supplies. In the upland areas where rainfall is high, surface run-off is sufficient to justify the large scale storage of water in reservoirs to meet the needs of nearby towns, in which connection three large reservoirs exist in Nidderdale. Only the lowest of these, the Gouthwaite reservoir occurs within the present area and this is merely a compensation reservoir, designed to ensure a constant source of water to those towns down the dale who would otherwise be affected by the reduction in flow of the river during periods of drought. The reservoirs belong to the Bradford Corporation and are supplemented by water intakes in Howstean Beck and Ramsgill Beck, all feeding into the main pipeline running south from Nidderdale. East of Nidderdale on Lumley Moor another reservoir supplies the needs of Ripon Corporation, whilst two further reservoirs in the valley of the Laver are planned by Leeds Corporation for early development. The gathering grounds for these reservoirs however, are considerably smaller than those in Nidderdale and therefore subject to greater seasonal fluctuations, but the ever growing water requirements of the mid-Yorkshire industrial centres insist on complete exploitation of the available reserves.

The local domestic and industrial requirements of the district can best be divided into two parts, namely those for the towns and those for the outlying farms. In the case of the former, the supply is derived from small reservoirs situated a short distance above the town. Towns supplied in this manner include Pateley Bridge, Glasshouses, Summerbridge and Burnt Yates, in each case the reservoir being fed from a spring or borehole. Rope and flour mills located within the area usually rely on their own reservoirs for their water supply and these are fed from nearby streams by a system of weirs and millracss.

The farms have in time past been supplied almost exclusively from springs, but in the lowland east and the area south of Pateley Bridge, seasonal variation in rainfall coupled with the growing use of water has made this supply unreliable. An increasing number of farms therefore are now sinking their own boreholes and pumping direct from these; elsewhere in the east, others are gradually being connected to the main Leeds Corporation pipeline.

Building Stone

Most of the sandstone beds of the Millstone Grit in this area have at some time or another been quarried for building stone, some more extensively than others. In general the finer-grained rocks have proved more useful for house construction than the coarse-grained, because of their well defined bedding and jointing, whilst the latter are widely represented in the stone walls that traverse the moors. The Libishaw Sandstone in particular has achieved repute as a building stone, being extensively quarried above Pateley Bridge. The First Brimham Grit also has been worked on a large scale for building purposes(Fountains Abbey is built of this material), but its main use in time past has been for the construction of mill stones. Local requirements of roofing slates have been met by the lower beds of the Lower Follifoot Grit, the Libishaw Sandstone and the upper beds of the First Brimham Grit, but more usually the thinly bedded sandstones of the Nidderdale Shales and the Nar Hill Beds are used for this purpose.

Roadstone

Only one horizon in the Millstone Grit of this area provides the requirements of a good roadstone and that is the Cayton Gill Shell Bed. This has therefore been widely quarried south of Pateley Bridge, but none of these quarries are now operated.

Coal

The coal seams which formed an important source of fuel in the area to the north are only imperfectly represented in this area and therefore of correspondingly limited value. Two seams however have been worked, one in Grassington Grit Group near Ramsgill and the other in the Laverton Sandstone near Dallowgill. The Woogill Coal, well known in Upper Nidderdale dies out on Riggs Moor in the north-west of this district, but apparently reappears to the south on Grassington Moor, where it has been worked on both sides of

Gate-up Gill.

Lead Ore

The area described in this account adjoins the important mineralisation centres of Greenhow and Grassington, and by its barrenness stands in striking contrast to the richness of those other areas. Only two mineralised veins have been exploited in this district, one near Westwood House Farm, Wath, and the other farther north at Lolly Scar. In the former case galena was extracted from a thin vein in the Grassington Grit(Kendall and Wroot, 1924, p.858), whilst at Lolly Scar, a mineralised N.E.-S.W. fault yielded galena, barytes and witherite. The vein, 3 to 4 feet wide in the Grassington Grit, thinned out completely in the underlying limestone and was apparently only worked intermittently when the price of lead was favourable(Raistrick, 1938, p.345). Its witherite content appears to have been rather important, the mineral occurring as radiating masses which were largely exported to Germany(Wilson et. al., 1922, p.62). In addition to the above two veins, a certain degree of mineralisation has also taken place along the Lofthouse Fault in Blayshaw Gill, and in a vein in Backstean Gill(056728); apart from these however, no other indications of lead mineralisation in the district exist. All the ore was smelted at Heathfield Smelting Mills in Foster Beck, together with the richer deposits from the Stoney Grooves and Merryfield Mines.

Fluorspar is a persistent gangue mineral in most of these veins and has recently assumed sufficient value to justify a re-examination of the mine tips on Grassington Moor with a view to its ultimate extraction.

Iron Ore

Ferruginous minerals are present in small quantities in most of the Millstone Grit sediments, as pyrite in the shales and limestone, and hematite and magnetite/ilmenite in the sandstones. Little is known of the details of the occurrence, but as noted in Chapter IV the lenticular sandstones in the Nidderdale Shales have formerly been exploited for their content of iron ore on Ramsgill Bents above Ramsgill.

Silica

The Follifoot Grits maintain a consistently high proportion of quartz over most of their outcrop, in some places the rock actually becoming monomineralic. Because of this quality the Lower Follifoot Grit has been extensively quarried for silica near Smelthouses, though local variations in the rock such as increasing felspar or carbonaceous content severely impair its suitability for commercial purposes. A survey of this horizon has recently been conducted by the quarrying company west of Dacre and revealed other areas suitable for exploitation in the near future.

Ganister

Ganister and ganisteroid sandstone are fairly common lithological types in the Millstone Grit of this area, though rarely of sufficient quality or quantity to justify exploitation. The Upper Follifoot Grit is however quarried for this purpose near Low Laithe and remains the only known record of quarrying for ganister in Nidderdale.

Petroleum

The fact that the Millstone Grit sediments of Nottinghamshire and Derbyshire have yielded oil in commercial quantities, and that the mode of occurrence of the oil there suggests that this horizon is a possible source rock(Lees and Cox, 1937, p.162), has led many to believe that oil should be found in the gently folded rocks of the mid-Pennines. Against this however, very few oil seepages at the surface have been reported and an analysis of the structure from the published Geological Survey maps revealed to Lees and Cox (p. 168) that most of the anticlines fail to close to the west, suggesting that the major Pennine uplift would have drained the bulk of the oil content from the rocks before the structures were sufficiently developed to act as traps. In view of these observed features, the present area was not considered to form a reasonable prospect for oil occurrence by the British Petroleum Company in their original exploration programme before World War II. The exigencies of war-time however, revoked this view, and in the course of a re-examination of all the possible areas of oil occurrence in the country, this district was selected for exploratory drilling. Two sites were chosen, one near Risplith on the Aldfield anticline(Hudson, 1939) and the other near Bishop Thornton on the Sawley anticline. Neither borehole yielded oil in any quantity and their importance now rests mainly on the geological information that they have provided.

Since the sinking of these boreholes, several new facts have been established with respect to the disposition of the strata in this area, to question the wisdom of drilling on the northern site chosen by the British Petroleum Company. In the first place the anticline illustrated by the primary geological survey in the neighbourhood of Risplith, and subsequently named the Aldfield anticline by Hudson(1939), can be demonstrated to have no basis in fact. This is shown by the occurrence of the Cayton Gill Shell Bed along the sides of Skell Gill, clearly denying any possibility of that horizon running as a thin band up from Fountains Abbey to Hazel Hill Farm(235683), as indicated on the published maps. That an anticline exists in the neighbourhood is however incontrovertible, though its axis must lie some distance(ca. half a mile) south-east of that suggested by the primary survey. If then, the structure drilled by the British Petroleum Company is that which Hudson(1939) earlier termed the Aldfield anticline - a not unlikely conclusion from the siting of the borehole- then its value as a test well would appear to be very limited, especially in view of the conclusions of Lees and Taitt(1946, p.305) that an error of a quarter of a mile in locating the highest structural point of a fold is sufficient to miss a crestal accumulation in areas of shallow oil columns. Furthermore, the occurrence of a quarry in the First Brimham Grit on the side of the Ripon road(240680), a short distance E.S.E. of another quarry in the Cayton Gill Shell Bed, when considered in the light of the stratal dips visible strongly suggests the presence of a fault between them. This fault can actually be proved some distance to the S.E. where its throw is 230 feet, but the point of significance is, that the fault passes within 100 yards of the site of the Aldfield borehole.

In the case of the Sawley anticline, evidence is forthcoming to support the occurrence of an anticlinal structure in the position indicated by the primary geological survey, but the fold is very shallow. The British Petroleum Company's borehole was sited a short distance north of the crest of the fold and penetrated a more or less complete succession from the Upper Follifoot Grit downwards, near the top providing valuable evidence for the extension of the mid-R_1 unconformity, but striking no oil. This structure nevertheless would appear to have been one of the most promising in the district and its failure to contain oil must be regarded as an indication of unfavourable conditions.

With the results of the past exploration in mind, it is now perhaps profitable to review the evidence supporting the possible occurrence of oil in the district. Firstly, the Millstone Grit sediments of this area contain a number of marine bands whose lithology and fauna closely resemble that of the comparable horizons in Nottinghamshire and Derbyshire, which are considered to be source rocks for petroleum. In the case of two of these, the Cockhill Marine Band and the Colsterdale Marine Series, a thick oily fluid has occasionally been observed in the body chambers of goniatites in the limestone, suggesting a likely source material for the oil. Besdides these marine beds, fossiliferous strata also occur in the Lower Carboniferous below and at Greenhow(Dunham and Stubblefield, 1945) this division is more than 1,400 feet thick.

In addition to source rocks, possible reservoir rocks also exist and are represented by the loosely cemented, coarse felspathic sandstones of the Grassington Grit Group, the Red Scar Grit and the Brimham Grits, the porosity of which is relatively high, though Gilligan(1919, p.262) has observed that this decreases markedly at depth. Subgreywazkes are also well develpped here and in most cases are overlain by impermeable shales which would provide the requisite impervious cover. Both these lithological types are host rocks at Eakring(Lees and Taitt, 1946) so that their presence here must be regarded as important.

Whilst possible source and reservoir rocks exist however, the structures affecting the Namurian rocks are most unpromising, the folds being generally shallow and with incomplete closure to the west. In addition they have been severely dislocated by later faulting, thus increasing the risk of oil escape, because in general the impermeable nature of the shales means that migration will take place along divisional and fault planes with the possible use of joints in the sandstones. As further indication of the unfavourable conditions no oil seepages have been found in the district. The conclusions of the author therefore are that the prospects of finding oil here are not high and that considerable risk would be attendant upon future drilling programme based on any of the structures depicted in Fig. 17. There is nevertheless the possibility that accumulations could occur in the Lower Carboniferous at depth, but this would imply the presence of suitable structures below the intra-E_1 unconformity, whose nature cannot be forecast from a knowledge of the surface structure only. That such concealed structures may occur is evident from the situation at Greenhow(Dunham and Stubblefield, 1945) where pre-unconformity domes lie on the northern side of the North Craven Fault. Such structures, if they exist farther east would be concealed beneath not only one, but two or three unconformities. Their effectiveness from an oil point of view, if they do exist, would depend upon the Carboniferous Limestone being sufficiently fractured to act as a suitable host rock. In this connection it may be noted that some oil was obtained at Eakring(Lees and Taitt, 1946, p.300) from limestones generally similar to those at Greenhow.

Peat

The major part of the upland moors in this district are covered by peat, ranging in thickness up to 12 feet. In only one instance has peat cutting and drying for fuel been observed and that is on Grassington Moor. This source of fuel must now be said to have been largely replaced by other solid fuels, chiefly owing to the ease of transportation of coal from town to household in the rural districts.

Sand and Gravel

Glacial gravel was formerly quarried at several places in the area, mainly in the neighbourhood of Aldfield, but this extraction has now completely ceased and only barren gravel pits remain.

A

Eavestone Lake, Grantley - a former glacial lake. The crags on the right hand side of the picture are formed of 1st. Brimham Grit.

B

Poorly sorted morainic gravel, Gravel Pit, Clip'd Thorn Hill, Aldfield

Mineral Springs

Only one mineral spring is known in this area, namely that in Spa Gill(255690) west of Aldfield, which is known as Aldfield Spa. Fox Strangways (1874) quotes several analyses of the water from this spring, but it is not now used and little is known of its present value.

APPENDIX I

Bore Hole Records

The site of each borehole is indicated on the accompanying geological map. Where possible the location has been fixed with precision, but in some instances the available information has permitted of an approximate siting only. In cases where no interpretation of the log is given, this is because the evidence did not permit of reasonable conclusions being drawn.

	Thickness		Depth	
	Ft.	In.	Ft.	In.
Pateley Cemetry				
First Brimham Grit				
Broken sandstone	20	0	20	0
Bewerley Shales				
Shale	37	0	57	0
Libishaw Sandstone				
Yellow sandstone	30	0	87	0
Slate plate	43	0	130	0
Broken shale	6	0	136	0
Hard shale	10	0	146	0
Broken sandstone	4	0	150	0
Sandstone	21	0	171	0
Hard black shale	20	0	191	0
Bastard rock bind	6	0	197	0
Brown sandstone	15	0	212	0
Grey rock	29	0	241	0
Shale	9	0	250	0

Old Spring Wood, Summerbridge

Boulders	8	0	8	0
Sandy clay	12	0	20	0
Boulders	2	0	22	0
Boulder clay	18	0	40	0
Blue shale	27	0	67	0
Grit rock	2	6	69	6
Hard blue shale	11	6	81	0
Broken hard shale	9	0	90	0

	Thickness		Depth	
	Ft.	In.	Ft.	In.
Blue shale	18	0	108	0
Grey sandstone	3	0	111	0
Blue shale	7	6	118	6
Yellow sandstone	2	6	121	0
Blue shale	19	0	140	0

East Head Farm, Wilsill

<u>Lower Follifoot Grit</u>				
Yellow sandstone	30	0	30	0
Shale and grit	30	0	60	0
Yellow sandstone	30	0	90	0
<u>Nar Hill Beds</u>				
Gritty shale	22	0	112	0

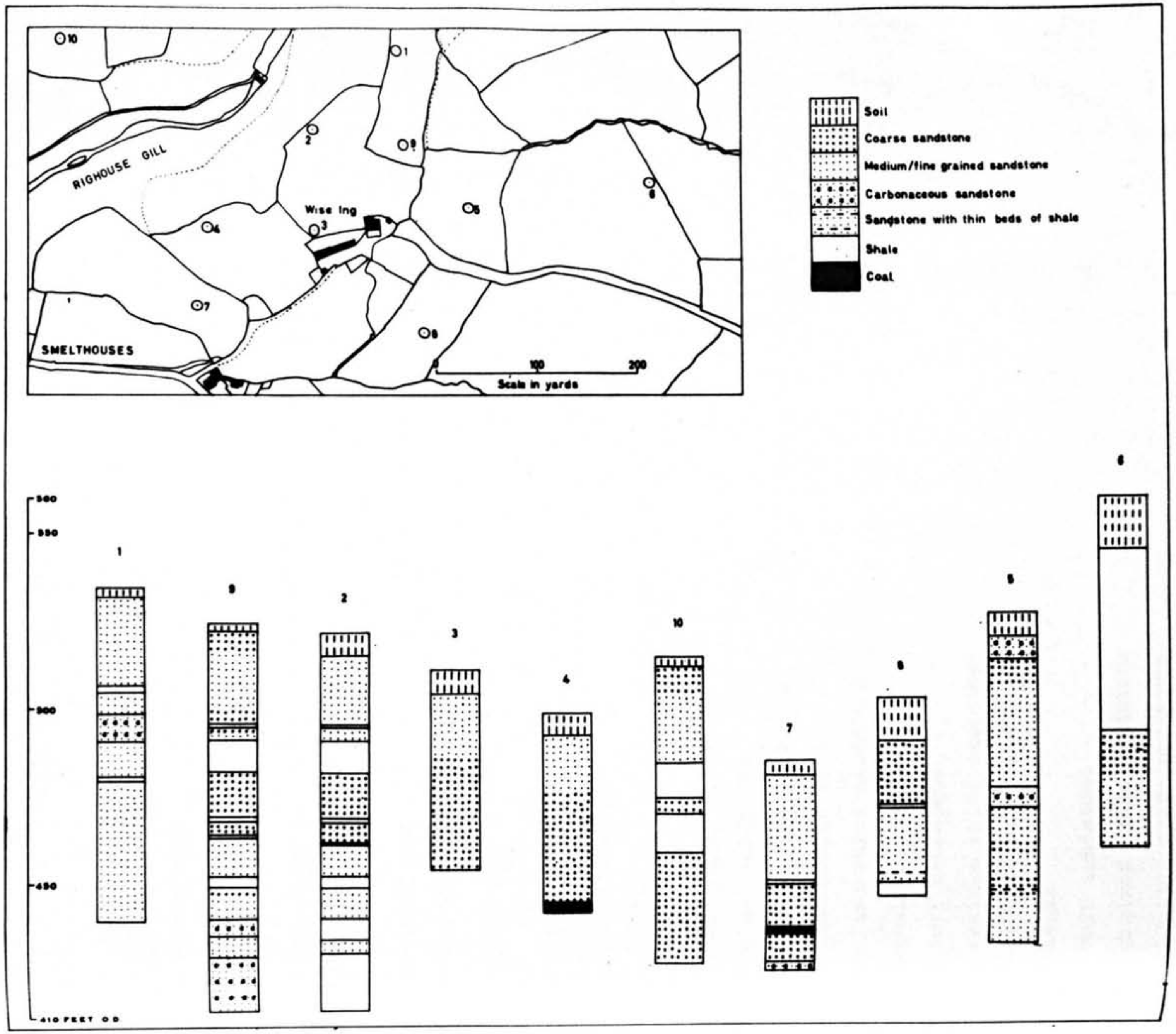
Associated Silicas, Smelthouses

1

<u>Lower Follifoot Grit</u>				
Coarse brown rock	3	0	3	0
Fine-grained white rock	25	0	28	0
Shale	2	0	30	0
Fine-grained white rock	6	0	36	0
Black rock	8	0	44	0
Fine-grained white rock	10	0	54	0
Shale	1	0	55	0
Fine-grained white rock	40	0	95	0

2

<u>Lower Follifoot Grit</u>				
Coarse brown rock	6	6	6	6
Fine-grained white rock	19	9	26	3
Shale	1	0	27	3
Rock	3	8	30	11
Shale	8	10	39	9
Rock	13	6	53	3
Shale	1	0	54	3
Rock	4	6	58	9
Shale	0	9	59	6
Rock	10	0	69	6
Shale	3	3	72	9



RIGHOUSE GILL
SMELTHOUSES
Wise Ing
1
2
3
4
5
6
7
8
9
10
0
100
200
Scale in yards
Soil
Coarse sandstone
Medium/fine grained sandstone
Carbonaceous sandstone
Sandstone with thin beds of shale
Shale
Coal
560
550
500
450
410 FEET O.D.

	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Rock	1	9	81	6
Shale	5	3	86	9
Rock	5	0	91	9
Shale	10	0	109	9

3

	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Lower Follifoot Grit				
Coarse brown rock	6	6	6	6
Fine-grained rock	18	9	25	3
Coarse-grained rock	31	8	56	11

4

	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Lower Follifoot Grit				
Coarse brown rock	6	6	6	6
Fine-grained rock	16	9	23	3
Coarse-grained rock	30	9	54	0
Coal	3	0	57	0

5

	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Sandy soil	7	0	7	0
Lower Follifoot Grit				
Carbon shale	3	0	10	0
Clayey sand	3	6	13	6
Coarse brown/grey sandstone	8	0	21	6
Fine-grained sandstone	15	6	37	0
Fine-grained white sandstone	13	0	50	0
Carbon impregnated rock	5	6	55	6
Fine-grained white sandstone	3	0	58	6
Medium-grained sandstone	6	6	65	0
Coarse buff sandstone	4	3	69	3
Medium-grained white sandstone	5	6	74	9
Coarse-grained buff sandstone	3	6	78	3
Carbon shale	0	9	79	0
Coarse buff sandstone	2	0	81	0
Medium-grained white sandstone	5	6	86	6
Coarse-grained white sandstone	7	6	94	0

6

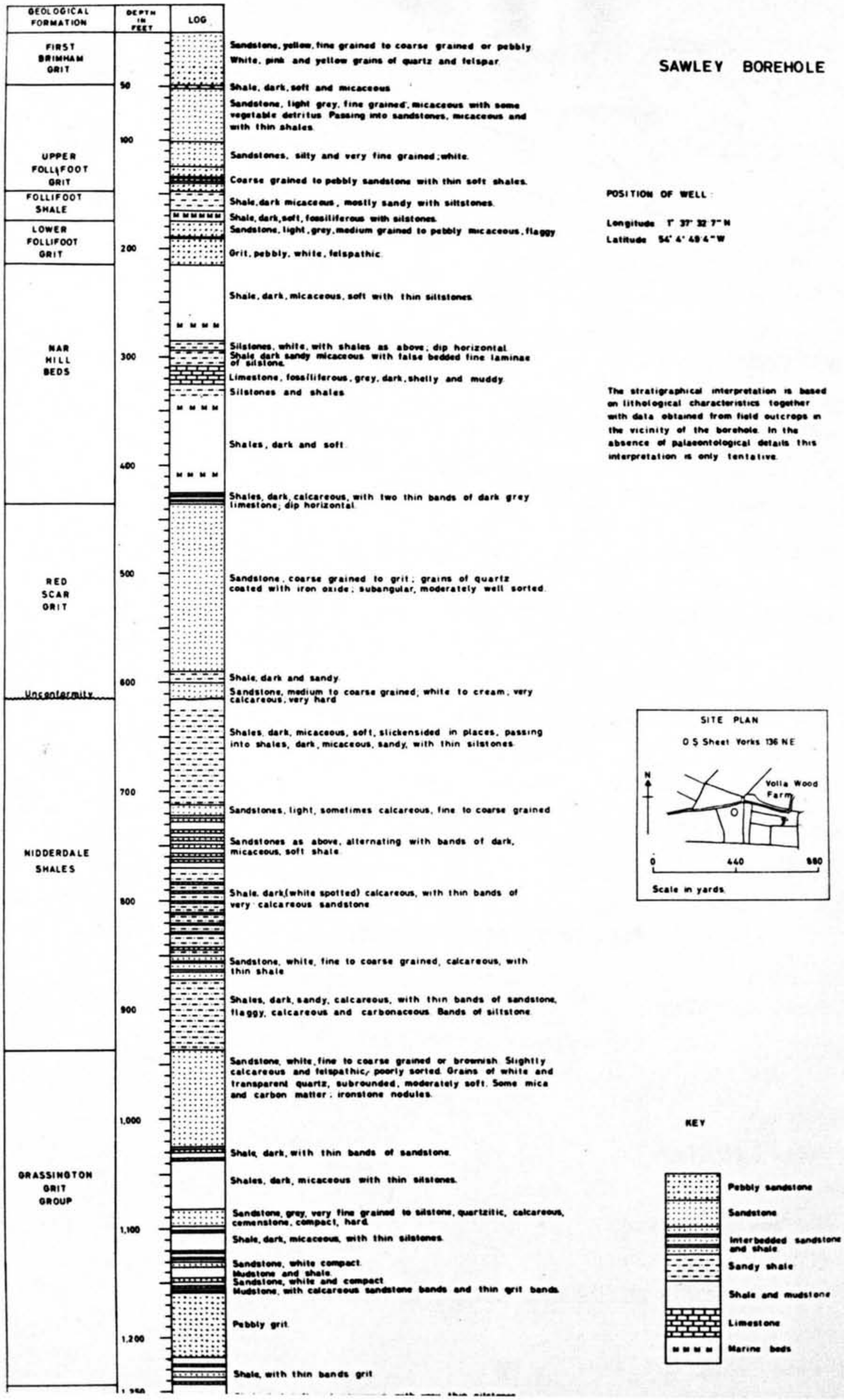
	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Sandy soil	15	0	15	0
Follifoot Shale	52	0	67	0
Lower Follifoot Grit				

	Thickness		Depth	
	Ft.	In.	Ft.	In.
Coarse-grained buff sandstone	12	6	79	6
White rock	20	6	100	0
7				
Drift	3	0	3	0
<u>Lower Follifoot Grit</u>				
Grey/white rock	31	0	34	0
Shale	1	0	35	0
Coarse brown/grey rock	12	3	47	3
Coal	1	9	49	0
Coarse-grained white rock	8	6	57	6
Sandy coal	2	6	60	0
8				
Drift soil	12	6	12	6
<u>Lower Follifoot Grit</u>				
Coarse brown/grey rock	18	0	30	6
Shale	1	2	31	8
Grey/buff rock	17	2	48	10
Black rock	0	5	49	3
Shale	0	9	50	0
Grey rock	2	6	52	6
Shale	4	0	56	6
9				
Drift	2	3	2	3
<u>Lower Follifoot Grit</u>				
Coarse brown/grey rock	26	3	28	6
Shale	1	0	29	6
Coarse grey/white rock	3	8	33	2
Shale	8	10	42	0
Coarse grey/white rock	13	0	55	0
Shale	1	6	56	6
Coarse white rock	3	6	60	0
Rock/shale	1	0	61	0
Coarse grey/white/buff rock	10	9	71	9
Shale	3	3	75	0
Coarse brown/white rock	8	9	83	9
Carbon rock	5	3	89	0

	Thickness Ft.	In.	Depth Ft.	In.
Grey rock	6	0	95	0
Carbon rock	17	0	112	0
Westfield Farm, Summerbridge				
Caly and stones	25	0	25	0
Blue shale	54	0	79	0
Grit rock	5	0	84	0
Maud's Farm, Brimham Rocks				
Soil	0	6	0	6
Coarse yellow sandstone	4	9	5	3
Yellow/brown sandy loam	4	3	9	6
Yellow/blue shale	7	6	17	0
Blue/brown shale	20	10	37	10
Yellow sandstone	1	2	39	0
Yellow/blue shale	5	0	44	0
Hard black/grey shale	53	4	97	4
Grey/yellow sandstone	3	8	101	0
Hard grey shale	16	0	117	0
Hard grey sandstone	3	0	120	0
Royal Oak Hotel, Dacre				
Gravel	30	0	30	0
Lower Follifoot Grit				
Coarse brown rock	40	0	70	0
Soft sand rock	2	0	72	0
Hard sandstone	23	0	95	0
Sunny House Farm, Dacre				
Soil	1	0	1	0
Yellow sandy clay	3	0	4	0
Upper Follifoot Grit				
Hard yellow sandstone	22	0	26	0
Grey shale	3	0	29	0
Soft yellow sandstone	1	6	30	6
Grey sandy shale	5	6	36	0
Yellow sandstone	6	0	42	0
Follifoot Shale				
Blue/grey sandy shale with thin beds sandstone near base	67	6	109	6

	Thickness		Depth	
	Ft.	In.	Ft.	In.
Lanefoot Road Quarry, Dacre				
<u>Upper Follifoot Grit</u>				
Debris	18	8	18	8
Sandstone	2	8	21	4
Shale	7	2	28	6
Broken grey sandstone	5	0	33	6
Hard shale	8	0	41	6
Shale and sandstone	6	6	48	0
Soft brown sandstone	4	0	52	0
Hard grey shale and sandstone	17	0	69	0
Hard shale	2	0	71	0
Broken grey sandstone	11	0	82	0
<u>Follifoot Shale</u>				
Hard shale	25	0	107	0
Grey shale and sandstone	13	0	120	0
Grit rock	3	6	123	6
Hard sandy shale	16	6	140	0
Lane's Foot Farm, Heyshaw				
Soil	1	0	1	0
Yellow sandy clay	9	0	10	0
Yellow/blue clay with stones	25	0	35	0
Tough blue clay	6	6	41	6
Hard grey sandy shale	60	6	102	0
High North Farm, Warsill				
<u>First Brimham Grit</u>				
Broken sandstone and clay	5	0	5	0
<u>Bewerley Shales</u>				
Shale	7	0	12	0
<u>Libishaw Sandstone</u>				
Broken sandstone and clay	10	0	22	0
Hard grit rock	6	0	28	0
Brown rock and shale partings	14	0	42	0
Shale with thin beds sandstone	8	0	50	0
Shepherd's Lodge, Hartwith				
Soil	0	9	0	9
Yellow/blue sandy clay	6	10	7	7
Blue/yellow shale	10	2	17	9

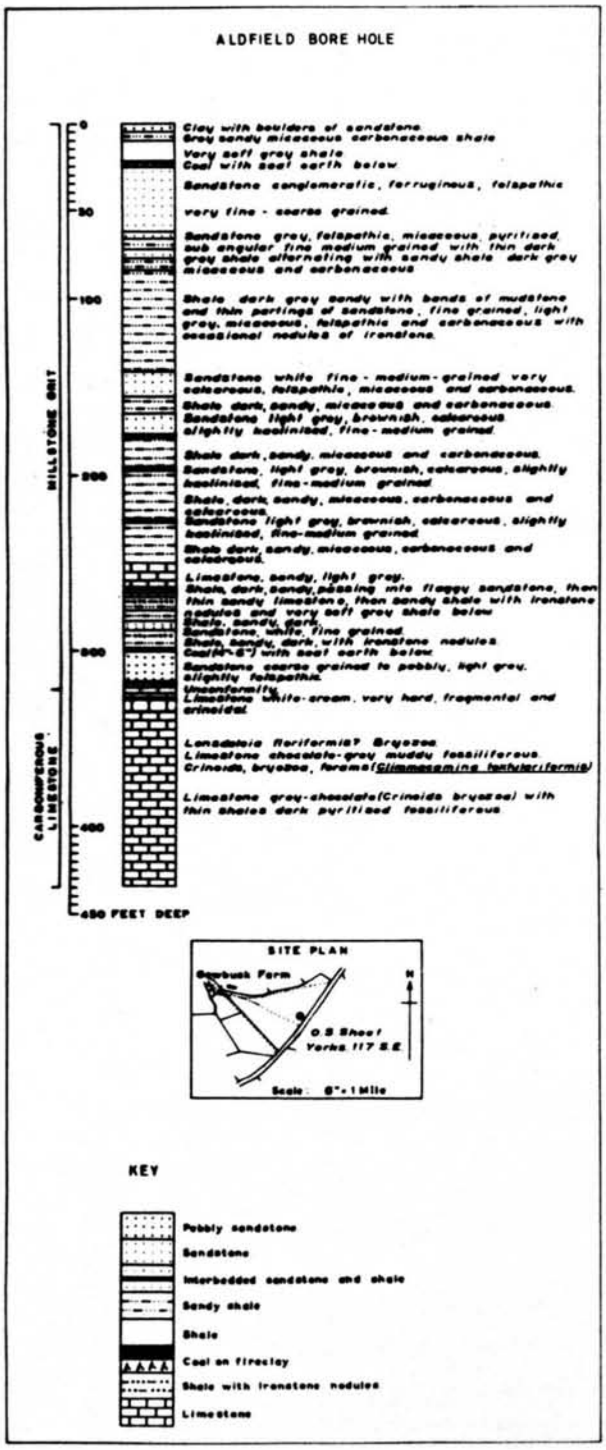
Figure 2



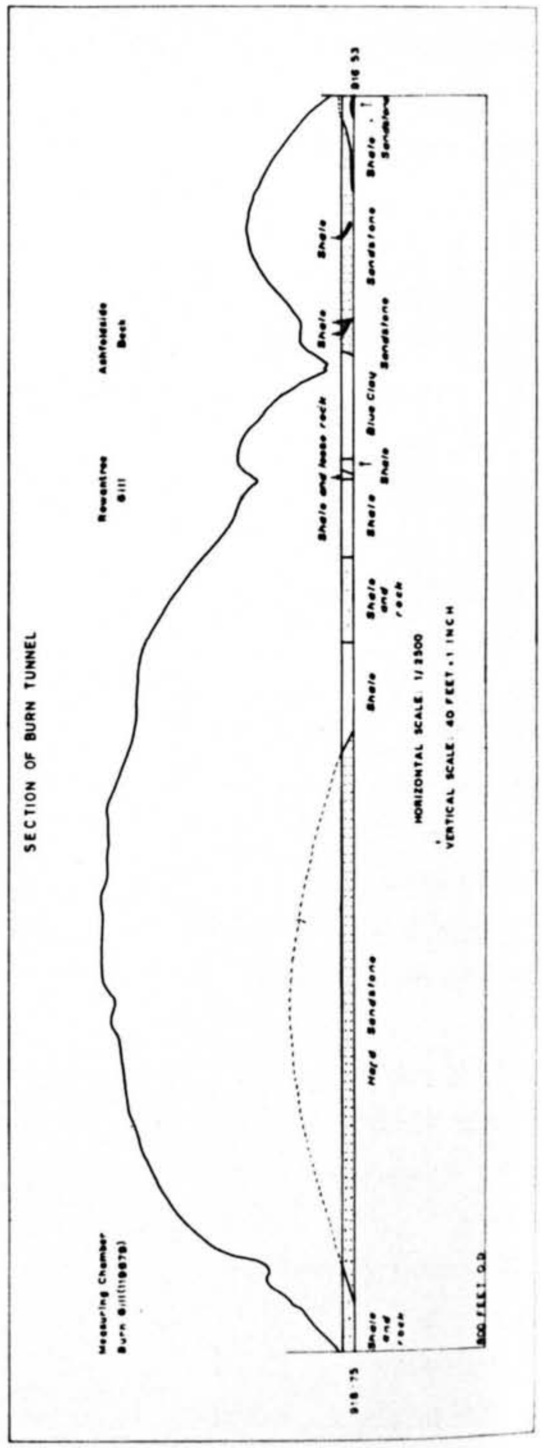
SAWLEY BOREHOLE
GEOLOGICAL FORMATION
DEPTH IN FEET
LOG
FIRST BRIMHAM GRIT
UPPER FOLLIFOOT GRIT
FOLLIFOOT SHALE
LOWER FOLLIFOOT GRIT
NAR HILL BEDS
RED SCAR GRIT
Unconformity
NIDDERDALE SHALES
GRASSINGTON GRIT GROUP
50
100
200
300
400
500
600
700
800
900
1,000
1,100
1,200
1,250
Sandstone, yellow, fine grained to coarse grained or pebbly
White, pink and yellow grains of quartz and felspar
Shale, dark, soft and micaceous
Sandstone, light grey, fine grained, micaceous with some vegetable detritus. Passing into sandstones, micaceous and with thin shales
Sandstones, silty and very fine grained; white
Coarse grained to pebbly sandstone with thin soft shales
Shale, dark micaceous, mostly sandy with siltstones
Shale, dark, soft, fossiliferous with silstones
Sandstone, light, grey, medium grained to pebbly micaceous, flaggy
Grit, pebbly, white, felspathic
Shale, dark, micaceous, soft with thin siltstones
Silstones, white, with shales as above; dip horizontal
Shale dark sandy micaceous with false bedded fine laminae of silstone
Limestone, fossiliferous, grey, dark, shelly and muddy
Silstones and shales
Shales, dark and soft
Shales, dark, calcareous, with two thin bands of dark grey limestone; dip horizontal
Sandstone, coarse grained to grit; grains of quartz coated with iron oxide; subangular, moderately well sorted
Shale, dark and sandy
Sandstone, medium to coarse grained; white to cream; very calcareous; very hard
Shales, dark, micaceous, soft, slickensided in places, passing into shales, dark, micaceous, sandy, with thin silstones
Sandstones, light, sometimes calcareous, fine to coarse grained
Sandstones as above, alternating with bands of dark, micaceous, soft shale
Shale, dark (white spotted) calcareous, with thin bands of very calcareous sandstone
Sandstone, white, fine to coarse grained, calcareous, with thin shale
Shales, dark, sandy, calcareous, with thin bands of sandstone, flaggy, calcareous and carbonaceous. Bands of siltstone
Sandstone, white, fine to coarse grained or brownish. Slightly calcareous and felspathic, poorly sorted. Grains of white and transparent quartz, subrounded, moderately soft. Some mica and carbon matter; ironstone nodules
Shale, dark, with thin bands of sandstone
Shales, dark, micaceous with thin silstones
Sandstone, grey, very fine grained to silstone, quartzitic, calcareous, comenstone, compact, hard
Shale, dark, micaceous, with thin silstones
Sandstone, white compact
Mudstone and shale
Sandstone, white and compact
Mudstone, with calcareous sandstone bands and thin grit bands
Pebbly grit
Shale, with thin bands grit
POSITION OF WELL:
Longitude 1° 37' 32·7" N
Latitude 54° 4' 49·4" W
The stratigraphical interpretation is based on lithological characteristics together with data obtained from field outcrops in the vicinity of the borehole. In the absence of palaeontological details this interpretation is only tentative.
SITE PLAN
O.S. Sheet Yorks 136 NE
N
Volla Wood Farm
0
440
880
Scale in yards
KEY
Pebbly sandstone
Sandstone
Interbedded sandstone and shale
Sandy shale
Shale and mudstone
Limestone
Marine beds

	Thickness		Depth	
	Ft.	In.	Ft.	In.
Hard grey shale	24	3	42	0
Hard grey/yellow sandstone	19	0	61	0
Hard grey sandy shale	22	0	83	0
Hard grey sandstone	10	0	93	0
Hard grey shale	6	0	99	0
Hard grey sandstone	25	6	124	6
Stone House Farm, Eavestone				
Soil	1	3	1	3
First Brimham Grit				
Coarse yellow sandstone	97	6	98	9
Sawley Hall, Sawley				
Soil	1	0	1	0
Clay and stones	5	0	6	0
Blue clay	6	0	12	0
First Brimham Grit				
Sandstone	89	0	101	0
Moor Lane Farm, Sawley				
Boulder clay	10	0	10	0
Brimham Shales				
Bind	16	0	26	0
Hard shale/mudstone	27	0	53	0
First Brimham Grit				
Hard coarse sandstone	49	0	102	0
Shale	5	0	107	0
Hard gritty rock	40	0	147	0
Hard sandy shale	83	0	230	0
Hard grey limestone	4	0	234	0
Grey shale	2	6	236	6
Hard blue/grey limestone	7	9	244	3
Hard grey shale	2	9	247	0
Blue limestone	0	9	247	9
Grey sandy shale	11	0	258	9
Grey sandstone	1	5	260	2
Grey sandy shale	27	6	287	8
Grey rock	6	0	293	8
Grey shale	7	2	300	10

Figure 22



ALDFIELD BORE HOLE
MILLSTONE GRIT
CARBONIFEROUS LIMESTONE
0
50
100
200
300
400
450 FEET DEEP
Clay with boulders of sandstone
Grey sandy micaceous carbonaceous shale
Very soft grey shale
Coal with seat earth below
Sandstone conglomeratic, ferruginous, felspathic
very fine - coarse grained.
Sandstone grey, felspathic, micaceous, pyritised, sub angular fine medium grained with thin dark grey shale alternating with sandy shale dark grey micaceous and carbonaceous
Shale dark grey sandy with bands of mudstone and thin partings of sandstone, fine grained, light grey, micaceous, felspathic and carbonaceous with occasional nodules of ironstone.
Sandstone white fine - medium - grained very calcareous, felspathic, micaceous and carbonaceous.
Shale dark, sandy, micaceous and carbonaceous.
Sandstone light grey, brownish, calcareous slightly kaolinised, fine - medium grained.
Shale dark, sandy, micaceous and carbonaceous.
Sandstone, light grey, brownish, calcareous, slightly kaolinised, fine-medium grained.
Shale, dark, sandy, micaceous, carbonaceous and calcareous.
Sandstone light grey, brownish, calcareous, slightly kaolinised, fine-medium grained.
Shale dark, sandy, micaceous, carbonaceous and calcareous.
Limestone, sandy, light grey.
Shale, dark, sandy, passing into flaggy sandstone, then thin sandy limestone, then sandy shale with ironstone nodules and very soft grey shale below
Shale, sandy, dark.
Sandstone, white, fine grained.
Shale, sandy, dark, with ironstone nodules.
Sandstone coarse grained to pebbly, light grey, slightly felspathic.
Unconformity
Limestone white-cream, very hard, fragmental and crinoidal.
Lonsdaleia floriformis? Bryozoa
Limestone chocolate-grey muddy fossiliferous.
Limestone grey-chocolate (Crinoids bryozoa) with thin shales dark pyritised fossiliferous.
SITE PLAN
O.S Sheet Yorks 117 S.E.
KEY
Pebbly sandstone
Sandstone
Interbedded sandstone and shale
Sandy shale
Shale
Coal on fireclay
Shale with ironstone nodules
Limestone



SECTION OF BURN TUNNEL
HORIZONTAL SCALE: 1/2500
VERTICAL SCALE: 40 FEET = 1 INCH
Shale
Hard Sandstone
Sandstone
Blue Clay

	Thickness		Depth	
	Ft.	In.	Ft.	In.
Ashfield Farm, Sawley				
Old well	23	0	23	0
Soft grey shale	29	0	52	0
Hard grey sandstone	28	0	80	0
Hard grey sandy shale	20	0	100	0
Hebden Wood House, Sawley				
Soil	1	0	1	0
Yellow clay	4	6	5	6
Yellow/grey soft sandstone	86	6	92	0
Grey shale	5	0	97	0
Grey shale with thin beds sandstone	13	0	110	0
Soft grey shale	2	0	112	0
Grey shale with thin beds sandstone	6	6	118	6
Hard grey sandstone	2	6	121	0
Winsley Hall Farm, Burnt Yates				
Soil	1	0	1	0
Clay and stones	3	0	4	0
Bedded yellow sandstone and shale	4	6	8	6
Hard yellow sandstone	8	6	17	0
Soft grey shale	11	0	28	0
Hard grey shale	72	0	100	0
Dinmore Farm, Burnt Yates				
Soil	8	0	8	0
Upper Follifoot Grit				
Yellow rock	12	0	20	0
Follifoot Shale				
Shale	12	0	32	0
Hard shale with thin beds sandstone	35	0	67	0
Lower Follifoot Grit				
Coarse grit	4	0	71	0
Bay Horse Inn, Burnt Yates				
Soil	1	0	1	0
Brown/yellow clay	6	0	7	0
Hard sandstone	22	0	29	0
Firm shale	31	0	60	0
Hard shale with thin beds sandstone	40	0	100	0

	Thickness		Depth	
	Ft.	In.	Ft.	In.
New Inn, Burnt Yates				
Soil	1	6	1	6
Yellow clay	10	6	12	0
Soft blue shale	5	0	17	0
Hard grey shale	33	0	50	0
Bank Top, Shaw Mills				
Old well	27	0	27	0
First Brimham Grit				
Grit rock	15	0	42	0
Hard blue shale with thin beds sandstone	67	0	109	0
Manor Farm, Clint, Shaw Mills				
Soil	1	0	1	0
Brown clay	23	0	24	0
Stone bed	3	0	27	0
Brown clay	7	0	34	0
Dark grey clay	16	0	50	0
Soft grey sandstone	5	0	55	0
Dark grey clay	27	0	82	0
Brown sandstone	3	0	85	0
Dark grey clay	90	0	175	0
Stone bed	2	0	177	0
Dark grey clay	13	0	190	0
Grey sandstone	6	0	196	0
Dark grey clay	4	0	200	0
Grey sandstone	5	0	205	0
Hard grey clay	64	0	269	0
Grey sandstone	31	0	300	0

	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Volla Farm, Bishop Thornton				
Glacials	6	0	6	0
Sandstone	13	0	19	0
Grey shale	31	0	50	0
Hard grey rock	10	0	60	0
The Bungalow, Gillmoor, Bishop Thornton.				
Soil	0	6	0	6
Yellow clay	3	0	3	6
Yellow sandstone and shale	9	6	13	0
Yellow/blue shale	12	0	25	0
Yellow sandstone and shale	4	3	29	3
Yellow/grey sandstone	6	9	36	0
Grey shale	39	0	75	0
Hard grey shale with thin beds sandstone	58	0	133	0
Coarse grey sandstone	12	0	145	0
High Gill Moor, Bishop Thornton				
Boulder clay	19	0	19	0
Black shale	19	0	38	0
Marl	6	0	44	0
Coarse sandstone	13	0	57	0
Haddockstones Grange, Markington				
Soil	0	9	0	9
Yellow/brown clay and stones	36	3	37	0
Blue/grey shale	26	0	63	0
Yellow sandstone	8	0	71	0
Ingerthorpe Hall, Markington				
Boulder clay	48	0	48	0
Boulders	9	0	57	0
Marly gravel	18	0	75	0
Hard limestone	7	0	82	0

	Thickness		Depth	
	Ft.	In.	Ft.	In.
Marl and limestone	53	0	135	0
Red shale	40	0	175	0
Hard rock	1	0	176	0
Blue shale	79	0	255	0

Barsneb Farm, Markington

Soil	1	6	1	6
Clay and stones	24	8	26	2
Grey/red rock	2	0	28	2
Clay and stones	3	6	31	8
Yellow limestone	5	0	36	8
Brown clay	12	4	49	0
Red/grey shale	6	0	55	0
Red sandstone	16	7	72	7
Grey shale	1	5	74	0
Yellow/grey shale	24	0	98	0
Yellow limestone	10	6	108	6
Hard grey shale	55	6	164	0
Light grey limestone	3	0	167	0
Grit rock	2	0	169	0
Hard grey shale	0	6	169	6
Grit rock	3	6	173	0
Grey shale	1	0	174	0
Grit rock	2	0	176	0

Markenfield Hall, Markington

Old Well	82	0	82	0
Limestone with calcite veins	43	0	125	0
Mudstone	3	0	128	0
Blue grit	2	0	130	0
Red sandstone	3	0	133	0
Fine grey sandstone	10	0	143	0
Hard blue shale	46	0	189	0
Red sandstone	23	0	212	0
Blue shale	9	0	221	0

	Thickness Ft.	In.	Depth Ft.	In.
Grey grit - copper veins	23	0	244	0
Blue shale	44	0	288	0
Red sandstone	4	0	292	0
Shale with thin sandstone beds	20	0	312	0
Grey sandstone	6	0	318	0
Blue shale with beds grit	27	0	345	0
Grey sandstone	3	0	348	0
Blue shale	60	0	408	0
Blue grit	2	0	410	0
Blue shale	10	0	420	0

Waterworks, Markington

Soil	1	0	1	0
Clay and stones	11	0	12	0
Sandy gravel	8	0	20	0
Blue shale	10	0	30	0
Shale and sandstone	30	0	60	0
Grey rock	5	0	65	0
Grey shale	27	0	92	0
Grey sandstone	3	0	95	0
Grey shale	195	0	290	0
Gritstone	22	0	312	0
Grey shale	4	0	316	0
Gritty sandstone	9	0	325	0
Grey shale	7	6	332	6

Leeds Corporation Waterworks Boreholes

Carlesmoor Reservoir Site

No. 1 (502.3' O.D.)

Topsoil	1	0	1	0
Sand and brown clay	6	0	7	0
Blue silty clay	10	0	17	0
Sand and stones	22	6	39	6
Brown grit - occasional shale wash	11	2	50	8
Grey micaceous sandstone	15	10	66	6

	Thickness		Depth	
	Ft.	In.	Ft.	In.
Blue shale	27	6	94	0
Grey sandy shale	10	0	104	0
Blue shale	8	6	112	6
Blue/grey sandstone - large quartz content	0	6	113	0
Micaceous sandstone	13	0	126	0
Grey grit	5	0	131	0

No. 2 (505.9' O.D.)

Weathered grit subsoil	16	0	16	0
Brown grit - iron stained	26	0	42	0
Soft grey/blue shale	8	0	50	0
Brown grit	16	0	66	0
Soft grey shale	1	0	67	0
Sand and blue silt	2	0	69	0
Soft grey shale	0	4	69	4
Brown grit	0	2	69	6
Grey micaceous laminated sandstone	0	6	70	0
Grey micaceous shale	5	0	75	0

No. 2a (486·51' O.D.)

Top soil	1	0	1	0
Sand and stones	4	6	5	6
Sand, stones and blue silt	4	6	10	0
Blue silt	2	0	12	0
Sand	19	0	31	0
Sandy blue clay	2	6	33	6
Sand and stones	8	6	42	0
Sand, stones and blue silt	5	0	47	0
Sand, blue silt and coal fragments	4	0	51	0
Blue clay/silt	3	6	54	6
Sand and blue silt	1	0	55	6
Coarse sandstone	6	0	61	6
Sand and stones	5	6	67	0
Soft grey sandstone	2	6	69	6
Grey sandstone and grey bind	2	6	72	0

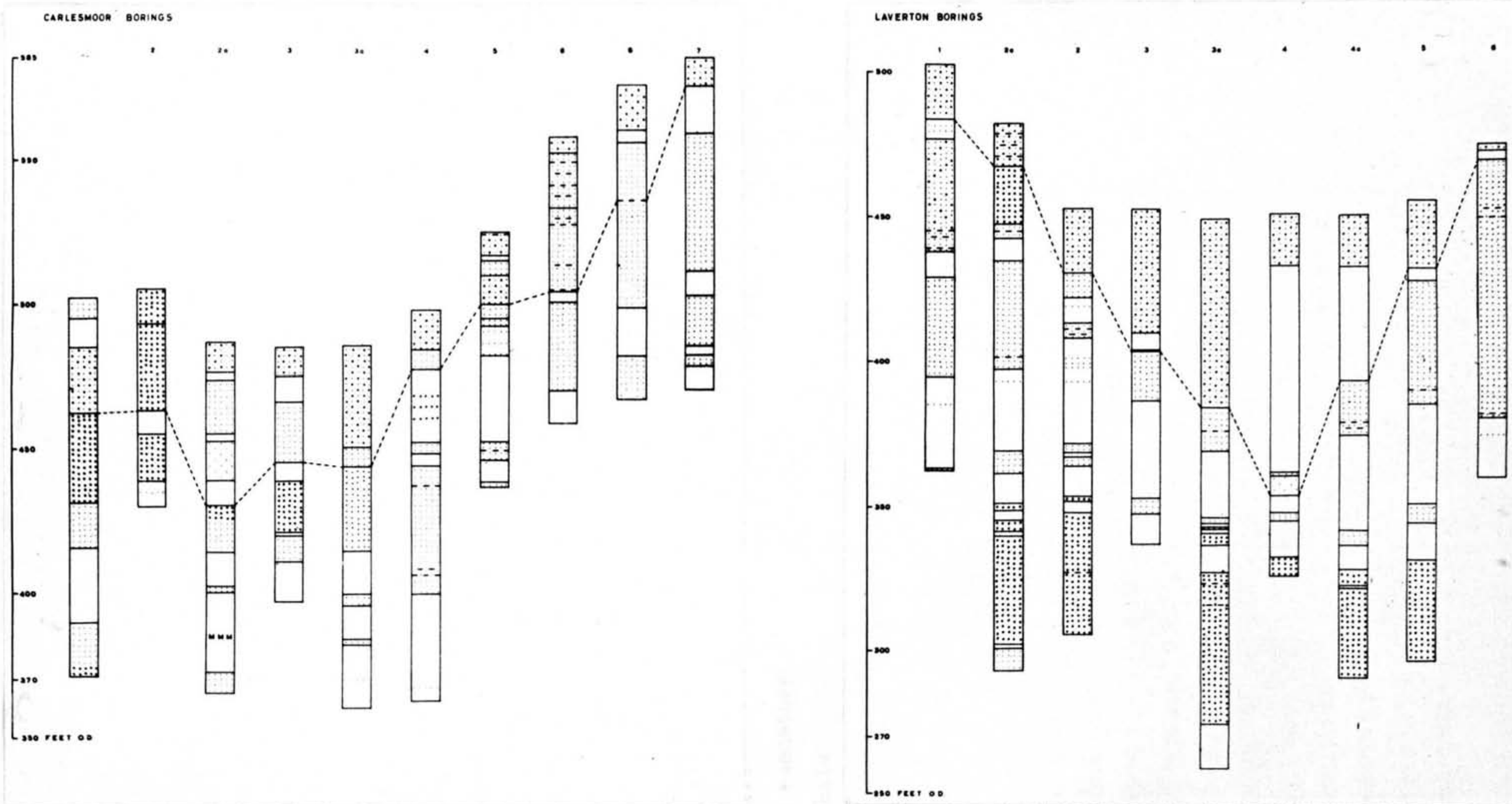


Figure 23. Comparative sections of the strata encountered in the exploratory boreholes sunk by Leeds Corporation in connection with the Carlesmoor and Laverton reservoirs.

	Thickness		Depth	
	Ft.	In.	Ft.	In.
Soft blue shale	11	6	83	6
Grey sandstone	2	6	86	0
Grey bind	1	6	87	6
Sandy blue shale - marine fossil near base	14	0	101	6
Grey bind	7	6	109	0
Soft blue shale	5	3	114	3
Shaley grey sandstone	1	0	115	3
Hard grey sandstone	5	9	121	0

No. 3 (484·8' O.D.)

Topsoil, clay and stones	5	0	5	0
Gravel	5	0	10	0
Blue silt	9	0	19	0
Brown micaceous sandstone	5	0	24	0
Coarse sandstone	15	6	39	6
Soft grey shale	4	0	43	6
Blue silt	3	0	46	6
Coarse sandstone	17	6	64	0
Grey shale	1	6	65	6
Grey grit	8	6	74	0
Soft blue/grey shale	14	0	88	0

No. 3a (485·37' O.D.)

Topsoil	2	0	2	0
Sand, blue silt and stones	33	0	35	0
Sand and sandstone	7	0	42	0
Coarse grey/brown sandstone	29	0	71	0
Sandy blue shale	15	0	86	0
Grey sandstone	4	0	90	0
Blue shale	11	5	101	5
Grey sandstone	2	0	103	5
Grey bind	2	9	106	2
Blue shale	8	0	114	2
Dark grey shaley sandstone	0	9	114	11
Sandy blue shale	4	0	118	11

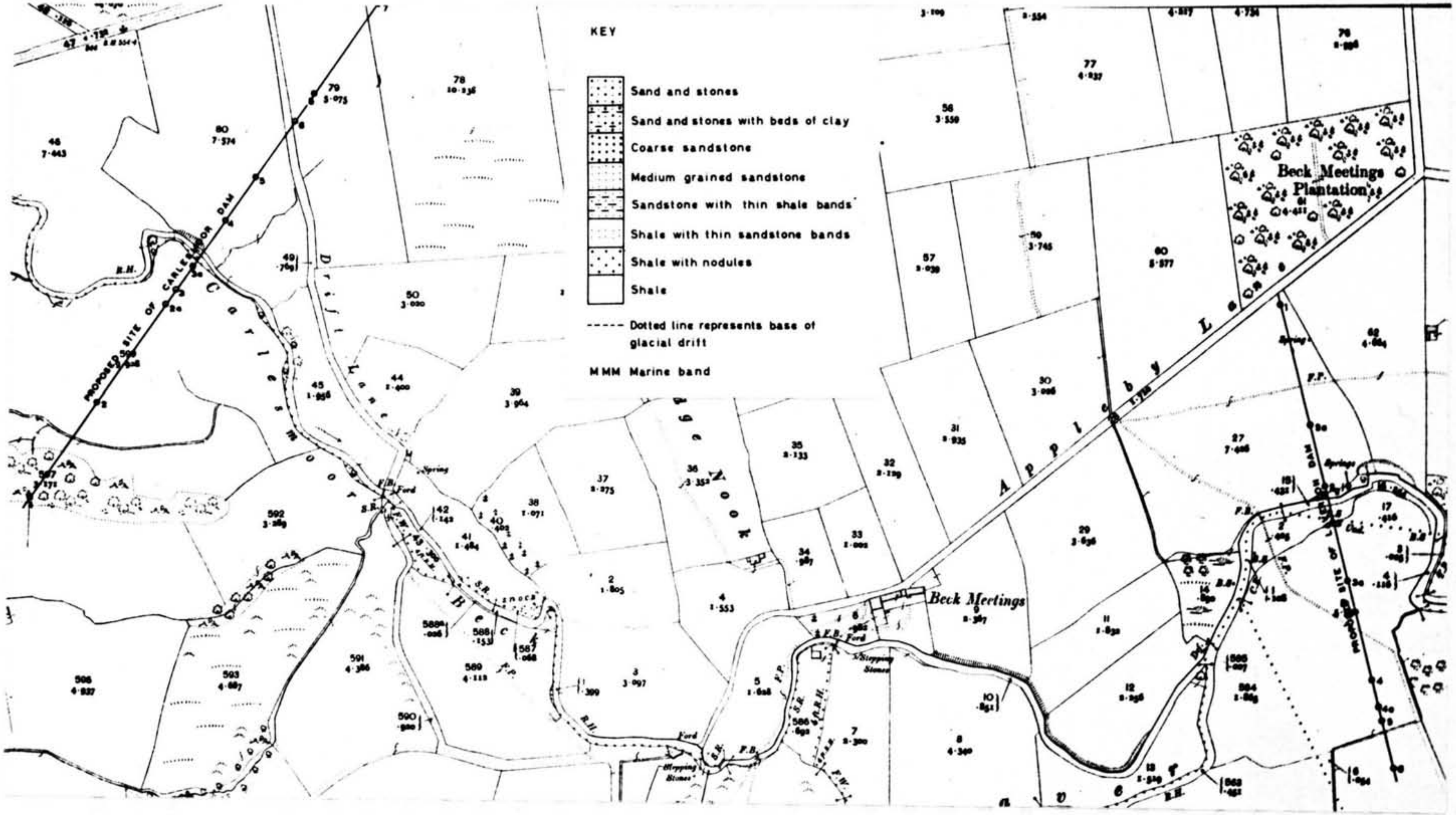


Figure 24. Location map of the boreholes sunk by Leeds Corporation in connection with the construction of the Leeds and Carlesmoor reservoirs.

	Thickness		Depth	
	Ft.	In.	Ft.	In.
Grey bind	0	3	119	2
Sandy blue shale	2	0	121	2
Hard grey bind	3	10	125	0

No. 4 (497·60 O.D.)

Topsoil	1	10	1	10
Sand and stones	4	5	6	3
Grey silt, sand and stones	7	6	13	9
Fine yellow sandstone	6	9	20	6
Soft grey shale and silt	6	6	27	0
Soft grey shale and stones	11	0	38	0
Soft blue shale	7	7	45	7
Soft grey sandstone	3	10	49	5
Blue shale	0	6	49	11
Soft blue shale and grey sandstone	3	9	53	8
Soft brown sandstone	4	0	57	8
Soft grey sandstone and blue shale	2	0	59	8
Brown sandstone	29	4	89	0
Soft grey shale	0	3	89	3
Sandstone	1	9	91	0
Soft grey shale	0	3	91	3
Sandstone	6	9	98	0
Soft blue shale	2	0	100	0
Grey bind	2	6	102	6
Blue shale	10	6	113	0
Grey bind	7	9	120	9
Blue shale	4	4	125	1
Grey bind	0	4	125	5
Blue shale	3	7	129	0
Grey grit	1	0	130	0
Grey bind	5	0	135	0

No. 5 (524·8' O.D.)

Bible clay, sand and stones	4	10	4	10
Sandstone and stones	3	2	8	0

	Thickness		Depth	
	Ft.	In.	Ft.	In.
Soft grey shale	2	0	10	0
Sandstone	5	0	15	0
Sand, small stones and grey shale	10	0	25	0
Soft shaley sandstone	5	0	30	0
Sandstone	2	6	32	6
Sand and shale	10	6	43	0
Sandstone	0	1	43	1
Sandy blue shale	3	5	46	6
Sand and shale	6	0	52	6
Blue sandy shale	20	0	72	6
Soft grey sandstone	2	6	75	0
Soft blue shale	0	3	75	3
Grey sandstone	3	9	79	0
Soft blue shale	7	6	86	6
Grey sandstone	1	6	88	0

No. 6 (558·3' O.D.)

Topsoil	2	4	2	4
Sand and stones	3	6	5	10
Soft sandstone with beds of yellow clay	19	3	25	1
Soft sandstone	3	6	28	7
Grey clay	0	4	28	11
Soft sandstone	1	8	30	7
Yellow clay and sand	0	5	31	0
Soft sandstone	9	0	40	0
Soft sandstone and clay	5	0	45	0
Grey sandstone with soft shale	2	4	47	4
Black wash only	0	3	47	7
Soft brown grey sandstone with beds grey/yellow clay	6	9	54	4
Black wash only	0	6	54	10
Grey bind	1	8	56	6
Blue shale	1	0	57	6
Grey sandstone	2	4	59	10
Brown sandstone	5	2	65	0

	Thickness		Depth	
	Ft.	In.	Ft.	In.
Hard brown/grey sandstone	23	6	88	6
Hard sandy blue shale	1	6	90	0
Soft broken blue shale and dark grey broken sandstone	10	0	100	0

No. 7 (584·90' O.D.)

Topsoil	0	6	0	6
Brown/blue clay, sand and stones	8	9	9	3
Soft blue clay and blue shale	16	3	25	6
Soft grey sandstone and clay	2	0	27	6
Soft coarse grey micaceous sandstone	46	6	74	0
Grey bind	2	0	76	0
Brown/grey sandstone	1	9	77	9
Grey bind	2	3	80	0
Blue shale and bind	2	6	82	6
Soft brown/grey sandstone	17	6	100	0
Grey bind	2	0	102	0
Grey sandstone	0	4	102	4
Grey bind	0	8	103	0
Brown/grey sandstone	3	9	106	9
Grey bind	7	3	114	0
Sandy blue shale	1	0	115	0

No. 8 (576·50' O.D.)

Topsoil, sand and stones	4	0	4	0
Sand, brown shale and stones	6	6	10	6
Stones and yellow clay	5	6	16	0
Soft blue shale	4	0	20	0
Coal	0	6	20	6
Grey/white clay and sand	5	6	26	0
Soft sand	5	0	31	0
Soft sand with beds yellow clay	10	0	41	0
Sandstone	22	0	63	0
Black wash only	0	9	63	9
Sandstone	2	9	66	6

	Thickness Ft.	In.	Depth Ft.	In.
Black wash only	0	3	66	9
Sandstone	2	3	69	0
Black wash only	0	1	69	1
Sandstone	2	11	72	0
Soft brown/grey sandstone with beds yellow clay	6	0	78	0
Soft blue shale	2	0	80	0
Soft grey bind	7	0	87	0
Soft grey sandstone	3	0	90	0
Soft blue shale	5	0	95	0
Soft brown/grey sandstone	15	0	110	0

Laverton Site

No. 1 (502·6' O.D.)

Topsoil and clay	1	0	1	0
Brown/grey clay, stones and sand	13	0	14	0
Blue clay and stones	1	0	15	0
Blue silt, sand and stones	1	4	16	4
Blue clay and shale	1	6	17	10
Sand and yellow clay	0	8	18	6
Soft grey/brown sandstone and clay	7	0	25	6
Grey/brown laminated sandstone	9	6	35	0
Soft coarse sandstone	19	0	54	0
Reddish sand wash	1	0	55	0
Sandstone	2	0	57	0
Brown shale and yellow clay	0	6	57	6
Soft grey sandstone and yellow clay	6	0	63	6
Grey sandstone	0	10	64	4
Sandy blue shale	0	8	65	0
Grey bind	8	6	73	6
Hard grey/brown laminated sandstone	34	6	108	0
Sandy blue shale	8	0	116	0
Shaley grey sandstone	1	4	117	4
Sandy blue shale	22	2	139	6
Hard grey sandstone	0	6	140	0

	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
No. 2 (452·8' O.D.)				
Sandy soil and blue silt	4	0	4	0
Blue clay and sandy blue silt	5	0	9	0
Blue silt, sand and stones	9	0	18	0
Sand and stones	4	0	22	0
Soft broken brown sandstone	8	10	30	10
Soft grey shale	0	5	31	3
Yellow clay and soft sandstone	2	0	33	3
Soft blue shale	2	3	35	6
Blue/brown shale and sand	4	0	39	6
Soft sandstone and yellow clay	5	6	45	0
Brown/blue shale, clay and sand	8	0	53	0
Soft brown/grey shaley sandstone	4	6	57	6
Soft blue shale	1	6	59	0
Soft grey sandstone	1	6	60	6
Soft blue shale	20	6	81	0
Hard brown sandstone	3	2	84	2
Sandy blue shale	1	8	85	10
Soft dark grey sandstone	3	4	89	2
Shale and grey bind	10	0	99	2
Soft grey sandstone	2	0	101	2
Soft grey bind	3	10	105	0
Soft grey sandstone	7	6	112	6
Hard grey sandstone	2	6	115	0
Soft coarse grey sandstone	10	0	125	0
Shaley material	0	6	125	6
Soft coarse brown/grey sandstone	21	6	147	0
No. 2a (482,6' O.D.)				
Topsoil	0	10	0	10
Brown/yellow clay, sand and small stones	11	8	12	6
Broken laminated sandstone with beds yellow/grey clay	2	6	15	0
Soft coarse sandstone	20	0	35	0
Laminated sandstone, grey clay and black shale	5	0	40	0

	Thickness		Depth	
	Ft.	In.	Ft.	In.
Soft black shale	8	0	48	0
Hard brown/grey sandstone	33	0	81	0
Soft sandy blue shale	0	4	81	4
Soft laminated grey sandstone	3	8	85	0
Sandy grey bind	0	4	85	4
Sandy blue shale	14	8	100	0
Black soapy shale	13	8	113	8
Hard brown/grey sandstone	7	6	121	2
Soft blue shale	10	4	131	6
Soft grey sandstone	2	6	134	0
Grey bind	2	6	136	6
Sandy blue shale	1	2	137	8
Soft grey sandstone	4	0	141	8
Sandy grey bind	1	6	143	2
Coarse brown/grey sandstone	37	6	180	8
Soft blue shale	1	4	182	0
Grey sandstone	8	0	190	0

No. 3 (452·3' O.D.)

Sandy topsoil	1	8	1	8
Sand	1	8	3	4
Blue silt and stones	5	8	9	0
Sand and stones	1	0	10	0
Blue silt, sand, stones and yellow clay	32	6	42	6
Soft blue shale	3	6	46	0
Carbonaceous material	2	0	48	0
Coarse sand and stones	1	0	49	0
Laminated sandstone	9	0	58	0
Coarse sand	2	0	60	0
Laminated sandstone	1	0	61	0
Sandstone	5	6	66	6
Yellow clay and soft shale	2	6	69	0
Soft grey bind	12	0	81	0
Sandy blue shale	18	6	99	6
Hard grey sandstone	5	4	104	10

	Thickness		Depth	
	Ft.	In.	Ft.	In.
Soft sandy blue shale	11	2	116	0
No. 3a (449·2' O.D.)				
Blue silt and a little soil	1	0	1	0
Small stones	1	4	2	4
Sand and stones	1	2	3	6
Stones with blue clay	4	0	7	6
Blue silt, stones and blue clay	40	8	48	2
Sand, stones and blue clay	1	10	50	0
Blue silt, stones and clay	15	2	65	2
Hard grey/brown sandstone	0	10	66	0
Soft sandstone	4	0	70	0
Soft sandstone with beds soft shale	3	0	73	0
Stones and soft laminated sandstone	7	0	80	0
Soft sandy blue shale	23	2	103	2
Hard grey sandstone	2	0	105	2
Hard sandy blue shale	1	4	106	6
Laminated grey sandstone	1	0	107	6
Hard sandy blue shale	1	2	108	8
Soft grey sandstone	4	0	112	8
Grey bind with beds grey clay	2	4	115	0
Grey bind	1	6	116	6
Sandy blue shale	5	8	122	2
Grey sandstone	0	11	123	1
Coarse grey sandstone	2	2	125	3
Soft dark bind	0	9	126	0
Soft grey/blue sandstone	4	0	130	0
Coarse grey sandstone	2	6	132	6
Soft dark bind	0	8	133	2
Soft grey/blue sandstone	1	10	135	0
Coarse grey sandstone	1	0	136	0
Hard shattered material	7	6	143	6
Hard carbonaceous broken sandstone	0	2	143	8
Hard coarse grey sandstone	6	6	150	2
Hard laminated sandstone	6	4	156	6

	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Hard coarse grey sandstone	18	0	174	6
Blue shale	9	6	184	0
Soft grey sandstone	0	6	184	6
Soft grey bind	5	6	190	0

No. 4 (451' O. D.)

Sandy topsoil	2	2	2	2
Red sand	1	0	3	2
Sand and stones	0	10	4	0
Blue silt and coarse sandstone	14	0	18	0
Blue clay and blue silt	59	6	77	6
Soft blue shale	4	6	82	0
Stones and blue clay	7	2	89	2
Coarse sand	1	6	90	8
Small stones and blue clay	6	4	97	0
Soft blue shale	6	0	103	0
Hard grey sandstone	3	0	106	0
Soft blue shale	12	6	118	6
Soft grey sandstone	6	6	125	0

No. 4a (450·8' O.D.)

Topsoil	1	0	1	0
Loamy sand and silt	2	10	3	10
Sand and silt	2	0	5	10
Silt and small stones	7	2	13	0
Blue clay and stones	5	0	18	0
Blue silt and clay	39	6	57	6
Soft broken sandstone	8	6	66	0
Laminated sandstone	4	0	70	0
Soft broken sandstone with beds of yellow clay	6	0	76	0
Soft shaley material	2	4	78	4
Soft grey bind	16	8	95	0
Soft sandy blue shale	13	0	108	0
Hard grey sandstone	1	0	109	0
Soft grey sandstone	5	0	114	0

	Thickness		Depth	
	Ft.	In.	Ft.	In.
Blue silt	6	0	120	0
Sandy blue shale	2	6	122	6
Laminated grey sandstone	5	6	128	0
Sandy blue shale	1	0	129	0
Soft laminated grey sandstone	31	0	160	0

No. 5 (455·5' O.D.)

Topsoil	0	9	0	9
Sand, yellow clay and silt	1	0	1	9
Blue silt, clay and stones	21	6	23	3
Broken laminated sandstone with beds yellow clay	47	0	70	3
Soft grey bind	12	3	82	6
Sandy blue shale	21	9	104	3
Hard grey sandstone	4	6	108	9
Soft grey sandstone	2	3	111	0
Hard sandy black shale	0	3	111	3
Soft grey material	4	6	115	9
Sandy blue shale	8	0	123	9
Soft laminated grey/brown sandstone	35	3	159	0

No. 6 (475·6' O.D.)

Topsoil	0	4	0	4
Sand, stones and yellow clay	2	2	2	6
Bible clay	3	0	5	6
Bedded sandstone	4	6	10	0
Broken sandstone with beds yellow clay	15	2	25	2
Coarse orange brown sandstone	15	4	40	6
Dark brown laminated sandstone	0	6	41	0
Yellow/white/grey clay with mica	2	2	43	2
Cementstone	1	10	45	0
Laminated brown/grey sandstone	42	0	87	0
Softer coarse sandstone	3	0	90	0
Soft laminated sandstone with beds black shale	3	0	93	0
Soft sandy shale	0	4	93	4
Soft grey laminated sandstone	1	8	95	0

	Thickness		Depth	
	Ft.	In.	Ft.	In.
Soft sandy blue shale	5	6	100	6
Soft grey sandstone	0	6	101	0
Sandy blue shale	14	0	115	0

LIST OF WORKS TO WHICH REFERENCE IS MADE

ANDERSON, F. W. 1928. The Lower Carboniferous of the Skyreholme Anticline, Yorkshire. Geol. Mag. 65, pp. 518–27.

BISAT, W. S. 1914. The Millstone Grit sequence between Masham and Great Whernside. Proc. Yorks. Geol. Soc. 19, pp. 20–4.

—— 1924. The Carboniferous Goniatites of the North of England and their zones. Proc. Yorks. Geol. Soc. 20, pp. 40–120.

—— 1928. The Carboniferous Goniatite Zones and their Continental Equivalents. Compte Rendu Congres de Strat. Carb. Heerlen, 1927, pp. 117–33.

—— 1933. The Carboniferous Goniatites of the neighbourhood of Tenby. Proc. Geol. Assoc. 44, pp. 412–4.

—— & R. G. S. HUDSON. 1943. The Lower Reticuloceras goniatite succession in the Namurian of the north of England. Proc. Yorks. Geol. Soc. 24, pp. 383–440.

BLACK, W. W. 1950. The Carboniferous Geology of the Grassington area, Yorkshire. Proc. Yorks. Geol. Soc. 28, pp. 29–42.

BRADFORD MEMOIR. J. V. STEPHENS, G. H. MITCHELL & W. EDWARDS. 1953. Geology of the country between Bradford and Skipton. Mem. Geol. Surv. 180 pp..

BUTTERFIELD, J. A. 1934. The Heavy Minerals of Sandstones of the Snail Green Boring. Trans. Leeds. Geol. Assoc. v, pp. 97–111.

—— 1936. An occurrence of anatase(var. Octahedrite) in the Millstone Grit of Yorkshire. Trans. Leeds. Geol. Assoc. v, pp. 145–52.

—— 1937. Analyses of sandstones from the Millstone Grit at Yeadon, Yorkshire. Proc. Yorks. Geol. Soc. 23, pp. 144–58.

—— 1939. Brookite in the Millstone Grit of Yorkshire. Geol. Mag. 76, pp. 220–8.

CARRUTHERS, R. G. 1938. Alston Moor to Botany and Tan Hill: an adventure in Stratigraphy. Proc. Yorks. Geol. Soc. 23, pp. 236–53.

CHUBB, L. J. & R. G. S. HUDSON. 1925. The nature of the junction between the Lower Carboniferous and the Millstone Grit of North-West Yorkshire. Proc. Yorks. Geol. Soc. 20, pp. 257–92.

CURRIE, E. D. 1954. Scottish Carboniferous Goniatites. Trans.roy. Soc. Edinb. 62, pp. 527–602.

DAKYNS, J. R. 1890. On the changes in the Lower Carboniferous rocks in Yorkshire from south to north. Proc. Yorks. Geol. Soc. 11, pp. 353–62.

—— 1892. The Geology of the country between Grassington and Wensleydale. Proc. Yorks. Geol. Soc. 12, pp. 133–44.

DAKYNS, J. R. 1893. A sketch of the Geology of Nidderdale and the Washburn, north of Blubberhouses. Proc. Yorks. Geol. Soc. 12, pp. 294-9.

——— 1903. Notes on the Millstone Grit of Grassington Moor. Geol. Mag. dec. 4, vol. 10, pp. 223-5.

DAVIS, J. W. & F. A. LEES. 1878. West Yorkshire. London.

DIXON, J. 1852. Fossil marine worms in the Flagstone Beds of Pateley Bridge, Yorkshire. The Naturalist(Morris) ii, pp. 130-1.

DUNHAM, K. C. 1933. Structural features of the Alston Block. Geol. Mag. 70, pp. 241-54.

——— 1948. Geology of the Northern Pennine Orefield. Vol. 1. Tyne to Stainmore. Mem. Geol. Surv. London. 357 pp.

——— & C. J. STUBBLEFIELD. 1945. The Stratigraphy, Structure and Mineralisation of the Greenhow Mining area, Yorkshire. Quar. Jour. Geol. Soc. 100, pp. 209-64.

EDWARDS, W. 1936. A borehole section at Yeadon near Leeds. Trans. Leeds Geol. Assoc. v, pp. 134-41.

——— 1938. The Glacial Geology in "The Geology of the Country around Harrogate". Proc. Geol. Assoc. 49, pp. 333-43.

——— & OTHERS. 1940. Geology of the Country around Wakefield. Mem. Geol. Surv. 215 pp.

FISK, H. N. & OTHERS. 1954. Sedimentary framework of the modern Mississipi delta. J. Sediment. Petrol. 24, pp. 76-99.

FOX STRANGWAYS, C. 1874. The geology of the Country North and East of Harrogate. 1st. Edition. Mem. Geol. Surv.

GARWOOD, E. J. & GOODYEAR, E. 1924. The Lower Carboniferous Succession in the Settle District and along the line of the Craven Faults. Quar. Jour. Geol. Soc. 80, pp. 184-273.

GAYNER, J. S. & S. MELMORE. 1937. The Glacial Geology of the district between Masham and Knaresborough. The North-Western Naturalist 12, pp. 279-84.

GEORGE, T. N. 1932. Brachiopods from the Cayton Gill Beds. Trans. Leeds Geol. Assoc. v, pp. 37-48.

GILLIGAN, A. 1919. The Petrography of the Millstone Grit of Yorkshire. Quar. Jour. Geol. Soc. 75, pp. 251-94.

——— 1921. A borehole for water at Meanwood, Leeds. Trans. Leeds Geol. Assoc. vi, pp. 15-6.

GREEN, R. 1954. The Upper Limestone Group, Millstone Grit and Lower Coal Measures of the Lower Tyne Valley. PhD Thesis, University of Durham, King's College.

HEDLEY, W. P. 1931. The Lower Carboniferous in "Contributions to the Geology of Northumberland and Durham". Proc. Geol. Assoc. 42, pp. 232-8.
HIND, W. 1907. Life zones in the British Carboniferous Rocks. The Naturalist 1907, pp. 90-6.
------ 1914. Palaeontological notes on the Millstone Grit Beds between Masham and Great Whernside. Proc. Yorks. Geol. Soc. 19, pp. 25-34.
------ 1918. On the distribution of the British Carboniferous Goniatites. Geol. Mag. dec.6, vol.5, pp. 434-50.
HUDSON, R. G. S. 1933. The Scenery and Geology of North-West Yorkshire in "The Geology of the Dales". Proc. Geol. Assoc. 44, pp. 228-55.
------ 1934. The Millstone Grit succession south of Harrogate. Trans. Leeds Geol. Assoc. v, pp. 118-24.
------ 1938. The Carboniferous Rocks in "The Geology of the Country around Harrogate". Proc. Geol. Assoc. 49, pp. 306-30.
------ 1939. The Millstone Grit Succession of the Simonseat Anticline, Yorkshire. Proc. Yorks. Geol. Soc. 23, pp. 319-49.
------ 1941. The Mirk Fell Beds(Namurian E_2) of Tan Hill, Yorkshire. Proc. Yorks. Geol. Soc. 24, pp. 259-89.
------ 1944. The faunal succession in the Cravenoceratoides nitidus zone in the mid-Pennines. Leeds Lit. Phil. Soc. 4, pp. 233-42.
------ 1945. The Goniatite Zones of the Namurian. Geol. Mag. 82, pp.1-9.
------ 1949. The Carboniferous of the Craven Reef Belt at Malham. Abstr. Proc. Geol. Soc. Lond. No. 1,447, pp. 38-41.
------ & G. A. COTTON. 1943. The Namurian of Alport Dale, Derbyshire. Proc. Yorks. Geol. Soc. 25, pp. 142-73.
------ & H. V. DUNNINGTON. 1939. A boring in the Lower Coal Measures and Millstone Grit at Bradford. Proc. Yorks. Geol. Soc. 24, pp. 129-36.
------ & G. H. MITCHELL. 1937. The Carboniferous Geology of the Skipton Anticline. Summ. Progr. Geol. Surv.(for 1935) part II, pp. 1-45.
------ & J. S. TURNER. 1933. Early and mid-Carboniferous earth-movements in Great Britain. Leeds Lit. Phil. Soc. 2, pp. 455-66.
HULL, E. 1868. On the thickness of the Carboniferous Rocks of the Pendle Range of Hills, Lancashire. Quar. Jour. Geol. Soc. 24, pp. 319-35.
JACKSON, J. W. 1946. Tylonautilus nodiferus(Armstrong) from the Cefn-y-Fedw Series at Nant-y-Ffrith. Proc. Liverpool Geol. Soc. 19, pp. 161-4.
JONES, H. Ll. L. 1957. The Stratigraphy and Structure of the area between Middleton in Teesdale and Woodlands. PhD Thesis. University of Durham. Durham Division.

JONES, T. W. 1943. The Geology of the Beamsley Anticline. Leeds Lit. Phil. Soc. 4, pp. 146-66.

KENDALL, P. F. 1911. The Geology of the District around Settle and Harrogate. Proc. Geol. Assoc. 22, pp. 27-60.

——— & A. E. WROOT. 1924. The Geology of Yorkshire. 2 vols. 995 pp. Privately printed in Vienna.

LEEDS MEMOIR. EDWARDS, W., G. H. MITCHELL & T. H. WHITEHEAD. 1950. Geology of the District North and East of Leeds. Mem. Geol. Surv.

LEES, G. M. & P. T. COX. 1937. The Geological Basis of the present search for oil in Great Britain by the D'Arcy Exploration Company Limited. Quar. Jour. Geol. Soc. 93, pp. 156-94.

LEES, G. M. & A. H. TAITT. 1946. The Geological results of the search for oilfields in Great Britain. Quar. Jour. Geol. Soc. 101, pp. 255-317.

LEWIS, H. CARVILL. 1894. The Glacial Geology of Great Britain. 469 pp. London.

MARR, J. E. 1899. On Limestone Knolls in the Craven District of Yorkshire and elsewhere. Quar. Jour. Geol. Soc. 55, pp. 327-58.

——— 1910. The Lake District and neighbourhood - Upper Palaeozoic and Neolithic times. Geology in the Field - Jubilee Volume of the Geologists Association, pp. 642-60.

——— 1921. On the rigidity of North-West Yorkshire. The Naturalist, pp. 63-72.

MENARD, H. W. & A. J. BOUCOT. 1951. Experiments on the movement of shells by water. Amer. Jour. Sci. 249, pp. 131-51.

MIALL, L. C. 1869. On a system of anticlinals in South Craven. Proc. Yorks. Geol. Soc. 4, pp. 577-88.

MOSELEY, F. 1953. The Namurian of the Lancaster Fells. Quar. Jour. Geol. Soc., 109, pp. 423-54.

——— 1956. The Geology of the Keasden area, west of Settle, Yorkshire. Proc. Yorks. Geol. Soc. 30, pp. 331-52.

NEVIN, C. M. 1942. Principles of Structural Geology. 3rd. Edition. 320 pp. John Wiley and Sons. Ltd., New York.

PALMER, J. & H. C. VERSEY. 1953. Field Excursion to Brimham Rocks and Lower Nidderdale. Yorks. Geol. Soc. Pamphlet 160.

PARKER, J. M. 1942. Regional jointing systematic in slightly deformed sedimentary rocks. Bull. Geol. Soc. Am. 53, pp. 381-408.

PETTIJOHN, F. J. 1942. Sedimentary Rocks. 526 pp. Harper Brothers, New York.

PHILLIPS, J. 1836. Illustrations of the Geology of Yorkshire, Part II. The Mountain Limestone District. 253 pp. London.

RAISTRICK, A. 1926. The Glaciation of Wensleydale, Swaledale and adjoining parts of the Pennines. Proc. Yorks. Geol. Soc. 20, pp. 366-410.

——— 1927. Periodicity in the Glacial Retreat Stages in West Yorkshire. Proc. Yorks. Geol. Soc. 21, pp. 24-9.

——— 1933. The correlation of the Glacial Retreat Stages across the Pennines. Proc. Yorks. Geol. Soc. 22, pp. 199-214.

——— 1938. The Mineral Deposits in "The Geology of the Country around Harrogate". Proc. Geol. Assoc. 49, pp. 343 -52.

RAST, N. & J. I. PLATT. 1957. Cross Folds. Geol. Mag. 94, pp. 159-67.

RAYNER, D. H. 1953. The Lower Carboniferous Rocks in the north of England: - A review. Proc. Yorks. Geol. Soc. 28, pp. 231-315.

READING, H. G. 1954. The Stratigraphy and Structure of the Syncline of Stainmore. PhD Thesis, University of Durham, Durham Division.

ROWELL, A. J. 1953. The Upper Limestone Group and Millstone Grit of the Stainmore outlier and the Askrigg Block from Tan Hill to Swarth Fell. PhD thesis. Leeds University.

SCANLON, J. E. 1955. The Upper Limestone Grit and Millstone Grit of the Askrigg Block from Swarth Fell to Rogan's Seat and Summer Lodge Moor. PhD Thesis. Leeds University.

SEDGWICK, A. 1835. Description of a Series of Longitudinal and Transverse Sections through a portion of the Carboniferous chain between Penigent and Kirkby Stephen. Trans. Geol. Soc. Lond. Ser. 2, iv, pp. 69-101.

SLINGER, F. C. 1936. The succession in the Rough Rock Series north of Leeds. Trans. Leeds Geol. Assoc. v, pp. 188-96.

——— 1936 A. Millstone Grit and Glacial Geology of Caton Moor, near Lancaster. Rep. Brit. Assoc. Blackpool, pp. 345.

SORBY, H. C. 1859. On the structure and origin of the Millstone Grit in South Yorkshire. Proc. Yorks. Geol. and Poly. Soc. 3, pp. 669-75.

SPEIGHT, H. 1894. Nidderdale and the Garden of the Nidd. 574 pp. Elliot Stock. London.

STEPHENS, J. V. & OTHERS. 1942. The faunal divisions of the Millstone Grit of Rombalds Moor and neighbourhood. Proc. Yorks. Geol. Soc. 24, pp. 344-72.

TIDDEMANN, R. H. 1890. On Concurrent faulting and deposition in Carboniferous times in Craven, Yorkshire, with a note on Carboniferous reefs. Rep. Brit. Assoc. Newcastle, pp. 600-3.

TILLOTSON, E. 1933. The Glacial Geology of Nidderdale. Proc. Yorks. Geol. Soc. 22, pp. 215-28.

TONKS, L. H. 1925. The Millstone Grit and Yoredale Rocks of Nidderdale. Proc. Yorks. Geol. Soc. 20, pp. 226-56.

TROTTER, F. M. 1952. Sedimentation facies in the Namurian of North-Western England and adjoining areas. Liverpool Manch. Geol. Jour. i,pp. 77-102.

——— & S. E. HOLLINGWORTH. 1928. The Alston Block. Geol. Mag. 65, pp433-48.

TUTE, J. S. 1868. The Geology of the country near Ripon. Proc. Yorks. Geol. Soc. 4, pp. 555-65.

——— 1886. On the Cayton Gill Beds. Proc. Yorks. Geol. Soc. 9, pp. 265-7.

——— 1887. Note on the occurrence of Lingula in the Millstone Grit series west of Ripon. Proc. Yorks. Geol. Soc. 9, p.425.

VERSEY, H. C. 1927. Post-Carboniferous movements in the Northumbrian Fault Block. Proc. Yorks. Geol. Soc. 22, pp. 1-16.

WAGER, L. R. 1931. Jointing in the Great Scar Limestone of Craven and its relation to the tectonics of the area. Quar. Jour. Geol. Soc. 87, pp. 392-424.

WALKER, C. T. 1952. Stratigraphical directional studies in the Kinderscout Grits of Wharfedale and adjacent areas. PhD Thesis. Leeds University.

WELLER, J. M. & H. R. WANLESS. 1939. Correlation of minable coals of Illinois, Indiana and Western Kentucky. Bull. Amer. Assoc. Petrol. Geol. 23, pp. 1374-92.

WELLS, A. J. 1955. The Stratigraphy and Structure of the Middleton Tyas-Sleightholme anticline, and the development of chert between the Undersett and Crow Limestones in North Yorkshire. PhD Thesis. University of Durham, Durham Division.

WENTWORTH, C. K. 1922. A scale of grade and class terms for clastic sediments. Jour. Geol. 30, pp. 377-92.

WESTOLL, T. S., D. A. ROBSON & R. GREEN. 1955. A guide to the Geology of the district around Alnwick, Northumberland. Proc. Yorks. Geol. Soc. 30, pp. 61-100.

WHITE, P. H. N. 1949. Gravity data obtained in Great Britain by the Anglo-American Oil Company Limited. Quar. Jour. Geol. Soc. 104, pp. 339-64

WHETTON, J. T., J. O. MYERS & I. J. WATSON. 1956. A gravimeter survey in the Craven District of north-west Yorkshire. Proc. Yorks. Geol. Soc. 30, pp. 259-87.

WILSON, A. A. 1957. The Geology of the country between Masham and Great Whernside. PhD Thesis. University of Durham, Durham Division. 2 vols.

WILSON, G. V., T. EASTWOOD & OTHERS. 1922. Special reports on the mineral resources of Great Britain. vol. II. Barytes and witherite. 3rd. Edition. Mem. Geol. Surv. 119 pp.