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THE GEOLOGY

of the

COUNTRY BETWEEN MASHAM AND GREAT WHERNSIDE

by

Albert A. Wilson B.Sc., F.G.S.

VOLUME I

A Thesis presented for the degree of Doctor of Philosophy

in Durham University (Durham Division)

DURHAM, 1957

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ABSTRACT AND STATEMENT OF THE CHIEF RESULTS

The present account is based on the geological survey of 110 square miles of dissected, upland country developed in the P_2,E,H, and R_1 faunal divisions of the Carboniferous system and located in the S.E. of the Askrigg Block in the Pennine Chain of Yorkshire (refer to Plate 2).

The succession embraces approximately 1750' of strata both of Yoredale (limestone, shale, sandstone) and of Millstone Grit facies (sandstones and shales). The sediments of Yoredale facies comprise eight rhythmic units, or cyclothems, five of which are of lower Carboniferous age. All remaining beds are of upper Carboniferous age. They include the three highest Yoredale cyclothems and rocks of Millstone Grit facies.

The Simonstone cyclothem varies greatly in thickness from north to south, this being due to a thinning of the shales and sandstones. The Middle cyclothem is characterised by great local thickening of the Middle Limestone. This latter horizon shows a tripartite division throughout the area, with a central part carrying abundant Gigantoproductus. A less persistent band with Orionastraea occurs at several localities near the base of the limestone. The measures above the Middle Limestone are everywhere thin and in the south of the area yield an extensive normal shale fauna, but are replaced by sandstones in the north which may however belong to the Five Yard or possibly the Three Yard cyclothem. Owing to the absence of the Five Yard Limestone in the north of the area no full proof of the age of these latter beds is forthcoming.

The Five Yard Limestone is restricted to the south of the area. Its lower leaf is characterised by a Lithostrotion-Gigantoproductus fauna in upper Coverdale and upper Waldendale. The shales above the limestone are confined to the south of the area and carry a large fauna which includes several new species and a new genus of ostracod. Sudeticeras ordinatum Moore, a P_2 goniatite, is also recorded. The Three Yard Limestone consists of two leaves, an upper persistent leaf and a lower impersistent one. The measures above the Three Yard Limestone are chiefly sandstones in the north of the area, but shales dominate in the extreme south. Revised correlations of the beds at the Three Yard-Five Yard Limestone level are put forward for the outcrops of these beds in upper Coverdale and Nidderdale on the basis of the present work, using the findings of Moore (1955) as essential evidence.

The Underset Limestone varies considerably in thickness and carries within it a coral bed in the extreme N.W. of the area. Local developments of chert above and below the limestone and of calcareous shales below the main leaf of the limestone are detailed. The sediments above the limestone are everywhere thick, except in the N.E. of the area, where they thin abruptly. ?Cravenoceras sp. has been recorded about 25' above the top of the Underset Limestone, providing confirmatory evidence for placing the base of the Pendleian about 10' above the top of this limestone.

The Main Limestone varies greatly in thickness, possibly owing to overstep at the base of the Little Limestone which is overlain by the Richmond Chert Series. These latter beds are

extremely thick in the N. of the area. A reassessment of the chert problem is presented in the light of the field evidence from the present ground. A case is put for local chertification below the plane of the intra-E_1 unconformity in upper Nidderdale. The Crow cyclothem is recognised in the north of the present area. It is overlapped by the sub-Grassington Grit (intra-E_1) unconformity which transgresses southwards across the sediments of the upper four cyclothems in the area. A synopsis of present knowledge relating to the intra-E_1 unconformity is given and the nature of the overstep in the present area is elucidated by means of a map and sections.

The Grassington Grit Group is shown to alter laterally into a series of shales with impersistent sandstones in the north of the area. Cravenoceras cowlingense is first recorded in situ from the area and is described from several localities together with a large supporting fauna. A widespread distribution of the Cockhill Marine Band is demonstrated and C. cowlingense is recorded from the extreme north of the area. By means of these occurrences a northwards thinning of the Grassington Grits and shales is shown to occur, a process of thinning which is shown to be continued farther to the N.W. in the work of Scanlon (1955).

Sediments of lower Arnsbergian age are the Nidderdale shales with local impersistent sandstones and the Red Scar Grit with an impersistent coal, the variations of which are treated in detail. The Red Scar Grit develops a fossiliferous phase in the upper leaf in the north of the ground and a fauna is also recorded

from the shales with the Woogill Coal. The Colsterdale Marine Series consist of shales with a thin limestone characterised by Cravenoceratoides nitidus (Phillips), overlain and underlain by shales with Anthracoceras paucilobum (Phillips) and Dimorphoceras sp. together with a large additional fauna. A local thickening of the beds beneath the Colsterdale Limestone accompanied by the development of a nuculid-gastropod phase occurs in the north, in Colsterdale. Diagrams and text with full details of the faunal divisions and changes at this level are given. The Nar Hill Beds and the Lower Follifoot Grit, also of Arnsbergian age, consist of variable sandstones with shales prominently developed in the former unit. Beds at these levels have been re-named following the discovery of Homoceras beyrichianum (Haug) and Homoceras aff. subglobosum (Bisat) in the Ganister Beds.

The Ganister Beds are the only sediments of Sabdenian age and include the above mentioned fossils which constitute the first record of H zone goniatites on the Askrigg Block.

The Cayton Gill Shell Bed yields an extensive suite of fossils and is overlain by the Agill Sandstone which has yielded the only extant Upper Carboniferous ophiuroid. The Libishaw Sandstone and Capelshaw Shales are locally fossiliferous. New correlations of sediments at the level of these R_1 shell beds are put forward. The massive Brimham Grits are separated by shales which yield a band with Lingula sp.

The beds dip in an easterly direction at about 2 degrees and though no continuous mesh of faults occurs, they are

locally abundant. An analysis of structural trends is given together with a structure contour map.

The margins of the drift and periglacial phenomena associated with the Main Dales Glaciation are described and include new records of overflow channels.

A synthesis of work on fossils is provided with comments on the zonal use of several forms, palaeo-ecology and techniques of separation of specimens.

The chief rock types are examined from the genetic and descriptive standpoints. Comparison is made with the conclusions of other authors relating to the genesis of sediments of the Yoredale and Millstone Grit facies.

Accounts of previous workings for coal, lead etc. are given together with a statement of the problems which have beset dam builders in the past when constructing reservoirs in the area.

ACKNOWLEDGEMENT

The author is indebted to numerous persons and organisations for help freely given in the pursuit of this research. His chief thanks are due to Professor K.C. Dunham, F.R.S. for originally suggesting the present area as a suitable one on which to carry out research and for his invaluable advice in laboratory and field during the course of the work.

Special thanks are due to Dr. G.A.L. Johnson who has given freely of his time in advising on palaeontological matters. Others to whom I owe a debt for help with fossils are Dr. F.W. Anderson, Mr. W.S. Bisat, F.R.S., Dr. F. Hodson, Dr. W.H.C. Ramsbottom, Dr. C.J. Stubblefield, F.R.S., and Mr. J.S. Turner, M.Sc. Great benefit has followed from discussion with my fellow research workers, in particular A.T. Thompson, B.Sc., who is at present engaged in work on the ground adjoining mine on the south side.

The photographic work owes much to the care of Mr. Colin Chaplin who was responsible for the photography of many diagrams, thin sections and specimens and for the prints of the views incorporated in this thesis.

The officials of the Bradford, Leeds and Harrogate Waterworks undertakings have been most courteous and helpful in providing me with information regarding the strata encountered during reservoir construction. In the field the co-operation of land owners and the comforts afforded me by the various good folk I have stayed with have greatly eased my task.

The course of research was carried out on a D.S.I.R. Maintenance Grant. The help of this body, and also the kind

offer of a grant by the Ministry of Education, is here acknowledged.

NOTE ON SYSTEM FOLLOWED IN THE THESIS

1. Six figure National Grid References are given for the majority of exposures, the location of which can then be found on the geological map, or on any topographic map furnished with the grid. 10 kilometre-grid lines have been used on all plates incorporating maps (with the exception of Plate 2, where the 100 km. grid is employed) and in cases where the detail warrants it, a 2 km. grid is used to provide accurate reference.

2. Petrographic descriptions of sandstones are based throughout on the Wentworth Scale of petrographic nomenclature and in the case of thin sections the average grain size in microns is often quoted. The word 'Grit' is only used as a stratigraphical term and is capitalised after the style of a proper name.

The following table gives the equivalents of the limits of the Wentworth Grades in microns, to facilitate the full understanding of petrographic descriptions:

1000-2000	very coarse sandstone
500-1000	coarse sandstone
250- 500	medium grained sandstone
125- 250	fine grained sandstone
62- 125	very fine grained sandstone
4- 65	siltstone
- 4	shale

3. Faunal Lists have been drawn up in the manner used by the Geological Survey of Great Britain. A gap is left between each class of animal. Each list is followed by a directory of localities which are located by a brief geographic description followed by a 6 figure National Grid reference.

4. Stratigraphical chapters are all planned in the same way and

incorporate a section on the history of research, synopsis of stratigraphy, details of stratigraphy, palaeontology and faunal lists (the last two are omitted in the case of unfossiliferous horizons).

5. Facies terminology - throughout the present thesis a distinction is made between strata of Yoredale and of Millstone Grit facies, since these are different both in appearance, fauna and genesis. No age connotation is implied in this usage since it is well known that some beds of Millstone Grit facies in the present area are represented on the Alston Block to the north by sediments resembling the Yoredale more closely than the Millstone Grit facies. In dealing with age relationships the zonal scheme based on goniatites is chiefly used. The Namurian stage names suggested by Hudson and Cotton (1943) and Hudson (1945) have been employed in this connection.

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FRONTISPIECE

Coverdale and Penhill from the tank road, Bellerby Moor.

The features on the skyline are from left to right: 1. Flamstone Pin 2. South Haw , 3. Great Haw , 4. Dead Man's Hill , 5. Little Whernside , 6. Great Whernside , 7. Penhill.

The range of hills on the left is the eastern fringe of Coverdale and marks the edge of the main outcrop of the rocks of Millstone Grit facies, of which Penhill is an outlier. The evenly dipping spur in the middle distance descending from Penhill , is the dip slope developed on the Richmond Chert Series on Middleham Low Moor. In front of this spur lies the valley of the River Ure.

CHAPTER 1

INTRODUCTION

Geography

The text of this Thesis is based on the survey of 110 square miles of dissected, upland country drained by feeders of the River Ure and by the River Nidd. This ground is located on the eastern slopes of the Pennine Chain, in Yorkshire, flanking the northern end of the Vale of York. The northern portion is drained by the River Cover and the Walden Beck, tributaries to the River Ure, which forms the north east margin of the area. The eastern ground drains into the River Burn, which is the chief stream of Colsterdale. The valley of the Nidd lies in the southern part of the area in the West Riding of Yorkshire whilst the remainder is in the North Riding. Most of this ground of which the geology is described in this thesis, is moorland or upland pasture, falling gradually in height towards the east, from over 2300' O.D. in Great Whernside to under 300' O.D. near Masham.

Waldendale is a fairly straight, deep valley, the line of Walden Beck being taken as the western limit of the mapped area. The spur on the east side of Waldendale, which divides it from Coverdale is high, unpopulated moorland, reaching 1904' O.D. in Brown Haw, and terminated to the north by the plateau summit of Penhill (over 1800' O.D.), which carries the site of a signal beacon at its east end. The profile of this spur between Waldendale and Coverdale is broken up by two saddles, on the north and south sides of Harland Hill which is the central eminence of the spur.

Coverdale is an unusually wide valley which is straight for most of its course. The lower dale shows a conspicuous valley-side

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bench which gives the valley an unusually great width in the vicinity of Carlton. This bench is due to the resistant Main Limestone and Richmond Chert Series which outcrop along the valley side at this level. The east side of Coverdale is dominated by a rampart of hills, which are the escarpment edge of the main outcrop of the Millstone Grit rocks on the Askrigg Block, of which this area forms a part (see Frontispiece). The moorland dip slopes east of this scarp edge form an elevated plateau tilted down to the east, in the direction of stratal dip, towards the Vale of York. The River Cover turns towards the east at Coverham (in contrast to the main body of the dale which runs south west - north east.) and runs on the south side of a long spur of Penhill, which is Middleham Moor, with the steep hills of the south side of Wensleydale stretching to the south of it, extending from near Coverham to Jervaulx.

Nidderdale is a steep sided valley, with numerous tributary streams, which rises on the east slopes of Great Whernside. Initially the Nidd flows east, but later turns to the south and is always hemmed in by the adjoining hills. Great Whernside is the highest point in the area, standing at over 2300' O.D. and commanding from its flanks extensive views over the Craven country to Pendle Hill, whilst the characteristic tops of Ingleborough and Pen-y-Ghent can also be recognised in clear weather. The valley of How Stean has also been partially surveyed, and is noteworthy for the picturesque nature of the limestone defile through which it flows near Stean hamlet. The upper waters of How Stean are outside the limits of the present area, and drain the desolate hills round Meugher.

Colsterdale differs from the other dales, because there is no valley far larger than the rest as in the other dales; instead it consists of a dendritic plexus of valleys draining east into the Ure at Masham. The principal river is the Burn which is joined by Pott Beck, a major tributary flowing in from the south, having two reservoirs on its course. The Yoredale rocks with numerous limestones are entirely absent from this dale which gives it a more sombre character, owing to the presence of dark grit scars on the valley sides. The headwaters of Colsterdale drain an extensive and desolate moorland terrain, which shelves gently to the east in the direction of the stratal dip. These moors are dominated by three singular cake-like hills, outliers on the monotonous dip slopes. They are named Great Haw, South Haw and Little Haw and command extensive views which include distant features round the heads of the Swale, Ure and Eden, the escarpment of the Hambleton hills and the distant cone of Roseberry Topping, an outlier on the northern face of the Cleveland Hills. These three hills in their turn can be recognised from the main railway in the Vale of York, standing sentinel on the skyline. The lower reaches of Colsterdale are low-lying arable and pastoral country with numerous farms; a cover of glacial drift here buries most of the features in the solid rock.

Vegetation in the area has been much altered by the hand of man, and even the moorlands are subject to periodic burnings to encourage the growth of new heather. The high plateaus and moorland dip slopes are chiefly peat-covered and clothed in moor grasses and heather. The valleys frequently contain bracken, this especially

so in the feeders of Colsterdale and in the lower eastern tributaries of Coverdale which tend to be choked in summer by its lush growth. The high moors are chiefly inhabited by sheep belonging to the valley farms, whilst there is grouse shooting on the Masham and Colsterdale moors.

The intake pastures carry rough grazing, while the lower slopes of the valleys are chiefly in cattle pastures and hay fields. The agricultural pattern, which is chiefly a dairy economy in the dales, is modified on the lower ground near Masham and on the gentler slopes of Wensleydale where cereal and cash crops are grown in addition to fodder crops, whilst store cattle are a commonplace, as opposed to the dominantly dairy herds in the dales.

The Middleham area is well known for its race horses. Numerous winners have been exercised on Middleham Moor and this has brought a certain air of prosperity to the area.

Natural woodland is a rarity and is restricted to the deeper valleys. An unusual case is that of Birk Gill, in Colsterdale, which is partially clothed in an Oak - Mountain Ash woodland, which is said to be one of the very few existing remnants of the mediaeval, forest cover of the Yorkshire Dales, unmodified by man. Small plantations belonging to the Forestry Commission are fairly numerous in the north eastern part of the area.

The area is at present almost lacking in industry and the road system is somewhat inadequate, there being a paucity of through roads between the major dales owing to the height of the interfluves between them. The only pass between major dales in the whole area which can be readily crossed by a vehicle is that connecting

Coverdale with Wharfedale, and this has only recently been made easily negotiable. Hill roads between Nidderdale and Coverdale, or Nidderdale and Colsterdale are exceedingly rough and steep for modern vehicles.

The climate of the area shows a gradual amelioration towards the Vale of York. The average annual rainfall for Great Whernside exceeds 60 inches, whilst near Masham it is under 30 inches. As the rainfall decreases eastward so also does the intensity of the cloud cover.

Relics of antiquity are fairly numerous. The oldest remains recorded are Mesolithic flints from Upper Nidderdale. Earthworks are seen at Tor Dyke, a long trench overlooking Park Gill, above Kettlewell. Further entrenchments occur on the west slopes of Penhill and above Braithwaite Hall.

Masham was probably a Roman station and remains have been discovered of a camp in Swinton Park, whilst it is known that the Romans mined lead in Nidderdale, since a stamped ingot of the metal was found near Pateley Bridge, south of the present area.

The ruined abbey of Jervaulx, a house founded in 1156 A.D. by the Cistercians and Coverham, a Praemontratensian priory, lie in the present area as does also Middleham Castle, associated with Warwick, the "Kingmaker". A graveyard ascribed to the Knights Templars stands on the lower, northern slopes of Penhill.

The Middle Ages saw the rise of a coal industry in Colsterdale, records of which date back to 1334 A.D. This was originally controlled by the monks of Jervaulx, but after the dissolution mining was carried on under the direction of the Lords of Swinton.

Swinton Castle, the seat of the Danby family, is the chief residence of note and several grottoes and mock ruins in Colsterdale were erected by their command. Of these the most interesting is the Druid's Temple, an authentic-looking sham dating from the last century, constructed of massive blocks of Brimham Grit.

The building of four reservoirs in the area in the early years of the Twentieth Century inundated several farms. These make important contributions to the supplies of the three towns (Leeds, Harrogate, and Bradford) which they serve.

Geology

The present ground is situated in an area of Carboniferous sediments belonging to the P, E, H and R_1 zones of this system. These rocks readily fall into two types, the Yoredale facies sediments and the Millstone Grit facies sediments.

The sediments of Yoredale facies are characterised by repetitions of limestone, shale and sandstone, in this ascending sequence, though this concept is a generalised one and many of these repetitions, or cyclothems, are imperfect. The sediments, which belong to the P and lower E_1 zones of the Carboniferous, show considerable lateral variations in facies and thickness which are detailed in subsequent chapters. Altogether eight cyclothems are described. Many of the beds of the Yoredale facies, particularly the limestones and certain of the shales, carry a fauna of marine invertebrates in which brachiopods, corals and to a lesser extent pelecypods are the dominant forms.

The sediments of Millstone Grit facies consist of repetitions

of sandstones and shales with occasional marine horizons, but with a nearly total absence of the limestones which characterise the strata of Yoredale facies. Whereas the arenaceous horizons of the Yoredale facies are nearly invariably fine grained, medium grained and coarse grained sandstones commonly occur in beds of the Millstone Grit facies. At the base of the lowest beds of the Millstone Grit facies, the Grassington Grit Group, there is an extensive unconformity which transgresses across the upper four of the Yoredale cyclothems which underlie this grit, cutting down to successively lower horizons in a southerly direction. The faunal zones falling into the Millstone Grit facies of the present area are the E, H and R_1 zones, (a portion of E_1 is in beds of the Yoredale facies, the upper portion of which is therefore of Upper Carboniferous age).

The fauna of the Millstone Grit facies sediments largely contrasts with the coral brachipod faunal assemblage of the Yoredale facies, in that goniatites and thin shelled pelecypods are usual. Towards the top of these sediments in the present area there are shelly sandstones developed, however, which show a brachiopod-pelecypod-gastropod faunal assemblage which is not typical of beds of Millstone Grit facies when a country-wide view of the faunas is taken, for they are almost invariably of the goniatite-pelecypod phase. In addition certain Yoredale faunal elements will be pointed out in subsequent pages which occur in proximity to strata yielding goniatites in the E zone; this is a faunal aspect which has not hitherto been much emphasised.

Of the surveyed area rather more than one-third exposes beds of Yoredale facies, which occur chiefly in the valleys of the western half of the area. The rocks of the remainder of the area are of Millstone Grit facies, which form hills in the west and both low and high ground in the east. The northern boundary of the area was taken at the River Ure whilst the base of the Simonstone Limestone was used in the west. The southern limit was largely fixed by arrangement with A.T. Thompson, a co-worker, surveying ground to the south of the present area. On the south-east side the base of the outcrop of the Second Brimham Grit on the edges of Colsterdale was taken as the limit.

In its regional setting, the present area is situated in the S.E. of the Askrigg Block, as defined by Hudson (1938) which is an area of Carboniferous sediments showing relatively simple tectonic structures. The bulk of the area of the Block is in sediments of the Yoredale facies, with outliers of the Millstone Grit facies sediments perched on top of the lower beds and forming conspicuous hills. In the south east corner of the Block, however, there is a continuous cover of Upper Carboniferous sediments of the Millstone Grit facies. It is the north part of this cover of Upper Carboniferous rocks which forms the surface geology of the east part of the present area. The edge of the main outcrop of beds of the Millstone Grit facies forms the line of hills flanking Coverdale on its east side. Penhill and Brown Haw are outliers of beds of the Millstone Grit facies lying west of the main outcrop on the west side of Coverdale, and constituting

two of the several outliers on these beds which form many of the summits of the high fells of the Askrigg Block.

Nidderdale is excavated in rocks of the Millstone Grit facies of the main outcrop, but denudation has been carried far enough to reveal three inliers of rocks of Yoredale facies, exposed in the bottom of the dale. The entire Colsterdale drainage is in Upper Carboniferous rocks of the Millstone Grit facies, as a consequence of the easterly dip of the rocks which carries Lower Carboniferous strata deep down under the Vale of York.

The rocks of the entire area dip in an easterly direction towards the Vale of York at an angle of about 2 degrees. As in most of the Askrigg Block, the fault pattern is a simple one and no continuous mesh of faults intersects the area, though local concentrations of fractures do occur, notably in the area round Lofthouse, in Nidderdale.

The effects of the Quarternary glaciation are most marked on the lower ground marginal to the Vale of York, but there are boulder clay deposits in the larger valleys and also a system of overflows marginal to the former Ure and Vale of York ice sheets, which occupied the lower ground where the drift cover is often thick and obscures much of the solid geology.

Geological Succession

Superficial deposits	Thickness in feet.
Hill peat	up to 10

River alluvium	-	
Fluvioglacial sand and gravel	up to at least 40	
Layered lake muds	up to 25	
Glacial moraines and boulder clay	up to at least 50	
Solid formations	Thickness in feet.	
Second Brimham Grit	22- over 50	KINDERSCOUTIAN STAGE
Shale	72-108	
First Brimham Grit	0-35	Lower Reticuloceras Zone (R_1)
Capelshaw Shales	up to 52	
Libishaw Sandstone	34-38	
Libishaw Shale	22-45	
Agill Sandstone	25-30	
Shales	0-13	
Cayton Gill Shell Bed	10-13	
Ganister Beds (with degenerate Upper Follifoot Grit occurring locally)		
<u>Homoceras beyrichianum</u>	26-50	SABDENIAN STAGE Homoceras Zone (H)
Lower Follifoot Grit	22-124	
Nar Hill Beds	120-195	
Colsterdale Marine Series		
<u>Cravenoceratoides nitidus</u>	12-30	ARNSBERGIAN STAGE
Upper Red Scar Grit	7-44	Upper Eumorphoceras Zone (E_2)
Measures with Woogill Coal	0-17	
Lower Red Scar Grit	12-60	
Nidderdale Shales, with sandstone lenses	220-270	
Cockhill Marine Band <u>Cravenoceras cowlingense</u>	5-6	

Grassington Grit Group	125-220	
Unconformity.		
Crow Limestone	20	PENDLEIAN STAGE
Sandstone	5-18	
Shale	15-22	Lower Eumorphoceras Zone (E_1)
Richmond Chert Series and Little Limestone	Maximum of 130	
Main Limestone	5-84	
Sandstone	0-22	
Shale	11-90	
Underset Limestone (cherty beds developed locally at top and base).	9-47	
Sandstone	11-45	
Shales	8-22	
Three Yard Limestone (locally includes a sandstone)	8-57	Upper Posidonia Zone (P_2)
Sandstone	0-55	
Shale	0-46	
Five Yard Limestone	0-14	
Sandstone	0-15	
Shale	0-9	
Upper Middle Limestone	10-132	
Gigantoproductus Beds	12-50	
Lower Middle Limestone	18-50	
Sandstone	0-18	
Shales	0-35	
Shales with limestones	6"-42	
Simonstone Limestone	26-41	

PLATE 2

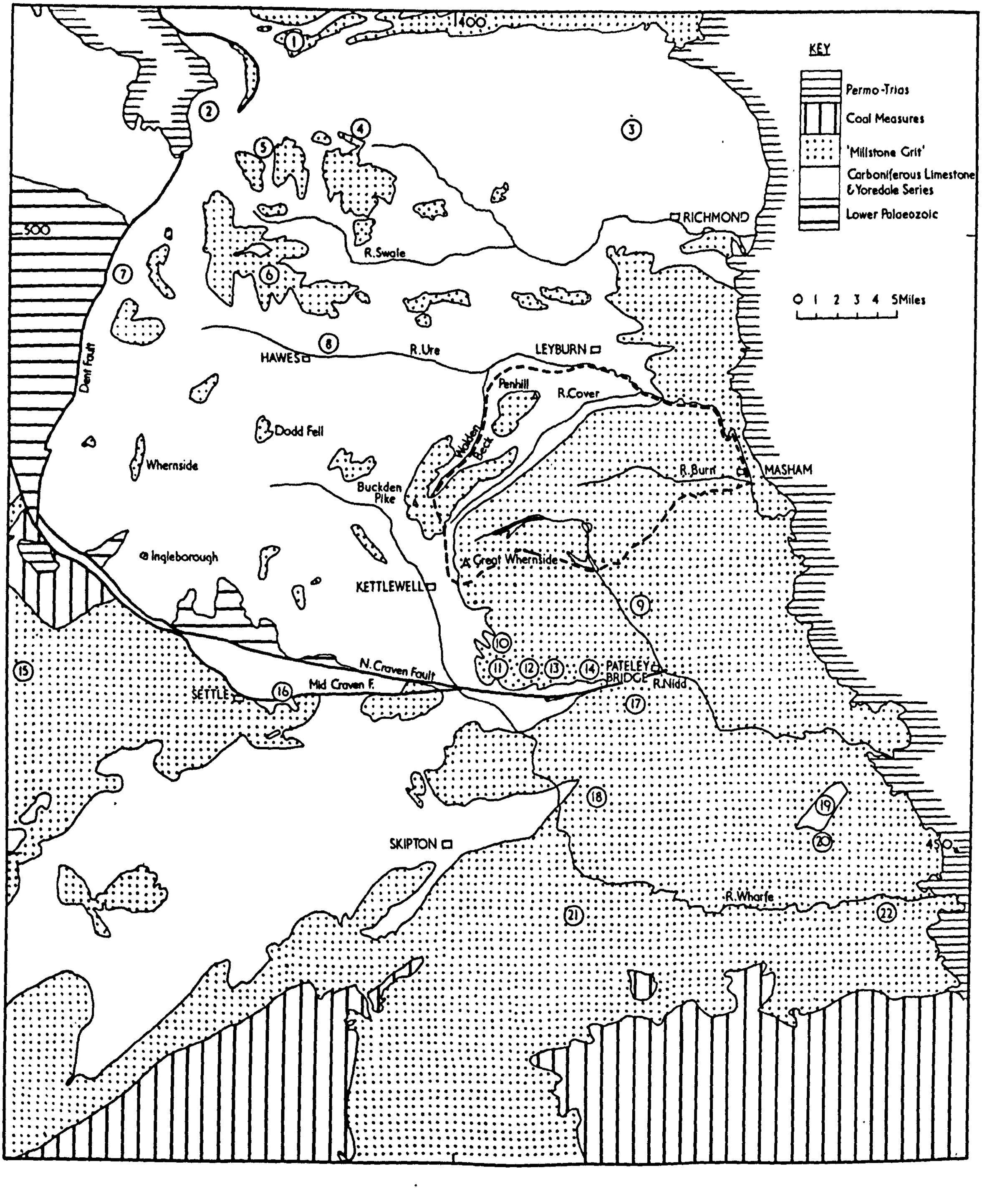
Map showing the location of the present area.

Broken line outlines area. Numbers indicate adjoining areas.

1. Reading, 1954.
2. Turner, 1927.
3. Wells, 1955a.
4. Hudson, 1941.
5. Rowell, 1953.
6. Scanlon, 1955.
7. Miller and Turner, 1931.
8. Moore, 1955.
9. Thompson, 1957 (in preparation).
10. Joysey, 1955.
11. Black, 1950.
12. Black and Bond, 1952.
13. Anderson, 1928.
14. Dunham and Stubblefield, 1945.
15. Moseley, 1954.
16. Hudson, 1930.
17. Hudson, 1939.
18. Jones, 1943.
19. Hudson, 1938.
20. Hudson, 1934.
21. Stephens et al., 1953.
22. Edwards et al., 1950.

Geological boundaries taken from the quarter inch maps of the Geological Survey of Great Britain.

The base of the 'Millstone Grit' in the north of the map is drawn at a somewhat lower level in the sequence than in the south.


KEY
Permo-Trias
Coal Measures
'Millstone Grit'
Carboniferous Limestone & Yoredale Series
Lower Palaeozoic
0 1 2 3 4 5Miles
1400
500
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
RICHMOND
R.Swale
HAWES
R.Ure
LEYBURN
Penhill
R.Cover
Walden Beck
Dodd Fell
Whernside
Buckden Pike
R.Burn
MASHAM
Great Whernside
Ingleborough
KETTLEWELL
Dent Fault
N.Craven Fault
Mid Craven F.
SETTLE
PATELEY BRIDGE
R.Nidd
SKIPTON
R.Wharfe
450

History of research

The history of research within the present ground is outlined in the following pages and several papers on the stratigraphy of nearby areas are commented upon. Owing to the bulk of the general literature dealing with topics such as structure, palaeontology and glaciology it is felt that, to avoid repetition, these topics are best considered separately in their respective chapters, at the beginning of which a survey of literature is given.

Research in the present area - Work commenced in the early nineteenth century by Phillips led to the publication of a volume on the geology of the Mountain Limestone district (1836) which ranks among the geological classics. A portion of this work deals with the present area. Phillips named the Yoredale limestones of Penhill according to the scheme which he had devised for the rocks of Wensleydale (Yoredale) after which he named these beds. He gave names to the limestones as follows: Simonside (now Simonstone following Dakyns et al., 1891), Middle, Underset, Main and Little. Phillips recognised the Little Limestone on Penhill and considered it to overlie the chert on top of the Main Limestone. He identified the Main Limestone at the head of Coverdale and noted the fact that it was locally cut out in this dale and finally died out southwards on the W. flank of Great Whernside, together with the Underset Limestone. The southerly thinning of the shales and sandstones of the Yoredale cyclothems in Coverdale was noted by Phillips and he postulated that this meant a deeper sea in the S.E. with a shoreline to the N.W. where the sediments were thickest.

The Millstone Grit facies sediments were briefly described from Upper Nidderdale by Phillips and though the names he gave have been largely superseded, the broad divisions of strata into the chief grit and shale members still stand in general. Phillips also records the first fossils from the area - the type specimen of Palaeosmilia regia from Lofthouse and five fossils from the Cayton Gill Shell Bed of Colsterdale.

The next important work was the primary survey of the Geological Survey, the only geological mapping known to have been carried out here previously, with the exception of a small area at Coverhead by Chubb and Hudson (1925). The results were incorporated in 1 inch Sheet 97 S.E. (New Ser. 51) which was published in 1879. The succession used for this survey was based on Phillips' stratigraphical terms for beds of Yoredale lithology, with the addition of the term 'Third Set' for the Five Yard Limestone. The 'Grits of Grassington Moor' (the Grassington Grit Group of the present work) and the Red Scar Grit were grouped with the Nidderdale Shales and correlated with the Kinderscout Grit.

Whilst no memoir was published in explanation of the Geological Survey map covering the present area, Dakyns, who was the senior geologist, published two papers (1891, 1892) dealing with the ground. Though several of the conclusions repeat the findings of Phillips (1836), some new discoveries were made during the survey. The southwards diminution of thickness of the shales and sandstones of the Yoredale cyclothems was emphasised, though little detail was given of the thinning, and the unusual thickness of the Middle

Limestone on the N.W. flank of Penhill was commented upon. The base of the Millstone Grits was taken at the top of the Richmond Chert Series of the present work. Whilst Dakyns (1892) is not explicit in his definition of the chert above the Main Limestone, it appears that he thought that at least part of it belonged to the Little Limestone.

The Grassington Grit was shown to deteriorate to the north in the present area and a part of these degenerate beds was tentatively correlated with the Ten Fathom Grit of the area to the north of Wensleydale. Dakyns (1892) gave the first record of the Tesselated Limestone (the Colsterdale Limestone of the present work) in the area and the value of the Cayton Gill Shell Bed for mapping and correlation purposes was noted by him.

The next worker on the area was Bisat (1914) who wrote a paper on the ground between Masham and Great Whernside. He was attracted to this ground at the time that the Leeds Corporation dam was being constructed at Leighton, in Colsterdale and used the data from the dam trenches and outcrops to write a brief geological account of the area. The chief contribution of Bisat was his description of the marine horizons, the Colsterdale Marine Series and the two shell beds of R_1 age, for which horizons extensive faunas were recorded. The faunal lists which accompany the text were determined by Hind and are the most detailed records for beds of E_2 and R_1 age from the area up to the date of the present work.

Tonks (1925) furnished a detailed contribution on the

inliers of rocks of Yoredale facies in Nidderdale, whose exact horizon had not previously been determined. The faunal lists, determined by Hudson, are long and indicate painstaking collecting. Tonks concluded that the limestones of the Nidderdale inliers were the Middle Limestone overlain by the Five Yard limestone, here split up into two leaves. The Middle Limestone was correlated with that found elsewhere on the occurrence of Productus (Gigantoproductus) giganteus (Martin) and other fossils. A thin limestone above the main body of the Middle Limestone was included with this horizon as part of the Middle Limestone on the basis of the occurrence of a zaphrentid fauna in the shales which overlie the thin limestone.

The beds of Millstone Grit facies were apparently not examined in detail by Tonks, but he gave the first record of Cravenoceratoides nitidus from the Colsterdale Marine Band and in addition provided the first record of what later became known as the Cockhill Marine Band within the area, though no goniatites were recorded by him and the correlation put forward was only tentative.

Much of the work of Chubb and Hudson (1925) was outside the present area, but their recognition of an unconformity at the base of the Grassington Grit Group is important, though this had been realised previously by Dakyns (fide Chubb and Hudson) who never published his views on this problem. The limestone forming the col at Coverhead was named the Underset Limestone during this work, but this correlation was later

called into question by Hudson (in Hudson et al., 1933).

The records of Orionastraea from the present area by Hudson (1929a) constitute a full record of the available occurrences of this form.

Apart from an account of the two day visit of the Geologists' Association to the area (Hudson et al., 1938) which incorporated several of the findings of Tonks, nothing further has been written on the present ground apart from the record of Orbitremites, a blastoid, from the railway cutting N.N.W. of Limley in Nidderdale by Joysey (1955) and the record of two sections in the Richmond Chert Series by Wells (1955b) at Thupton Gill and Howden Gill.

Research in adjacent areas - The volume of work which runs collateral to the present topic in its various aspects is very large, and since each chapter of this work deals separately with the historic aspects of the matter in consideration, it is not proposed to give a detailed account of these works here.

In dealing with beds of Yoredale facies, the work of Turner (1927) Miller and Turner (1931) and of Moore (1955) has been useful for comparative purposes, whilst further afield the writings of Dunham (1948), Short (1954) and Johnson (1953) afford further comparisons with the present work.

In work on beds of Millstone Grit facies, reference is made to a large number of accounts of areas which are chiefly south of the Rigid Block, and to other papers which deal with the zonal problems associated with the subdivision of the Namurian

sequence. The chief works cited in this connection are Schmidt (1933), Hudson (1938), Hudson (1939), Hudson and Cotton (1939), Hudson (1941), Stephens et al., (1942), Jones (1943), Bisat and Hudson (1943), Hudson and Cotton (1943), Dunham and Stubblefield (1945), Hudson (1944), Edwards et al., (1950), Hodson (1952), Moseley (1952) and Stephens et al., (1953).

The most modern phase in the history of research is the accumulation of results in the Ph.D. thesis which has gained much impetus since the late war. In view of the fact that the relevant theses read in connection with the present work number eight, it is thought profitable to consider these specialised works together. These eight workers were all engaged on stratigraphic studies, varying quite widely in the type of treatment adopted. This variation in treatment and the mass of new ideas which are incorporated in these works has provided a considerable stimulus to the present work.

Johnson (1953) was engaged in a study primarily of the biological composition of the limestones of a tract of Yoredale facies sediments adjacent to the Stublick faults in Northumberland. Several of the suggestions of this author are considered in more detail in the palaeontological section of this present work (Chapter 22), in view of the fact that Johnson gives the names of a variety of fossils with restricted ranges which might be used for zoning the Yoredale facies strata.

Walker (1953) carried out a sedimentological study of beds of R_1 age in the country around mid-Airedale in Yorkshire. He comes to far reaching conclusions in suggesting modern analogues

in terms of depositional environment for the chief types of sediment in rocks of Millstone Grit facies. Walker's suggestions are considered in some detail in Chapter 23, in view of the fact that a large area of Millstone Grit facies sediments were mapped during the present work and several generalisations can be made on this basis.

Rowell (1953) and Scanlon (1955) were engaged on the resurvey of outliers of Namurian beds at the heads of the Ure and the Swale. The work of Scanlon is especially interesting since he provides new evidence for the age of the Shunner Fell Beds, by finding Tylonautilus nodiferus Armstrong, an E Zone guide fossil, and he also elucidates the overstep of the two Stonesdale Limestones and the Crow Limestone by the Mirk Fell Ganister-Lower Howgate Edge Grit Horizon which is a continuation of the intra E_1 unconformity of the present area. The findings of Scanlon are largely presented in a type of diagram which was also used by Moore (1955). These diagrams are maps with a large amount of semi-diagrammatic information superimposed on them, relating to thickness and facies changes. This form of rationalising stratigraphic, and occasionally faunal, information has hitherto been used chiefly in the United States, and is also used, with modifications, by the present author for selected horizons.

Short (1954) described the geology of a portion of the Pennine escarpment and at the same time made a detailed study of the foraminifera of limestones of Yoredale facies. The photographs of microfossils in this work have been valuable in identifying some of the forms found during the present study. Detailed comment on

his work on foraminifera will be found in Chapter 22.

Moore (1955), in a thesis collating a monumental body of facts, presents a large volume of data on the sedimentology of beds of Yoredale facies up to the horizon of the top of the Main Limestone. This information has been rationalised in a large number of lithotope and isopachyte diagrams, which show that there is an overall southerly thinning of the sediments of several of the cyclothems, with the exception of the limestones which are more constant in thickness. The data given by Moore has proved invaluable for the interpretation of beds at the level of the Three Yard and Five Yard limestones, which have hitherto been miscorrelated, both in upper Coverdale and Nidderdale. The faunal lists given by Moore are very long, and they make a useful comparison with the lists from the present area from rocks of similar age. In addition to the descriptive material, Moore puts forwards a new theory of sedimentation of cyclothemic beds of the Yoredale type which is commented upon in Chapter 23.

Wells (1955) describes the succession in the Middleton Tyas-Sleigtholme anticline, lying 15 miles north of the present area, which shows beds of Yoredale facies of similar age to those mapped during this work. He demonstrates a southwards overstep of beds of the Main cyclothem by the Little Limestone which is crucial to the interpretation of beds above the Main Limestone in the present area, whilst his views on the origin of chert (1955b) are an admirable summary of the evidence for the primary origin of the bulk of the Yoredale cherts. Detailed comment on the views of Wells is made in Chapter 7.

Reading (1954) provides valuable evidence for the northwards correlation of the beds dealt with during the present work, with successions north of the Stainmore syncline, where he worked. His views are further discussed when dealing with correlation problems. (Chapter 18).

CHAPTER 2

THE SIMONSTONE CYCLOTHEM

The chief limestone of the Simonstone cyclothem was first given a name by Phillips (1836) who named it the Simonside Limestone. This was later modified to 'Simonstone' Limestone during the mapping of 1" sheet 40 by the Geological Survey (see also Dakyns et al., 1891) on the grounds that Simonside was a non-existent place, and Phillips was construed to have meant 'Simonstone'.

The Simonstone cyclothem of the present area has been little mentioned in the literature. Dakyns (1891) appreciated that the shales and sandstones of the Yoredale cyclothems tended to thin in a southerly direction towards Grassington, and this comment no doubt included these beds in the Simonstone cyclothem which in fact show a drastic thinning in this direction.

Tonks (1925), in working in Nidderdale, referred the limestone in the axis of the Limley anticline, where this structure meets the R.Nidd, to the Simonstone Limestone. This limestone is here overlain by only 6" of shale which appear to be the sole representatives of the shales and sandstones of the cyclothem. The present author supports this correlation, since the presence of Orionastraea in the base of the Middle Limestone here seems to be almost conclusive, and additional evidence to show southerly thinning at this horizon is given in this chapter. The present author is however unable to agree with Tonks' statement that the beds of the Simonstone cyclothem overlying the Simonstone Limestone at Ridge Scar, Woodale are only 12' thick - the present exposure shows 22'

of beds in a cliff at this level and the total thickness cannot be much less than 30'. This error does not in any way invalidate Tonks' statement however that the beds above the Simonstone Limestone are thinning rapidly to the south.

Hudson (1929a) gives details of the occurrence of Orionastraea in the top of the Simonstone Limestone. The uppermost beds of this horizon in the present area are rarely exposed, and have only once yielded this fossil, and this as a fragment whose species is not determinable.

The most useful and detailed records are undoubtedly those of Moore (1955) who worked on ground in upper Wensleydale, to the N.W. of the present area. He confirms the discovery of Orionastraea and shows that the Simonstone Limestone varies little in thickness; 22'6"-35'6" is the total variation and this appears to be matched by broadly similar changes in thickness within the present area. The shales and sandstones of the Simonstone cyclothem are demonstrated by Moore to thin tho the S.E. The results of the present work are in a good measure complimentary to those of that author. Given an adjustment of certain of his isopachs prolonged beyond their control points, a close similarity is apparent in the systematic thinning to the S. and S.E. of these beds to a minimum in upper Nidderdale. Moore records 3 limestones within the shales of the cyclothem, the lowest of which carries a coral fauna. Whilst exposures are not good in the present area it is confirmed that the lower limestone carries a coral fauna in the section at Ashes Farm, Waldendale, whilst a higher limestone which

is seen appears to be unfossiliferous. The uppermost of the limestones investigated by Moore is not definitely represented in the present area, but since he states that it locally joins up with the Middle Limestone, it seems possible that a local, thin limestone developed below the sandstone of the Simonstone cyclothem in the extreme north of the area, may be a correlate of this bed.

Stratigraphy

The Simonstone cyclothem is exposed in Waldendale, Coverdale, west of Great Whernside and probably in the core of the Limley anticline in Nidderdale. It consists of a variable thickness of sediments of Yoredale facies which occur in characteristic cyclothemic order, viz. limestone, shale, sandstone. A thinning of beds takes place from north to south (with a distinct easterly component) and affects the non-calcareous measures of the cyclothem, the shales and sandstones, whilst the Simonstone Limestone varies only locally in thickness. The maximum change of thickness in the shales and sandstones of the cyclothems in the measured sections is from 92' to 6". The Simonstone Limestone varies from 26' to over 40' in thickness and is a grey or blue detrital limestone. At one locality the diagnostic coral Orionastraea was found in the top of the limestone, but generally this horizon is not exposed in the present area. The base of the limestone was not seen in Coverdale and Nidderdale, where this bed forms inliers. The shales of the Simonstone cyclothem are never fully exposed, but in the lower part are calcareous shales with a normal shale fauna, which carry thin limestones, some of which carry a coral-

brachiopod fauna. These shales with thin limestones vary from 42' to 6" in thickness.

The upper part of the shales of the cyclothem are nearly always unfossiliferous and brittle, with bands of chalybite nodules or layers of micro-currentbedded siltstone. These shales vary from 16'-35' in thickness. The sandstone member of the cyclothem varies from 18' to nil in thickness and in the extreme north of the area carries at its base a thin limestone. Towards the south and east, in upper Coverdale, the sandstone thins and is associated with fireclays.

In the process of thinning of the shales and sandstones of the cyclothem to the south of the area, the beds which thin most are the sandstones and fossiliferous shales with limestones, whilst the unfossiliferous shales in upper Coverdale are not much thinner than in areas further north. In the inlier in Nidderdale where the measures above the Simonstone Limestone appear to be only 6" thick, the only beds which appear to be present are the fossiliferous shales, though it is not possible to verify this assumption.

The Simonstone cyclothem is usually ill-exposed, but the Simonstone Limestone makes a mappable feature on North Penhill and at Scale Park. The limestone within the shales of this cyclothem makes a local feature near Layrus Wood on the N.W. side of Penhill. Control of mapping was chiefly by means of features in the Middle Limestone which overlies the sediments of this cyclothem, whilst occasional stream exposures occur in the shales of the cyclothem, especially in the upper beds, in Waldendale.

Details

Simonstone Limestone - The Simonstone Limestone is very rarely fully exposed in the present area and for the purpose of this investigation the lowest horizon which was examined in detail was the top of this limestone. The main body of the limestone was not fully examined for its fauna or detailed lithology, though its thickness was measured at a few points.

Waldendale - A limestone which is probably the Simonstone Limestone is exposed in the bed of Walden Beck, upstream from Kentuckey House, (982802) where a maximum of 2' of grey limestone is seen. The absence of a fauna makes it unlikely that it belongs to the lowest limestone in the shales of the cyclothem. 300 yd. further downstream a 6" shale parting occurs in limestone which is referred to the Simonstone Limestone for lack of contrary evidence.

The limestone is exposed 100 yd. S. of Routon Gill Farm where the base is seen resting on sandstone. The upper beds are seen, but overlie a gap in the section, and include a layer 2'6" in thickness with algal nodules - a development not seen elsewhere in the present area, but with parallels in the ground to the N.W. (Moore, 1955). The section below Ashes Farm is the most complete one in the present area (Plate 3). The Simonstone Limestone is here a blue, detrital limestone 34' thick with traces of Orionastraea sp. and small haploid corals in the top 6" of the rock.

Whilst the Simonstone Limestone is unexposed on the E. side of lower Waldendale, apart from small incomplete exposures, it forms

a persistent feature on the N.W. flanks of Penhill which dies out to the E. of West Witton. The Simonstone Limestone is never fully exposed along this feature, though it frequently forms scars in blue or dark grey limestone. Its thickness was estimated at 26' above Swinithwaite and over 40' at West Witton (059884) where it is fairly well exposed in a cliff-girt gill. (see Plate 4 for thickness data). The topmost beds of the limestone are never exposed here and it seems that the horizon with Orionastraea, if present is not available in exposures for examination. A roadside quarry near Swinithwaite (048889) yielded Saccaminopsis fusilinaformis from the upper part of the limestone.

Since the feature on the Simonstone Limestone dies out to the E. of West Witton it is less easy to identify this horizon to the E. An exposure at Mount Park (081883) shows grey limestone in situ and it is assumed that this is the Simonstone Limestone. This occurrence lends some support for an easterly component in the thinning of the beds above the Simonstone Limestone on the north face of Penhill, for a rough estimate, based on exposures of the Simonstone and Middle Limestones can here be made.

An exposure which falls inside the present mapping area in an old quarry N.E. of Gale Bank (098888) is possibly in the basal part of the Hardrow Limestone. It is a blue, foetid limestone with a prolific fauna of brachiopods, compound corals and fenestellids in the lowest 6", which here overlies a sandstone. The full thickness of this limestone is about 25'. It seems unlikely from the mapping evidence that this horizon is the Simonstone Limestone, though this remains a possibility.

Coverdale - The full thickness of the limestone is not seen in this dale since it only occurs in valley inliers at two points. In the inlier below Tunstall Scar over 15' of limestone are seen. The limestone is here grey and crinoidal and approaches a biostromal facies in some of its beds, owing to the size of the articulated stems in some of the layers. Another small inlier occurs in the Cover near Ridge Scar, Woodale (024793) where 3' of blue limestone are exposed. These probably belong to the uppermost beds of the Simonstone Limestone which does not yield Orionastraea however.

The section in Park Gill Beck (986751) shows 41' of limestone; the base is clearly seen, but the top is not exposed (Plate 3). No sign was seen of Orionastraea either here or in the inlier in the core of the Limley anticline in Nidderdale (099764), where 1' of grey limestone with a few quartz grains are exposed in the bed of the R.Nidd. This limestone is very probably the Simonstone Limestone, since Orionastraea garwoodi var. pristina Hudson has been found near the base of the limestone which overlies the supposed Simonstone Limestone (this fossil is characteristic of the lowest part of the Middle Limestone). The sinking of the R.Nidd into a subterranean channel at Manchester Holes, upstream from this point suggests that a considerable body of limestone here underlies the bed of the river and makes the presence of any large body of shales below the river-bed here at small depth extremely unlikely. The presence of Saccaminopsis fusilinaformis in the top of the Simonstone Limestone here is slight additional evidence, since this fossil has been found

elsewhere in the present area at this level and also in the Westmoreland Pennines where it is characteristic of this horizon (Turner 1927).

Shales with limestones - exposures are described in sequence from Waldendale, Coverdale and Park Gill Beck.

Waldendale - No exposures are seen in upper Waldendale, and the gill at Ashes Farm shows the most complete section in the present area (008822). The lowest beds are blue-grey shales with an abundant normal shale fauna in a moderate state of preservation as calcite films. These are overlain by limestones with shale partings. The thickest limestone stratum, 3'6" thick, is a blue, fossiliferous calcite mudstone with a Lithostrotion-clisiophyllid-latissimoid productid faunal assemblage. Unfossiliferous grey shales are exposed higher up the section (see Plate 3) and include thin beds of blue calcite mudstone at the top of the series.

North Penhill - In the vicinity of Layrus Wood, though the shales with limestones are badly exposed, a limestone is mapped within the series which appears to be at a level equivalent to the higher limestones seen at Ashes Farm. The most complete section here visible is below West Layrus Wood (032884):

2'6"-3'	compact, blue limestone
1'6"	silty calcareous shale with irregular limestone layers carrying a Lithostrotion, productid-fenestellid fauna
4"	impure, blue limestone
5'	gap
6"	soft, brown sandstone

The limestone at the top of the above measured section can be mapped for over a mile along the outcrop on the line of a feature with occasional exposures which runs eastward from the exposure detailed above. This limestone, which is from 3' to 3'6" in thickness

is a blue calcite mudstone. It is never notably fossiliferous.

Coverdale - Several exposures occur in this group in the River Cover which is excavated in these beds for several miles. These exposures, though incomplete, yield extensive faunas. On the left bank of the River Cover near Bradley (039803) the following beds are seen:

1'	blue limestone
4'	shale
1'6"	limestone with thin shale parting
2'	shale

Upstream at 037801 a more complete section occurs:

-	shale
-	blue limestone nodules
3'6"	shale
1'6"	limestone with shale parting. Productus (Gigantoproductus) latissimus J. Sowerby group occurs in the limestone.
6"	fossiliferous shale
3'	shale
3'	fossiliferous dark blue-grey shale with a normal shale fauna preserved in calcite.

Below the scars on the River Cover near West Bottom Lathe, exposures of fossiliferous shale with thin limestones are seen in the bed of the river. Two limestones occur, separated by 2'-3'6" of rather silty, dark shale; neither limestone appears to exceed 1' in thickness. The limestones are blue calcite mudstones carrying a large quantity of organic material which appears to approximate to a life assemblage, since specimens of Productus (Echinoconchus) punctatus (Martin) with spines still attached occur, whilst crinoid ossicles are partly articulated. The shales are dark grey and contain calcitised calices of haploid corals which are almost invariably crushed. They have apparently been transported into place and always lie along the bedding and have an abraded

epitheca. All the recognisable forms are Aulophyllum fungites Fleming.

Whilst the section in Park Gill Beck, above Kettlewell is unexposed at this level, 6" of shale below the Middle Limestone in the core of the Limley Anticline in Nidderdale, Though inacessible, probably belong to this group. This 6" shale parting between the Middle and Simonstone Limestones appears to be the only representative of the shales and sandstone of the Simonstone cyclothem here.

Unfossiliferous Shales

Waldendale - At several points in upper Waldendale unfossiliferous shales are exposed in the courses of tributaries of Walden Beck. The most complete section, at 980798, shows 19½' grey-blue fairly fissile shale with numerous bands and lenses of grey ganisteroid siltstone up to 3" in thickness. Annelid castings occur on the external surfaces of these bands. Some of the siltstone bands are chalybite rich, being heavy in weight and of a bluish, rather than a grey colour. The siltstone layers increase in frequency upwards, towards the sandstone which overlies these shales. At several other points in upper Waldendale unfossiliferous shales occur (up to 19' are seen) with sandstone ribs and chalybite nodules (Plate 4 gives details of the thickness and lithological variations in these beds).

Coverdale - In upper Coverdale in the vicinity of Bradley and Hunter's Hall there are nearly complete exposures in this group. The section on the left bank of the River Cover W. of Arkleside (042805) shows 16' shales with thin beds of micro-current bedded

siltstone. In all respects this section is like those described from Waldendale. At Ridge Scar (022791) (Plate 3) the top 22' of these shales are excellently exposed and include some ribs of current bedded siltstone and chalybitic siltstone. In the left bank of the Cover above Cover Bridge (012786) 18' of dark blue shales with chalybite nodules are exposed. These shales are fossiliferous in the lower 5', but are nevertheless brittle. The principal fossil is Chonetes hardrensis (Phillips) group preserved in calcite with an accompanying fauna of gastropods and pelecypods rich in species, but poor in individuals. The presence of a specimen of Productus (Eomarginifera) sp. with its spines intact and up to 6 cm. in length indicates that the fauna is at least in part a life assemblage.

Near the bottom of Slape Gill (001779) 25' of shales are incompletely exposed, with bands of micro-current bedded siltstone in the upper beds (Plate 3). In Park Gill Beck, overlooking Kettlewell, 1' of shale was seen of the unfossiliferous variety which probably belongs to this group, but the section is here not fully exposed. It is probable that these beds are absent in Nidderdale where the total shale of the cyclothem is only 6" thick, and this probably belongs to the fossiliferous shale division.

Sandstone of Simonstone Cyclothem - The outcrops at this horizon are considered from north to south.

Penhill - On the north side of Penhill, several sections in the vicinity of West Witton show the sandstone to be thin. A limestone occurs at this horizon in addition as at Capplebank Farm (064880) where it is seen under the sandstone. The section here shows:

-	Limestone (Middle Limestone)
4'	sandstone
2'6"	limestone
1'	shale seen

To the west the sandstone appears to thicken and was estimated at 18' on features below Langthwaite Wood. The lowest 7' was actually seen here and is a very thinly bedded, very fine grained sandstone with mica and carbonaceous flecks, in its lower part, but the bedding thickens upwards. The full thickness of the sandstone is never seen on the N.W. and W. sides of Penhill, but it appears to be in the vicinity of 20' thick. The upper beds are seen below the Middle Limestone - of Morpeth Scar (029876) where the section shows:

-	Middle Limestone
1'	sandstone
5'	calcareous, fine grained sandstone, weathering with a slight honeycombed structure and containing vertical tubes in the top 2' which may be annelid borings having affinity with Arenicolites sp.

In the crags above Long Ing Wood (022861) the section shows:

-	Middle Limestone
6"	black fossiliferous shale
2'	gap
4'	hard, blocky limonite spotted, cream coloured, fine grained quartz sandstone (base not seen)

Upper Waldendale - The Middle Limestone is seen to rest on sandstone at Scar Folds, but the full thickness of the sandstone is only seen in the stream below Ashes Far and at exposures up-dale from this point. All these exposures show little variation (Plate 4). The variation in thickness is from 18' to 12'6", with the thinning of the sandstone taking place in the direction of thinning of the measures of the cyclothem which overlie the Simonstone

Limestone. The sandstone is a touch, grey well bedded fine grained quartz sandstone, lithologically similar to the ribs of sandstone which occur in the top of the underlying shales. As in the case of these thin sandstones, the main body of the sandstone shows small scale current bedding.

Lower Coverdale - the Full thickness of the sandstone is not exposed in lower Coverdale, but 7' of sandstone are seen at two points south of Carlton (see Plate 4). The sandstone has been worked for roofing tiles at Tunstall Scar (061831), the most southerly of these two places and here there are seen:

3' massive, spotted fine grained quartz sandstone
4' flaggy, fine grained quartz sandstone, splitting up into slabs suitable for roofing stone

Upper Coverdale - The sandstone is seen to be consistently very thin between Bradley and Coverhead and fireclays are commonly associated with it. The sections in the scars on the right bank of the Cover upstream from Cover Bridge show either sandstone, sandstone resting on fireclay, or fireclay (the thickness of these measures is shown on Plate 4 for all localities and fireclay is noted when present). The beds at this level are subject to considerable variation in a very rapid manner. In Ridge Scar, Woodale (022791) at the W. end of the cliff, the Middle Limestone rests directly on the unfossiliferous shale group of the Simonstone cyclothem, whilst 140 yd. upstream the scar section shows:

- Middle limestone
1' black, fossiliferous shale
3' fireclay
- mudstone

A somewhat similar section is seen in a stream immediately S.W. of Slate Gill (031794) which shows:

- Middle Limestone
8" black shale and fireclay
2' grey fireclay
1'6" flaggy sandstone (no base seen, but a shale occurs a short distance downstream)

West of Arkleside, exposures show 4' of sandstone under the Middle Limestone, but with no trace of a fireclay.

The furthest south of all exposures is in Park Gill Beck (989752), overlooking Kettlewell, where the sandstone is 5' thick. This horizon is apparently absent entirely in the exposure in the axis of the Limley anticline in Nidderdale (Plate 3).

Palaeontology

The Simonstone Limestone was not examined in detail during the present work, except for the uppermost few feet which were often searched for Orionastraea, but in fact the extreme top of the limestone where this coral occurs is very seldom seen in the present area. Orionastraea is widely known from this horizon (Turner, 1927, Hudson, 1929a, Moore, 1955) and was once found during the present work, but as a fragment whose species could not be identified. The records of Saccaminopsis are of interest because the Simonstone Limestone is characterised by abundant Saccaminopsis in the outcrops on the N.W. fringes of the Lake District (Turner, 1927), though this fossil does not appear to be common in the present area and was not recorded by Moore (1955), when working in Upper Wensleydale.

The lower part of the shales of the Simonstone cyclothem are highly fossiliferous and carry an extensive normal shale fauna (as defined by Hudson, 1924), preserved as calcite films. The most

prolific locality was that near Bradley, and though the Ashes Farm locality was almost as fossiliferous, the preservation of specimens is here somewhat indifferent. The bulk of the fauna consists of long ranged forms, but the presence of Eomarginifera setosus and E. tissingtonensis is noteworthy, since they occur to the exclusion of E. longispinus and E. lobatus, forms which appear to take the place of the two former species higher stratigraphic levels (see also Johnson, 1953). These two last species do not appear to be recorded below the Scar Limestone. The record of Cancrinella undatus, which is prolific at the Bradley exposure, is matched by a similar record by Moore (1955).

Fenestellids are numerous and well preserved and specimens from the exposure near Bradley indlude the only dorsonodulose forms recorded from the present area. The remaining bryozoa include a variety of genera, which are chiefly stick and strip shaped cryptostomes.

The ostracods include several genera commonly recorded from shales of Yoredale facies, namely Bairdia, Kirkbyia and Paraparchites, preserved in moderate abundance as three dimensional calcite films (determinations which follow are by Dr. F.W. Anderson). The species of foraminifera recorded are similar in all respects to those listed from the limestones of Yoredale facies.

The shale fauna from the remaining locality differs from the normal shale fauna and appears to come from a markedly higher stratigraphic level than the previous records i.e. from the lowest part of the unfossiliferous shales of the Simonstone cyclothem.

These locally develop a fossiliferous phase, seen only in the exposure near Cover Bridge. The most abundant forms by far are numerous and well preserved Chonetes hardrensis Phillips which occur in conjunction with several other fossils, chiefly orthotetids, pelecypods and gastropods. The fauna is apparently indigenous since it includes a specimen of Pomarginifera sp. bearing its full complement of fragile spines. Brachiopods are rare however, with the exception of the prolific Chonetes. Thus the fauna at this locality contrasts markedly with the normal shale assemblage with its abundant and varied brachiopods. Bryozoa are almost unrepresented in the present records though they occur in abundance in a normal shale assemblage.

The limestones in the shales of the Simonstone cyclothem yield a prolific fauna at some localities. Specimens from the sections near West Bottom Lathe include limestone made up very largely of organic debris, which are chiefly brachiopods and crinoids. The fragments do not appear to have been transported far, since two specimens of Echinoconchus punctatus still bearing numerous, fragile spines were recorded. The records of Aulophyllum fungites are from shales between two limestones in the section near West Bottom Lathe and are based on a large collection of calcitised calyces, many of them crushed and all of them preserved in a horizontal position on the bedding planes.

The present records cannot be compared with those of Moore in full detail since the nomenclature of the limestones of the Simonstone cyclothem is on a firm footing only in upper Wensleydale. On the basis of tentative correlations, the lowest limestone seen

at the exposure near Bradley, Coverdale and at Ashes Farm, Waldendale, is correlated with limestone IVa of Moore which also has yielded Gigantoproductus latissimus. Limestone IVb may be tentatively correlated with the highest limestone of the section near West Bottom Lathe which yields a somewhat similar fauna, incorporating species of Echinoconchus, and Dictyoclostus, recorded in considerable abundance in the present area from this one locality.

Faunal Lists

Simonstone Limestone

Archaediscus karreri Brady var. B Short ms., 1
Endothyra sp., 1
Orobias ornata (Brady), 1
Saccaminopsis (Saccamina) fusilinaformis (McCoy), 1
Tetrataxis decurrens (Brady), 1

Crinoid ossicles, 1

Rhombopora sp., 1

Orionastraea sp., 4

Palaeosmilia regia (Phillips), 1

Ostracods, 1

Index of localities for the above

1.	R. Cover below Tunstall Scar, Coverdale	061831
2.	Axis of Limley anticline in R.Nidd, Nidderdale	099764
3.	Road cutting S.E. of Swinithwaite, Wensleydale	048889
4.	Stream below Ashes Farm, Waldendale	008822

Fossiliferous shales of Simonstone cyclothem

plant remains, 2

Ammodiscus incertus (D'Orbigny), 2
Endothyra bowmani Phillips, 2
Orobias ornata (Brady), 2
Tetrataxis decurrens (Brady), 2
Tetrataxis palaetrochus (Ehrenberg), 2

Cladochonus sp., 2
Zaphrentid indet., 1,2

Archaeocidarid spine, 1,2
Platycrinus sp., 2

Crinoid ossicles, 2,3

Fenestella cf. compressa var. nododorsalis (Ulrich), 2
Fenestella plebeia McCoy, 2
Fenestella sp., 1,3
Penniretepora sp., 2
Rhabdomeson sp., 2
Rhabdomeson or Rhombopora sp., 1
? Rhombocladia sp., 1
Steblotrypa sp., 2
Trepostome (encrusting form), 2

Annelid trails, 2

Actinoconchus planosulcatus (Phillips), 2
Brachythyris decora (Phillips), 1
Camaratoechia pleurodon (Phillips), 2,3
Chonetes (Chonetes) hardrensis (Phillips), 2,3
-------- (Tornquistia) politus McCoy, 2
Crurithyris urei (Fleming), 2
Dielasma hastata (J. Sowerby), 1
Hustedia radialis (Phillips), 2
Martinia glabra (Martin), 2
Orbiculoidea nitida (Phillips), 2
Orthotetid indet., 2
Phricodothyris sp., 1,2
Productus (Buxtonia) cf. scrabiculus (Martin), 3
--------- (Cancrinella) undatus Defrance, 2
--------- (Echinoconchus) elegans McCoy, 1,2
--------- (Eomarginifera) cf. setosus Phillips, 2,3
--------- (----------) tissingtonensis Sibly, 2
--------- (----------) sp., 1
--------- (Gigantoproductus) latissimus J. Sowerby group, 1
--------- (Productus) concinnus J. Sowerby, 1
---------(---------) productus (Martin), 2
Schellwienella rotundata Thomas, 3
Spirifer bisulcatus (J. Sowerby) group, 2
Spirifer trigonalis (Martin) group, 2

Actinopteria ? persulcata (McCoy), 1
---------- sp., 2
Amusium concentricum Hind, 2
Aviculopecten cf. clathratus (McCoy), 2
---------- intermedius (McCoy), 2
---------- interstrialis (Phillips) juv., 2
? Conocardium sp., 1
Edmondia cf. pentonensis Hind, 3

Edmondia primaeva (Portlock), 1
Leda attenuata (Fleming), 2
---- luciniformis (Phillips), 3
Leiopteria thompsoni (Portlock), 1
Limatulina scotica Hind, 2
Nucula cf. palmae J. Sowerby, 3
------ cf. undulata Phillips, 3
Pinna mutica McCoy, 2
Pseudamusium anisotum (Phillips), 2
Sanguinolites angustatus (Phillips), 1
Schizodus cf. axiniformis (Phillips), 3

Aclisina sp., 1,2
Bucaniopsis sp., 2
Euphemites urei (Fleming), 2,3
? Loxonema sp., 1
Macrochilina sp., 2
Platyschisma sp., 2

Conularia quadrisulcata McCoy, 2
Hyolithus sp., 2

Epistroboceras sp., 2
Orthocone nautiloid, 1

Bairdia hisingeri (Münster), 2
Cardiniferella scrobiculata Jones, Kirkby and Brady, 2
Kirkbyia permiana Jones, 2
Paraparchites scotoburdigalensis (Hibbert) juv., 2
? Waylandella cuneola (Jones and Kirkby), 2
Waylandella sp., 2
Ostracods, 1

Index of localities for the above

1. Stream below Ashes Farm, Waldendale 009825
2. R. Cover E.N.E. of Bradley, Coverdale 037801
3. Left bank of R. Cover above Cover Bridge 013787

Limestones in fossiliferous shales of the Simonstone cyclothem together with their attendant shales in which fossils are preserved in solid calcite.

Aulophyllum fungites (Fleming), 1
Diphyphyllum cf. furcatum Thomson, 1
Lithostrotion junceum (Fleming), 1

Archaeocidarid spine, 1

Crinoid ossicles, 1,2,3

Fenestella sp., 1
Rhabdomeson or Thombopora sp., 1
trepostome bryozoan, 1

Actinoconchus planosulcatus (Phillips), 1
Camaratoechia pleurodon (Phillips), 1
Dielasma hastata (J. Sowerby), 1
Orthotetid (possibly Meekella sp.), 1
Productus (Dictyoclostus) aff. antiquatus (J. Sowerby), 1
--------- (----------) aff. pinguis Muir-Wood, 1
--------- (----------) pugilis (Phillips), 1
--------- (Echinoconchus) eximius Thomas, 1
--------- (----------) punctatus (Martin), 1
--------- (Gigantoproductus) latissimus (J. Sowerby) group, 2,3,
Rhipidomella michelini (Léveillé), 1
Schellwienella aff. rotundata Thomas, 1
Spirifer striatus (Martin), 1
Spirifer triangularis (Martin), 1
Spiriferellina octoplicata (J. de C. Sowerby), 1

Spirorbis sp., 1

? Ostracods, 1

Phillipsiid trilobite (mucro, if present, is not preserved), 1

Index of localities for the above

1.	River Cover E.N.E. of Bradley, Coverdale	037801
2.	Bed of R. Cover near West Bottom Lathe	003780
3.	Stream below Ashes Farm, Waldendale	008822

PLATE 3 Comparative sections in the Simonstone Cyclothem.

PLATE 4 A Information and isopachyte diagram for the Simonstone cyclothem, excluding the Simonstone Limestone.

1. Isopachytes are at 10' intervals for the measures of the Simonstone cyclothem between the top of the Simonstone Limestone and the base of the Middle Limestone. Large numerals denote the thickness measurements on which the isopach lines are based. The prefix 'C' before a numeral implies that the figure is an approximation derived by inspection of the geological map at a point where the evidence is good for making such a determination.

2. Small numerals denote the thickness of the sandstone at the top of the cyclothem , immediately underlying the Middle Limestone.

'L' denotes a thin limestone at the base of this sandstone (the thickness of this bed is included in the figure for the sandstone).

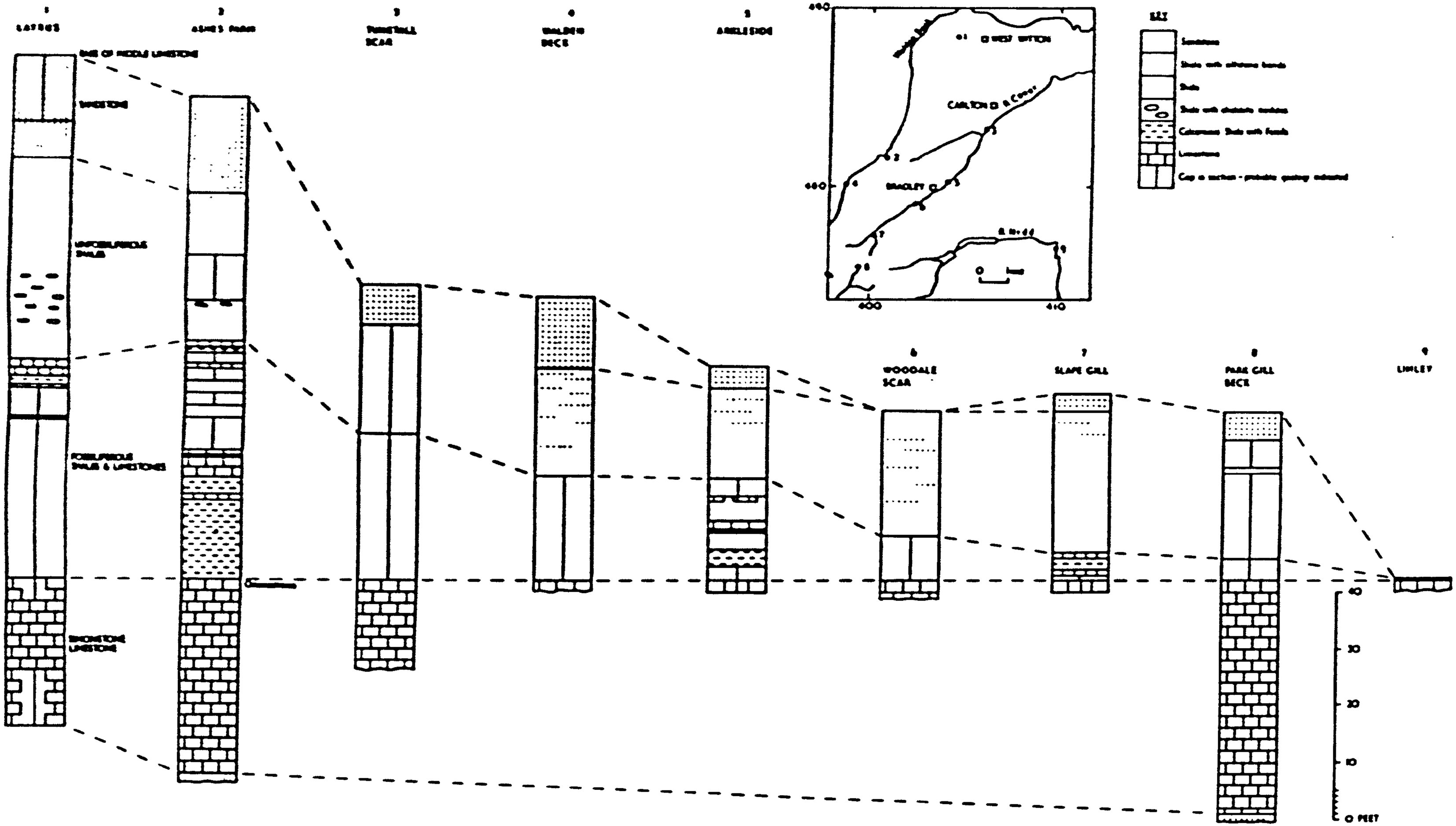
'F' denotes fireclay , with the sandstone , or by itself where it actually replaces the sandstone in the section (the thickness of the fireclay is included with the figure quoted for the sandstone).

A plus sign after a figure denotes incomplete exposure, the visible thickness being quoted. (this applies to all subsequent plates of this nature).

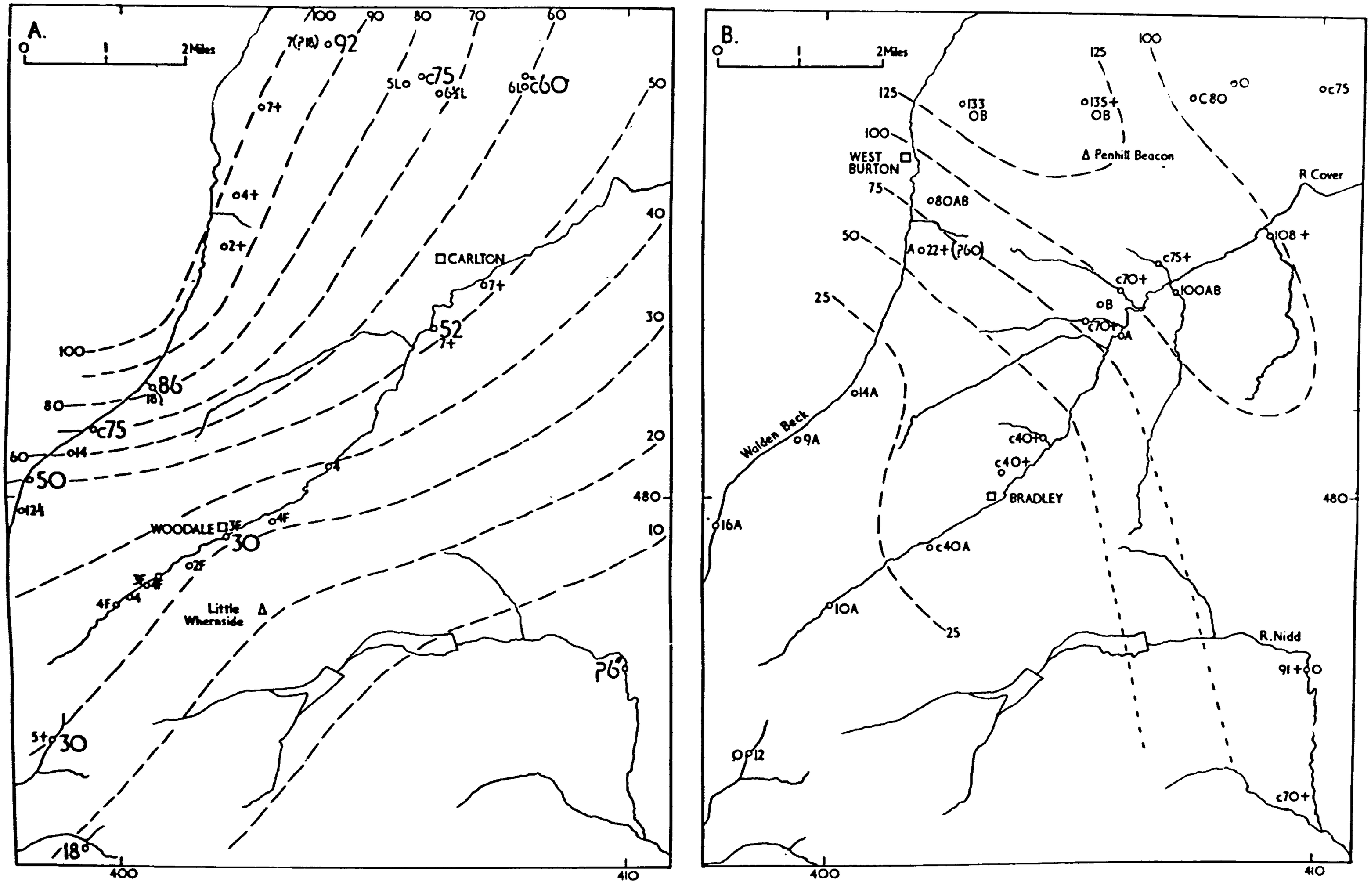
PLATE 4 B Information and isopachyte diagram for the upper Middle Limestone (above the Gigantoproductus beds).

1. Isopachytes are at 25' intervals. Long dashes indicate well founded isopachs; short dashes , uncertain ones. The thicknesses on which the isopachs are based are given in small numerals.

2. The following capital letters are used to indicate features of the Lower Middle Limestone - 'O'- Orionastraea Band , 'A'- Orionastraea Band absent, 'B'- Pseudobreccia occurs.



1
LATRUS
2
ASHES FARM
3
TURNSTALL SCAR
4
WALDEN BECK
5
ARKLESIDE
6
WOODALE SCAR
7
SLAPE GILL
8
PARK GILL BECK
9
LIMLEY
BASE OF MIDDLE LIMESTONE
SANDSTONE
UNFOSSILIFEROUS SHALES
FOSSILIFEROUS SHALES & LIMESTONES
SANDSTONE LIMESTONE
WEST WITTON
CARLTON
BRADLEY
0 1 mile
400
410
SEY
Sandstone
Shale with siltstone bands
Shale
Shale with abundant nodules
Calcareous Shale with fossils
Limestone
Gap in section - probable geology indicated
40
30
20
10
0 FEET


A.
0
1
2 Miles
100
90
80
70
60
50
40
30
20
10
480
400
410
7(?18) o92
o7+
o4+
o2+
5Lo
o c75
o6½L
6Lo
o c60
CARLTON
o7+
o52
7+
100
80
60
o86
18
o c75
o14
o50
o12½
WOODALE
3F
o4F
o30
o2F
3F
4F
4F
o4
Little Whernside
?6
5+
o30
18
B.
0
1
2 Miles
125
100
75
50
25
o133 OB
o135+ OB
o C80
o0
o c75
Δ Penhill Beacon
WEST BURTON
R Cover
o80AB
A o22+ (?60)
o108+
c75+
c70+
o100AB
oB
c70+
oA
o14A
Walden Beck
o9A
c40+
c40+
BRADLEY
o16A
o c40A
o10A
25
R. Nidd
91+ o0
o12
c70+

CHAPTER 3

THE MIDDLE CYCLOTHEM

The Middle Limestone was so named by Phillips (1836) who recognised this horizon in the present area and measured its thickness at 150' to 160' in Lead Up Gill, Coverdale. Apart from a mention by Dakyns (1892) who noted the unusual thickness of this horizon near West Witton, the Middle Limestone of the present area has only been described from Nidderdale by Tonks (1925) who gives a full account of it in that area. He records the presence of Orionastraea from the base of the limestone (which was first noted in the dale by Chubb, fide Tonks, 1925) and gives details of two bands with Gigantoproductus which occur in a thick development of the limestone. The occurrence of the upper Gigantoproductus band mentioned as outcropping in the quarry on the W. side of Howstean Beck 500 yd. W. of Lofthouse Station and below Lofthouse footbridge could not be verified by the present author, who did not find this horizon in the Lofthouse inlier. Palaeosmilia regia is recorded from below the Lofthouse footbridge by Tonks, but has not been recorded during the present work, possibly because this locality has been extensively collected by previous workers.

The limestone taken as the upper leaf of the Middle Limestone by Tonks is here referred to as the Five Yard Limestone, for reasons stated in Chapter 4.

Hudson (1929) records Orionastraea garwoodi from the base of the Middle Limestone of localities in the area here described and the present work adds little detail to this contribution.

The most recent reference to the Middle Limestone is by Joysey (1955) who records Orbitremites from the railway cutting N.N.W. of Limley in Nidderdale at a horizon similar to that at which this blastoid occurs in numbers N. of Grassington.

Stratigraphy

The Middle Limestone in the present area is a horizon of variable thickness (60'-198') and is always divisible into three divisions:

The lower Middle Limestone is a massive grey, detrital limestone usually blue near the base and top and poor in macrofossils. Very locally a horizon with Lithostrotion maccoyanum and productids is developed at the extreme base, and more commonly a horizon with Orionastraea garwoodi Hudson and variants is seen about 4' from the base of the limestone. This latter horizon is however absent over a large portion of that area, especially in Coverdale and upper Waldendale. The lower limestone is fairly constant in thickness, the usualy variation being from 18' to 40', a variation which is not systematic in any geographical direction. It is possible that a thickness of about 59' is attained in the Limley inlier in Nidderdale, but it may be in fact nearer 40'.

The Gigantoproductus beds are a constant horizon in the area and their occurrence serves to divide up the Middle Limestone into three units in most sections, namely the lower Middle Limestone, the Gigantoproductus beds and the upper Middle Limestone. The Gigantoproductus beds are usually well bedded, blue, fine grained limestones which are frequently calcite mudstones, carrying a

prolific fauna of Productus (Gigantoproductus) giganteus (Martin) with an accompanying fauna of productids and bryozoa which appear to be much less numerous than the specimens of Gigantoproductus. Large sops of Lithostrotion junceum Fleming, in a position of growth, are a common feature of the lower part of the Gigantoproductus Beds, especially in the north of the area. Nodules of black chert frequently occur, often inside the curve of the valves of Gigantoproductus. The Gigantoproductus Beds vary rather haphazardly in thickness, from 8' to 50'. The centre of the series is locally free from Gigantoproductus. In the measured sections (Plates 5,6) the base of these beds has been taken as a time line. Whilst it cannot be proved that the characteristic brachiopod achieved widespread distribution in a very short time, it appears likely.

The upper Middle Limestone shows the greatest variation in thickness and, unlike that in the lower horizons, this appears to be systematic and can even be approximately isopached. The thickening of the upper Middle Limestone continues from the N.W. slopes of Penhill into middle Coverdale and also occurs in the Limley area in Nidderdale (Plate 4B). The total variation in thickness which is seen is 9'-135'. This horizon also shows great facies variations and varies from a detrital grey limestone or grey calcite mudstone with organisms to a completely organogenic, pale grey, incoherent limestone made up almost entirely of crinoid stems of unusually large diameter in a state of complete articulation. This is indicative of rapid accumulation of crinoids in situ with little resorting of the material which made up the

stems. Original dips of accumulation of these debris are frequently seen and it is thought that these in most cases mark the original mounding up of the crinoid biostromes. The limestones made up almost solely of stems do not contain calicular plates which were, it is assumed, winnowed out by currents and deposted elsewhere. Macrofossils, other than crinoid stems are rare in these accumulations of crinoid stems, with the exception of a bryozoan bank accumulation at Long Ing Wood, Waldendale (023861) which has yielded a fauna of cryptostome and trepostome bryozoa with productids and athyrids.

The beds of the Middle cyclothem above the limestone are everywhere thin and do not exceed 23' in thickness. In the south of the area they are dark shales with a normal shale fauna preserved as calcite films with occasional thin limestones, which are usually seen in the lowest part which is transitional with the top of the Middle Limestone. The total variation in the thickness of this shale development, which reaches its maximum thickness in Nidderdale at Angram, is from 5-20'.

In the north of the area, on the north face of Penhill and in lower Coverdale the measures above the Middle Limestone, when seen to completeness are always fine grained pale sandstones with obscure shelly remains at several localities, varying from 23' to 13'6" in thickness and complete sections of which are only seen in lower Coverdale. Whilst the mapping evidence is not quite conclusive, the evidence of features on the N.W. slopes of Penhill suggests that the sandstones forming the feature at Oswald High Wood which appear to directly follow the Middle Limestone (with a possible

thin shale below them) can be mapped southwards into the sandstone which underlies the Three Yard Limestone which occurs in features above Long Ing Wood. In addition, beds which are referred to the Middle cyclothem with some confidence which form a feature above Long Ing Wood appear to die out in a northerly direction, together with the Five Yard Limestone which they underlie. No trace of either of these horizons appears to occur north of the Hudson Quarry. Since the features are not absolutely continuous at the level of the sandstone below the Three Yard Limestone there is no final certainty that the sandstones of Oswald High Wood belong to the Five Yard cyclothem, but this seems a likely explanation which is followed in the interpretations put forward in Plate 21. In the text a conservative view is taken however and the beds above the Middle Limestone in lower Coverdale and on the N. slopes of Penhill are referred to the Middle cyclothem, since they overlie the Middle Limestone and other evidence of their age is not finally conclusive.

The Middle Limestone is one of the best exposed horizons of Yoredale facies strata and usually forms features where the drift is thin as on the N. face of Penhill. Elsewhere it is partially obscured by valley drift, but in the deeper tributary valleys it forms picturesque gorges and cliffs, this especially where the Middle Limestone is abnormally thick. The beds of the Middle cyclothem above the Limestone are only exposed sporadically and are usually seen only in stream sections. The shales between the Middle and Five Yard Limestones in upper Waldendale and upper

Coverdale are one of the least well exposed horizons in the present area.

Details

Middle Limestone - Exposures are described seriatim, first in Waldendale, progressing down-dale, then on the N. flank of Penhill, in Coverdale, progressing up-dale, in Park Gill Beck and finally in the Nidderdale inliers.

Walden Head - The section in upper Walden Beck (979797) is in a stream of low thalweg - nearly all the beds are exposed, but the measurement of thicknesses of beds is subject to small errors. (Plate 5). The lower Middle Limestone is about 35' thick and is a massive, grey detrital limestone in the middle part with a blue colouration in the lowest 8' and top 7'. The uppermost 7' lithologically resembles the Gigantoproductus Beds, that is they are dark grey and blue calcite mudstones bedded in 1' posts. The strata with Gigantoproductus are typically blue and well bedded limestones with abundant specimens of G.giganteus (Martin). The upper Middle Limestone is thin and appears to contain shale layers towards the top. The thin limestone bands which are separated from the Middle Limestone by these shale layers are also regarded as part of the Middle Limestone. This correlation is upheld owing to the presence of a giganteid- Lithostrotion fauna in the lower leaf of the Five Yard Limestone described by Moore (1955) from the country to the N.W. of this point. This fauna appears in the next limestone in the succession of beds at Walden Head, immediately above the beds described above. Between the sections at Walden Head

and Dales Barn, streams draining off Brown Haw show sections similar in all respects to those at Walden Head and Dales Barn.

The section at Dales Barn (992808) closely resembles that seen at Walden Head, there being a well defined tripartite division of the Middle Limestone. The Gigantoproductus beds carry sops of Lithostrotion sp., a feature which becomes increasingly evident in exposures further down the dale. The upper Middle Limestone is unusually thin here; only 6'6" are seen, and it is unlikely that these beds are substantially thicker (Plate 5). The lowest 6" of the lower Middle Limestone contain numerous organic fragments, but no corals were collected.

N.E. of this section the lower Middle Limestone outcrops as an impersistent line of scars running along the side of the dale. The Gigantoproductus beds occur in two stream sections between Dales Barn and Ashes Farm. At Ashes Farm a stream section (008822) shows the Middle Limestone divided, as is usual, into three divisions. The upper Middle Limestone is quite thin, and is not over 13' thick (Plate 5). Down-dale from Ashes Farm the Middle Limestone forms a weak feature and is exposed sporadically.

Scar Folds (020848) shows an uninterruped section in the lower part of the Middle Limestone (Plate 5). The lower Middle Limestone is typically developed and shows in the top 2' of beds a horizon of pink nodules which weather out slightly. This is the identical horizon at which Hudson (1929) and later Moore

(1955) described Erythrosponcia lithodes Hudson and it is probable that these are poorly preserved specimens of this sponge. The lower part of the Gigantoproductus Beds which are here very thick, consists of blue, well bedded calcite mudstones with occasional Lithostrotion in the upper part, and abundant Gigantoproductus. 16' of limestone without giganteid productids follow, which are blue in the lower beds and grey in the upper portion. They are overlain by further beds with Gigantoproductus; these are grey, crinoidal limestones with abundant giganteids together with chert nodules. The lowest beds of the upper Middle Limestone are seen, but the upper beds are completely unexposed. The visible beds are grey crinoidal limestones with a 6" horizon with a granular texture and composed of crinoid remains which approximate in appearance to the phase of the upper Middle Limestone with abundant crinoid stems typically developed further to the north. The size of the gap in the section suggests that the upper Middle Limestone is thick here, probably in the vicinity of 58'.

Long Ing Wood shows excellent exposures in the Middle Limestone (023861), (Plate 5). The lower Middle Limestone is a 12' massive, grey limestone with crinoid ossicles, blue at the base and almost unfossiliferous, except for the basal 6" which is an irregular bed with Dyphyphyllum cf. lateseptatum McCoy. The upper beds of the lower Middle Limestone are blue, blocky irregularly bedded calcite mudstones with nodules of black glassy chert in ovoid and elongate masses, parallel to the bedding and occurring near the top of this horizon. The

Gigantoproductus Beds which follow are, in their lower part, lithologically similar to the blue calcite mudstones which underlie them. These beds are very well exposed and carry an abundant fauna of Gigantoproductus giganteus (Martin) with large sops of Lithostrotion junceum (Fleming) at several different levels which have evidently grown in place. Solitary corals are fairly abundant and include clisiophyllids together with small productids, the most common of which is Sinuatella sinuata (de Koninck). In the middle of the Gigantoproductus Beds a horizon of calcite mudstone contains a fauna of bryozoa and brachiopods preserved in a platy-weathering rock. The upper 14' of the Gigantoproductus beds is lithologically different from the lower part, since it is a rubbly weathering detrital limestone of grey colour, with occasional lenses and lenticular layers of crinoid-rich debris which may include large stems. These upper beds, unlike the limestones below, do not carry a Lithostrotion fauna, and thus resemble the upper part of the Gigantoproductus Beds of Scar Folds both faunally and lithologically. Brachiopods are abundant and include, in addition to giganteid productids, of both giganteus and latissimus types, Sinuatella sinuata (de Koninck). Unlike the section at Scar Folds, there is no horizon which is devoid of Gigantoproductus, though there is a zone 5' thick near the centre of the series which has only occasional specimens.

The lower portion of the upper Middle Limestone is a grey, detrital limestone, which has been locally dolomitised along the line of a joint. Higher up the succession (Plate 5) strata

with abundant crinoid ossicles occur; many of the ossicles are large and these beds resemble the crinoid biostrome facies in lithology, which is more typically developed further north on the N.W. flank of Penhill. These beds are overlain by limestone of a bryozoan facies, not seen elsewhere at this horizon. The forms include a tubular trepostrome, Rhabdomeson sp., Dibunophyllum bipartitum konincki and a fauna of small brachiopods, preserved in a grey calcite mudstone containing a very high proportion of well preserved organisms, chiefly bryozoans.

Morpeth Scar (029878) (Plate 5) shows an excellent section in the Middle Limestone which is here at its thickest development in the present area. The lower Middle Limestone is a grey, crystalline, fairly massive limestone with a coral fauna in the basal 6", which includes Dyphyphyllum ?lateseptatum and Lithostrotion maccoyanum with several productids and Sinuatella sinuata. 4' above the base of the limestone sops of Orionastraea garwoodi Hudson are seen at intervals along a restricted, thin horizon. 12' above the base of the Middle Limestone pinkish blebs were noted, which were not sufficiently distinctive to merit identification as Erythrospongia. Indeed they may be inorganic, since pink blebs were also noted by Moore (1955) and were not identified as organic, these occurring at a closely similar horizon in the lower part of the Middle Limestone. A stratum near the top of the lower Middle Limestone is a grey calcite mudstone, a lithology not usually encountered at this horizon. The incoming of the fauna with Gigantoproductus

giganteus (Martin) is anticipated by a change in the colour of the sediment to a dark blue with a decrease in the grain size as the sequence is ascended; this feature is characteristic of the upper part of the lower Middle Limestone in all the sections described from Waldendale. Immediately below the lowest stratum with Gigantoproductus giganteus a platy blue calcite mudstone yields a very well preserved fauna of latissimoid productids and bryozoa, with other subsidiary productids. This horizon is followed by blue, compact, fine grained well bedded limestones with thin shale partings and numerous specimens of Gigantoproductus giganteus with occasional sops of Lithostrotion. The upper 14' of beds with Gigantoproductus are grey in colour as in other sections described from Waldendale and carry a single horizon with Lithostrotion.

The lower beds of the upper Middle Limestone are grey limestones with a single horizon yielding sops of Lithostrotion sp. These are followed by a distinctive facies which is a white, or pale grey incoherent limestone consisting entirely of crinoid stems, with the ossicles fully articulated. Re-sorting of the stems appears to have been minimal and it seems probable that the dips of the layers which show angles of up to 12 degrees, are due to the crinoids having built up biostromal mounds. There is little to suggest that they have been heaped up this way by currents, though this is possible. The lack of calicular elements is remarkable and this is presumably due to the winnowing out of the fragile calicular elements by currents, with their deposition in an adjacent area.

Between Oswald Pasture and Knarlton Knot numerous exposures of parts of the upper 100' of the Middle Limestone occur, and a mappable feature persists along the outcrop of the upper Middle Limestone, being developed near the top of this division. The beds are variable, but include layers rich in crinoid stems - these are apparently most abundant near the middle of the upper Middle Limestone and less so in the upper part of the limestone which forms a mappable feature. Knarlton Knot (026868) and gulleys to the N.N.E. of this point show excellent developments of coarsely crinoidal limestone consisting almost solely of stems of this animal, and almost always showing original depositional dips.

Sections near Chantry Farm (055881) show the massive, grey crystalline lower Middle Limestone typically developed with a single sop of Orionastraea 4'6" from the base. The Gigantoproductus beds are not definitely seen at Chantry, since the diagnostic fossil is absent and exposures are incomplete, but the exposures at Capple Bank Farm (064879) have yielded this braciopod. The upper Middle Limestone includes a shale parting in the section near Chantry which is overlain by a steeply bedded, presumably current bedded limestone composed entirely of abraded crinoid ossicles, with occasional pebbles of calcite. The occurrence of rounded calcite pebbles suggests that the steep dips are a form of current bedding in the limestone. The highest beds exposed in this section (Plate 6) show alternations of limestone composed wholly of crinoid debris and normal limestone, composed of broken down organic detritus.

The feature on the Middle Limestone which forms Nossill Scars,

W.N.W. of Chantry dies out to the east, and the mapping evidence points to an eastward thinning of the upper Middle Limestone. The feature on the upper Middle Limestone which is readily seen below Chantry persists eastward to Bristow High Gill (080882). Exposures on it show that the lower Middle Limestone is persistently a massive, grey detrital limestone which is overlain by a blue, well bedded, fine grained limestone with Gigantoproductus giganteus and Lithostrotion sops, with some nodules of black chert. The upper Middle Limestone is not well exposed, but where it is seen it is a granular rock composed entirely of crinoid debris. At a horizon which overlies an ill-exposed shale parting correlated with that of the Chantry section, 15' of blue limestone with Gigantoproductus giganteus are locally developed S.E. of Chantry (057877).

At Mount Park the Middle Limestone is involved in a plexus of faults causing a large segment of the limestone to lie parallel to the hillside, with a long section in the lowest beds of the Middle Limestone, forming a low scar. Sops of Orionastraea garwoodi Hudson occur 6' from the base of the Middle Limestone here. East of Mount Park, occasional exposures in the upper and lower portions of the Middle Limestone occur, but the Gigantoproductus beds are not exposed. From the mapping evidence it appears that the upper Middle Limestone is thinning substantially to the E., though it is still thick to the south, in lower Coverdale.

Coverdale - The Middle Limestone, seen in the R. Cover near Coverham Abbey, is not well exposed enough to merit a measured section, but appears to contain horizons with Gigantoproductus sp.

at two levels. The highest of these is at the very top of the Middle Limestone, at a horizon close to that seen in the railway cutting in Nidderdale, north of Limley Farm. 7' of beds with Gigantoproductus are seen at the top of the Middle Limestone at 115864, but the full thickness may be in excess of this figure.

The upper Middle Limestone is thick in lower Coverdale, and is well exposed in the R. Cover and in the gorges of Ulfers Gill and Elm Gill. The section in Ulfers Gill (091851) is a continuous one in a picturesque cliff-bounded defile, cutting through 84' of massive, grey limestone with a paucity of large macrofossils. A horizon with Lithostrotion sp. near the base of the section occurs at a similar horizon to a band of sops low in the upper Middle Limestone of Morpeth Scar. A single 6" shale parting occurs in the section, at a level similar to that of a thin shale in the Chantry section. (compare Sections 7, 8, Plate 6). In spite of the unusual thickness of the upper Middle Limestone, no reef facies is seen, though crinoid ossicles are often large. A specimen from above the road-bridge in Caldbergh Gill is a pale grey crinoidal limestone composed of ossicles, some of which are still articulated, and of large size, with Heterophyllum sp., small brachiopods and a rod cryptostome set in a matrix of calcite mud. At St. Simon's Bridge on the R. Cover the Gigantoproductus beds are exposed in the bed of the stream. They rise rapidly upstream and form a river-side cliff below the confluence with Thorow Gill (082847). The section in Clint Gill (075848) shows blue, well bedded

limestone underlying the Gigantoproductus Beds (this series of transitional beds at the base of the Gigantoproductus beds is characteristic of the sections in Waldendale), which are followed by a thick series of grey limestones which form cliffs along the stream course.

The section in Lead Up Gill (073840) is the most complete in lower Coverdale, but the upper part of the section only admits of approximate measurement (Plate 6). The base of the limestone is well exposed on the right bank of the River Cover and is apparently devoid of macrofossils. Approximately 14' from the base a 1' nodular weathering pseudobreccia occurs. This is overlain by grey limestones, followed by well bedded, blue calcite mudstones with Gigantoproductus and also sops of Lithostrotion which is confined to the lower part of these beds as it is in the Waldendale outcrops. A 7' zone within the Gigantoproductus Beds contains only sparse specimens of the characteristic fossil and may be possibly equivalent to a similar impoverished zone seen in some of the Waldendale sections. The upper Middle Limestone in Lead Up Gill is extremely thick and is a massive, grey limestone, occasionally showing original dips of deposition and more rarely articulated crinoid stems similar to those seen in the sections on the N.W. slopes of Penhill. Owing to the massive nature of these beds, they have formed an imposing cliff and waterfall in the gill below the village of West Scrafton.

The section in Hobgill Kern (060841) does not admit of accurate measurement, but shows Gigantoproductus beds overlain

by the upper Middle Limestone, here over 70' thick, but nevertheless thinner than in the lower part of the dale, near Carlton and West Scrafton (see Plate 4B for information on thickness changes in the upper Middle Limestone).

Ridding Gill (057838) shows a small thickness of limestone with a biostromal facies, composed of crinoid stems of large size. Apart from a thin layer in Lead Up Gill, this is the only record of beds of this facies in Coverdale, and is similar to thicker developments on the N.W. slopes of Penhill.

. Turn Beck (054834), like Hobgill Kern, shows a section in the Gigantoproductus Beds overlain by a thick development of the upper Middle Limestone, which is here over 50' thick. Fleemis Gill (051831) is similarly an incomplete section and the upper Middle Limestone is only partially seen, together with the Gigantoproductus beds.

At Tunstall Scar (061831) the lower Middle Limestone forms a cliff on the right bank of the River Cover where 14'6" of massive, grey limestone, are exposed. The beds near the base which are of a bluish colour, were searched for Orionastraea without success. The upper Middle Limestone has been quarried in this vicinity and is a pale grey detrital limestone.

Within a mile radius of Horse House, numerous streams draining into the River Cover expose partial sections at this horizon. In most of them the Gigantoproductus Beds have been recognised, occasionally in conjunction with Lithostrotion sp. The upper Middle Limestone is never fully exposed, but is probably about 40' thick in the vicinity of Horse House.

At Ridge Scar and Ridge Gill, Woodale (022790) (Plate 6)

the tripartite division of the Middle Limestone is clearly in evidence. No trace is seen of any coral bands at the base of the limestone which is a massive, grey rock without macrofossils in its lower part. The Gigantoproductus Beds are of typical lithology, blue well bedded calcite mudstones, with Gigantoproductus and two horizons of Lithostrotion sops in the lower portion of the series. As is usual, the beds immediately underlying the Gigantoproductus Beds are blue in colour and also the uppermost strata with Gigantoproductus show a blue, rather than a grey colouration, as in the Waldendale exposures. The full thickness of the upper Middle Limestone is not exposed, but the beds appear to be about 34' thick and are grey limestones, indicating a progressive thinning from the area of maximum thickness further down the dale. (refer to Plate 4B).

Lords Gill (019788) is an incomplete section which was not fully measured. Gigantoproductus appears to occur at two different levels as at Coverham and Limley. The upper beds with this fossil are very thin - only 1'6" are seen and the maximum thickness cannot be over 3'6". In Slape Gill (002778) a nearly complete section occurs in the Middle Limestone which shows its tripartite division very clearly. The lower Middle Limestone is a massive, grey detrital limestone with no coral band visible, which forms a line of cliffs along the right bank of the R. Cover upstream and downstream from the confluence with Slape Gill. The Gigantoproductus beds show the typical lithology, being blue fine grained, well bedded limestones with some Lithostrotion sops. The top layer of the upper Middle Limestone, which is very thin here (Plate 6) contains a coral fauna which appears to be localised

in only a portion of the stratum in the section; a few yards away the fauna seems to be absent. The fossils seen are Palaeosmilia regia and lithostrotionoid corals, the chief of which is Lithostrotion maccoyanum, preserved in a grey, detrital limestone. Other sections in Coverdale which show portions of the Middle Limestone are Downs Gill (near Hunters Hall), Fall Gill and the River Cover below Great Hunters Stone.

In Park Gill Beck (987752) the limestone is well exposed in a small gorge. The lowest 32' are massive grey detrital limestones carrying a 6" band of lithostrotionoid corals 1'6" from the base. A single sop of Orionastraea garwoodi is seen 4' from the base. This occurrence of two coral bands is characteristic of the bulk of localities where Orionastraea occurs in the present area. A band of pseudobreccia, similar to that seen in Lead Up Gill, Coverdale also occurs (Plate 6). The beds with Gigantoproductus appear to be unusually thick, as they are also at Crag Brea, Waldendale, whilst the upper Middle Limestone is thin, as in upper Coverdale.

South of Park Gill Beck the Lower Middle Limestone forms a feature on Caseker Pasture and also at Caseker Scar, whilst a feature and crags occur along the outcrop E. of Hay Tongue.

Nidderdale - Portions of the Middle Limestone were exposed during dam construction in the Angram and Scar House trenches, but the most complete section is in the railway cutting N.N.W. of Limley (099765). The lower Middle Limestone appears to be unusually thick below the railway cutting, but owing to there being a gap in the exposures it is not possible to verify if a fault occurs in the line of the measured section or not.

Measurements from the axis of the Limley anticline where the base of the limestone is exposed in the bank of the Nidd to Manchester Holes, where the Gigantoproductus Beds are seen suggests that the measurements taken up hill to the exposure of the Gigantoproductus beds in the railway cutting are excessive (Plate 6).

The lower Middle Limestone is fairly massive and contains sops of Orionastraea garwoodi var. pristina at a horizon 2'6" above the base. The lower part of the limestone here is a blue fine grained rock, nearly a calcite mudstone, with crinoid ossicles, which alters upwards in colour to a grey limestone. The Gigantoproductus Beds are 8' thick in the scar in the left bank of the R. Nidd at Manchester Holes and in the railway cutting where they are moderately well bedded blue limestones with Gigantoproductus (see Plate 10A and also Plate 38A for a view showing the location of this inlier in the Middle Limestone). The upper Middle Limestone is a massive, grey limestone of somewhat variable lithology. A specimen from the lower portion is a calcite mudstone with partially articulated crinoid columnals and Rhombopora sp. set in the matrix. A specimen from below the upper Gigantoproductus bed is a grey crinoidal limestone with fairly large ossicles. However, despite the apparent large thickness of the upper Middle Limestone at Limley the crinoid bank (biostrome) facies seen on Penhill in association with a unusual thickening of the upper Middle Limestone, is not here seen.

The upper bed with Gigantoproductus contains a less profuse fauna of giganteids than the lower one and is a pale grey

detrital limestone. This is overlain by 19' of grey, detrital limestone which may be almost the entire thickness of the remaining Middle Limestone. The occurrence of an upper bed with Gigantoproductus giganteus at this locality is parallelled elsewhere, in Lords Gill, Coverdale, at a locality on the north flank of Penhill and at Coverham.

The lower beds with Gigantoproductus are also seen in the R. Nidd, 50 yd. upstream from Goydin Pot whilst the upper bed is seen in the cliff at this pothole. The beds seen in Boysoak Scar (101759) may belong to the uppermost Middle Limestone. About 25' of strata without Gigantoproductus are seen. If these beds belong to this horizon is probably means that the thickness of 19' allotted for the beds above the upper Gigantoproductus Beds of the Limley inlier is to small (see Plate 6).

The upper Beds of the Middle Limestone are exposed below Lofthouse footbridge (101735) where they are massive grey limestones forming cliffs along the stream course. In spite of a search, no specimens of Gigantoproductus were seen, as Tonks (1925) has claimed, nor did a protracted examination yield Palaeosmilia regia which has been recorded from this locality. The lack of this latter fossil may have been due to its having been extensively collected on previous occasions by geological parties. (Tonks, 1925, Hudson et al., 1938).

An extensive section is exposed in the picturesque but inaccessible gorge of Howstean (093735) where the upper Middle Limestone is massive and grey with a paucity of macrofossils. At the bottom of the beck leading from How Stean village (092734)

the upper Middle Limestone is very crinoidal and shows an approach to the biostromal facies seen on N.W. Penhill. No specimens of Gigantoproductus were seen in Howstean Gorge or Stud Fold Quarry and Tonks' statement that this fossil is seen in this quarry cannot be here confirmed. The maximum thickness of the Middle Limestone which outcrops in the Lofthouse inlier is about 70' in the area of the Howstean Gorge.

A portion of the upper part of the Middle Limestone is exposed in Blayshaw Gill (100729), but no horizon with Gigantoproductus is here seen.

Shales and sandstones of the Middle cyclothem (i) beds referred without doubt to the Middle cyclothem. Exposures are described in sequence from Waldendale, proceeding down-dale, Coverdale, proceeding down-dale and from Nidderdale, also describing progressively from the top of the valley.

Waldendale - a partial exposure is seen in Walden Beck, near Walden Head (979794) (Plate 5) where the following section is seen:

-	Five Yard Limestone with a Gigantoproductus-Lithostrotion fauna
6"	fossiliferous shale with thin limestone ribs
3'6"	gap (probably shale)
6"	blue limestone
3"	shale
3"	limestone
1'3"	shale
2'	limestone
3'	approx. gap (probably shale)
-	Middle Limestone

In a section above Dales Barn (990808) (Plate 5) the shales between the Middle and the Five Yard Limestones are not exposed, but the gap in which they must occur is only 5' thick.

The section at Ashes Farm (009821) (Plate 5) provides the only nearly complete section in these beds in Waldendale. 8' of dark grey shale with an extensive and well preserved normal shale fauna preserved as calcite films is exposed and rests on 1' of blue calcite mudstone which may be equivalent to one of the thin limestones near the base of the section in Walden Beck. This latter limestone may rest on shales, which are probably thin.

Above Long Ing Wood (024860) (Plate 5) a feature with pot holes into its crest occurs which carries blocks of fine grained sandstone on its face. This is interpreted as containing the measures above the Middle Limestone which are chiefly sandstone, but may also include a shale, These are overlain by the Five Yard Limestone. The total thickness of the measures between the Five Yard and Middle Limestone is here about 22' and the bulk of this is the cream coloured, fine grained sandstone, which is not represented at this level in the exposures further up the dale. North of the latitude of the Hudson Quarry (026864) the feature dies out and there is no positive evidence of the presence of either the Five Yard Limestone of the measures of the Middle cyclothem which underlie it.

Coverdale - The best section is in Slape Gill where the following incomplete section is seen (002777) (Plate 6):

-	Five Yard Limestone with a <u>Lithostrotion</u>-<u>Gigantoproductus</u> fauna
4'	unexposed - presumably shale
6"	silty shale with latissimoid productids
6"	shale with normal shale fauna moderately well preserved
2'	pale grey limestone with <u>Lithostrotion maccoyanum</u> (taken to be upper leaf of Middle Limestone
3'	unexposed (possibly shale)
2'	limestone (Middle Limestone)

No other good exposures occur at this level in Coverdale, but the occurrence in Deerclose Gill is of some importance since this is the furthest north that the Five Yard Limestone is seen in this dale. At this exposure (045811) 1' of black shale with marine fossils underlie the Five Yard Limestone which carries its characteristic fauna of Lithostrotion and productids.

Nidderdale - important records are available from the Engineer's plans for the Angram and Scar House Dam trenches. The shales above the Middle Limestone are thicker than in upper Coverdale and include thin limestones. It is not possible in the case of the records from Scar House to draw a distinct top to the Middle Limestone owing to the presence of alternations of shale and limestone. The section in the Angram Trench shows:

5'	limestone - Five Yard Limestone (correlated by means of the thick shales with trilobites and chalybite nodules which overlie it)
9'	shale
1'	limestone
10'	shale
-	limestone

The trench for the Scar House Dam shows:

5'6"	limestone (the Five Yard Limestone, correlated with that of the Angram trench on the occurrence of a thick shale above it)
1'	soft shale
2'6"	shaley limestone (possibly part of the Five Yard Limestone)
3'	soft shale and limestone
1'	limestone (possibly the highest leaf of the Middle Limestone)
1'	soft shale and limestone
1'	shale
4"	limestone
3'	shaley limestone
-	limestone (main body of Middle Limestone)

The section in the R. Nidd above Lofthouse footbridge (101737) shows the following section:

- Five Yard Limestone
7" calcareous mudstone
5" dark grey fine grained nodular limestone, partly chertified
3'6" calcareous mudstone with braciopods, bryozoa, crinoid columnals; the latter element is especially abundant in some layers.
- Middle Limestone

The thickness of the beds at this level is smaller than in the dam trenches further up the dale and is more similar to the thicknesses which obtain in upper Coverdale and upper Waldendale.

The strata at this level are also completely exposed in Howstean Beck (086741) but the rock is too rotten to yield a fauna. The section exposed shows:

- Five Yard Limestone
8' calcareous mudstone with an impersistent limestone rib at the base
- Middle Limestone

In Blayshaw Gill (098728) 5' of fossiliferous mudstone yielding a poorly preserved brachiopod fauna appears to be both overlain and underlain by limestone. It seems likely that this is the entire thickness of shales of the Middle cyclothem here.

Beds referred tentatively to the Middle Cyclothem - as the introductory remarks on stratigraphy show, there is a good case for assigning the sediments above the Middle Limestone in lower Coverdale and on the north slopes of Penhill to the Five Yard cyclothem. It also seems possible that these sandstones may even be equivalent to the sandstone between the upper and lower leaves of the Three Yard Limestone in upper Coverdale and upper Waldendale, as is pointed out in the chapters which follow. A conservative attitude is taken in the text and these sediments are treated as part of the Middle Limestone since they overlie

the bed of that name without any visible break.

North slopes of Penhill - the measures between the Three Yard and Middle Limestones are never fully exposed, but there is no trace of the Five Yard Limestone either as a feature or in sink holes and it is assumed to be absent as it can be proved to be in similar sections in lower Coverdale. The Three Yard Limestone of Oswald High Wood is exposed at numerous points and overlies a sandstone which is seen to a thickness of 9'; this horizon overlies a gap in the section of 13' (see Plate 5) which may possibly include some shale. Further east the sandstone is exposed in a stream at 058877 where 15' of compact sandstone are seen, making it most likely that the measures between the Middle and Three Yard Limestones are here almost entirely, if not entirely, sandstones.

Below Capple Bank at 072877 a section shows 6' limestone on 6" of shale. Whilst this is an isolated exposure, it seems possible that locally the Three Yard Limestone rests on shales and not sandstones. Several partial exposures in sandstone occur below the E. end of Capple Bank and include old stone pits at 095878 and 09878 which show exposures in a tough, blocky sandstone which underlies the Three Yard Limestone which forms a separate feature further uphill. The same sandstone is exposed intermittently on The Parks at 107881 and elsewhere and is always pale in colour, compact and sometimes limonite spotted. Shelly traces were noted in an exposure in a coppice at 105881 and also at 117882. At both these two points it has been wrought for wall stone and is a compact, fine grained sandstone as in all other outcrops.

Lower Coverdale - Exposures on the R. Cover above Hullo Bridge (117865) show the following section:

- Three Yard Limestone
12' pale, blocky, tough very fine grained sandstone with shelly traces
5' gap (probably sandstone, but too thin for anything but a very attenuated representative of the Five Yard Limestone).

A section in the R. Cover above Coverham Bridge shows the same section, but with less complete exposure (104861). All the visible beds are sandstones which overlie the top of the Middle Limestone after a small gap.

A virtually complete section is seen in Caldbergh Gill (092851), as follows:

- Three Yard Limestone
6' white, compact fine grained ganisteroid sandstone
2'6" fireclay
3' ganisteroid sandstone
2' gap
- Middle Limestone

This section appears to prove conclusively that the Five Yard Limestone is absent, even in its most attenuated form, in lower Coverdale, and by analogy and because of a complete lack of indications, on the north slopes of Penhill.

In Lead Up Gill (074835) the Middle Limestone is directly overlain by a sandstone which is badly affected by faults a little further upstream. One of the exposures strongly tilted by faulting shows this sandstone overlain by limestone, which is no doubt the Three Yard Limestone.

In the Carlton district of Coverdale the mapping evidence indicates that the measures between the Middle and the Three Yard Limestone are thin. One of the infrequent exposures in these beds

is in Cat Gill (071852) where 2' of sandstone are exposed which are overlain and underlain by limestone after small caps in the succession.

Palaeontology

Middle Limestone - The fauna from this horizon has been considered by previous authors, in Nidderdale by Tonks (1925) who provides faunal lists and by Hudson (1929a) who investigated the distribution of Orionastraea and named several new species. Joysey (1955) records Orbitremites from the railway cutting N.N.W. of Limley in Nidderdale.

The basal coral bands of the Middle Limestone are only sporadically developed. Hudson (1929a) recorded Orionastraea from the northern slopes of Penhill, from Whernside Pasture above Kettlewell and from the Limley anticline in Nidderdale. The present author confirms these occurrences which appear always as scattered sops, with the colony base downwards, in the living position. These occur at a horizon everywhere about 4' above the base of the limestone and without any accompanying fauna. O.garwoodi Hudson is recorded from several localities on the N. slopes of Penhill and from Park Gill Beck. The band appears to be entirely absent in Coverdale and was not seen in upper Waldendale (plates 5,6). The form which occurs in Nidderdale is near O.garwoodi var. pristina, a conclusion reached by Hudson. This latter form is more characteristic of the horizon with Orionastraea at the top of the Simonstone Limestone (Hudson, 1929a). When the Orionastraea band occurs, a coral band is sometimes developed at the extreme base of the Middle Limestone which carries Lithostrotion, Dibunophyllum and

Sinuatella sinuata, an unusually shaped brachiopod also found in the Gigantoproductus beds.

The main body of the lower Middle Limestone is usually devoid of macrofossils and when the basal coral bands are absent as they frequently are, this horizon is practically unfossiliferous. Specimens referred doubtfully to Erythrospongia occur in the top of the lower Middle Limestone at some localities in lower Waldendale. They show nodular structure and haematite straining, and are possibly poriferids, their horizon of occurence being closely comparable with that described by Hudson (1929b) and Moore (1955).

The Gigantoproductus beds yield abundant G. giganteus Martin (usually var. typica Sarytcheva; more rarely var. crassa. In one instance G. gigantoides Paeckelmann was recorded in addition) with commonly, large sops of Lithostrotion which attain a length of several feet and a height of a foot, and are evidently in the position of growth. Whilst no attempt was made to collect from all localities, extensive collections were made at two points along the outcrop. Restricted horizons within the Gigantoproductus beds yielded faunas which do not appear to be characteristic of the beds as a whole. Thus, at the base of the beds at Morpeth Scar, an excellently preserved assemblage of latissimoid productids and bryozoa occurs in blue calcite mudstone. A noteworthy feature is the unusually good preservation of Rhabdomeson rhombiferum (Phillips) which often splits longitudinally to expose the axial column. In the section at Long Ing Wood, a small brachiopod fauna other than

Gigantoproductus sp. was collected, and several corals occur. It seems that given extensive collecting, a varied fauna may be got from several localities in these beds, as in the case of the records of Moore (1955).

The position of the fossilised G. giganteus is, as Moore remarks, almost invaribly convex downwards (Plate 10 A) and the valves are very commonly articulated. It appears that, like the sops of Lithostrotion, this element of the fauna is also in the original living position. It seems that convex-downwards is the best position since it allows the lighter brachial valve to be lifted so that the shells can gape in order to collect a food supply. Whilst it does not seem possible to assess the reasons for the sudden profusion of Gigantoproductus it seems significant that the incoming of this form is always heralded by a change in the colour of the limestone to blue, with the development of thin bedding. This blue colour persists up to the middle of the Gigantoproductus beds, where these are thick, above which point it gradually becomes paler and the gigantoproducti die out. It seems that the conditions which favoured the development of Gigantoproductus also favoured the growth of Lithostrotion, which is common in lower Coverdale and lower Waldendale in the lower part of the Gigantoproductus beds.

The extent of the Gigantoproductus beds is now known in some detail. Whilst they are everywhere present in the area here described, they appear to have a southern limit close at hand since they are not described from Greenhow and die out southwards at Bare House near Grassington (Joysey, 1955). A clear western limit

was described by Moore (1955) who showed that the beds with Gigantoproductus are absent from upper Wensleydale, but are found in the east of his area, closest to the present ground. Wells (1955) describes Gigantoproductus from the area 15 miles north of the present one and this horizon is known to have an extensive occurrence on the Alston Block.

The upper Middle Limestone is usually poor in macrofossils. Occasionally sops of lithostrotionoid corals occur, as at Caldbergh Gill, and Morpeth Scar, but there is no abundance of this form as there patently is at localities further north (Turner, 1927, Trotter and Hollingworth, 1932, Short, 1954). The commonest macrofaunal development is the incoming of a crinoid biostrome facies which is thickest on the N.W. slopes of Penhill. Masses of limestone are made up solely of stems of unusual thickness (up to $\frac{1}{2}$ ").

The occurrence of a bryozoan fauna in the top beds of the Middle Limestone at Long Ing Wood, Waldendale is not parallelled elsewhere in the area. The bryozoa, which are accompanied by an athyrid-productid fauna make up a large proportion of the rock. The local occurrence of Gigantoproductus giganteus in the upper Middle Limestone at three widely separated localities is noteworthy. Whilst the profusion is not as great as in parts of the Gigantoproductus beds, this upper development strongly resembles the lower one.

A rich coral fauna occurs in the uppermost beds of the Middle Limestone of Slape Gill, Coverdale. The coral band appears to die out within the compass of the section and includes

L.maccoyanum, a form which is much more characteristic of the Five Yard Limestone which overlies this horizon in this section.

Comparisons of the faunal lists of the present author with those of other writers shows the closest parallel with those of Moore (1955) who gives very full records from restricted horizons, which permit of detailed comparison. The coral beds at the extreme base of the Middle Limestone show the following forms in common with the present records: Diphyphyllum fasciculatum, Dibunophyllum bipartitum bipartitum, basaltiform Lithostrotion, and Sinuatella sinuata. The records from the Gigantoproductus beds are also closely similar, with the following forms recorded in common: G. giganteus, G. latissimus, Lithostrotion junceum, L. pauciradiale, D. bipartitum bipartitum, S.sinuata.

Shales of the Middle cyclothem - This horizon is restricted to the S. part of the area and is in any event poorly exposed, but does however yield a fauna at two localities. A comparison of the two lists shows little similarity, which may be a function of grain size. The fauna from Slape Gill is preserved in a coarser shale than the material from Ashes Farm, Waldendale, which is a normal shale fauna (Hudson, 1924b) with an extensive suite of bryozoa, brachiopods and pelecypods. The presence of several types of holothuroid element referable to wheels and plates of different kinds makes a record comparable with that from the shales of the Five Yard cyclothem, which yield a similar extensive fauna incorporating many phyla.

The records from Slape Gill include a high proportion of latissimoid productids, referred to ?'Productus' semiplanus

sp. Schwetzov by W.H.C. Ramsbottom, and a giant transversely elongate orthotetid, which appears to be an undescribed form.

Faunal Lists

Middle Limestone

1. coral bands in basal 4' of Middle Limestone.

Dibunophyllum bipartitum bipartitum (McCoy), 3
---------- sp., 6
Diphyphyllum cf. lateseptatum McCoy, 6
Lithostrotion maccoyanum Thomson and Nicholson, 3
---------- pauciradiale (McCoy), 3
Orionastraea garwoodi Hudson, 1, 2, 3, 5
---------- garwoodi var. pristina Hudson, 4

Productus (?Eomarginifera) sp., 3
Sinuatella sinuata (de Koninck), 3

Index of localities for the above.

1.	The Mount, N.E. slopes of Penhill	(084883)
2.	Chantry Farm, N. slopes of Penhill	(057881)
3.	Morpeth Scar, Penhill	(029878)
4.	Axis of Limley anticline in R. Nidd	(099764)
5.	Park Gill Beck nr. Kettlewell	(987752)
6.	Long Ing Wood, Waldendale	(023861)

2. Gigantoproductus beds

Saccaminopsis fusilinaformis (McCoy), 1

Dibunophyllum bipartitum bipartitum (McCoy), 1
---------- bipartitum crairianum (Thomson), 1
Diphyphyllum fasciculatum (Fleming), 1
Lithostrotion junceum (Fleming), 1
---------- pauciradiale (McCoy) group, 1

Crinoid ossicles, 1,2

Fenestella aff. polyporata (Phillips), 2
Penniretepora sp., 2
Rhabdomeson rhombiferum (Phillips), 2
Rhombopora sp., 2
Trepostome (encrusting type), 2

Crurithyris sp., 2
Productus (Echinoconchus) elegans (McCoy), 2
Productus (Dictyoclostus) sp., 1
Productus (Gigantoproductus) giganteus (Martin) var crassa Sarytcheva, 2
-------- (----------------) giganteus (Martin var typica Sarytcheva, 1,2

Productus (Gigantoproductus) gigantoides Paeckelmann, 1
--------- (----------------) latissimus, J. Sowerby group, 2
--------- (Pustula) rugata (Phillips), 2
"Productus" ?semiplanus Schwetzov, 2
Sinuatella sinuata (de Koninck), 1

Aviculopecten sp., 2

Ostracods, 2

Index of localities for the above:

1. Long Ing Wood, Waldendale, (023861)
2. Morpeth Scar, Penhill, (029878)

3. Upper Middle Limestone

Ammodiscus incertus d'Orbigny, 1
Calcisphaera ? Johnson mss., 1
Endothyra sp., 1
Howchinia bradyana (Howchin), 1

Dibunophyllum bipartitum konincki (Edwards and Haime), 4
Diphyphyllum fasiculatum (Fleming), 1
Heterophyllum sp., 2
Hexaphyllum sp., 1
Lithostrotion maccoyanum Edwards and Haime, 5
Lithostrotion proliferum (Thomson and Nicholson), 5
Palaeosmilia regia (Phillips), 5

Archaeocidarid spine, 1,4

Crinoid ossicles, 1, 2, 3, 4, 5

Fenestella spp., 4
Rhabdomeson sp., 4
Rhombopora sp., 1, 2
Trepostome, 4

Actinoconchus planosulcatus (Phillips), 4
Dielasma sp., 4
Phricodothyris ?verecunda George, 4
Productus (Eomarginifera) sp., 4
Productus (Pustula) rugata (Phillips), 4
Pugnax pugnus (Martin,) 4

Aviculopecten sp., 4

Index of localities for the above:

1. Railway cutting N.N.W. of Limley, Nidderdale (thin section) 099764

2.	Caldbergh Gill, Coverdale (thin section)	092851
3.	Morpeth Scar, Penhill	029878
4.	Crags above Long Ing Wood, Waldendale	023861
5.	Slape Gill, Coverdale	002778

Shales of the Middle Cyclothem

Orobias ornata (Brady), 3

Cladochonus sp., 3
Zaphrentid indet., 1, 3

Archaeocidarid spine, 1, 3
Ancistrum sp., 3
Protocaudina traquairii (Etheridge), 3
Holothuroid plates, 3

Crinoid ossicles (3 includes barbed variants), 1, 3, 4

Fenestella sp., 1, 3
Penniretepora sp., 1, 3
Rhabdomeson sp., 3
Rhombocladia sp., 3
Rhombopora sp., ?1
Sulcoretopora sp., 3

Actinoconchus lamellosa (Léveillé), 1,3
Brachythyris decora (Phillips), 1
Camaratoechia pleurodon (Phillips), 3
Chonetes (Chonetes) hardrensis (Phillips) group, 3
-------- (Tornquistia) sp., 1
Cleiothyridia roysii (Léveillé), 3
Crurithyris cf. amoena (Hall), 1
---------- magnispina George, 3
Dielasma hastata (J. Sowerby), 1
Martinia glabra (Martin), 3
Orthotetid indet, 3
Orthotetid sp., nov.? giant species, 1
Phricodothyris verecunda George, 1
Productus (Dictyoclostus) pinguis mut. senilis Muir Wood, 1
--------- (Eomarginifera) lobatus J. Sowerby, 2
--------- (----------) longispinus J. Sowerby, 3
--------- (----------) minutus Muir Wood, 3
--------- (----------) tissingtonensis Sibly, 3
--------- (Productus) concinnus J. Sowerby, 3
"Productus" semiplanus? Schwetzov, 1.
Rhipidomella michelini (Leveille), 3, 4
Spirifer bisulcatus J. Sowerby group, 2
Spirifer trigonalis (Martin), 1
Tylothyris laminosa (McCoy), 3

Actinopteria spp., 1
Amusium concentricum Hind, 3
Aviculopecten clathratus (McCoy), 3
Leda attenuata (Fleming), 3
Leiopteria laminosa (Phillips), 1
Limipecten dissimilis (Fleming), 1, 3
Nucula cf. laevirostrum Portlock, 3
Mytilimorpha angulata Hind, 3
Pernopecten (Syncyclonema) sowerbyii (McCoy), 3
Posidonia cf. corrugata (R. Etheridge jun.), 3

Bucaniopsis sp., 3
Glabrocingulum sp., 3
?Soleniscus sp., 3
Turriculate gastropod indet., 3

Nautiloid indet., 1

Bairdia sp., 3
Ostracods, 1

Weberides sp. (non-mucronate), 3

Fish scale, 3

Index of localities for the above

1.	Slape Gill, Coverdale	002778
2.	Blayshaw Gill, Nidderdale	098728
3.	Stream near Ashes Farm, Waldendale	008821
4.	R. Nidd above Lofthouse footbridge	101737

PLATE 5

Comparative sections of the Middle Limestone - Waldendale.

PLATE 6

Comparative sections of the Middle Limestone - Coverdale.

The key map given on Plate 5 is for both Plates.

Comparison with Plate 4 B can be profitably made in connection with thickness variations in the upper Middle Limestone (above the Gigantoproductus Beds).

1
MORPETH SCAR

2
LONG ING WOOD

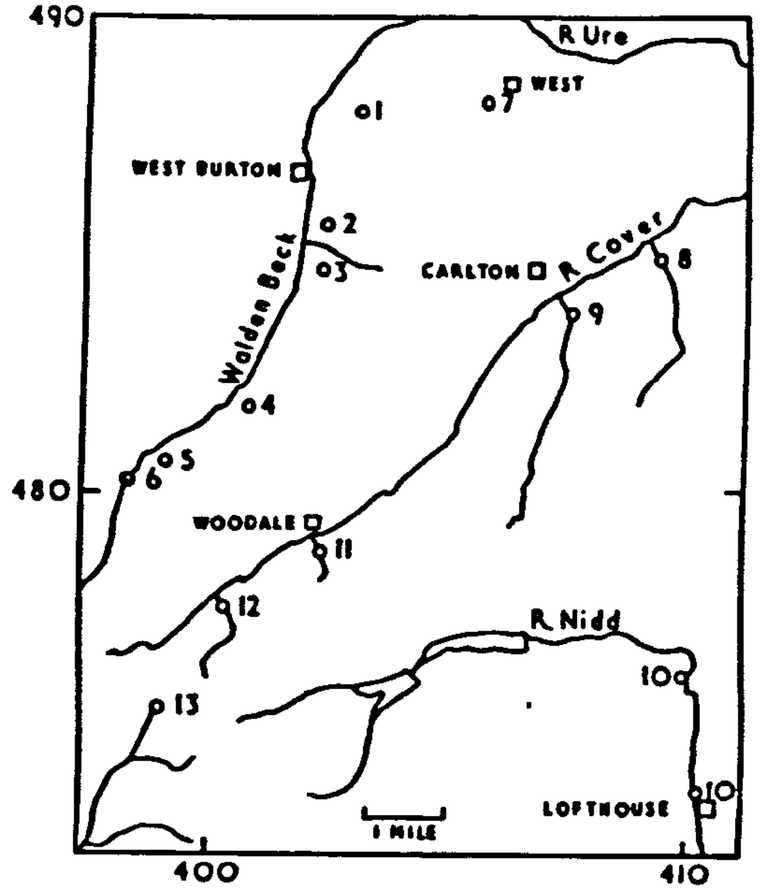
3
SCAR FOLDS

40 FEET
30
20
10
0

Upper Middle Lst.

Gigantoproductus Beds

Lower Middle Lst.



KEY

- SANDSTONE
- SHALE
- CALCAREOUS SHALE
- LIMESTONE
- GIGANTOPRODUCTUS LIMESTONE
- DITTO SPARSE GIGANTOPRODUCTUS
- BIOSTROMAL LIMESTONE
- ? ? ? FIRECLAY
- GAP IN SECTION PROBABLE GEOLOGY INDICATED

O Orionastraea Band

A ditto absent

L Lithostrotion Sops

C Crinoid Biostrome

P Bryozoan Biostrome

B Pseudobreccia

4
ASHES FARM

5
DALES BARN

6
WALDEN BECK

7
CHANTRY &
CAPPLEBANK

8
ULFERS
GILL

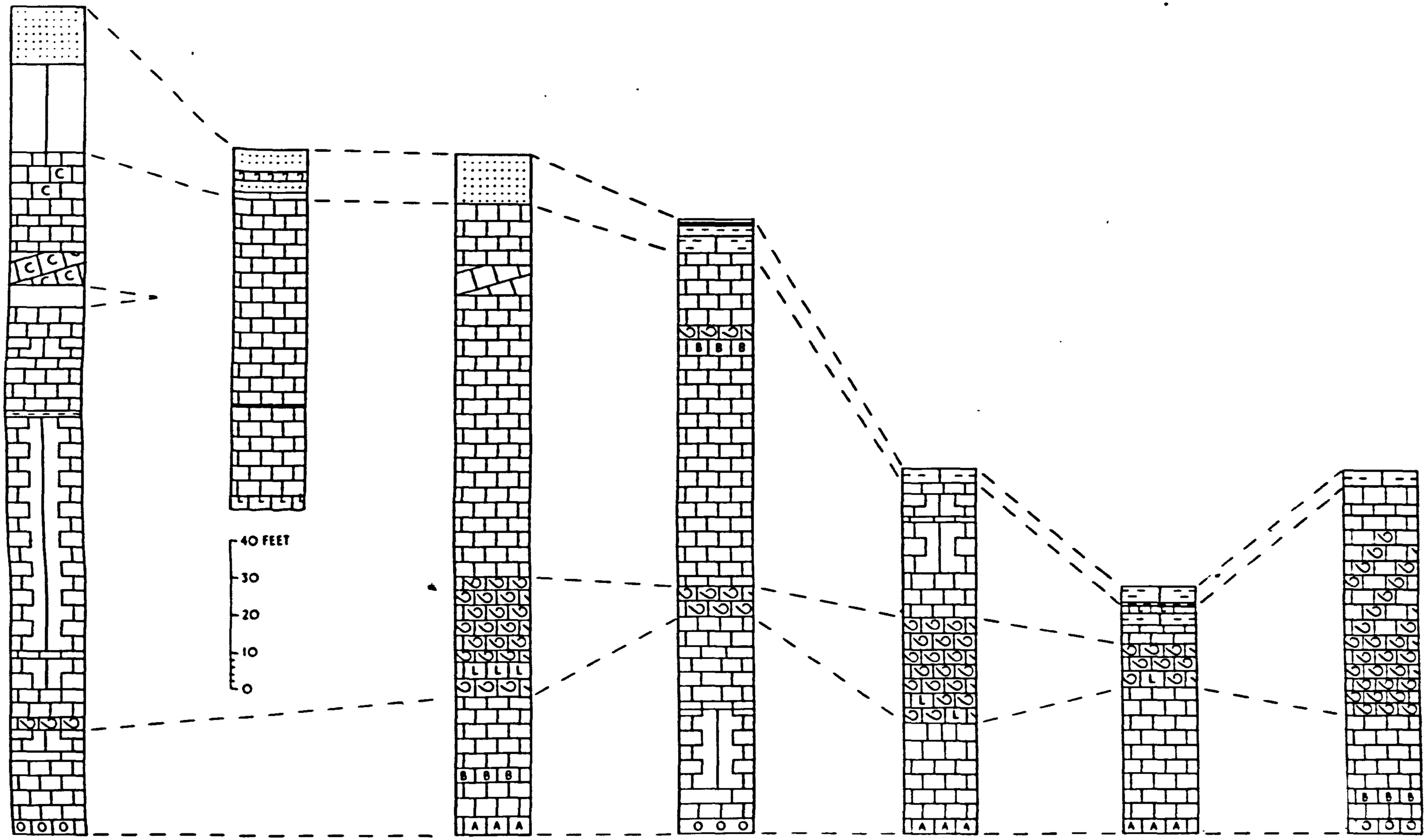
9
LEAD UP
GILL

10
LIMLEY &
LOFTHOUSE

11
RIDGE GILL

12
SLAPE GILL

13
PARK GILL



CHAPTER 4

THE FIVE YARD CYCLOTHEM

The Five Yard Limestone was so named by the lead miners and is equivalent to the 'Impure Productal Limestone' of Phillips (1836). The former term was used by the Geological Survey (Dakyns et al, 1891), though the map covering the present area lists the Third Set Limestone at this level, which was the term applied to this horizon in Swaledale, also by miners.

In the present area the Five Yard Limestone was thought to have been recognised by Tonks (1925) and Chubb and Hudson (1925). It appears that these workers have listed the Three Yard Limestone mistakenly as this horizon. The real Five Yard Limestone was erroneously considered to be the uppermost part of the Middle Limestone. It is only since the work of Moore (1955) that a true picture of the south eastwards thinning of the shales and sandstones of the Middle cyclothem has been built up. The present author, using his detailed conclusions has been able to establish with little doubt that both the Five Yard and Three Yard Limestones are represented in the present area. Moore shows that the Five Yard Limestone occurs in two leaves separated by a fossiliferous shale. The lower leaf of the limestone carries a fauna of Gigantoproductus and compound corals. In the present area the Five Yard Limestone of upper Waldendale and upper Coverdale similarly shows two leaves, though the intervening shales are never satisfactorily exposed. The lowest leaf is highly fossiliferous and carries a fauna which corresponds in its broad

elements with that recorded by Moore from a similar horizon; the upper one is in contrast much less fossiliferous, as in the experience of Moore in upper Wensleydale. The measures above the limestone are thinner in the present area than in upper Wensley dale and are more consistently s haley and more wholly fossiliferous. The present records from this level are more extensive than those of Moore, though it appears that a paucity of exposures in the fossiliferous beds of this age in upper Wensleydale may have something to do with this discrepancy.

Stratigraphy

The Five Yard Limestone has been mapped in the present area in upper Coverdale, upper Waldendale and in Nidderdale, but appears to be absent in lower Waldendale, lower Coverdale and on the north slopes of Penhill. Beds of the Five Yard cyclothem overlying the limestone have been mapped everywhere the limestone is present, but in places where the limestone is absent difficulties of interpretation arise which are discussed further in the present chapter.

The Five Yard Limestone of upper Waldendale and upper Coverdale is about 7'6" in thickness and is rarely fully exposed. Characteristically the lower portion consists of blue calcite mudstone, this forms a massive stratum carrying a distinctive fauna of Gigantoproductus and lithostrotionoid corals, which when washed by water, show up white against the polished blue limestone surrounding them. The most distinctive forms are Lithostrotion maccoyanum and species of Diphyphyllum, with rarer haploid corals

(see Plate 9A for the distribution of this fossiliferous horizon). The upper leaf of the limestone in Coverdale and Waldendale is apparently about 2' thick and appears to be separated from the lower leaf by shales which are never fully seen and are probably less than 1' thick. The upper leaf of the limestone is not notably fossiliferous.

The Five Yard Limestone in Nidderdale varies from 5' to 14' in thickness and is seen in situ at Lofthouse and in How Stean Beck. It is here a grey, detrital limestone with a brachiopod fauna which differs markedly from that of the beds seen at this level to the N.W. in Coverdale and Waldendale. A shale parting exists within the limestone. The more massive part of the limestone underlies this parting as in the area to the N.W. The parting is usually much chertified in the Nidderdale sections.

In the north of the present area, in lower Waldendale, lower Coverdale and on the N. flank of Penhill the Five Yard Limestone appears to be absent (see Plate 9A). Exposures at this level are not seen on the N. flanks of Penhill, but in lower Coverdale only one limestone occurs between the Middle and Underset Limestones. It is a virtual certainty that this is the Three Yard Limestone since the survey of the N.W. slopes of Penhill strongly suggests that the Five Yard Limestone dies out to the north. Other reasons for the view that only the Three Yard Limestone persists in the north of the area are given in the next chapter.

The measures above the Five Yard Limestone in the present area are almost entirely shales in upper Coverdale and upper Waldendale. They contrast with the more varied lithologies

described by Moore (1955) at this level in Upper Wensleydale where these beds are substantially thicker. In the present ground these shales vary from 0' to 45'6" in thickness and are at their thickest at Angram in Nidderdale. The shales are developed in upper Waldendale and upper Coverdale, are fairly constant in thickness - 30' is a good average (see Plates 7,8) and always contain fossils, especially in the lower beds. The fauna is preserved in a dark grey shale as calcite films and comprises a large normal shale assemblage. Chalybite nodules are frequently developed at this level and are also seen in the exposures at Angram in Nidderdale where the shales are of a somewhat similar lithology to those seen in upper Coverdale, though the rock is fresher at Angram. In the exposures in the Nidderdale inliers near Limley and in the Howstean valley these same shales are thinner and more silty, but are still fossiliferous, with a fauna consisting largely of brachiopods. The correlation of the exposures at Angram with those in Coverdale is assisted by the lithology and thickness of the division and also by the commonness with which trilobite remains occur - these are much more abundant at this than other horizons and include both non-mucronate and mucronate forms.

In central Waldendale and central Coverdale a sandstone is developed under the Three Yard Limestone (Plate 7,8; the southern limit of sandstones under the limestone is shown in Plate 9B). In Waldendale, north of Ashes Farm outcrops suggest that the sandstone is locally very thick and virtually cuts out the fossiliferous shales which figure in the sections in the upper

part of the dale (Plate 7). The exact horizon of the sandstones developed below the Three Yard Limestone is a little puzzling since it is possible that two sandstones may be involved. It is possible that the sandstone developed in lower Waldendale and in the area around Horse House in Coverdale below the Three Yard Limestone is in fact a continuation of the sandstone between the upper and lower leaves of the Three Yard Limestone in upper Waldendale and upper Coverdale; this view is unfortunately not subject to proof, but is suggested as possible answer to this problem in Plate 7 and Plate 21B. Due to the fact, however, that the sandstonœs below the Three Yard Limestone, whether it be developed as one or two leaves, have a definite southern limit this has been given in Plate 9B. It seems possible however that the sandstone of Hindlethwaite Gill, Coverdale and of Scar Folds, Waldendale is equivalent to that developed between the upper and the lower leaves of the Five Yard Limestone in upper Waldendale and upper Coverdale, and therefore has not the southern limit assigned to it in this diagram. The limits of the development of sandstonœs within the Three Yard Limestone are shown in Plate 9A. If the view is correct that the sandstone widely developed below the Three Yard Limestone (upper leaf) in mid-Waldendale and mid-Coverdale is in fact the correlate of the sandstone above the lower leaf of limestone in the upper part of these dales, the sandstones below the lower leaf of the limestone in Fall Gill and West Gill, Coverdale are at a distinctly lower horizon and must be regarded as a local development, as the correlation lines for sections 9, 10, Plate 7 suggest.

The beds between the Middle and Three Yard Limestones of lower Coverdale are chiefly sandstones and have been considered in the text as part of the Middle cyclothem since no proof of their exact age has been forthcoming. They are however lithologically dissimilar to the strata above the Middle Limestone in the S. of the area where the Five Yard Limestone is developed, where they are all shales. It is possible that all or part of these sandstones in lower Coverdale are equivalent to that which is developed below the Three Yard Limestone further south. This sandstone is either equivalent to the sandstone parting between the upper and lower leaves of the Three Yard Limestones (and therefore properly part of the Three Yard cyclothem) or simply to the sandstone member of the Five Yard cyclothem, if in fact this last horizon exists as a widespread bed. The section on Plate 21 have been used to express the former of these two possibilities, but in the text, for purposes of orderly presentation and to avoid speculation, these sediments have been referred to as part of the Middle Cyclothem since they directly overlie the limestone of that name, and details of their thickness have been incorporated in sections for the Middle cyclothem in Plates 5, 6.

The survey of the beds of the Five Yard cyclothem has only involved feature mapping on the N.W. slopes of Penhill where the limestone appears to die out according to the evidence based on features and sink holes. Normally beds of this cyclothem are poorly exposed and are seen only in stream sections. The Five Yard Limestone is usually only partially seen in Coverdale and Waldendale, but more complete sections are seen in Nidderdale

where it is thicker. The shales above the limestone seldom form clear exposures, except in rare river-side scars and the mapping of these beds has been carried out on indications of fossiliferous shale and of chalybite nodules which are abundant at this level. This technique is especially applicable in Waldendale. The mapping of lines of sink holes in the top of the Middle Limestone, especially in Waldendale, provides a fairly accurate indication of the horizon of the Five Yard Limestone which sometimes outcrops in the walls of the sink.

Details

Five Yard Limestone - exposures are described in sequence from Waldendale, Coverdale and Nidderdale.

Waldendale - The Five Yard Limestone is exposed in several stream courses draining into Walden Beck, but outcrops rarely show the entire thickness of this horizon.

In Walden Beck, near Walden Head (979794), the following section is seen (Plate 7):

-	section obscured
6"	blue, fine grained limestone
9"	fossiliferous shale
3'	blue, fine grained limestone with a Lithostrotion-Gigantoproductus fauna. Characteristic forms include Aulophyllum fungites pachyendothecum and Lithostrotion pauciradiale
6"	fossiliferous shale with thin limestone ribs

The beds mapped as the Five Yard Limestone are at least 4'3" thick and occur in two leaves.

The Five Yard Limestone with a characteristic Lithostrotion-Gigantoproductus fauna is exposed at several points down-dale from the above exposure. At Dales Barn (990808) the limestone is probably

in two leaves as at Walden Head. The section here seen is:

1' blue, fine grained limestone
6' gap
1' blue, fine grained limestone with Lithostrotion fauna.

The section at Ashes Farm (009821) is slightly disturbed by slipping of beds and there are two, or possibly three separate beds of limestone. The measured section here is:

1'9" fine grained, blue limestone without conspicuous fossils
- possibly thin shale parting
1' fine grained blue limestone (apparently distinct from the beds above and below)
6" approx. gap
2' fine grained blue limestone with a Lithostrotion-Gigantoproductus fauna

The Five Yard Limestone outcrops at two points north of Ashes Farm (Plate 9A shows the position of these exposures) and is again almost certainly present in a feature carrying potholes above Long Ing Wood (023861). Whilst there is no trace of the Five Yard Limestone along the line of the measured section at Scar Folds, intermediate between Long Ing Wood and Ashes Farm, its probable position has been inserted on Plate 7. The feature above Long Ing Wood dies out to the north and there is no evidence either from exposure or potholes of the presence of the Five Yard Limestone on the N. side of Penhill. It is therefore assumed that the limestone is absent north of the broken line on Plate 9A which incorporates all the known exposures of the Five Yard Limestone. Whilst the evidence for the absence of the limestone on the north face of Penhill is largely negative, the sections in lower Coverdale show that it is definitely absent in that area.

Coverdale - sections are rare and incomplete. The best section seen is in Slape Gill (002778) which shows two leaves of limestone:

1' grey-blue limestone (top not seen)
2' unexposed
5' fine grained, blue limestone with a Gigantoproductus-Lithostrotion fauna. The forms recorded were - Lithostrotion maccoyanum, Dibunophyllum bipartitum bipartitum, and Diphyphyllum lateseptatum

The several sections seen in upper Coverdale (Plate 9A) frequently show the part of the limestone which carries the Lithostrotion-Gigantoproductus fauna which typifies this horizon in upper Waldendale and upper Coverdale. Occasionally an upper leaf is seen which overlies a gap in the section which is probably located on a thin shale parting. The most complete section is in Lords Gill (019788) which shows:

2'6" blue limestone (top not seen)
3' gap
2' blue limestone with a fauna of basaltiform Lithostrotion and Gigantoproductus (base not seen)

The furthest north of all the exposures in Coverdale is in Deerclose Gill (045811) where the following section is seen:

2' blue limestone with Lithostrotion and Gigantoproductus
1' black shale with marine fauna

All the available evidence in lower Coverdale, north of the broken line on Plate 9A, points to the absence of the Five Yard Limestone as a result of non-deposition or of erosion subsequent to deposition.

Nidderdale - The Five Yard Limestone in Nidderdale unfortunately does not show the coral-brachiopod fauna which characterises it

in ground to the N.W. Hence the correlation of this horizon is largely based on the lithology and fauna of the shales which overlie it, as well as its position in the sequence.

The Five Yard Limestone was encountered during the construction of the dam trenches at Angram (5' thick) and Scar House (7' thick) and is still visible near the head of the Scar House Reservoir, when the water in the dam is very low. The limestone is well exposed in the R. Nidd above Lofthouse footbridge (101735) where the following section is seen:

1'8"	massive, fine grained blue chert which is probably secondary after limestone
11"	platy cherts, presumably secondary after shales
15"	brittle, partly chertified shale
8'	fine grained, pale grey limestone with scattered crinoid ossicles showing a blue colouration towards the base

In How Stean Beck (085742) a similar section is seen. The lower leaf is thick and is followed by more variable thin limestones with shales and chertified shales. The section here seen is as follows:

1'6"	grey, detrital limestone
1'6"	blue, partly chertified limestone
2'	black chert
1'6"	platy chert
7'6"	approx. grey to grey-blue limestone with a brachiopod fauna, including Dictyoclostus hindi, Echinoconchus punctatus and smooth brachythyrids.

The beds above the main leaf of the limestone show a deal of variation within the limits of the protracted stream section. The maximum development of limestone in this upper leaf is 4'6", which is separated from the lower part of the limestone by shales or their chertified equivalents. It seems possible that the two leaves of the limestone, a lower well developed leaf and an upper

thin and variable leaf, are equivalent to similar developments in the sections in Coverdale and Waldendale. The fauna and lithology of the lower leaf contrast with that recorded from Coverdale and Waldendale however - no trace was found of the Lithostrotion-Gigantoproductus fauna in Nidderdale, whilst it is widespread to the N.W. (Plate 9A).

11' of grey, detrital limestone exposed in the section at Blayshaw Gill (098728) is here referred tentatively to the Five Yard Limestone. This same horizon is also seen in the bed of the Nidd at Lolley Scar.

Shales and Sandstones of the Five Yard cyclothem - complete sections are very rare. Whilst it cannot be proved that these beds are absent in the north of the present area, the convention has been followed in the text of treating all strata in lower Coverdale which occur between the Middle and Three Yard Limestones as part of the Middle, rather than the Five Yard cyclothem.

Waldendale - complete exposures are lacking, but fossiliferous shales carrying a normal shale fauna preserved as calcite films, with scattered chalybite nodules, are seen at several points. These are here detailed progressing north, up-dale.

The section on the right bank of Walden Beck, near Walden Head (980793) shows 15' of scree in fossiliferous shales carrying chalybite nodules, immediately underlying the Three Yard Limestone. This is the most complete exposure on the E. side of Waldendale and the total estimate thickness of beds is here about 30' (Plate 7). At Dales Barn (990808), two feet of shale scree with chalybite nodules occur. The total thickness of the shales appears to be

here about 27'. As the outcrop is traced down the dale, occasional stream sections shows indications of shale chips and chalybite nodules.

The section at Ashes Farm (009821) is also incomplete and shows 7' of soft, brown shales with a normal shale fauna preserved in calcite. The total thickness of beds here is quite possibly about 36' (Plate 7).

Above Scar Folds (021849) the next indications of this horizon are seen. It appears that the shales of the Five Yard Cyclothem have been replaced laterally by a sandstone which forms a well defined feature with numerous sandstone blocks (Plate 7). The rock is here a white to golden coloured compact, very fine grained quartz sandstone which is sometimes spotted by limonite. This is lithologically very similar to the beds between the Middle and Three Yard Limestones on the N. Slopes of Penhill and it is possible that they were deposited at the same time. The convention has however been followed of regarding the sandstones on Penhill as part of the Middle cyclothem owing to the lack of conclusive evidence as to whether they belong to the Middle cyclothem, or to an attenuated Five Yard cyclothem. Alternatively they may be eqivalent to the sandstone within the Three Yard Limestone further south.

At Long Ing Wood (024860) the section is similar to that at Scar Folds. The measured section (Plate 7) was based on features and there appears to be a thick sandstone here also, which possibly overlies a thin shale. The blocks on the surface are of a very fine grained quartz sandstone with a few kaolinised feldspar grains.

Coverdale - the exposures in Coverdale at this stratigraphic level are seldom complete, but include one excellent section, that in the right bank of the R. Cover below Hunterstone Bank (993769). The entire 24' of shale which here comprises the strata between the Five Yard and Three Yard Limestones is fossiliferous. The upper portion is least well exposed, but appears to be coarser grained and less coherent, with less well preserved fossils. The best fossils were collected at 5' from the base of the shales, which are blue grey in colour and contain chalybite nodules. Good specimens also occur in some abundance at 7', 9' and 15' from the base of the section, and constitute a normal shale fauna preserved as calcite films, a detailed record of which is given in the palaeontological section at the end of this chapter.

At Slape Gill (002778) the shales are inadequately seen at this level, but the adjoining exposures suggest that they are here about 40' thick. A small exposure yields fossiliferous shale chips with chalybite nodules (Plate 8). In Downs Gill (007785) (Plate 7) the complete shale parting is not seen, but the upper beds are here abundantly fossiliferous and include two thin limestones. These are the only limestones recorded in the shales of the Five Yard cyclothem in the present area, but Moore (1955) provides records of a limestone at this horizon in upper Wensleydale, where the beds of the cyclothem are thicker. West Gill (013789), Fall Gill (018796) and Lords Gill (019788) (Plate 7) show exposures of portions of the shales and all these localities have yielded faunas. In Fall Gill and West Gill the Three Yard Limestone rests on a sandstone, whereas usually in upper Coverdale it rests

directly on the shales of the Five Yard Cyclothem. The southern limit of this sandstone, which is a fine grained sandstone 17' thick in West Gill is shown on Plate 9B.

The exposures in Hindlethwaite Gill are also within the area in which the shales of the Five Yard cyclothem are overlain by sandstone which is here at least 9' thick. The sandstone carries heavy limonite staining and a pronounced calcareous band 2' above the base which is possibly a degenerate representative of the lower leaf of the Three Yard Limestone which is developed further up the dale. If this is the case, this sandstone should be more properly considered together with the Three Yard Limestone. The sandstone rests on 30' of beds which are inadequately exposed, but appear to be shales in which no fossils are seen in the available exposures.

Since the Five Yard Limestone is absent in lower Coverdale, the sandstone which occurs there between the Middle and Three Yard Limestone has been tentatively considered as part of the Middle cyclothem. However it seems likely that it is in reality the sandstone of the Five Yard cyclothem or the equivalent of that between the two leaves of the Three Yard Limestone higher up the dale, though this cannot be proved (see Plate 21 which summarises the available data).

Nidderdale - all the beds of the Five Yard cyclothem are shales in this area and show large thickness variations. The thickest development of the shales of the Five Yard cyclothem is seen in the section near the Head of Scar House Reservoir.

The Nidd below Nidd Washfold (025760) and the head of the Angram Dam show several scars in shale which show a maximum of 15' of unfossiliferous beds which contain limestone nodules in the uppermost part. The Angram Dam trench passed through the full thickness of beds at this level. The upper 28' of beds are exposed in a scar on the S. bank of the Scar House reservoir, below Angram Dam (046766) (Plate 8). The section shows:

18'	black, brittle unfossiliferous, micaceous shale
10'	black, brittle fossiliferous shales with a normal shale fauna preserved as calcite films and containing numerous chalybite concretions. The most fossiliferous beds occur in the lowest 5' of strata seen in this section.
18'	shales - not seen, but recorded in Angram trench, and presumably containing a fauna
-	Five Yard Limestone recorded from the Angram trench

In the Scar House dam trench these same beds are only 29' thick, compared with the thickness of 45'6" at Angram. Whilst no exposures are now seen at Scar House it may be supposed that these beds were here also fossiliferous.

At Dry Wath an exposure on the right bank of the R. Nidd (102755) shows (Plate 8):

-	Three Yard Limestone
2'6"	calcareous shale, breaking unevenly and with a badly preserved brachiopod fauna
2'6"	gap, presumably shale
-	Five Yard Limestone

The shales are here much thinner than at Angram, and there seems to be little doubt about the horizon of these beds, which are considerably thinner in the Lofthouse area than in the Angram region. The shales round Lofthouse are consistently coarser in

grain and split less readily; the fauna is also more restricted and consists chiefly of brachiopods.

Shales of the Five Yard cyclothem are exposed at two points in the right bank of Howstean Beck, near Well House. The exposure at 082743 shows:

-	Three Yard Limestone
12'	friable weathering shales with a brachiopod fauna preserved as calcite films present in the lower portion
3'	shales with calcareous fossils and three thin limestones
-	Five Yard Limestone

The exposure at 084742, which is further downstream, shows 20' of shale at this horizon.

In Blayshaw Gill (099728) 5' of silty shales underlie a limestone presumed to be the Three Yard Limestone which in turn appears to be overlain by the Grassington Grit. The shales yield a poorly preserved brachiopod fauna. The section at Lolley Scar is the furthest south that Yoredale facies beds are seen in the Nidderdale inliers. About 12' of shale scree rest on a limestone and are in turn overlain by limestone blocks which are not in situ, but almost so. These are probably overlain by sandstone of the Grassington Grit Group, blocks of which occur here on the hill side.

Palaeontology

The fauna of the Five Yard Limestone in upper Coverdale is a distinctive coral-brachiopod assemblage consisting very largely of lithostrotionoid corals and Gigantoproductus preserved in pale calcite, contrasting with the dark blue matrix of calcite mudstone. The fossils show up in a distinctive manner on water polished

sections of the rock which show the structures of the corals in a very detailed manner. The most common corals, Lithostrotion maccoyanum and Diphyphyllum spp., occur in sops which are apparently not much disturbed from their growth position. The accompanying fauna, with the exception of Gigantoproductus which is a common record, is a sparse one and the corals constitute the chief faunal element. The lists from the ground here described largely contrast with those of Moore (1955) in the absence of Lithostrotion junceum in the present records, whilst Moore records several pelecypods and provides an altogether more full faunal list. The records of Aulophyllum fungites, Dibunophyllum bipartitum, and Diphyphyllum are held in common by Moore and the present author. The absence of compound Lithostrotion in his list is remarkable since the exposures in Coverdale and Waldendale show these forms commonly. Biofacies change does occur at this horizon in the present area however, since the records from Nidderdale do not include corals. The collection from Howstean Beck provides forms which are not recorded elsewhere at this horizon and includes a purely brachiopod assemblage. The records of Tonks (1924) from this horizon at Lofthouse yield a similar faunal assemblage with corals apparently absent.

The shales of the Five Yard cyclothem are fossiliferous throughout the present area and consist of moderately fissile dark blue shale with numerous fossils preserved as calcite films. The faunal list given here is the longest from shales of Yoredale facies recorded during the present work and is a very complete normal shale assemblage, the largest collection of which was made

from Hunterstone Bank where the bulk of these beds are well exposed. Zaphrentids occur in small numbers at the majority of exposures and are sometimes uncrushed; preservation is in calcite. Holothuroid elements are present in an abundance unparallelled at other horizons. They are plates of varying shape, the most characteristic of which are referred to Ancistrum sp. and Protocaudina traquairii, both of which are perforated plates with the holes arranged in a distinctive pattern. Ancistrum seems always to be more common than Protocaudina and it is thought that the two plates possibly came from the same animal, but the element called Ancistrum was present in larger numbers, since it is well known that the skeleton of the holothuroid is made up of a variety of plates which include petaloid plates and hooked rods, also recorded from the separations made from the shale of Hunterstone Bank. Crinoid ossicles are chiefly round forms, but polygonal types also occur. Bryozoa are common and include the bulk of common genera found in shales of Yoredale facies.

Brachiopods are prolific in genera and species and include a variety of forms referred to Productus and Chonetes. The record of Gigantoproductus latissimus is interesting because it is only from one locality, but occurs there in some abundance. This is in keeping with the apparently gregarious habits of Gigantoproductus spp. Pelecypods and gastropods are rich in species, but less so in numbers of individuals. Ostracods are quite numerous and the exposure at Hunterstone Bank has yielded a large fauna containing several new species and a new genus (determinations are by Dr. F.W. Anderson). The list of ostracods includes several well known

genera which occur in beds of Yoredale facies, notably Bairdia, Kirkbyia and Paraparchites, forms also recorded from shales of the Simonstone cyclothem in the present area. Trilobites are more common in these shales than at any other locality in the present area and include both mucronate and non-mucronate forms. Mucronate formas have only been recorded from the locality at Hunterstone Bank where they occur at several levels and are not confined to one thin band. The records include several complete carapaces and one specimen with hypostome preserved. The non-mucronate forms collected at the head of the Scar House Reservoir, Nidderdale are fragmentary, but sufficient parts of the animal were collected to support their identification as Weberides barkei (Woodward), a new species first recorded from the Angram area of Nidderdale (Woodward, 1906).

The records of Moore (1955) from the shales of the Five Yard cyclothem come from more than one horizon, since these beds are very thick in the north and west of his ground. A siltstone in the lower part of these beds yielded Weberides mucronatus and a few brachiopods with long ranges which are also recorded in the appended lists.

Faunal Lists

Five Yard Limestone

Aulophyllum fungites (Fleming) var pachyendothecum Thomson, 3
Dibunophyllum bipartitum bipartitum (McCoy), 1
Diphyphyllum fasciculatum (Fleming), 1
Diphyphyllum lateseptatum McCoy, 6
Lithostrotion maccoyanum M. Edwards and Haime, 1,2
---------- pauciradiale McCoy, 3,4

Crinoid ossicles, 3,4,5

Trepostome bryozoan, 1

Athyrid indet, 4,5
Brachythyris ? decora (Phillips), 5
Chonetes (Chonetes) zimmermanni Paeckelmann, 5
Productus (Buxtonia) scrabiculus (Martin), 5
--------- (Dictyoclostus) hindi Muir-Wood, 5
--------- (Echinoconchus) punctatus (Martin), 5
--------- (Gigantoproductus) sp., 1,3,4
Spirifer trigonalis (Martin) group, 5

Ostracod, 1

Index of localities for the above

1.	Slape Gill, Coverdale	002778
2.	Crab Gill, Coverdale	009781
3.	Walden Beck, near Walden Head	979794
4.	Stream above Kentuckey House, Waldendale	989807
5.	How Stean near Well House	082743
6.	Stream below Ashes Farm, Waldendale	009821

Shales of Five Yard Cyclothem

Plant remains, 1

Ammodiscus incertus (d'Orbigny), 1
Endothyra bowmani Phillips, 8
Orobias ammonoides (Brady), 1,5

Cladochonus sp.
Fasciculophyllum carruthersi Hill, 1
Zaprentoids indet. 1,2,3,5,8

Ancistrum sp., 1,8
Holothuroid plates (undifferentiated), 1,5,8
Protocaudina traquairii (Etheridge), 1

Crinoid ossicles 1,2,5,7,8

Fenestella plebeia McCoy, 1,2,?8
Fenestella sp. 1,2,4,5,6,8
Penniretepora sp., 2,3
Polypora sp., 1
Rhabdomeson sp., 2, ?8
Rhombopora sp., 1
Trepostome bryozoan, ?1

Annelid trails, 1,3

Actinoconchus lamellosa (Léveillé), 1
Brachythyris decora (Phillips), 1,?3
Camaratoechia pleurodon (Phillips), 1,3
Chonetes (Chonetes) hardrensis (Phillips) group, 8
-------- (--------) cf. mosensis Demanet, 1
-------- (Isogramma) concentrica de Koninck, 5
-------- (Plicochonetes) sp., 1,5
-------- (Tornquistia) politus McCoy, 5
Cleiothyridina roysii (Léveillé), 1,5
Crurithyris magnispina George, 2,3
---------- urei (Fleming), 1,7
Martinia glabra (Martin), 1,3,6
Orbiculoidea nitida (Phillips) ovate variety, 1
Phricodothyris sp., 2,5, 7
Productus (Cancrinella) undatus (Defrance), 1
--------- (Dictyoclostus) cf. antiquatus J. Sowerby, 1
--------- (----------) cf. multispiniferus Muir-Wood, 1
----------(Echinoconchus) punctatus (Martin), 1
----------(Eomarginifera) sp., 1,2
----------(Gigantoproductus) latissimus J. Sowerby group, 8
--------- (Productus) concinnus J. Sowerby, 3
Pugnax pugnus (Martin), 5
Rhipidomella michelini (Léveillé), 1,4
Schellwienella crenistria (Phillips), ?3
Schizophoria resupinata (Martin), 5,7
Schuchertella sp., 1
Spirifer bisulcatus J. Sowerby group, 3,5, 7
-------- convolutus Phillips, 5
-------- trigonalis (Martin) group, 3

Amusium concentricum Hind, 1,3,5,7,8
Aviculopecten clathratus (McCoy) juv. 1,2
---------- gentilis (J. Sowerby), 2,8
---------- knockonniensis (McCoy), 1
---------- sp., 5
Cypricardella rectangularis (McCoy), 2
Edmondia arcuata (Phillips), 1
Grammatodon reticulatus (McCoy), ?3
Leda attenuata (Fleming), 3
---- aff. laevistriata (Meek and Worthen), 3
Limipecten dissimilis (Fleming), 3
Mytilimorpha angulata Hind, 2
Nucula laevirostrum Portlock, 3
Nuculopsis cf. gibbosa (Fleming), 2
---------- ventricosa (Hall), 3
Nuculid indet., 5
Parallelodon semicostatus (McCoy), 1
Pernopecten (Syncyclonema) sowerbyi (McCoy), 1,3
Pinna mutica McCoy, 1
Pseudamusium ellipticum (Phillips), 8

Aclisina sp., 2,5
Bellerophon costatus J. de C. Sowerby, 8

Bucaniopsis decussatus (Fleming), 1
Bucaniopsis sp., 2
Euphemites urei (Fleming), 1
Macrochilina sp, 5
Straparolus carbonarius (J. Sowerby), 1,2,8
Zygopleura sp., 1
Turriculate gastropod indet., 8

Hyolithus sp., 1,2

Dolorthoceras attenuatum (Fleming), 1
Epistroboceras sp., 1, ?6

? Acronotella sp. nov., 1
Bairdia hisingeri (Münster), 1
Cardiniferella scrobiculata Jones, Kirkby and Brady, 1
Coryellites sp., 1
Cribroconcha cf. costata Cooper, 1
Cribroconcha sp. nov., 1
Ctenobolbina sp. nov., 1
Healdia cornigera (Jones and Kirkby), 1
Kirkbya permiana Jones, 1
Paraparchites sp., 1
Roundyella aff. simplicissima (Knight), 1
Ostracod gen. et sp. nov., 1
Undertermined ostracods, 5,8

? Metaphillipsia seminiferus (Phillips), 1
Weberides barkei Woodward (non-mucronate species), 3
Weberides mucronatus (McCoy), 1,2
Weberides sp. (mucro not seen, if present), 5,8

Index of localities for the above

1. Right bank of R. Cover below Hunterstone Bank, Coverdale 992769
2. Stream below Ashes Farm, Waldendale 011819
3. Scar on S. bank of Scar House Reservoir, Nidderdale 046766
4. West Gill, Coverdale 013789
5. Lords Gill, Coverdale 019788
6. Right bank of R. Nidd near Limley Farm, Nidderdale 002755
7. Right bank of Howstean Beck, near Well House 082743
8. Fall Gill, Coverdale 018796

PLATE 7

comparative sections of the Five Yard and Three Yard cyclothems- Coverdale and Waldendale.

PLATE 8

Comparative sections of the Five Yard and Three Yard cyclothems- upper Coverdale, Park Gill Beck, and Nidderdale.

The key map is a guide to the sections given on both diagrams.

Refer also to Plate 9 for further details of these beds.

50 FEET
40
30
20
10
0

1 LOW DOVESCAR

2 HULLO BRIDGE

3 ELM GILL & CALDBECH GILL

4 HINDLETHWAITE GILL

5 LONG ING WOOD

6 SCAR FOLDS

7 ASHES FARM

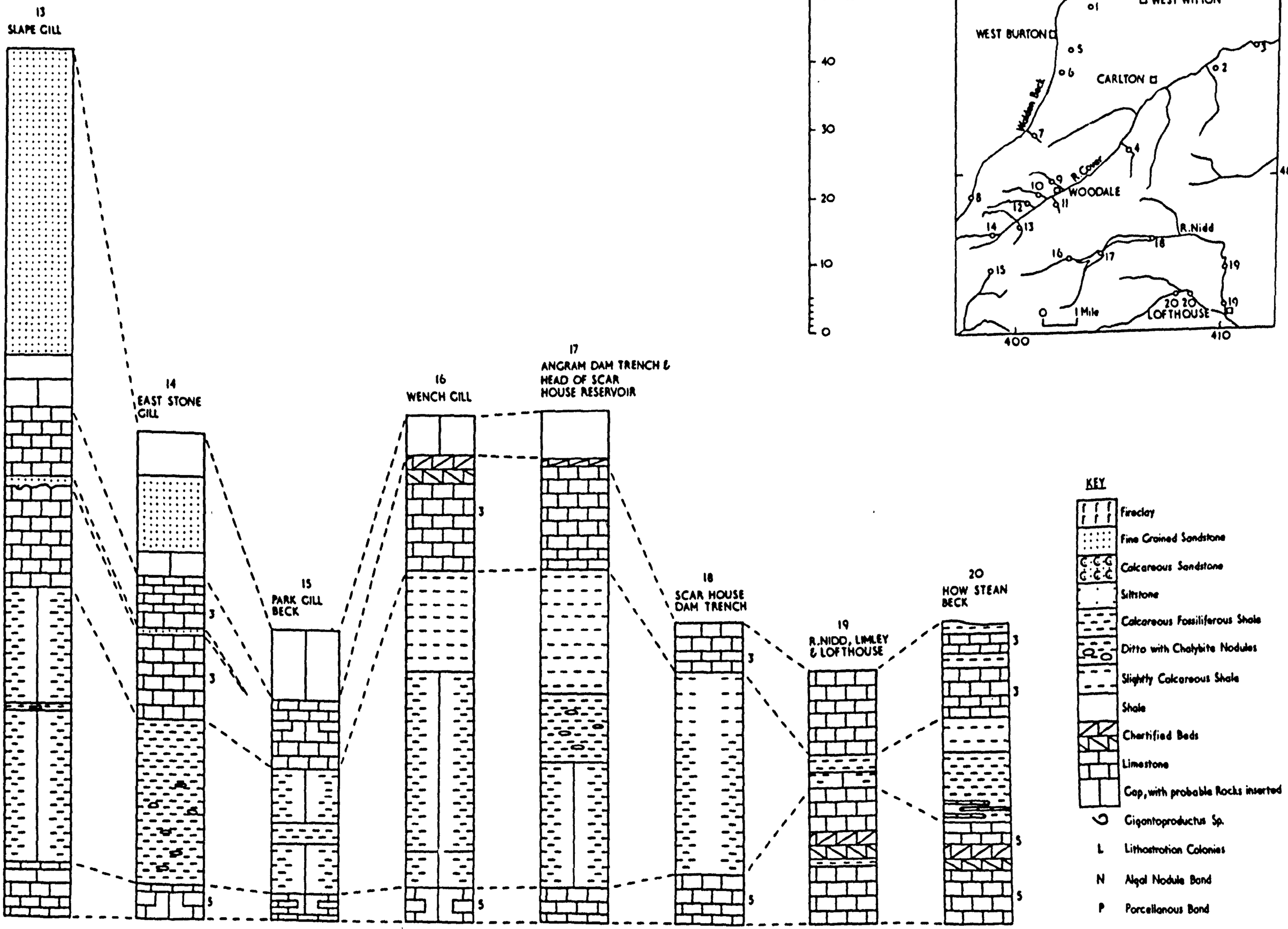
8 WALDEN BECK

9 FALL GILL

10 WEST GILL

11 LORDS GILL

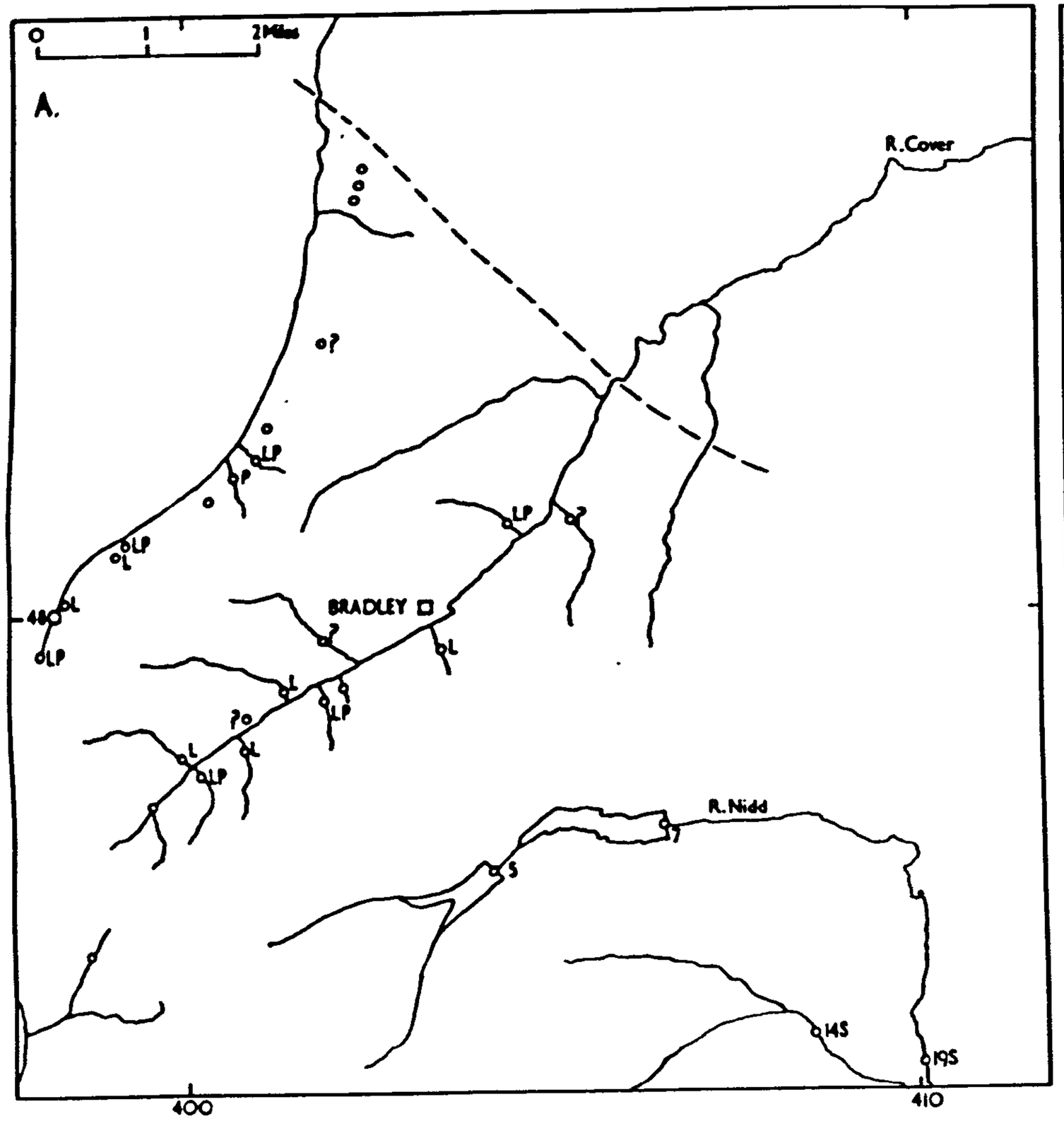
12 DOWNS GILL

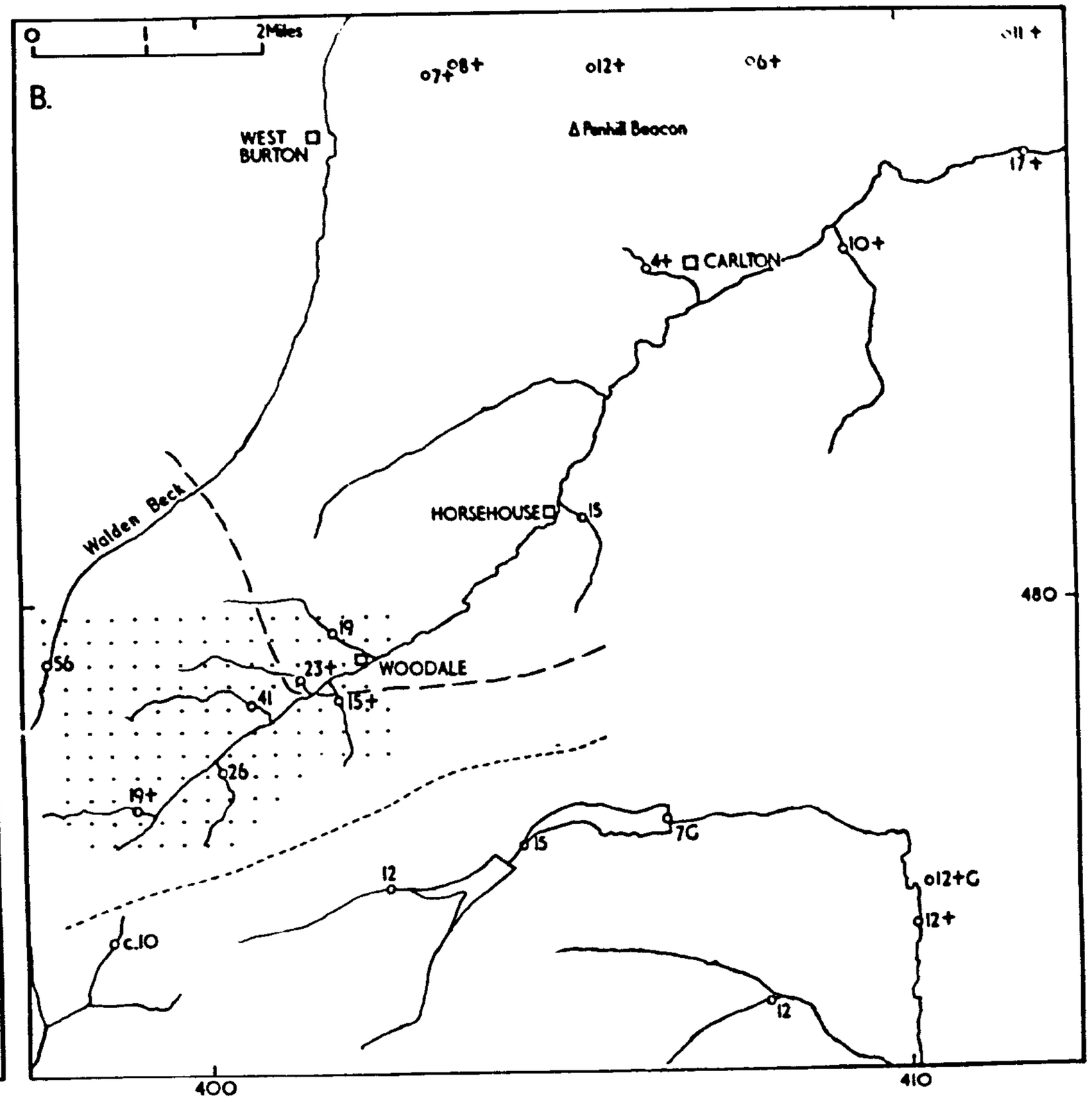

13
SLAPE GILL
14
EAST STONE GILL
15
PARK GILL BECK
16
WENCH GILL
17
ANGRAM DAM TRENCH & HEAD OF SCAR HOUSE RESERVOIR
18
SCAR HOUSE DAM TRENCH
19
R.NIDD, LIMLEY & LOFTHOUSE
20
HOW STEAN BECK
3
3
5
3
5
3
3
5
3
3
5
5
KEY
Fireclay
Fine Grained Sandstone
Calcareous Sandstone
Siltstone
Calcareous Fossiliferous Shale
Ditto with Chalybite Nodules
Slightly Calcareous Shale
Shale
Chertified Beds
Limestone
Cap, with probable Rocks inserted
Gigantoproductus Sp.
L Lithostrotion Colonies
N Algal Nodule Band
P Porcellanous Band

50 FEET
40
30
20
10
0
WEST WITTON
WEST BURTON
CARLTON
Walden Beck
R.Cover
WOODALE
R.Nidd
1 Mile
LOFTHOUSE
400
410
480

PLATE 9 A Information diagram for the Five Yard Limestone.
All known exposures are indicated by rings (the four most northerly occurences are based on features with sink holes which do not show exposures.
The full thickness of the bed is rarely seen in Waldendale and Coverdale, but is probably over 6'. Thickness figures are quoted for Nidderdale where exposures are better and the bed is thicker.
'L'- Lithostrotion sops - these include basaltiform and fasciculate forms. 'P'- Gigantoproductus sp. 'S' - shale parting in limestone.
Broken line- approximate limit of bed beyond which it dies out or is cut out.

PLATE 9 B Information diagram for the Three Yard Limestone.
Numerals denote thicknesses of the limestone , inclusive of all sandstones and shales separating leaves of the limestone.
The stippled area is one in which there are two, or more leaves of the Three Yard Limestone, separated by non-calcareous beds.
The coarse broken line denotes the southern limit of the sandstone underlying theThree Yard Limestone (properly part of the Five Yard cyclothem).
The fine broken line denotes the southern limit of sandstones in the Three Yard cyclothem (underlying the Underset Limestone)
'G' denotes that the Grassington Grit rests directly on limestone, some of which may have been eroded away prior to the deposition of the Grit.


0 1 2Miles
A.
R.Cover
BRADLEY
R.Nidd
480
400
410


0 1 2Miles
B.
WEST BURTON
Penhill Beacon
CARLTON
HORSEHOUSE
Walden Beck
WOODALE
480
400
410

CHAPTER 5

THE THREE YARD CYCLOTHEM

The Three Yard Limestone was so named by miners. This term was later used by the officers of the Geological Survey, when mapping the Askrigg Block. The key of Geological Survey 1" Sheet 97 S.E. (New Ser. 51) covering the present area shows an un-named limestone between the Third Set (Five Yard) and Underset limestones, which is in the position of the Three Yard Limestone. Chubb and Hudson (1925) named the Underset Limestone of upper Coverdale mistakenly as the Three Yard and called the true Three Yard the Five Yard Limestone. Tonks (1925) recognised a limestone in Nidderdale which he called the lower Five Yard Limestone; this is also properly called the Three Yard Limestone. Moore (1955) described the Three Yard Limestone of upper Wensleydale which is usually unfossiliferous with a local coral fauna. Locally it is split up into leaves by intervening sandstone. The upper beds of the cyclothem are predominantly arenaceous. In all these respects the strata of the Three Yard cyclothem in the present area closely resemble those of the same rhythmic unit in upper Wensleydale. This lends additional weight to the new correlation of beds at the level of the Three Yard and Five Yard Limestone proposed by the present author (see Chapter 5 and 18).

Stratigraphy

The Three Yard Limestone is a variable horizon consisting of one or two limestones. Inclusive of the intervening beds between the limestones, the total thickness variation is from 8'

to 56'.

In the north of the ground in lower Coverdale and on the N. slopes of Penhill a single, grey, detrital limestone is seen which varies from 8' to 17' in thickness. It carries a coral-brachiopod fauna below Low Dove Scar, Penhill, characterised by Dibunophyllum bipartitum vars. and Dictyoclostus sulcatus, but is elsewhere only sparsely fossiliferous. Since this is the only limestone between the Middle and Underset Limestones in the N. of the present ground its identification as the Three Yard is dependent on mapping evidence based on features on the W. slopes of Penhill. Here it is evident that a lower limestone (presumed to be the Five Yard Limestone) dies out to the north whilst the feature on the Three Yard Limestone which occurs above it persists in the same direction. Corroborating evidence in Coverdale, near Horsehouse, shows that the Five Yard Limestone is distinct from the Three Yard in lithology, thickness and fauna. The horizon which persists to the north is the upper one i.e. the Three Yard Limestone.

In Coverdale, upstream from Woodale, the Three Yard Limestone is much thicker than in the lower part of the dale owing to the development of a lower leaf, separated from the upper one by a varying thickness (1'6" to 29') of fine grained sandstone together with some shale and fireclay. The lower leaf is restricted to upper Coverdale and upper Waldendale (Plate 9B shows the limits of this bed). The greatest thickness seen is 15'. The horizon is variable and shale partings may occur (Plate 7). Locally large gigantoproducti occur in the basal part of this

lower leaf (at Downs Gill, near Hunters Hall, Coverdale). In upper Coverdale three exposures show a band of algal nodules. These are overlain in two of the sections by a distinctive stratum of pale grey calcite mudstone. The lower leaf of limestone appears to die out down Coverdale. In Fall Gill it is only 5' thick and further down the dale at Hindlethwaite Gill it is absent. In Waldendale this horizon also dies out down-valley and may be present as far north as Ashes Farm (Plate 21 shows the approximate points where the lower leaf thins to zero).

The strata above the lower leaf vary much in thickness and lithology. In three exposures in upper Coverdale the sandstone between the upper and lower leaves of the limestone is only 1'6" thick. In Slape Gill this thin sandstone rib fills pot holes in the uneven surface of the lower leaf of limestone. The occurrence of fireclays in some of the sections indicates emergent conditions prior to the formation of the upper leaf of limestone.

The exact age of the sandstones below the single leaf of the Three Yard Limestone in lower Coverdale and Waldendale is not known. It is possible that they are at least in part equivalent to the sandstones between the two leaves of the Three Yard Limestone in the upper part of these dales. If this is so it is also possible that the sandstones between the Middle and Three Yard Limestone in the N. of the area (where the Five Yard Limestone is absent) are their equivalents. In the text these sandstones have been treated as part of the cyclothems in which they appear to occur and the above interpretation is not followed.

Plate 21 was constructed on the supposition that all these sandstones were deposited simultaneously, though this cannot be proved.

The upper leaf of the Three Yard Limestone in upper Coverdale is only sparsely fossiliferous and is of more constant thickness than the lower one.

The Three Yard Limestone of Nidderdale is identified as such because it overlies fossiliferous shales of similar thickness, lithology and biofacies (Weberides is especially common) as the shales between the Five Yard and Three Yard Limestones of upper Coverdale. Normally the limestone occurs as a single leaf up to 15' thick, but locally shows an upper leaf separated from the lower one by a shale, as at Howstean and Blayshaw Gill. The correlation of these two leaves with the two seen in Coverdale does not appear to be sound, since the lower leaf is the best developed and persistent in Nidderdale. It remains a possibility that the thin upper leaf is an attenuated representative of the Underset Limestone, brought close to the Three Yard by the thinning of the sediments above that bed to the S.E. corner of the Askrigg Block.

The measures above the Three Yard Limestone vary from 10' to 55' in thickness and show a tendency to thin to the S.E. In most of the sections in Coverdale and Waldendale the upper two thirds of these beds consist of flaggy and sometimes blocky, fine grained sandstones. In the more fissile beds worm trails (Crossopodia) are seen. The shales above the Three Yard Limestone tend to be thin and grade upwards into flaggy sandstones.

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Near Hullo Bridge, Coverdale, the upper part of the shales is fossiliferous, but elsewhere, as in Hindlethwaite Gill they are silty and without a fauna. Towards the south, sandstones below the Underset Limestone, which are often over 30' thick in mid-Coverdale, die out. In upper Waldendale, in Park Gill Beck south of Coverhead and in Nidderdale only shales or their chertified equivalents are seen. The shales are rarely fossiliferous, but a small assemblage was obtained from silty shales at Walden Head. In the areas where the sandstone is absent the strata above the Three Yard Limestone are unusually thin.

In Nidderdale platy cherts are seen immediately above the Three Yard Limestone and the shales of the cyclothem are partly chertified. The cherts which usually occur below the Underset Limestone in Coverdale are unusually thickly developed. In addition cherts are seen immediately above the Five Yard Limestone at Lofthouse and in Howstean Beck. At all these levels, except that under the Underset Limestone, cherts are not seen in Coverdale and Waldendale. It is a somewhat remarkable fact that the local cherts at this level should occur over an area where the intra-E_1 unconformity is within 20' of the affected strata. In contrast, in the areas where cherts are not seen at this level, in Coverdale and Waldendale, the plane of erosion rests on beds at least 140' higher in the sequence. There therefore appears to be a strong relationship between the erosion surface and chertification. It is suggested that this chertification was the result of siliceous waters which derived

their supply from a large area of cherty beds of the Richmond Chert Series lying exposed on the plane of unconformity to the north. The reasons for supposing that the chertification in the Richmond Chert Series was not induced in the same manner are given in Chapter 7.

The mapping procedure for the Three Yard Limestone has been almost solely based on data from stream sections. This is due to the fact that it very rarely makes a feature; the one exception is on the N. slopes of Penhill. The bulk of the data about the overlying beds is also from streams.

Details

Three Yard Limestone - Exposures are described in sequence from Waldendale, north Penhill, Coverdale, the slopes above Kettlewell and Nidderdale.

Waldendale - Exposures are first considered at the head of the valley and followed in sequence, down-dale.

Near Walden Head on the banks of Walden Beck (979798) the limestone is divided into two leaves, separated by a sandstone, a condition which obtains in many localities in upper Waldendale and upper Coverdale. The lower leaf overlies a sandstone and is a blue limestone with thick shale partings. The upper shale parting yields traces of fossils. The limestone is unusually fossiliferous here (by and large the Three Yard Limestone is poor in fossils in the present area) and yields a fauna at several levels in the lower leaf. Forms collected near the base of the lower leaf include Gigantoproductus latissimus,

Aulophyllum fungites and Diphyphyllum fasciculatum. The lower leaf of the limestone is overlain by a fine grained sandstone. This latter bed has a calcareous zone 6' thick near the base which weathers in a honeycomb fashion and is a tough orange and grey flecked fine grained sandstone when fresh. It is overlain by the upper leaf of the limestone which is at least 7' thick and is not notably fossiliferous.

The streams draining into Walden Beck from Brown Haw show small portions of the Three Yard Limestone, together with a sandstone. The stream course above Dales Barn (990808) shows beds of limestone in place at two or three levels. Blocks of compact, fine grained, blue limestone with phaceloid lithostrotionoid corals also occur, which may be at the same horizon as a coralliferous layer seen in situ at 983801. Streams draining Crook Pasture show incomplete outcrops, but always suggest that a sandstone splits up the limestone into two leaves. The stream at Ashes Farm (820010) shows 14' of sandstone (see Plate 7 in which the upper leaf of the limestone was put in tentatively at the level of a strong spring). It is possible that the lower leaf of the Three Yard Limestone is here thin or absent.

Above Scar Folds (021849) the lower leaf of the Three Yard Limestone is probably absent since the sandstone forming the feature above the scar is very thick. Tt is assumed to be overlain by the top leaf of the limestone which is probably present since there is a shallow sink hole where the top of the limestone is expected to occur (see Plates 7 and 21 which

show the probable facies changes associated with the Three Yard Limestone and the sandstone which occurs within it in the upper part of the dale).

The features above Long Ing Wood unfortunately show no exposures, and all the data incorporated in the section on Plate 7 is obtained from the interpretation of good features, blocks and sink holes. The evidence points here towards a single leaf of limestone only, resting on a sandstone, here considered as part of the Five Yard cyclothem, though it also seems possible that it may be equivalent to the sandstone separating the two leaves of the Three Yard Limestone further up the dale. The feature on the Three Yard Limestone can be mapped north to Oswald High Wood where there is a succession of exposures showing up to 8' of limestone (Plate 7). In hand specimen this is a grey calcite mudstone with scattered crinoid ossicles, carrying a coral-brachiopod fauna of greater variety than has been found elsewhere at this stratigraphic level which is unusually poor in macrofossils. The dominant forms are Dictyoclostus sulcatus and Dibunophyllum bipartitum vars.

The limestone is intermittently exposed in Oswald High Wood, but the thickest development seen is in a stream S.E. of Chantry Farm (057877) where 12' of limestone (probably nearly the full thickness) are seen directly overlying sandstone. Below Capplebank Plantation small exposures show 6' of grey limestone (not the full thickness) resting on sandstone. An exposure below Park Lane (115881) shows 11' of crinoidal limestone, probably almost the entire thickness at this point.

Coverdale - The exposures are described first from the lower

part of the dale and then are considered successively up the valley towards Coverhead.

The section in the R. Cover at Hullo Bridge (118865) (Plate 7) shows approximately 17' of grey, detrital limestone (nearly the full thickness) resting on a sandstone. The top of the limestone is not seen (it is remarkably seldom that this contact is seen in the present area). In Caldbergh Gill (091850) 10' of limestone (a partial exposure) are seen overlying sandstone. Partial sections of the Three Yard Limestone occur in Cat Gill, Melbeck, Howden Gill, and Turn Beck, whilst the section in Fleemis Gill shows the lowest 4'6" of the limestone resting on a sandstone. Occasional exposures of parts of this limestone are seen between Horse House and Bradley, in the streams draining Horsehouse Moor.

In Hindlethwaite Gill a complete section occurs in the Three Yard Limestone, here 15' thick. It carries a sparse coral-brachiopod fauna which includes Aulophyllum fungites pachyendothecum, and Dibunophyllum sp., preserved in a grey, detrital limestone with many crinoid ossicles. It seems possible that a calcareous development in the lower part of the sandstone under the Three Yard Limestone in this section is an equivalent of the lower leaf of the Three Yard Limestone in the upper part of the dale (see Plate 7 and Plate 21). All completely exposed sections which occur further up-dale than Bradley show two leaves of limestone separated by intermediate measures which are chiefly sandstones. These southwards facies changes are shown in the measured sections on Plates 7, 8. Plate 98 shows the thickness of the limestone in measured sections which attains

its maximum value in the S. of the area.

In Fall Gill (018796) the lower leaf of the limestone is very thin (5'). This supports the view that this horizon deteriorates down-dale, since it is thicker in sections further up the valley. The beds above this limestone include a fireclay and coal smut, pointing to conditions of emergence between the two marine episodes, marked by the deposition of the two leaves of the Three Yard Limestone. The upper leaf is thicker than the lower leaf and forms a waterfall. It seems most likely that it is equivalent to the one, existing leaf of limestone in Hindlethwaite Gill (see Plate 7 for details of this section).

Streams draining High Pasture show incomplete sections in the Three Yard Limestone, the best of which is in Side Gill (036794) with limestones at two distinct levels. The lowest exposures shows 2' of grey limestone with a phaceloid lithostrotionoid coral overlying a mottled weathering limestone. It seems probable that this horizon is the lower leaf, since compound corals have not been recorded from the upper leaf of the limestone during the present work. The upper exposure in this section shows 6' of limestone, probably a partial exposure in the upper leaf, also partially seen in Ridge Gill. The relations of the two leaves may be easily seen in Lords Gill (019787) (Plate 7) where there are two distinct leaves of limestone separated by 1'6" of tough fine grained, limonite spotted sandstone. The lower leaf shows a layer of grey limestone with nodules of dark grey calcite mudstone, probably of algal origin. These are no doubt equivalent to the mottled layer seen in Side Gill (see above).

The section in West Gill (012790) (Plate 7), though somewhat disturbed by faults, is a good one and reveals a section similar to that seen in Fall Gill. It is here detailed since it is fairly typical of the development in upper Coverdale:

9'	grey, detrital limestone with many crinoid ossicles
5'	compact, fine grained, grey sandstone
9"	grey fireclay
9"	grey siltstone
1'6"	grey calcite mudstone, weathering orange, with algal nodules which weather pale grey in contrast
1'6"	grey, nearly porcellanous calcite mudstone
6"	gap
4'	coarse dark grey crinoidal limestone
-	sandstone

Downs Gill (006785), in common with most other sections, shows two leaves of limestone with a thick sandstone between them. The lower limestone, as at West Gill, shows an algal bed resting on a porcellanous one, whilst the lowest stratum contains a fauna of Gigantoproductus sp., never seen elsewhere in profusion at this level, though G. latissimus is recorded from a similar horizon in Walden Beck. A thin fireclay occurs between the upper and lower leaves of the limestone as at West Gill, indicating a period of local emergence between the two marine episodes during which the two leaves of the Three Yard Limestone were being laid down, The sandstone which occurs between the upper and the lower leaves of the limestone (see Plate 7) is a grey, fine grained rock with small scale current bedding. The upper leaf of the limestone is a grey, detrital limestone with strings and nodular streaks of hardened limestone on top of the uppermost stratum, in conjunction with nests of pyrite.

The section in Slape Gill (002777) (Plate 8) resembles that

of East Stone Gill (991771) because, though the Three Yard Limestone occurs in two separate leaves, the parting is a sandstone only 1'6" thick in the first section and 1' thick in the second one. The sandstone of Slape Gill rests on a potholed surface of limestone, the holes being several inches deep and steep sided, with a filling of sandstone. The upper leaf rests directly on the flat upper surface of the sandstone stratum. No potholing of the lower leaf was seen in the section in East Stone Gill.

Portions of the Three Yard Limestone are also seen in Hem Gill Beck, Downs Gill, Coverhead and along the right bank of the R. Cover between the mouths of these two gills. An exposure also occurs in Lock Gill but is inadequate to determine if the parting between the limestones is in fact present.

At Park Gill Beck, south of Coverhead (753990), a partial exposure indicates that at least 10' of limestone occur. Exposures farther south occur in potholes, but the relation with the underlying beds is not clear. It is possible that 18' of limestone exposed in a sink hole N. of Little Fell pasture (990741) are at this horizon. The Five Yard, Three Yard and Underset Limestones are very close together in this area and are difficult to distinguish from each other in the few available exposures.

Nidderdale - Exposures in the upper part of the dale occur in Crook Dike (mis-named 'Wench Gill' in Plate 8) and at the head of the Scar House Reservoir. At both these points the limestone is over 12' thick, but an intermediate exposure (029760) is in only 5' of limestone,

associated with a thick development of platy cherts which may be at least partly secondary after the limestone. A partial exposure in Wench Gill (045767) shows that the limestone is there at least 7' thick. The section in the Scar House Dam trench showed that it is here thin, namely 6' thick. In the Thrope House inlier, further down-dale (102754), 12' of blue-grey limestone which overlie fossiliferous shales are referred to this horizon. It is not clear whether the beds exposed between the Thrope Edge Fault and Thrope Bridge are the Three Yard Limestone repeated by the fault, or whether they are the Underset Limestone. The known throw of the fault at Thrope Edge and on Rainstang suggests that it is probable that the Underset is here present. Tonks (1925) was of the opinion that the Upper Five Yard Limestone (here re-named the Underset) was present in this inlier, but not further down the dale.

The section in the Nidd above Lofthouse suggests that the highest limestone of the Yoredale succession seen immediately below the Grassington Grit Group in Sampson's Wood is the Three Yard. This is because only one distinct limestone appears to occur in the Nidd above the Five Yard. Further exposures at this level occur in the vicinity of Nidd heads, the vauclusian resurgence of the river below Lofthouse. The most complete section is in an old quarry (108729) in which 13'6" of limestone with cherty bands and shale partings is exposed; it is assumed that these beds belong to the Three Yard Limestone. The highest limestone in Blayshaw Gill (099728) appears to be immediately overlain by the Grassington Grit. The section here

seen is:

1'	limestone
6'	gap
13'	grey limestone (probable Three Yard)

This closely resembles the section in Howstean Beck where two leaves of limestone are seen, separated by shales. It remains a remote possibility that the upper leaf of limestone at this locality and at Blayshaw Gill is in fact the Underset Limestone, here very close to the Three Yard Limestone due to the thinning of the measures between the two limestones to the S.E. The farthest south of all the sections in Nidderdale, that of Lolley Scar, shows limestone blocks which appear to indicate that the Three Yard Limestone is here also present. This conclusion is identical with that of Tonks, relative to this exposure, except that the naming of horizons is different.

Shales and Sandstone of the Three Yard Cyclothem - The sediments at this level are chiefly arenaceous; the shales immediately overlying the Three Yard Limestone are usually thin and seldom exposed.

Waldendale - exposures are never complete at this level. They are considered in sequence from north to south.

The section in Walden Beck, near Walden Head (979792), is anomalous since there is an unusual development of shales which does not appear to be matched elsewhere. Exposure is incomplete, but the beds seen are all shale except for 2' of grey, compact siltstone, and the lowest exposure shows poorly preserved fossils in silty blue shale (Plate 7). This is a sparse normal shale fauna

with very large specimens of Weberides mucronatus (McCoy). Further down the dale the exposures at this level are obscured by the Crag Brea landslip.

The section near Ashes Farm (011819) shows a portion of these beds (Plate 7). They are siltstones in the lower part, grading up into a flaggy sandstone, overlain by a blocky sandstone, an upward sequence which is duplicated at several exposures in Coverdale. Exposures are lacking on the E. side of Waldendale north of this point, though by measuring features an approximation to the thickness of the beds was obtained above Scar Folds (Plate 7).

Above Long Ing Wood (024860) features are good. Numerous blocks which occur appear to indicate that the sandstone below the Underset Limestone is here about 28' thick (Plate 7). The sandstone member probably overlies a small thickness of shales. It can be traced via the Hudson Quarry (027864), in which it was worked, to several old stone pits and scars below Low Dover Scar where exposures show 16' of sandstone. This rock is a fine grained and coarser than most Yoredale sandstones. It carries some specks of limonite together with scattered kaolinised feldspars. Below Low Dover Scar (037876) the bryozoan plate below the Underset Limestone can be seen resting directly on this sandstone. At occasional localities on the N. slopes of Penhill portions of these beds are seen. They always appear to be flaggy sandstones in the upper part and silty shales towards the base, though the lowest beds above the Three Yard Limestone are never exposed.

Coverdale - exposures are better than in Waldendale and are

described in sequence from N. to S.

The sections in the R. Cover below Hullo Bridge (120865) (Plate 7), in the upper portion of the Three Yard cyclothem, show a blocky, fine grained sandstone grading down via flaggy sandstones and silty shalew into 2' of fossiliferous shale with a brachiopod fauna. This is the only locality where fossiliferous strata have been found at this horizon. Exposures are usually lacking elsewhere at this level, though the fossiliferous shales seen in Walden Beck may be an equivalent horizon. It is possible that all the sediments in the gap of 11' between these shales and the Three Yard Limestone are fossiliferous.

In Melbeck, Carlton (063849) the top 15' of the cyclothem are compact sandstone and a further 6' of sandstone is seen in a lower exposure. At least 3' of unfossiliferous shales occur at a lower level. In Turn Beck (047835) the following section is seen:

1'	fossiliferous shale (probably directly underlies the Underset Limestone)
2'	sandstone
9"	shale
8'	sandstone
3'	silty shale with numerous tracks of Crossopodia sp. (base not seen)

Keemis Gill shows numerous exposures of the sandstone below the Underset Limestone which outcrops for a distance in the bed of the stream below Fleensop Farm (034823). It is a current bedded flaggy, fine grained sandstone with some spotting by limonite. Though the section is very disjointed, it seems the bulk of the Three Yard cyclothem above the limestone is here sandstone.

In Hindlethwaite Gill (054812) (Plate 7) the sandstone member

of the Three Yard cyclothem is excellently exposed and, as in other cyclothems, gets more massive upwards. The lowest beds seen are silty, unfossiliferous shales grading upwards into flaggy sandstones which form a waterfall. The top 4' is a massive single stratum of fine grained quartz sandstone with specks of limonite. The gill draining into Bradley (031801) and Fall Gill both show partial sections in these sediments in which the upper beds are sandstones and the lower ones are shales, which are however much less well exposed than the sandstones (Plate 7).

Harkera Gill and several streams draining High Pasture show partial sections of the sandstone of the Three Yard cyclothem, which are characteristically flaggy, fine grained and limonite spotted. Ridge Gill and Lords Gill show sections chiefly in sandstone with room only for a thin shale above the Three Yard Limestone (Plate 7). West Gill and Downs Gill all well exposed. The exposures are very largely in arenacous beds, but are hard to measure accurately owing to the protracted nature of the sections (Plate 7). The sandstone is a flaggy, very fine grained quartz sandstone with mica and carbon flecks. Occasional horizons with annelid trails occur (Crossopodia sp.). A layer of flaggy rock in Downs Gill contained a very high proportion of mica, which may be hydrobiotite. The more massive beds, as elsewhere, immediately underlie the Underset Limestone. The section in Hem Gill Beck shows 41' of beds between the Three Yard and Underset Limestones, the bulk of which are sandstones. East Stone Gill provides a contrast; though the exposure is only 600 yds. from Hem Gill Beck, the total thickness of beds between

the Underset and Three Yard Limestones is only 21' and a portion of the upper part of this is unfossiliferous shale (Plate 8).

Exposures south of Coverhead - The section in Park Gill Beck (753990) is incomplete at this level. The beds seen (Plate 8) include a large proportion of cherty 'plates'. No sandstone is visible; if one occurs it can only be thin. The section is as follows:

-	Underset Limestone
5'	cherty plate
6'	gap
2'	cherty plate
10'	gap
-	Three Yard Limestone

The cherts have not been shown in the section in plate 8, because the normal chert development below the Underset Limestone is usually referred to this horizon. It is possible however that some of these thick beds may be the product of the chertification of pre-existing shales and properly belong to the Three Yard cyclothem.

Nidderdale - The sections in upper Nidderdale show some variation at this level and are devoid of sandstones. They are invariably partly chertified. In Crook Dike ($_{O}$26761) (Plate 8, section 16, erroneously referred to as Wench Gill) only 10' of beds occur at this level. The lowest 4', the only beds exposed, are platy cherts presumed to be secondary after shales, since no cherts are known at this level in Coverdale. A section 350 yds. E. of this point shows a thicker development of beds at this level as follows:

8'	platy cherts
2'6"	shale
12'	platy cherts
-	Three Yard Limestone

It seems likely that a portion of the platy cherts above the Three Yard Limestone, here unusually thin, are secondary after it. The same beds are exposed near the head of Scar House Reservoir (046766) where there are seen:

8'6"	platy cherts
7'	cherty, black shale
1'	platy cherts
-	Three Yard Limestone

Some of the above cherts are probably those which normally are associated with the Underset Limestone in Coverdale, but the chertification in the shales, at least, is secondary. The Scar House Dam trench provided a record of 11' of shales at this level.

Shales above the Three Yard Limestone appear to be almost entirely absent lower down Nidderdale due to intra-E_1 erosion. 1'-2' of calcareous shales directly overlie the Three Yard Limestone in Howstean Beck. These are directly overlain by sandstone of the Grassington Grit Group, the variation in thickness which occurs being due to the uneven base of this horizon.

Palaeontology

The Three Yard Limestone is a poorly fossiliferous horizon, taking the area as a whole. The upper leaf, which is considered to be the persistent one is only sparsely fossiliferous.

In upper Wensleydale Moore (1955) also records only a small fauna. The present records from Low Dove Scar are exceptional in that they have yielded several species of productids including Dictyoclostus sulcatus. This appears to be the characteristic fossil together with a moderately profuse coral fauna, chiefly of haploid type but also including Dyphyphyllum. The corals recorded are somewhat similar to those of the coral bands in the Underset Limestone since they both contain Aulophyllum fungites and Dibunophyllum bipartitum vars. The foraminifera appear to be long ranged forms which are characteristic of all the Yoredale limestones up to the Main Limestone in the present area. Tonks (1925) collected a small fauna from this horizon in upper Nidderdale where most of the records are of brachiopods and include species of Dictyoclostus. These exposures and other less fossiliferous ones in the upper leaf of the Five Yard Limestone have not been collected during the present work.

The lower leaf of the Three Yard Limestone, which shows a more restricted development than the upper one is more commonly fossiliferous and carries an algal band over an area in upper Coverdale. A local layer full of Gigantoproductus occurs in Downs Gill, Hunters Hall, Coverdale. The Walden Beck exposure yields a small fauna including latissimoid productids.

The shales immediately above the Three Yard Limestone, though they may quite probably yield fossils, are never exposed in the present area. The only fossils records are from slightly higher horizons which were only collected at one locality, that of Walden Beck. The fauna includes Weberides mucronatus, up to

2.8 mm. in length, which is larger than any of the several specimens from shales of the Five Yard cyclothem below Hunterstone Bank.

The sandstones of the Three Yard cyclothem are virtually unfossiliferous, except for records of Crossopodia which sometimes occurs in abundance on the bedding planes of the most flaggy varieties of sandstone. The presence of worm prints on successive flaggy layers indicates that each lamina is built up of a separate pulse of sediment.

Faunal lists for the Three Yard cyclothem

Three Yard Limestone

Ammodiscus incertus (D'Orbigny), 1
Calcisphaera Johnson ms., 1
Textulariid, 1
Endothyra bowmani Phillips, 1
Orobias ornata (Brady), 1
Tetrataxis palaetrochus (Ehrenberg), 1

Aulophyllum fungites (Fleming), 3
---------- fungites (Fleming) mut. pachyendothecum (Thomson), 2
Clisiophyllum keyserlingi McCoy, 1
Dibunophyllum bipartitum bipartitum (Mc Coy), 1
---------- bipartitum craigianum (Thomson), 1
---------- sp., 2
Diphyphyllum fasciculatum (Fleming), 3

Archaeocidarid spine, 1

Crinoid ossicles, 1,2,3

Fenestella sp., 1
?Rhabdomeson sp.
Trepostome (encrusting form), 1

Camaratoechia pleurodon (Phillips), 2
Chonetes sp., 3
-------- (Plicochonetes) aff. maccoyanus Semenew, 3
Cleiothyridina roysii (Léveillé), 1
Productus (Dictyoclostus) sulcatus J. Sowerby, 1
--------- (Echinoconchus) punctatus (Martin), 1
--------- (Eomarginifera) praecursor Muir-Wood, 1
--------- (Gigantoproductus) latissimus J. Sowerby group, 3

Productus (Gigantoproductus) sp.
Pugnax pugnus (Martin)
Spiriferina aff. octoplicata J. Sowerby, 3

Ostracod, 1

Acanthodian tooth, 3

Index of localities for the above

1.	Quarry below Low Dove Scar, Penhill	034875
2.	Hindlethwaite Gill, Coverdale	055812
3.	Walden Beck	979793
4.	Lords Gill, Coverdale	019787

Fossiliferous shale (a local development instead of the sandstone of the cyclothem)

Fenestella sp.

Chonetes (Tornquistia) sp.

?Pseudamusium sp.

Orthocone nautiloid

Weberides mucronatus (McCoy) (up to 2.8 mm. in length)

All the above forms are from one locality: Walden Beck (978786)

Sandstone of the Three Yard cyclothem

Crossopodia sp, 1, 2, 3

Index of localities for the above.

1.	Turn Beck, Coverdale	047835
2.	West Gill, Coverdale	012790
3.	Lords Gill, Coverdale	019787

CHAPTER 6.

THE UNDERSET CYCLOTHEM

The Underset Limestone was so named by Phillips (1836). This term was subsequently used by the Geological Survey during the mapping of the Askrigg Block. The horizon has not been described in detail from the present area, but Phillips (1836) provided measured sections in which it figures. Dakyns (1892) emphasised the variability in thickness of the limestone in the present area. Whilst the Underset Limestone is probably present in the Angram area in upper Nidderdale, Tonks (1925) misidentifies this horizon as the upper leaf of the Five Yard Limestone. The Main Limestone of Coverhead was subsequently misidentified by Chubb and Hudson (1925) as the Underset Limestone and the true Underset was erroneously referred to the Three Yard Limestone. This correlation was later rectified by Hudson (1933) without explanation.

Moore (1955) furnished a detailed description of the Underset cyclothem in upper Wensleydale. In the limestone he recorded two coral bands, the lower of which is the more persistent and contains a fauna of haploid corals, the chief of which are Dibunophyllum bipartitum vars., Aulophyllum fungites and Konickophyllum magnificum. The upper coral bed contains a fauna of diphyphylloid lithostrotions, is the least persistent of the two beds and is restricted to the N.E. of Moore's area. Whilst two coral beds occur at Low Dove Scar in the present ground, there being a higher persistent one and a lower impersistent one, they both contain haploid corals, with the more profuse fauna

in the upper band. The more persistent, lower coral band of Moore also dies to the south. It seems that this horizon has definite southern and eastern limits since it is not recorded from the S. of Moore's area, never in the Middleton Tyas - Sleightholme anticline (Wells, 1955) and only in the extreme N.W. of the present area. Moore records sudden thickness variations in the Underset limestone which are parallelled in the present ground, though the overall thicknesses quoted by Moore are in general greater than those encountered in this work.

The developments of chert above the Underset Limestone were found by Moore to be localised; in the present area this is also the case. Platy beds below the Underset limestone were recorded by Moore from the S.E. of his ground, and occur sporadically through the present area. The fauna of fenestellids and small brachiopods which he records does not appear to be detailed in the faunal lists, but seems to be of a similar biofacies to that found in beds of like lithofacies in the present area.

The shales and sandstones of the Underset cyclothem are generally thinner in upper Wensleydale then in the present ground, with the exception of the beds in the area of Coverham where they are much thinner than elsewhere in the area here described. The sandstones at this level were found by Moore and by the present author to be impersistent.

Stratigraphy

The Underset cyclothem outcrops along the length of Waldendale and Coverdale and was also surveyed in Park Gill Beck, draining

into the R. Wharfe. Beds considered to belong to this cyclothem also occur in the upper Nidderdale inlier at Angram.

The Underset Limestone is always present and varies in thickness from about 9' to 47', inclusive of the developments of cherty beds which occur locally at the top and base of this horizon. The Underset Limestone varies in thickness and lithology in a more haphazard manner than most of the other limestones of Yoredale facies, but certain systematic variations are observable. It is typically a grey, detrital limestone with numerous crinoid ossicles, sometimes cemented by a matrix of calcite mud and is throughout the area almost devoid of macrofossils. The chief exception is the Low Dove Scar exposure where the Underset Limestone shows two coral beds, the lower of which is the least well marked and least persistent. Both bands carry a fauna of phaceloid rugose corals, chiefly Dibunophyllum bipartitum vars. and Aulophyllum fungites pachyendothecum. Brachiopods occur commonly in conjunction with the corals. Thickness variations are rapid, especially at the E. end of Low Dove Scar, and appear to be of the same order of magnitude as described by Moore (1955).

At the base of the Underset Limestone of several localities, chiefly in the N. and S. parts of the present area, there is a horizon of dark grey siliceous 'plate'. This splits into plates, which when correctly weathered display a bryozoan - brachiopod faunal assemblage having no equivalent at any other horizon within the area. The conjunction of a characteristic fauna with a particular lithology is held to be good evidence for

the primary origin of this particular chert. It is further difficult to envisage the selective chertification of this one horizon which shows sharp contacts with the overlying limestone and, locally, with underlying shales, at several places so widely separated (Plate 12 A).

In upper Coverdale, the lower beds of the Underset Limestone are brashy weathering fossiliferous shales with thin limestones, the thickest of which is locally 4' thick, thus making it more logical for these shales with limestones to be referred to the Underset Limestone rather than to beds of the preceding cyclothem (in Plates 7, 11 they have been appended to sections for both the Three Yard and Underset cyclothems, since there is some slight doubt as to which cyclothem they should be assigned). Moore (1955) for instance referred the platy beds which overlie these shales with limestones in the present area to the Three yard cyclothem). It is noteworthy that the area in which this early marine episode occurred is the same as that in which the lower leaf of the Three Yard Limestone (also a local development) was deposited.

The development of cherts above the Underset Limestone is, with one exception (that at Walden Head) limited to the N. part of the present area, where they attain a maximum thickness of about 11'. They vary somewhat in lithology, but are usually 'plates' in the lower part and glassy, banded black and grey cherts in the upper part.

The shales and sandstones of the Underset cyclothem are throughout most of the ground of a fairly constant thickness, between 75' and 100'. Locally, in the vicinity of Cover Scar, near

Coverham, they are much thinner, about 11' only, whilst intermediate points confirm this reduction in thickness towards a minimum at Cover Scar (Plate 12 B).

The shales of the Underset cyclothem are normally free from sandstone bands for about 60' above the Underset Limestone, but locally, sandstones are developed at the base and in the middle of these beds. The shales immediately overlying the Underset Limestone are rarely exposed, but when seen, are dark blue shales with chalybite nodules, carrying a normal shale fauna, the most characteristic forms being Martinia glabra and Camaratoechia pleurodon. The main bulk of the shales of the Underset cyclothem are however unfossiliferous, or sparsely fossiliferous with a fauna of dwarfed pelecypods. Exceptionally a more fossiliferous development is seen, yielding an abundant fauna which is of the normal shale thpe, though somewhat modified. Locally a Lingula - palaeoniscid phase is developed with large Lingula squamiformis.

The chief sandstone of the Underset cyclothem, which underlies the Main Limestone is variable in thickness and is locally absent, but attains a thickness of 22'. It is usually a flaggy, fine grained quartz sandstone which at one locality develops a shelly fauna somewhat similar to that of the Cayton Gill Shell Bed, of R_1 age.

The Underset Limestone only rarely forms a feature as at Low Dove Scar, Penhill. It is usually too thin to form features and is seen only in stream sections, though rarely to completeness. The overlying beds, being chiefly soft shales, form steep slopes below the outcrop of the Main Limestone. Landslips are common

on these beds with resultant lack of undisturbed exposures, this especially so in Waldendale. The shales also so soft that they are frequently dissected into gulleys, yielding good sections for mapping purposes, especially in upper Coverdale.

Details

Underset Limestone - exposures are described in sequence from Waldendale, Coverdale and Nidderdale. Waldendale and N. Penhill - the Underset Limestone of Waldendale is badly exposed and the outcrop is obscured by landslips for long distances. Walden Beck (978789) is an exception to the above statement. The beck cuts a small gorge through the limestone which has a cherty development at the top and base (Plate 11). The basal 4'6" consists of cherty plates overlain by the main body of the limestone, here grey with numerous crinoid ossicles set in calcite mud. There are few macrofossils except for a horizon 19' above the base of the limestone yielding fragmentary corals and brachiopods. The uppermost 14' are tough, blue, platy limestones with the straight joints typical of cherty beds. It is probable that these beds are the product of secondary silicification.

For half a mile north of the above mentioned locality, sporadic exposures are seen of cherty blue limestone from the beds overlying the unchertified Underset Limestone, Further north, the Crag Brea landslip obscures large sections of the hillside and exposures are lacking. The stream draining to Ashes Farm (at 012819) shows 1' compact purplish-blue limestone, which is part of the Underset. North of this point the limestone makes a feature and a row of sinkholes descend into it south of Low Dove Scar. Slips obscure

the outcrop to the N. of High Dovescar, but the limestone again makes a feature below Chance Hill (around 022849).

The cliff of Low Dove Scar (034876), on the N.W. slopes of Penhill, is the best and by far the most fossiliferous exposure in the Underset Limestone of the present area, here unusually thick, the total unchertified beds totalling about 26'. The lowest strata are 4' of purplish-black, brittle plate. This contains a numerous calcitised fossils lying crushed on the bedding planes of the fissile rock. The fauna belongs to a brachiopod - bryozoan assemblage in which the brachiopods are frequently small spinose forms and the fenestellids, which make up the bulk of the bryozoa, are of large size and often unbroken, indicating that these fragile organisms had not travelled far.

The lower 7' of the Underset Limestone proper is blue in colour and carries a coral band 3' from the base. A further coral horizon is seen at the top of these beds, which are followed by pale grey, detrital limestones. These last limestones in polished section are pale grey calcite mudstones with many crinoid debris and brachiopod fragments, showing signs of abrasion, and therefore probably washed around by currents and no doubt thus moved in from elsewhere. Of the two coral bands, the upper is the more persistent and well defined; it carries, like the lower band, a fauna which consists almost exclusively of haploid corals, the dominant forms being Dibunophyllum bipartitum vars. and Aulophyllum fungites pachyendothecum. The unchertified limestone is overlain by the Underset Chert at this locality, which is 4' about thick. It consists of at least 2' of black, glassy, well jointed chert, weathering into small, angular blocks a few

centimetres across, overlying more platy cherty beds which have yielded the problematic marking 'cauda - galli'. In thin section the glassy chert is a banded aggregate of cryptocrystalline quartz, whilst in hand specimen pale grey and black banding is also evident and is apparently an original texture. Reaction is nil with dilute HCl and it is assumed that this rock is almost 100% pure SiO_2, with occasional carbonate rhombs.

The feature which the Underset Limestone forms at Low Dove Scar dies out rapidly to the east and it is certain that the limestone thins in this direction. It is partially exposed in a stream course W. of New Plantation (046876) where the total thickness is probably 13', with evidence of a glassy chert above the limestone (Plate 12A). A small stream E. of Harrow Ridge (057875) shows 4' of limestone overlain by shales. It seems that the limestone is not much thicker here than the exposed thickness. To the E., undoubted Underset Limestone is next seen at a quarry to the S.S.W. of Park Farm (108877) in 15' of thinly and evenly bedded grey, detrital limestone. This is probably nearly the entire thickness of the bed at this point, which here forms a rather vague but mappable feature.

Coverdale - The section on the R. Cover E. of Hullo Bridge (122865) shows the Underset Limestone overlain by cherty beds, here unusually thick. The limestone rests directly on sandstone, shows no development of cherty beds at its base and is a 12' grey, detrital limestone overlain by 8' of cherty plate. These beds are followed by 3' of black, brittle, glassy chert, splitting with an uneven to subconchoidal fracture and with traces

of colour banding. Veins of milky white chalcedony intersect the rock which also shows brachiopods preserved in calcite. The sequence limestone-plate-glassy chert is the same as that observed at Low Dove Scar, but the plate below the limestone does not occur in the sections along the R. Cover.

At Elm Gill (094853) (Plate 11) the general succession is similar to that at Low Dove Scar. The lowest beds are cherty plates with a bryozoan-brachiopod fauna. These are overlain by a limestone which is blue in the lowest 6' and is a pale grey massive rock in the upper beds with abundant crinoid detritus and brachiopod remains, but with no trace of a band of corals. These beds are followed by 5' of dark, cherty plate with a fauna which includes bryozoa and pelecypods. They are overlain by 4' of limestone with chert nodules, capped by 2' of black chert, probably the equivalent of a similar one seen overlying platy beds at Low Dove Scar and on the R. Cover, below Hullo Bridge.

An exposure in Cat Gill, near Carlton (069853) is in 4'6" of chert, very probably that over the Underset Limestone.

At Mel Beck, Carlton (063849) the section is complicated by faulting, but it seems that the cherty beds over the limestone are missing, whilst those immediately below the limestone are certainly absent.

Fleemis Gill (032822) differs from other sections in lower Coverdale in showing a shale parting in the Underset Limestone. The lower leaf of limestone is of a purplish colour and 3'6" thick, being overlain by 5' of rubbly shale with Aulophyllum and

brachiopods preserved in calcite. An impersistent rib of limestone occurs in the shale, which is overlain by at least 4' of limestone (Plate 11). In Hindlethwaite Gill (055811) the section is difficult to measure accurately, but the entire limestone appears to be under 10' thick and does not carry any shale partings. The streams draining High pasture, on the east side of Coverdale show exposures in the limestone, most of which are in over 5' of beds; it is probable that the total thickness of the limestone does not exceed 10'.

In Fall Gill (017797) 3' of fossiliferous shales rest on 6" limestone which in turn lies on sandstone. It is not possible to prove that this limestone is the equivalent of the 3'6" limestone in Fleemis Gill, though this seems to be probably the case, since both are overlain by fossiliferous shales. Whilst the upper leaf of the Underset limestone is not exposed in Fall Gill due to faulting, it is probably almost on top of the fossiliferous shales seen in the section. In Lords Gill (019786) the upper leaf of the limestone appears to be completely exposed and is 9' thick. It overlies a gap in the section which may include fossiliferous shales with thin limestones similar to those described from Fleemis Gill and Fall Gill and also common in upper Coverdale.

The section in West Gill (009791) is complete and shows the development of cherty, platy beds at a horizon tentatively correlated with the base of the upper leaf of the Underset Limestone of Fleemis Gill and elsewhere and with the base of the Underset limestone of Low Dove Scar Penhill, where similar cherty beds are seen. The section here shows (see also Plate 11):

-	shale
11'	shale purplish-grey fine grained detrital limestone, bluish in colour at the base and top
2'	dark grey plate with bryozoa
6'	brashy, silty fossiliferous shale, but with the fauna badly preserved. (probably equivalent to similar shales at Fall Gill etc.)
9"	impure, dark blue limestone
-	sandstone

The section at Downs Gill (005787) is similar to the previous one and is here also detailed, since it is not shown on Plate 11:

-	shale
9'	pale grey detrital limestone
1'9"	dark grey plate with bryozoa
3"	shale
6"	blue limestone
3"	shale
9"	blue limestone
3'6"	approx. silty, brashy weathering fossiliferous shale with a badly preserved fauna
-	sandstone

The shales with thin limestones in the lower part of the above mentioned section are equivalent to similar beds recorded from West Gill, above.

Crab Gill and Burn Gill show incomplete exposures at this level, but in Slape Gill (Plate 11) the section is fuller and shows 9' of limestone. This overlies a gap which may possibly include the fossiliferous shales with thin limestone seen in many of the sections in upper Coverdale.

Hazel Bank Gill shows platy beds (2'6") below the Underset Limestone, here 12' thick.

The section in East Stone Gill (003776) is an excellent one in platy beds and c alcareous shales with limestones, underlying the Underset Limestone (Plate 11). The calcareous shales with thin

-	shale
11'	shale purplish-grey fine grained detrital limestone, bluish in colour at the base and top
2'	dark grey plate with bryozoa
6'	brashy, silty fossiliferous shale, but with the fauna badly preserved. (probably equivalent to similar shales at Fall Gill etc.)
9"	impure, dark blue limestone
-	sandstone

The section at Downs Gill (005787) is similar to the previous one and is here also detailed, since it is not shown on Plate 11:

-	shale
9'	pale grey detrital limestone
1'9"	dark grey plate with bryozoa
3"	shale
6"	blue limestone
3"	shale
9"	blue limestone
3'6"	approx. silty, brashy weathering fossiliferous shale with a badly preserved fauna
-	sandstone

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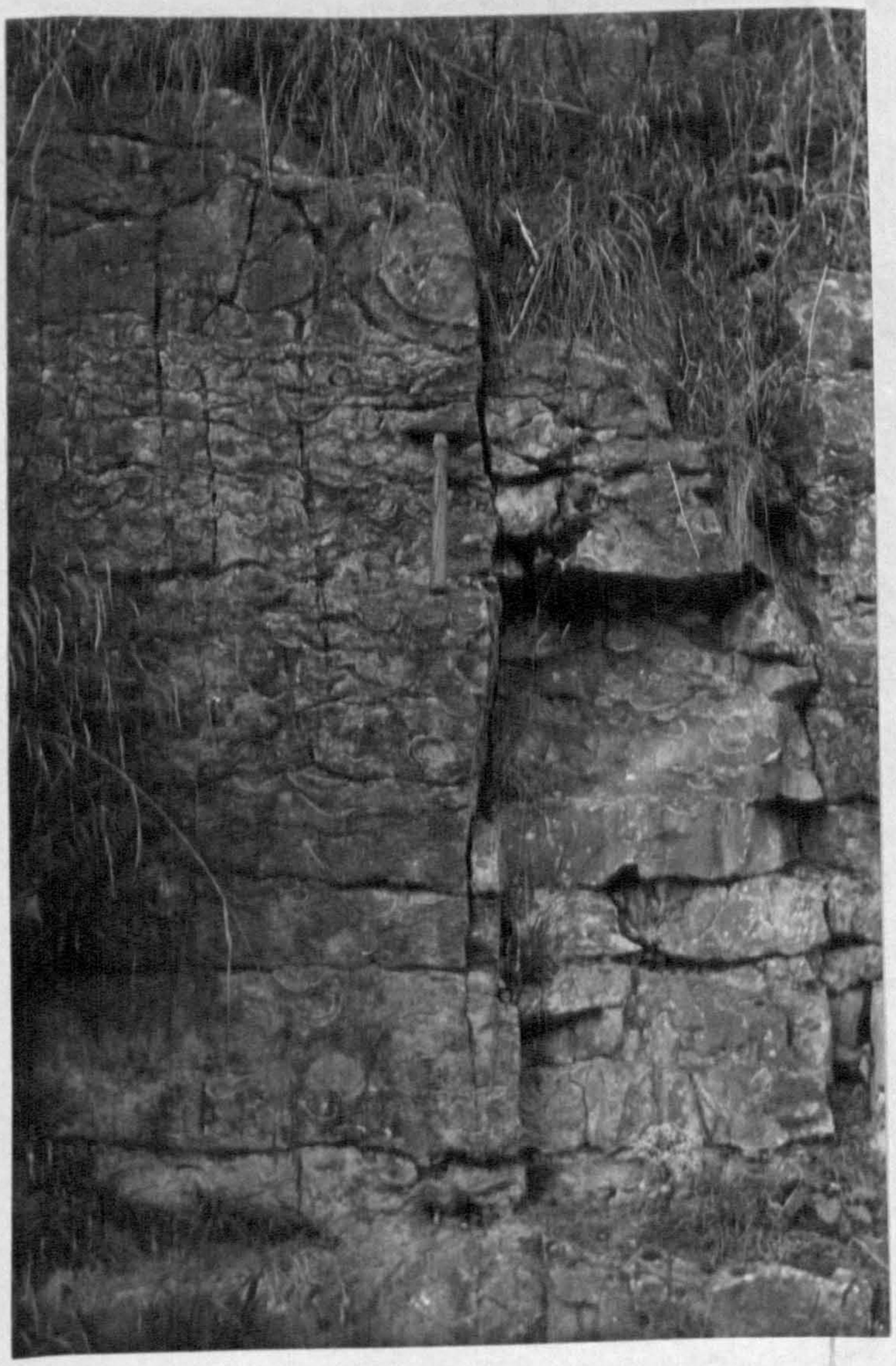


PLATE 10 A

The Gigantoproductus beds of the Middle Limestone at the entrance of the railway tunnel N.N.W. of Limley in Nidderdale, (099764). The well developed bedding and jointing and the convex-downwards position of the giganteids is typical of this horizon throughout the area. (The hammer is 1'3" in total length).



PLATE 10 B

The Underset Limestone in East Stone Gill (990771). The beds seen are from base to top, shales with thin limestones, showing up dark, centre, and cherty plates, weathering blocky (left centre) overlain by the Underset Limestone forming an outcrop which is seen on the right and left sides of the photograph and also it forms a waterfall below the observer. The dark feature on the sky-line is the outcrop of the Grassington Grit in Fox Stones. The flank of Great Whernside is seen, right, top.

limestones show thickness variation within the compass of the small section in East Stone Gill. 3' of beds are cut out by transgression; the shales shown as 7'6" thick on the figure in reality vary from 6' to 9' in thickness. This development of fossiliferous shales is here at its thickest and shows the typical brashy weathering and poorly preserved fauna (chiefly crinoid ossicles) characteristic of these beds. The fossiliferous shales are overlain by blocky, siliceous plate with a bryozoan-brachiopod-pelecypod fauna similar in all respects to that collected from beds of like lithology at Low Dove Scar and Elm Gill, with which correlation is tentatively made. If this correlation is correct, it implies that the marine shales with thin limestones which underlie this horizon are unrepresented north of Fleemis Gill, the furthest north that these beds have been recorded.

The Underset Limestone proper in East Stone Gill is 18' thick, as compared with the thickness observed in Hazel Bank Gill, 170 yd. away, where only 12' occur. The limestone is also seen in Hem Gill Beck and Downs Gill, Coverhead, but exposure is not complete.

The Underset Limestone is not fully exposed south of Coverhead. The most complete section is in a tributary of Park Gill Beck (990752), which is as follows:

2'	limestone (top not seen) Underset Limestone
5'	cherty plate
6'	gap
2'	cherty plate
10'	gap
-	Three Yard Limestone

It is not possible to assess the extent to which the measures below the limestone are secondarily chertified, but the very thick cherty plate at this locality is at least in part equivalent to the thinner

developments of these beds seen elsewhere.

An exposure at Lime Kiln Pasture (983754) shows 5' of limestone. Further west at Diamond Hill (980753) the limestone is not exposed, but cherty developments appear to occur both above and below it. A black chert is seen in place which strongly resembles the chert above the limestone in the north of the area, because it weathers white and splits up into small pieces. Below the scree in this chert are blocks of fossiliferous cherty plate with Hyalostelia and productids. Whilst this may belong to the cherty plates which commonly underlie the Underset Limestone in upper Coverdale, it seems also possible it may belong to a platy development at the top of the limestone. No undoubted exposures of the limestone or its attendant cherts was seen south of Park Gill Beck and it assumed that it is thin.

In upper Nidderdale a limestone occurs in a position (relative to the Three Yard Limestone) corresponding to the Underset of Park Gill Beck. The most complete section is near a scar close to the head of the Scar House Reservoir (04766):

-	Grassington Grit Group
4'	cherty plate
8'	chertified limestone; the supposed Underset Limestone
8'6"	cherty plate
7'	cherty, black shale
1'	cherty plate
-	Three Yard Limestone

As in the section in Park Gill Beck there is an abnormal development of cherty beds below the limestone which may be partially secondary in origin. The thickness of strata (16'6") compares quite closely with that at the corresponding level in Park Gill Beck (23').

The Underset Limestone is partially seen in several of the

streams draining into the two Nidderdale reservoirs, but the most complete exposure is in Crook Dike (026761) where 14' of grey limestone are exposed. These overlie a cherty series which may include some of the beds that are commonly cherts, immediately below the limestone in Coverdale.

In the Scar House Dam trench there is some variation at this horizon which is well shown in Tonks, 1925, Plate xvii Fig. 2. A persistent limestone about 10' thick overlies an impersistent shaley limestone, separated from the main leaf by a shale in the N. part of the section. Beds exposed below the dam in the bed of the R. Nidd (071769) are almost certainly at this horizon. The section is as follows:

12'	limestone
2'	gap
2'	platy chert, forming the bed of the R. Nidd.

It seems likely that the platy chert is equivalent to the shaley limestone recorded by Tonks. In thin section the limestone in the above exposure consists of abraded calcite ossicles with a little shelly debris in a matrix of calcite mud, now recrystallised to such an extent that the ossicles are being replaced marginally.

Tonks (1925) claimed that this horizon (his 'Upper Five Yards Limestone') is exposed in the Thrope House Inlier, near Limley. The present author cannot confirm this, though it remains a possibility. The highest limestone exposed in the section appears to be one which rests on fossiliferous shales strongly resembling those seen below the Three Yard Limestone (the 'Lower Five Yards Limestone' of Tonks). Owing to faulting it is not possible to prove whether high horizons are here represented. The highest limestone is undoubtedly

exposed near Thwaite House, but lack of exposures does not permit the relations with the underlying limestones to be examined.

Shales and sandstones of the Underset cyclothem - exposures are considered in sequence, firstly in Waldendale, progressing down-dale, in Coverdale moving up-dale, and at Park Gill and in Nidderdale.

Waldendale - beds of this group are ill exposed in Waldendale, and are frequently obscured by landslips in the upper part of the valley.

In Walden Beck, near Walden Head (978787), the succession is unique within the present area, owing to the presence of a sandstone directly over the Underset Limestone, in a position where fossiliferous shales usually occur elsewhere. The beds seen are (see also Plate 11):

-	Main Limestone
15'	flaggy, micaceous, fine grained quartz sandstone with Crossopodia sp. and vertical burrows which deflect the bedding downwards into pittings, where referred to cf. Arenicolites sp.
4'	flaggy sandstone with shale partings
56'	shale scree, with few exposures, but almost certainly all shale
9'	flaggy, micaceous sandstone with annelid trails

North of this section exposures are concealed by the Crag Brea landslip. On the hillside near Ashes Farm it was possible to get an approximate figure of 90' for the thickness of the cyclothem by levelling between exposures of the Underset Limestone and the feature on the Main Limestone. North of this point large landslips occur on beds of the Underset cyclothem, and nothing is seen of these rocks south of Thupton Gill.

North of Thupton Gill, at 026855, a sandstone, approximately 30' above the Underset Limestone has been worked in levels, possibly for roofing stone. North of this point and on the N. face of Penhill

the beds of the Underset cyclothem form steep slopes with sometimes a mappable feature on to the Underset Limestone. Below a limestone scar at 029866, further adit workings into a sandstone within the cyclothem are seen, and again at the same stratigraphic level as the sandstone above Stony Gate, pointing to there being a continuous arenaceous horizon about 30' above the Underset Limestone on the N.W. flanks of Penhill. Sporadic exposures in the beds above the sandstone are in shales, whilst at three points along the base of Dove Scar the Main Limestone can be seen resting on the highest sandstone of the Underset cyclothem.

A partial section is seen in a stream course below the springs W. of New Plantation (046876) (Plate 11). The lowest beds visible are unfossiliferous shaley mudstones which pass up into flaggy sandstone here only 6' thick directly under the Main limestone. Since sandstone blocks occur through a thickness of 10' below the exposed shale, it is possible that the sandstone which has been worked to the west here persists, but at a markedly lower stratigraphic level, namely 11' approx. above the Underset Limestone. The scar of a small landslip below Hunter Thorn (051876) shows the sandstone at the top of the Underset cyclothem to be 15' thick, but it includes a shale parting. At Moor Bank (061875) adits were driven in a sandstone about 30' above the Underset Limestone. This sandstone is seen in situ in a small stream on Capple Bank (071875). It is presumed that it is equivalent to that at the same horizon on the N.W. slopes of Penhill. At Spigot Lodge Plantation the beds of the cyclothem above the Underset Limestone appear to be over 60' thick, but are very imperfectly exposed. The sandstone at the top of the cyclothem

is seen at two points under the edge of Capplebank where it is at least 19' thick (Plate 12B). Below Limekiln Hill (080875) the sandstone is developed as follows:

15'	compact, blocky micaceous fine grained sandstone
4'	thin bedded flaggy sandstone, probably transitional downwards into shales

Whereas the Underset cyclothem above the Underset Limestone is over 60' thick at Spigot Lodge Plantation, one mile to the east the evidence of features suggests that these beds thin strongly towards Sharp Hill Farm, from about 50' to 20' (see Plate 12 B, which presents all the thickness data in map form).

Coverdale - the section in the R. Cover at Cover Scars (133867) confirms this easterly thinning, for here the beds are only about 11' thick. The section shows:

-	Main Limestone
1'	fossiliferous shale with limestone nodules
5'6"	unfossiliferous shale with 2' zone of chalybite nodules
6"	siltstone with spiriferids
6"	coal (of workable quality)
9"	grey fireclay seen
3'	approx. gap
-	cherts above the Underset Limestone

The sediments listed above are entirely different to any seen at this level elsewhere in the present area and show the only development of coal in this cyclothem. The section at Elm Gill (095852) is only a partial one, but it is here evident that the Underset cyclothem is much thicker than at Cover Scars. About 65' is seen, which is however a significantly lower figure than the average thickness observed in middle and upper Coverdale (see Plates 11, 12 B). The upper beds only are here exposed and carry thin beds of sandstone, whilst the sandstone which usually occurs below the Main Limestone is

thin or not developed at all.

The section at Melbeck, Carlton (063849) shows good exposures in the lowest beds of the Underset cyclothem above the Underset limestone, though the actual contact with the top of the limestone is not seen (see also Plate 11):

16'	flaggy, fine grained quartz sandstone
23'	Unexposed (assumed shale)
37'	brittle ferruginous shales without fossils
6"	blocky, well jointed blue calcareous siltstone, weathering on the surface to a brown rottenstone and carrying bedding planes crowded with badly preserved specimens of Spathella cylindrica (McCoy), which appears to be the only species in this bed
3'	ferruginous shale without fossils
3'	compact, dark blue shale with a moderately prolific, well preserved normal shale fauna preserved in calcite. The dominant form is Martinia glabra together with Leda attenuata, gastropods and ostracods
	small gap (probably under 1'); presumed shales.
-	Underset Limestone.

Between the upper part of Turn Beck and Mount Pleasant, the beds of the Underset cyclothem above the limestone appear to be very thick, possibly 100' in all. Exposures are incomplete, but the lowest 50' is shale, intermittently exposed, carrying one fossiliferous horizon with a brachiopod-pelecypod fauna. It is possible that a sandstone occurs in the midst of the shales of the cyclothem, as on the N.W. slopes of Penhill, but only chips of flaggy sandstone and no exposures are seen. The sandstone below the Main Limestone is thick; 20' are seen at 040834 (Plate 12 B).

In Fleemis Gill (819024) excellent exposures occur in the upper beds of the cyclothem. The section measured in Coal Gill, coupled with exposures in Fleemis Gill is (see also Plate 11):

8'6"	flaggy, fine grained quartz sandstone
7'6"	alternations of flaggy sandstone and shale. The s andstone includes rain prints and annelid trails

40' blue shales with occasional brachiopods in a poor state of preservation

On the E. side of the valley, between Elm Gill and Hindlethwaite Gill, there are no exposures in the Underset cyclothem, above the limestone, apart from exposures on Rampshaw Bank, a drift-free area (059820). The shales above the Underset Limestone are seen in a small exposure. The exact horizon is in doubt, being probably a few feet above the top of the limestone. They are dark, somewhat ferruginous shales with fairly numerous Productus concinnus and Camaratoechia pleurodon, but little else. The overlying beds are not exposed except for the sandstone under the Main Limestone, about a foot of which occurs nearly in place above a spring (059818).

The rock is here a very fine grained grey, compact sandstone when fresh, but is more typically a brown, leached rather rotten sandstone with shelly casts, the commonest forms being Productus carbonarius, Buxtonia scrabiculus and Camaratoechia pleurodon. The section in Hindlethwaite Gill (055810) is an almost complete one except for some of the lower beds. The section seen is (Plate 11):

-	Main Limestone
2'6"	unexposed; a coal may occur here (workings occur nearby)
8'6"	fine grained sandstone with carbonaceous impressions and brachiopod casts.
2'	shaley sandstone
50'	shales without fossils
1'	black, compact, finely micaceous black shale with carbonised plant remains, often lying parallel as if washed by currents, Lingula cf. squamiformis, Schizodus sp. and palaeoniscid scales
20'	approx. gap; probably shales
4'	rotten shale, possibly of the fossiliferous variety
-	Underset Limestone

On the W. side of the dale above Horse House, landslips involving the shales of the Underset cyclothem occur. Fossils have been found in the debris of the landslip in Deerclose Gill (043812). The

upper beds of the cyclothem are seen in the stream draining past Slated Lathe (034805). The section shows:

13'	fine grained sandstone grading down into siltstone
35'	blue shale with scattered, badly preserved small pelecypods referable to Nucula sp.

Fall Gill shows a similar section, with incomplete and slipped exposures on the shale member of the cyclothem which is sparsely fossiliferous. The sandstone is only 9' thick (Plate 12 B).

On the E. side of the valley, sections are lacking on Arkleside Pasture, but Harkera Gill (040794) shows a good section in the upper beds, with the sandstone member of the cyclothem in a degenerate condition, thus:

-	Main Limestone
2'	siltstone
3'	silty shale
6'	blocky siltstone
25'	blue shale seen

The numerous streams draining into the R. Cover from High Pasture show sections in shales of the Underset cyclothem, here eroded into deep gulleys. These beds yield occasional small pelecypods. The sandstone member of the cyclothem which is degenerate in Harkera Gill (detailed above) gains in thickness to the S.E. and is well developed in Ridge Gill and Lords Gill (Plate 11). Several of the streams between Slape Gill and Ridge Gill show partial exposures in the shales of the Underset cyclothem.

In West Gill (009791) the shales are chiefly exposed, but the sandstone at the top of the cyclothem is here absent. The approximate section (Plate 11) is:

-	Main Limestone
75'	unfossiliferous shales

5'	fossiliferous dark shales with Martinia glabra, Camaratoechia pleurodon
-	Underset Limestone

In Downs Gill (005787) the section is:

-	Main Limestone
-	possible gap due to faulting
45'	shale partially exposed
2'3"	pale grey, granular limestone
15'	shale with plant and shell fragments in the top portion
-	small gap due to faulting
-	Underset Limestone (overlain by inaccessible, rotten shales)

It seems possible that the limestone is equivalent to the calcareous siltstone in Melbeck, but it appears to be at a somewhat higher level above the top of the Underset Limestone.

A gorge in East Stone Gill (989771) shows an extensive section which is almost complete (Plate 11):

-	Main Limestone
4'6"	flaggy mudstone and flaggy sandstone (this bed is variable and laterally 8' of sandstone comes in)
8'	micaceous mudstone
3'	flaggy sandstone and flaggy mudstone
35'	unfossiliferous mudstone with small reniform nodules
18'	dark mudstone with scattered dwarf pelecypods and small reniform nodules
-	horizon with productids in nodular weathering shale
10'	black brittle shale with dwarf pelecypods in the lower portion and rare Palaechinus sp.
15'	approx. unexposed, except for the lower beds which are sparsely fossiliferous at a horizon a few feet above the base
-	Underset Limestone

In Downs Gill (990765) sections occur in shales involved in landslips. One horizon is markedly fossiliferous and appears to be at about the same level as that yielding productids at East Stone Gill, (i.e. it is about 25' above the top of the Underset Limestone). The fauna, preserved in dark grey, ferruginous shale, is a normal shale assemblage with corals, brachiopods, pelecypods and some sponge remains. The most important fossil is undoubtedly ?Cravenoceras sp.,

a fragmentary goniatite not permitting of certain identification, found in the shales at this exposure. At least 22' of thin bedded flaggy sandstones occur here at the top of the cyclothem (Plate 12 B).

South of Coverhead the shales of the Underset cyclothem maintain their thickness as far as Caseker Crag, south of which point they are gradually cut out by intra-E_1 erosion. The shales are exposed in several scars in the headwaters of Park Gill Beck and are affected by minor slippages. At two points a short distance below the base of the Grassington Grit Group, south of Park Gill Beck, they have yielded organic fragments. The sandstone below the Main Limestone is at least 15' thick south of Coverhead (991753), but appears to be cut out completely a little north of Caseker Crag and is not seen further south, owing to intra-E_1 erosion.

Palaeontology

The Underset Limestone - this horizon yields a bed of corals over a large area of the Askrigg Block (Miller and Turner, 1931, Moore, 1955), characterised by Dibunophyllum bipartitum vars.

The fauna of the coral band in the Underset Limestone, restricted to the N.W. of the present area, consists of rolled calices, not in the growth position, of haploid corals. The most abundant of these are Dibunophyllum bipartitum vars. (the most common variant appears to be D. bipartitum bipartitum), Aulophyllum fungites and more occasional Konickophyllum. Moore records similar forms with, as in the present work, a large additional fauna, chiefly of brachiopods. The present list gives several productids, the

most abundant of which appears to be Gigantoproductus latissimus group, whilst Spirifer bisulcatus J. Sowerby group is also common. The record of Gigantoproductus giganteus from the present area is duplicated by Miller and Turner (1931) and by Moore (1955).

Since the macrofauna of the appended list is drawn from one locality, it must be emphasised that whilst the development of the Underset Limestone at Dove Scar is very fossiliferous (chiefly at the horizon of the coral bands) the Underset Limestone of the area as a whole is exceedingly poor in macrofossils. Collecting was not therefore attempted at any other locality, though prolonged search will no doubt yield a restricted macrofauna at other places.

The record from Fleemis Gill, incorporated in the lists at the end of this chapter, is from shales which lie in between two leaves of the Underset Limestone, which yield forms also common to the limestone.

Platy beds below the Underset Limestone - The platy cherts below the Underset Limestone at three widely separated localities have yielded in each case a characteristic fauna not matched at any other horizon. The chief form is Fenestella, growing in colonies up to several centimetres across. These are preserved as films in calcite which, when correctly weathered, may show sections of the zooecia in a rather crushed condition. Other bryozoa, notably Pennireteporа, are fairly common. The brachiopod fauna consists typically of small productids; no large forms occur and it may be surmised that living conditions tended to be unfavourable. This is parallelled in the Richmond Chert Series, where the productids

also appear to be small forms, chiefly species of Eomarginifera. These stunted developments are possibly connected with an unusual abundance of silica in the water at the time that primary cherts were forming. The pelecypod, Lithophaga carbonaria occurs at two localities in moderate numbers, and is only recorded from this horizon in the present area. The size of the fenestellid zoaria is remarkable since colonies of up to 8 cm. across were noted of Fenestella plebeia McCoy. A further characteristic form is F. haemispherica McCoy which shows the peculiar circular shape (crushed bell-like colonies) excellently (Plate 18 B).

No comparative fossil lists exist for this horizon elsewhere. Whilst Moore records these beds he does not provide a separate faunal list, though he states that they are characterised by a bryozoan-brachiopod assemblage and it seems likely that the forms are similar. A remarkable feature of this horizon in the present area is the similarity of the faunal lists from the three, scattered localities from which this fauna was collected, this resemblance being especially striking in the case of the bryozoa.

Shale roof of the Underset Limestone - This horizon is probably fossiliferous over a large area and includes the lowest 4' or so of shales in the Underset cyclothem which are dark and fine grained, with a fauna preserved as calcite films. Exposures of this horizon are rare, but the preservation of fossils at the existing localities is good. The records from Melbeck are of a normal shale fauna in excellent preservation, but not in large numbers. Whilst no ostracods were separated from their matrix, they appear to be numerous and well preserved and a special study, given time, would have been rewarding. The fauna recorded from

Rampshaw Bank is more restricted than that at Melbeck and appears to be made up almost entirely of Productus (Productus) concinnus and Camaratoechia pleurodon, forms which occur in considerable numbers and include a specimen of the dorsal valve of P. concinnus showing the characteristic trail to perfection.

Shales of the Underset Cyclothem (excluding basal 4') - generally these shales are very sparsely fossiliferous. Preservation is usually poor and the appended list is drawn up chiefly from an exposure in Downs Gill, Coverhead which yielded an unusually prolific fauna in a dark blue, ferruginous shale about 20-30' above the Underset Limestone. The fauna from this exposure is somewhat unusual in some respects, since productids are rare, whilst pelecypods are abundant. The record of ?Cravenoceras sp., identified by W.H.C. Ramsbottom, is important since it adds a little additional evidence for the placing of the base of the Namurian about 15' above the Underset Limestone. This corresponds well with the record of Eumorphoceras pseudobilingue (which, like Cravenoceras, is a form occurring in E_1, but not in the P zone) from below the Main Limestone of Fountains Fell by Hudson (1941) and Black (1950). It is also complementary to the evidence given by Johnson (1953) and Rayner (1953 - using information from Johnson) regarding the occurrence of highest P_2 goniatites in the Mount Pleasant Borehole, near Bishop Auckland, at a horizon which is probably between the Underset Limestone and the Underset Chert. The available records therefore suggest that proven P_2 forms occur below the Underset Chert, whilst probable E_1 forms exist about 20' higher in the succession and more certain E_1 forms at a slightly

higher stratigraphic level, but also below the base of the Main Limestone. This latter horizon is now the base of the Namurian accepted by the Geological Survey for mapping purposes. It is, from a perfectionist point of view, higher than the probable actual base which is not an accurately mappable horizon, being in the middle of a shale series. Thus this line of demarcation between other Upper and Lower Carboniferous is of academic, rather than of practical interest.

The record of a compact black fossiliferous shale in Hindlethwaite Gill at a horizon 24' above the top of the Underset Limestone appears to be an unusual and isolated occurrence. The assemblage consists of Lingula and palaeoniscid remains. The linguli̇ds are noteworthy for their large size, the largest specimens attaining 3 cm. in length; these are forms which are referable to Lingula cf. squamiformis Phillips. Whilst the above mentioned shale contains spines of an echinoid, shales at a similar horizon in East Stone Gill yield ambulacrals, interambulacrals and spines. Several of the plates are still articulated, and hence probably not far travelled. These remains have been tentatively referred to Palaechinus sp. by Dr. Ramsbottom, who notes that the typical Palaechini usually shows more tubercles per plate than the specimen from East Stone Gill.

The record from Melbeck, Carlton is from a calcareous siltstone 6' above the top of the Underset Limestone which is not exposed elsewhere and carries numerous badly preserved specimens of Spathella cylindrica crowded on the bedding planes.

The records from the shales of the Underset cyclothem are of interest, because they show that a fauna persists in this cyclothem

virtually through the shales. For the most part it is a patchy development and includes dwarfed pelecypods and little else, except locally, where larger faunas appear to occur in isolated pockets, whilst the shales as a whole are sparsely fossiliferous. It seems that the shales of the Underset cyclothem are not fossiliferous in upper Wensleydale, since Moore provides no records of fossils from between the Underset and Main limestones.

Sandstone of Underset cyclothem - This horizon is usually lacking in fossils, but yields an abundant fauna locally at Rampshaw Bank in Coverdale. Preservation is in full relief, but is somewhat indistinct owing to the grain of the stone. In appearance and faunal content this rock closely resembles the R_1 shell beds of the present area, but differs in being more calcareous. The brachiopod fauna is partly duplicated species for species. Productus carbonarius is one of the most common fossils in the Cayton Gill Shell Bed, whilst Buxtonia scrabiculus and Derbyia hindi are also recorded from the Libishaw Sandstone. The pelecypod fauna is also similar to that of the Cayton Gill Shell Bed, but is much poorer in species.

Faunal Lists

Underset Limestone

'Cauda-galli' (problematic markings), 1

?Bevocastria sp., 3
?Girvanella sp., 1, 3

Ammodiscus incertus (D'Orbigny), 3
Archaediscus karreri Brady var. β Short ms., 1, 3

Aulophyllum fungites (Fleming) var. pachyendothecum (Thomson), 1
Aulophyllum fungites (Fleming), 2

Dibunophyllum bipartitum bipartitum (McCoy), 1
---------- bipartitum craigianum (Thomson)
---------- bipartitum konicki (Edwards and Haime), 1
Hexaphyllum sp., 1
Konickophyllum interruptum Thomson and Nicholson, 1
Lithostrotion pauciradiale (McCoy), 1

Archaeocidarid spine, 1,3

Crinoid ossicles, 1, 3

Fenestella sp., 1, 2
Rhombopora sp., 1

Actinoconchus planosulcatus (Phillips), 2
Brachythyris decora (Phillips), 1
Chonetes hardrensis Phillips, 1
Crurithyris sp., 1
Phricodothyris sp., 1
Productus (Dictyoclostus) aff. griffithianus de Konick, 1
--------- (Echinoconchus) punctatus (Martin), 1
--------- (Eomarginifera) longispinus J. Sowerby, 1
--------- (Gigantoproductus) giganteus (Martin), 1
--------- (----------) latissimus J. Sowerby group, 1, 2
Schizophoria resupinata (Martin), 1, 2
Spirifer bisulcatus J. Sowerby group, 1

Conocardium sp.

Index of localities for the above

1. Low Dove Scar Penhill (includes thin section) 034876
2. Fleemis Gill, Coverdale (shales between two limestones) 031821
3. Hindlethwaite Gill (thin section only) 055811

Platy beds below Underset Limestone

Textulariid, 1

Hyalostelia parallella (McCoy), 1, 2

cf. Ancistrum sp., 3

Crinoid ossicles, 1, 3

Arthrostylus sp., ?1, 3
Fenestella haemispherica McCoy, ?1, 2, 3
---------- morrisii McCoy, 1, 2, 3
---------- plebeia McCoy, 2, 3
---------- sp. (square fenestrules), 1, 2
Penniretepora sp., ?1, 3

Rhabdomeson sp., 1, ?2, 3
Trepostome, ?3

Actinoconchus planosulcatus (Phillips), 2
Athyrid indet., 3
Camaratoechia pleurodon (Phillips), 1, 3
Crurithyris urei (Fleming), 2, 3
---------- sp., indet., ?1
Lingula mytiloides J. Sowerby, 1, 3
Productus (Dictyoclostus) cf. muricatus Phillips, 2
--------- (----------) sulcatus J. Sowerby, 1
--------- (Eomarginifera) cf. longispinus J. Sowerby, 3
----------(Productus) cf. productus (Martin), 3
----------(Pustula) aculeata (Martin), 2,3
--------- (sp. indet., 1, 2
?Schuchertella sp., 2, 3

Aviculopecten plicatus (J. Sowerby), 3
---------- tabulatus (McCoy), 3
Leiopteria thompsoni (Portlock), 3
Limipecten dissimilis (Fleming), 3
Lithophaga carbonaria de Koninck, 1, 3
?Nuculid, 1

cf. Angiomphalus junior (de Koninck), 3
Gastropod indet (?Spirorbis sp.), 1

Ostracods, 1, 3

Index of localities for the above

1.	East Stone Gill, Coverdale	990792
2.	Elm Gill, Coverdale	094852
3.	Low Dove Scar, Penhill	037876

Shale roof of Underset Limestone

Sponge spicules, 3

?Penniretepora sp., 1
?Streblotrypa sp., 1

Crinoid ossicles, 1, 2

Camaratoechia pleurodon (Phillips), 2, 3
Crurithyris urei (Fleming), 1
Martinia glabra (Martin), 1, 2
Productus (Productus) concinnus J. Sowerby, 3
Pugnax pugnus (Martin), 1
Schellwienella crenistria (Phillips), ?3

Aviculopecten sp., 1
Leda attenuata (Fleming), 1

Euphemites urei (Fleming), 1
Straparolus carbonarius (J. Sowerby)
Zygopleura robroystonensis Longstaff, 1

Bairdia sp., 1
Hollinella sp., ?1
Paraparchites sp., 1

Index of localities for the above

1.	Melbeck, Carlton, Coverdale	062849
2.	West Gill, Coverdale	009791
3.	Rampshaw Bank, Coverdale	059820

Shales of the Underset cyclothem (exepting the lowest 4')

Plants, 1

Hyalostelia parallella (McCoy), 2
Poriferid, 2

Zaprentid coral indet., 2

Archaeocidarid spines, 1
?Palaechinus sp., 5

Crinoid ossicles, 2

Fenestella plebeia McCoy

Actinoconchus lamellosus (Léveillé), 2
Camaratoechia pleurodon (Phillips),
Crurithyris sp., 2
Dielasma sp., juv., ?2
Hustedia radialis (Phillips), 2
Lingula elongata Demanet, 2
------- mytiloides Phillips, 1
------- cf. squamiformis Phillips, 1
Phricodothyris cf. insolita George, 2
---------- sp., 2
Productus (Productus) concinnus J. Sowerby, 2
Schellwienella sp., ?2
Spirifer bisulcatus J. Sowerby group, 2

Amusium concentricum Hind, 2
------- cf. planicostatum (McCoy), 2
Aviculopecten cf, semicostatus (Portlock), 1
---------- sp., 2
Edmondia aff. laminata (Phillips), 2
Leda attenuata (Fleming), 2
Nucula luciniformis Phillips, 4

Nucla laevirostrum Portlock, 2
Nuculana laevistriata (Meek and Worthen), 2
Palaeolima simplex (Phillips), 2
Pseudamusium cf. ellipticum (Phillips), 2
Schizodus sp., 1
Spathella cylindrica (McCoy), 3
Streblopteria sp., 2

Coleolus sp., 2

?Cravenoceras sp., 2

Ostracods, 1

Weberides sp. (non-mucronate), 2

Palaeoniscid scales, 1

Index of localities for the above

1.	Hindlethwaite Gill	056809
2.	Downs Gill, Coverdale	990765
3.	Melbeck, Carlton	062849
4.	Slate Gill, Coverdale	032792
5.	East Stone Gill, Coverdale	989771

Sandstone of the Underset cyclothem under the Main Limestone

Carbonised plant

Crinoid ossicles

Camaratoechia pleurodon (Phillips)
Derbyia hindi Thomas
Dielasma sp.
Productus (Buxtonia) scrabiculus (Martin)
--------- (Productus) carbonarius de Koninck
--------- (---------) cf. carbonarius de Koninck

Edmondia sulcata Phillips
Cypricardella sp.

All the above are from one locality: Rampshaw Bank, Coverdale (059818)

PLATE 11

Comparative sections of the Underset cyclothem

PLATE 12 A Information diagram for the Underset Limestone.

Small circles- good exposures. Black semicircle- chert above limestone. Black triangle- cherty 'plate' below the Underset Limestone. Black circle- calcareous shales usually with thin limestones below the 'plate' and main part of Underset Limestone. Line of dots and dashes- southern limit of chert over the Underset Limestone (this excepting a single occurence at Walden Head). Coarse broken line- northern limit of calcareous shales with thin limestones below the main body of the Underset Limestone. Fine broken line- southern limit of Underset Limestone resulting from pre-Grassington Grit erosion. Small solkd circles- Underset Limestone removed by intra-E_1 erosion.

PLATE 12 B Isopachyte diagram for the Underset cyclothem above the Underset Limestone. Isopachs are at 25' intervals. Large figures denote thicknesses on which isopachs are based. Preface of 'c.c.' before a figure denotes that the figures are based on reliable estimates from the 6" geological map. Preface of 'c' denotes aa thickness determined by levelling of features.

Solid line margined by a stipple- approximate southern limit of the Main Limestone below the sub-Grassington Grit unconformity and south of which the Underset Cyclothem is progressively cut out in the manner shown by the isopachs. Small solid circles- Underset Cyclothem above the Limestone is absent owing to intra-E_1 erosion. Small figures- thickness of sandstone of Underset Cyclothem , underlying the Main Limestone.

50 Feet
40
30
20
10
0

BASE OF MAIN LIMESTONE

1
COVER SCAR

2
ELM GILL

3
NEW PLANTATION

4
DOVE SCAR

5
MEL BECK

6
FLEEMIS GILL & COAL GILL

7
HINDLETHWAITE GILL

8
LORDS GILL

9
WEST GILL

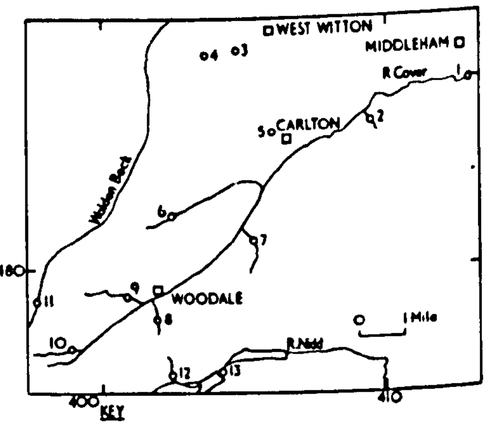
10
EAST STONE GILL

11
WALDEN BECK

12
CROOK DIKE

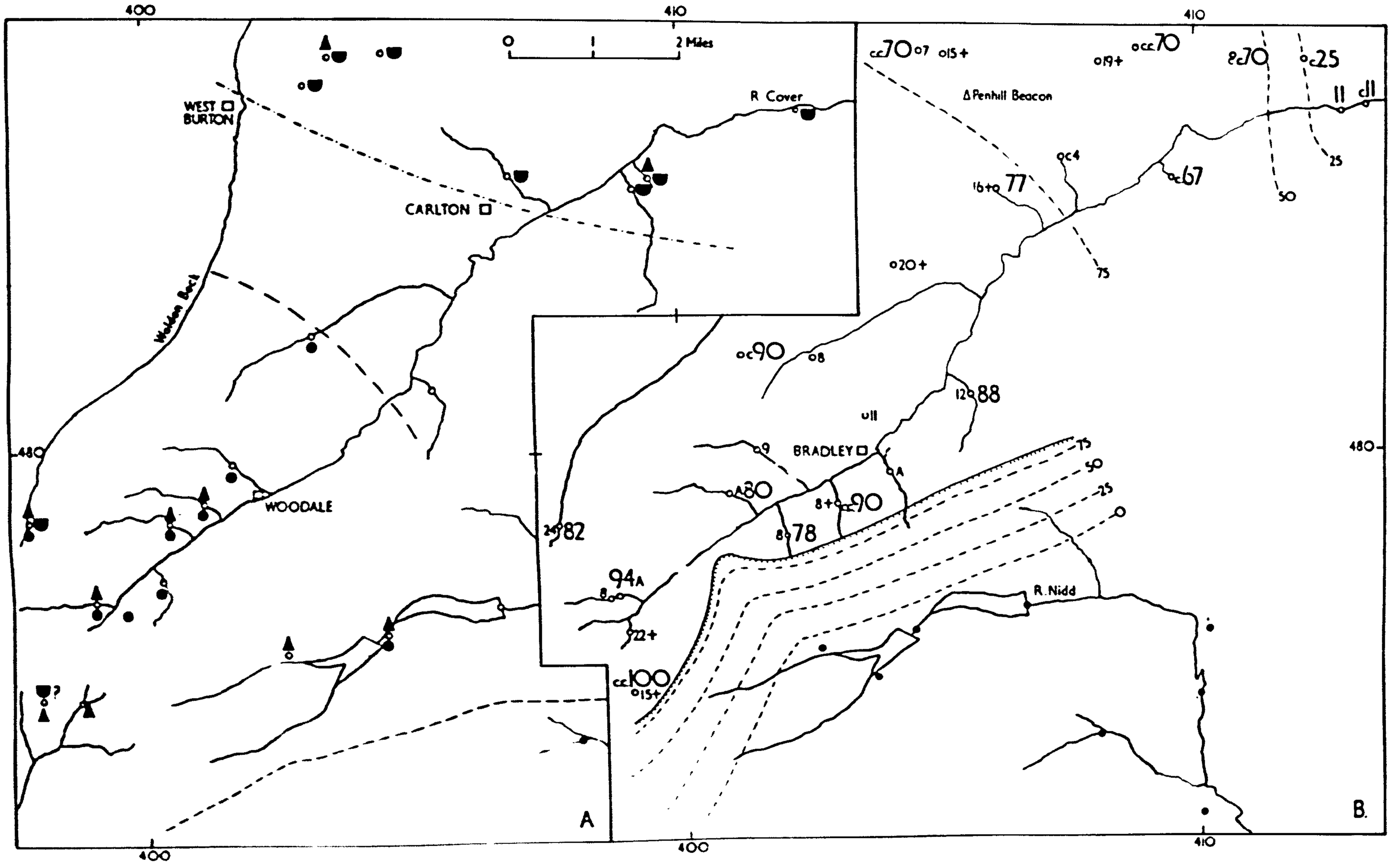
13
HEAD OF SCAR HOUSE RESERVOIR

← UNDERSET LIMESTONE



KEY

- Coal or Fireclay
- Fine Grained Sandstone
- Alternating Shale and Sandstone
- Shale with Chalybite Nodules
- Shale with Calcareous Siltstone
- Shale
- Calcareous Shale with fossils
- Cherts
- Limestone
- Gap, with probable rocks inserted
- L- L- Lingula Band



400
410
0
1
2 Miles
WEST BURTON
CARLTON
R Cover
Walden Beck
WOODALE
480
A
Penhill Beacon
BRADLEY
R. Nidd
B.

PLATE 13

Comparative sections in the Main, Little and Crow cyclothems.

PLATE 14 A Isopachyte diagram of the Main Limestone. This is also the key to sections 1-28 on Plate 13. Isopachs are at 10' intervals, starting at 20'. Numerals denote thicknesses (section numbers in circles) on which isopachs are based. The solid line edged with a stipple is the southern limit of the Main Limestone , south of which it is absent due to intra-E_1 erosion (at localities indicated by solid circles).

PLATE 14 B Isopachyte diagram of the Richmond Chert Series. Isopachs are at 25' intervals. The solid line edged with a stipple is the southern limit of the Chert Series. Numbers denote thicknesses on which isopachs are based. Figures in brackets denote reliable estimates based on features, which give a thickness larger than that actually visible.

1 FLINT LANE
2 MIDDLEHAM LOW MOOR
3 COVER SCAR
4 RED BECK GILL
5 ELM GILL
6 GRIFFHEAD
7 LEAD UP GILL
8 HOWDEN GILL
9 MOUNT PLEASANT
10 CUMMA GILL
11 RAY GILL
12 FLEENSOP GILL
13 THUPTON GILL
14 HARLAND HILL

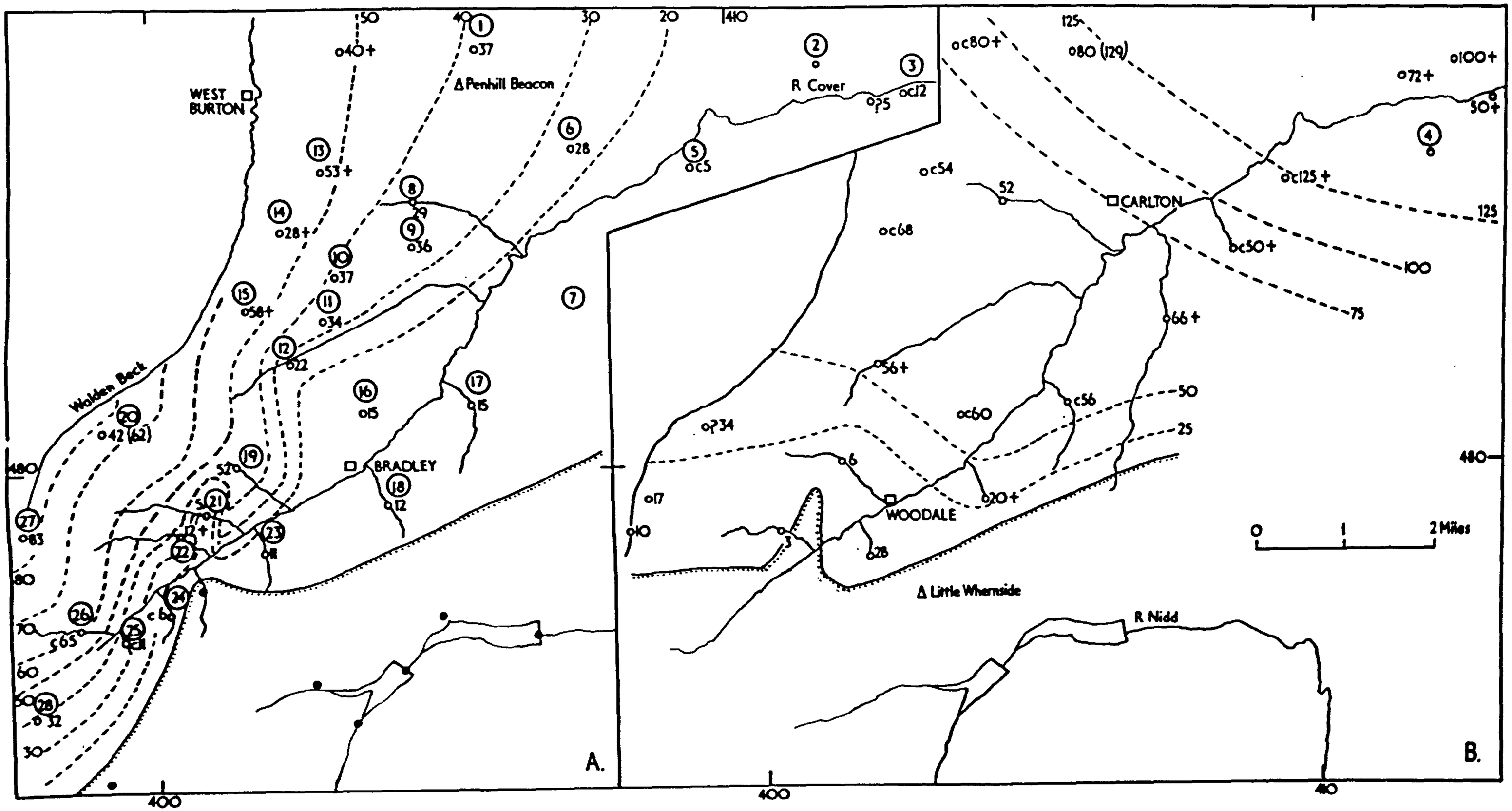
CROW LIMESTONE
TEN FATHOM GRIT
60 Feet
40
20
0

RICHMOND CHERT SERIES
MAIN LST.
BASE OF GRASSINGTON GRIT GROUP

KEY
Chert
Chert in limestone
Crinoidal limestone
Little Lst. Pipe Bed
Limestone
Sandstone
Shale
Gap probable geology indicated

15 DOVE SCAR
16 HORSEHOUSE MOOR
17 HINDLETHWAITE GILL
18 HARKERA GILL
19 FALL GILL
20 CRAG BRAE
21 WEST GILL
22 DOWNS GILL
23 LORDS GILL
24 SLAPE GILL
25 HEM GILL
26 EAST STONE GILL
27 WALDEN HEAD
28 TOR DYKE

RICHMOND CHERT SERIES
MAIN LST
BASE OF GRASSINGTON GRIT GROUP


WEST BURTON
Δ Penhill Beacon
R Cover
CARLTON
BRADLEY
WOODALE
Walden Beck
Δ Little Whernside
R Nidd
0 1 2 Miles
A.
B.

CHAPTER 7

THE MAIN, LITTLE AND CROW CYCLOTHEMS

The Main Limestone

The Main Limestone was so named by Phillips (1836) who recognised it in the present ground, below the 'black chert and plate' of Penhill. He noted that the limestone was locally cut out in Coverdale and finally died out south of Coverhead due to "overlap" by the overlying Grit. Dakyns (1891) followed Phillips in correlating the limestone at Coverhead with the Main Limestone. This correlation was subsequently altered to the Underset Limestone by Hudson and Cotton (1925), but changed back to the old one by Hudson (1933) without stating any reason. Mapping in Coverdale confirms that the limestone at Coverhead is in fact the Main.

The work of Moore (1955) shows that two coral bands occur locally in upper Wensleydale and also beds with Gigantoproductus. None of these fossiliferous layers persists into the present ground, but a highly fossiliferous horizon with Phricodothyris and Schellwienella occurs in Lock Gill, Coverdale.

Stratigraphy - The Main Limestone is a grey fairly massive rock consisting chiefly of crinoid ossicles and calcite mud. It seldom is rich in microfossils. Throughout the area it rests on sediments, usually sandstone, of the Underset cyclothem. The Main Limestone is everywhere overlain by the Little Limestone and Richmond Chert Series, except in upper Coverdale and south of Coverhead where the Grassington Grit Group has transgressed on to it. The limestone is absent entirely in Nidderdale and

south of Caseker Crag, near Kettlewell, owing to intra-E_1 erosion.

The Main Limestone shows the most extreme thickness variation of any calcareous horizon in the present area. The total change is from 83' to about 5' and takes the form of south easterly thinning under the Little Limestone. This thinning is unusual since the Main Limestone is one of the most constantly thick horizons on the Rigid Block. The thinning is quite independent of transgression at the base of the intra-E_1 unconformity except in the S.E. of the ground. In view of the fact that Wells (1955b) believed that there was an unconformity below the Little Limestone in the vicinity of Leyburn it seems possible that the present case of thinning of the Main Limestone below the Little is due to the same cause. The absence of a clear-cut break at the base of the Little Limestone in the area here described does not aid confirmation of this view however. Further there is some evidence in the quarry at Limekiln Hill on the N. flank of Penhill of easterly thinning of beds within the Main Limestone independently of any supposed transgression at the base of the Little Limestone.

In Waldendale the Main Limestone is at its thickest and always exceeds 50'. It attains its maximum at Raven Scar, at the head of the dale. The large thickness is maintained towards Coverhead where about 65' of Limestone occur in East Stone Gill. Rapid south easterly thinning occurs here however under the intra-E_1 unconformity and the limestone is cut out entirely south of Caseker Crag and under Little Whernside. A local channel occurs at the base of the Grassington Grit Group in Coverdale below which the Main Limestone has been completely removed on the S.E.

side of the valley around Crab Gill. On the N.W. flank of the dale the limestone is only 5' thick in West Gill. It is again thick in Downs Gill and Fall Gill on each side of West Gill (Plate 14A is an isopach map showing the sum total of variation of thickness in the Main Limestone due to all causes; the area affected by intra-E_1 erosion is that between the lines margined by stipple shown in Plates 14A and 14B).

The top of the limestone is always difficult to fix quite accurately. It can be indicated with greatest precision where the Little Limestone Pipe Bed is present. This marker bed occurs a few feet above the base of the Little Limestone (and indicates the top of this horizon) which is itself not a clearly recognisable lithological unit. The six points where this bed is present are localities 2, 6, 9, 10, 11, 14 in Plate 14A. At other places in the north of the present ground the lithological change from limestone to cherts at the top of the Main Limestone is quite sharp. In the south this is not so. The junction appears to be transitional independent of whether the lower beds of the Richmond Chert Series are cherts or crinoidal limestones. It is convenient to assume that this is due to the dying out to the south of the postulated plane of transgression at the base of the Little Limestone giving continuous deposition of calcareous sediments through the Main and Little cyclothems. Whilst this may be true, it does not serve to explain the thinning of the Main Limestone in the S. of the ground from 83' at Raven Scar, Walden Head, to 11' at Lords Gill, Coverdale to the east. In this instance it does not appear to be correct to assume overstep

at the base of the Little Limestone since there is a more vague line of demarcation at this level than there is in the north.

The mapping of the Main Limestone is aided by the presence of crags on it at several points. In the N. of the ground the outcrop often forms the rim of a bench. This is the case on Penhill and in Lower Coverdale where the upper slopes of valley-side shoulders are in the Richmond Chert Series. The upper contact of the limestone is often marked by sink holes which are especially well developed in drift-free ground near the heads of the Walden Beck and the Cover.

Details - exposures are described in sequence from Waldendale, from the dale head to Penhill, from the N. slopes of Penhill, Coverdale progressively, up-dale and from the slopes above Kettlewell.

Waldendale - The Main Limestone is exposed in Raven Scar on the right bank of Walden Beck near Walden Head (978792) (Plates 13, 19A) where 94' of grey, massive limestone are excellently seen. The basal few feet are of blue colour, but a grey colouration is maintained for the remainder of the thickness of the limestone. Between 10' and 22' from the base, irregular nodules of buff coloured chert, assumed to be of secondary origin, occur within the limestone. The bulk of the limestone is without chert and macrofossils appear to be virtually absent. The uppermost 10' of beds show crinoid stems of a size similar to those seen at several horizons in the Richmond Chert Series, and so these beds are referred tentatively to them, though there is no strong line

of demarcation between these beds and the Main Limestone. This reduces the thickness of strata referred with some certainty to the Main Limestone to 84'.

Northwards from the cliff in Walden Beck, the Main Limestone forms a feature and a line of cliffs in Crag Brea. The cliff section in Crag Brea (Plate 13) is not easily accessible owing to the steepness of the rock face. At the north end of the principal line of scars (990804) the section is however easily got at, but the base of the limestone is not exposed and its exact position is hard to fix. The lowest 42' of the beds visible in the section consists of grey detrital limestone without macrofossils. This is overlain by 10'6" of grey detrital limestone with beds and strings of chert, apparently of secondary origin. The upper 5'6" of these beds contains large crinoid stems and also more chert than the beds immediately underneath. Large stems do not occur in the Main Limestone elsewhere in the present area and these beds are tentatively referred on this account to the Richmond Chert Series, where this lithology is common. N.E. of Crag Brea the Main Limestone is mapped by means of a continuous feature. Below Mease (007812) the limestone appears to be much thinner than at Walden Head; it is unlikely that it is much over 40' thick. Sporadic exposures in grey limestone mark the outcrop running in the direction of Dove Scar, where good exposures again occur in the Main Limestone, though as at Crag Brea, the base is not exposed.

At Dove Scar (016826) (Plate 13) the section shows 53' of beds ascribed to the Main Limestone, though it is possible that this is an excessive estimate, owing to slippage of beds, The

lowest 25' seen are unchertified grey detrital limestones, whilst the upper 28' are similar beds with layers of chert, probably of secondary origin. These latter beds are overlain by granular textured and incoherently weathering limestones probably belonging to the Richmond Chert Series. This is a facies typical of beds of the Richmond Chert Series of the present area, which is not found in the Main Limestone. To the north of Dove Scar the Main Limestone forms a feature with sporadic exposures. The upper portion is exposed on the W. flank of Harland Hill, where over 20' of beds occur, but the full thickness is difficult to estimate. (Plate 13). These are overlain by the Little Limestone Pipe Bed. Scars occur on the Main Limestone at Chance Hill and on the S. side of Thupton Gill, where they form a cliff in the valley. (031852). The thickness of unchertified Main Limestone seen is about 50' (Plate 13) and the uppermost beds are also exposed on the N. side of the valley at Rinchill Scar. North of this point exposures occur in cliffs on Burton Moor and these continue northwards with local breaks into Dove Scar (Plate 17A). The thickest section seen is at the eastern end of the scar (036874) where 40' of grey, detrital limestone are exposed, with occasional corals and brachiopods. Low cliffs continue along the north face of Penhill in an interrupted line in the lower beds of the Main Limestone. Levelling below Flint Lane (057874) gave a thickness of 40' for the limestone, based on outcrops and good features (Plate 13), the top of the limestone being clearly delimited by a strong feature on the Richmond Chert Series. The lowest 18' of limestone, which are exposed at this point are fine grained, grey, moderately well bedded limestones with few macrofossils.

The lowest beds of the Main Limestone form a broken line of cliffs standing on an edge which overlooks Witton Steeps and continues along the N. fringe of Middleham High Moor overlooking Capple Bank. Good exposures are seen near Limekiln Hill (080875) where the lowest 20' are grey limestone, forming a line of cliffs overlooking Capple Bank. In Limekiln Hill Quarry (081874) 25' of grey limestone are seen with nodules and impersistent bands of chert. Some of the strata in this quarry thin noticeably to the S.E., which is in fact the same direction in which the Main Limestone is known to decrease in overall thickness. Whilst it seems more feasible to attribute this thinning to over-step at the base of the Richmond Chert Series, it may possibly be due to simple thinning of the Main Limestone in an easterly direction in the manner indicated in this quarry section.

On the basis of the mapping the Main Limestone thins considerably in an easterly direction along the north side of the spur of Middleham Low Moor so that on the N. side of Naylors Hill it is probably not over 30' thick. It appears to thin further in an easterly direction, where it is exposed sporadically in quarries on the N. slopes of Middleham Low Moor.

Coverdale - The cliff of Cover Scar shows a very large section in the lowest 50' of the Richmond Chert Series which are seen to overlie the Main Limestone at 128864 . The section here shows (Plate 13):

30'	limestone with chert layers
6"	shale
6'	cherty plate (lowest beds of Richmond Chert Series)
2'	shale
9'	unchertified Main Limestone

The Main Limestone at Cover Scar is thus exceptionally thin, and shows a probable thickness variation within the limits of the above section between 16' and 5'. Where seen it is a grey detrital limestone, unaffected by chertification.

In Every Bank Quarry (114870) the upper beds of the Main Limestone are overlain by the Pipe Bed of the Little Limestone. The complete thickness of the Main Limestone is not here visible but on the evidence of the available features it is almost certainly small, probably not in excess of 20'. No good exposures occur along the outcrop to the W. of this point until Griff Head, near Melmerby (074857), where about 30' of Main Limestone are overlain by the Little Limestone Pipe Bed (Plate 13). The Main Limestone is here a grey detrital limestone free of chertification From the sections thus far given from lower Coverdale it is evident that the Main Limestone is thickening in an easterly direction (Plate 14A). This is the same change of thickness which was observed in tracing outcrops eastward along the N. faces of Penhill and of Middleham Low Moor.

On the S.E. side of Coverdale the limestone is still thin however and is only about 5' thick in Elm Gill (096852) (Plate 13). Apart from this exposure the Main Limestone is only rarely exposed on the S.E. side of lower Coverdale, but is seen in Caldbergh Gill (096844), where the horizon is probably not over 20' thick.

On the W. side of the valley around Carlton exposures are fairly frequent. At the head of Melbeck about 40' of unchertified limestone are seen in a cliff above a vauclusian spring. The limestone here shows steep dips, probably partially tectonic, but

are also in part due to cave collapse at the point of resurgence of the underground waters which form the beck. The well jointed aspect of the limestone at this exposure, due to enlargement of joints following collapse, was first noted by Phillips (1836). The Main Limestone forms the lower parts of a line of cliffs on the Richmond Chert Series in Howden Gill (045846) where it is a grey and blue detrital limestone at least 28' thick; the base is not here seen (Plate 13). On the hill side S. of Howden Gill sporadic limestone scars occur, one of which (046837) shows the Main Limestone to be at least 35' thick. In Cumma Gill the Main Limestone is at least 36' thick. The base is not here seen, but the Pipe Bed is exposed (Plate 13 sections 9, 10). The limestone is a grey rock poor in macrofossils. A single stratum with chert nodules occurs and a horizon with a few cross-sections of productids occurs 6' below the base of the Pipe Bed. At Ray Gill (030825) the Main Limestone is at least 32' thick and contains chert nodules at a few horizons, whilst the top 3' of beds, below the Little Limestone Pipe Bed, contain chertified ribs. Further south, at Coal Gill, the Main Limestone is only 21'6" thick and is grey in colour with some productids 9' from the top. No exposures occur on the spur of Fleensop Moor, but on the slopes above Bradley several are seen. A stream draining Horse House Moor shows only 15' of limestone, which appears to be the complete thickness of these beds, here overlain by platy rocks belonging to the Richmond Chert Series. These overlie the Main Limestone with a transitional zone in between with no sign of a Pipe Bed (Plate 13.)

On the S.E. side of Coverdale the limestone appears to be very thin on the outcrop above East Scrafton and West Scrafton. It is rarely exposed and may be only about 10' thick. In lead Up Gill (074825) the lowest beds of the Richmond Chert Series form a waterfall below which are exposures in 13' of the Main Limestone. A gap of 2' occurs at the horizon where the Pipe Bed is to be expected. The entire thickness of the limestone at this point is probably under 20'. It continues as a thin horizon to Hindlethwaite Gill (056809). Here it is completely exposed; the total thickness is 15' of detrital, grey limestone, overlain by platy cherts, presumed to belong to the Richmond Chert Series. In Harkera Gill (040795) the base of the Chert Series is ill-defined. Though the contact of the cherty beds on the Main Limestone is clearly exposed the junction is gradational and shows no sign of the Pipe Bed. It is possible that some of the cherty beds may be secondarily chertified Main Limestone. Unchertified Min Limestone persists up-dale to Lords Gill, where it totals about 12' and is immediately overlain by cherty beds. To the S.W. of Burn Gill the Main Limestone is cut out by channelling at the base of the Grassington Grit Group, and reappears again at Slape Gill. S.W. of this stream the limestone remains thin owing to intra-E_1 erosion and there is no trace of the Richmond Chert Series.

On the W. side of the dale near Horsehouse, the limestone remains thin in the outcrops on Bradley Moor. The next good exposure, that of Fall Gill, shows an unexpectedly thick Main Limestone. Here 52' of grey limestone occur, overlain by blocky cherts. The upper 20' of the limestone contain chert

nodules, but there is nothing to suggest that it should be referred to the Richmond Chert Series. In the nearby section of West Gill the Main Limestone is greatly attenuated (the 5' of beds exposed are almost the entire thickness) by pre-E_1 channelling. It seems very likely that this is a continuation of the channel which cuts out the limestone completely on the S.E. side of the dale (Plates 13, 14). In Downs Gill faulting has interfered with the section; the limestone appears to be at least 20' thick and is overlain by a few feet of beds resembling the Richmond Chert Series. The beds in Lock Gill include a fossiliferous band 7" thick with an unusually profuse and well preserved fauna which includes Schellwienella crenistria and Phricodothyris lineata. Preservation is in pale grey calcite mud with a quantity of shelly debris, crinoid ossicles and some foraminifera. The limestone is almost completely exposed at Hazel Bank Gill and East Stone Gill where it is about 65' thick, with no trace of the Richmond Chert Series which has been removed by intra-E_1 erosion. It is evident that the Main Limestone has thickened strongly in this neighbourhood independently of the intra-E_1 unconformity which however cuts it out rapidly to the south of Coverhead.

The platform at Coverhead shows numerous exposures and sink holes in the Main Limestone which makes up the entire col between Coverdale and Wharfedale. It is here over 40' thick. At the S.W. corner of the plateau (978756) it is 32' thick. The outcrop was mapped westwards into a feature overlooking Starbotton Pasture. Measurements showed that the limestone gains thickness to the west, being 44' at the head of Fears Gill Beck (974756)

and about 50' $\frac{1}{2}$ mile W. of this point. The thickness variation is presumed to be caused by intra-E_1 erosion.

S. of Coverhead the limestone forms a feature with its top defined by a row of sinkholes. 28' of limestone are exposed at the head of a tributary of Park Gill Beck (990705). For 350 yd. S. of this point the presence of the limestone is indicated by a row of sink holes and a feature at its top. The sink then abruptly die out and are not seen again to the south. The mapping evidence suggests that the limestone and the beds which immediately underlie it form a low, south facing intra-E_1 scarp, at the base of which sandstones of the Grassington Grit Group were deposited immediately on top of shales of the Underset cyclothem.

The Little Cyclothem

Phillips (1836) and Dakyns (1892) mentioned the occurrence of cherts above the Main Limestone in the N. of the present area. Phillips believed that the Little Limestone was present, overlying "black chert and plates", Dakyns referred to the "cherty series and its equivalent the Little Limestone".

Wells (1955a, b) maintained that the Little Limestone came to rest on progressively lower strata to the south of Richmond. Whereas 150' of strata of the Main cyclothem occur below the Little Limestone N. of the Middleton Tyas-Sleightholme anticline, due to overstep at the base of the limestone coupled with southerly thinning of the Coal Sills, they are reduced to zero at Leyburn. The identification of the Little Limestone was principally by a bed of vertical cherty tubes about 1' long, located at the top of

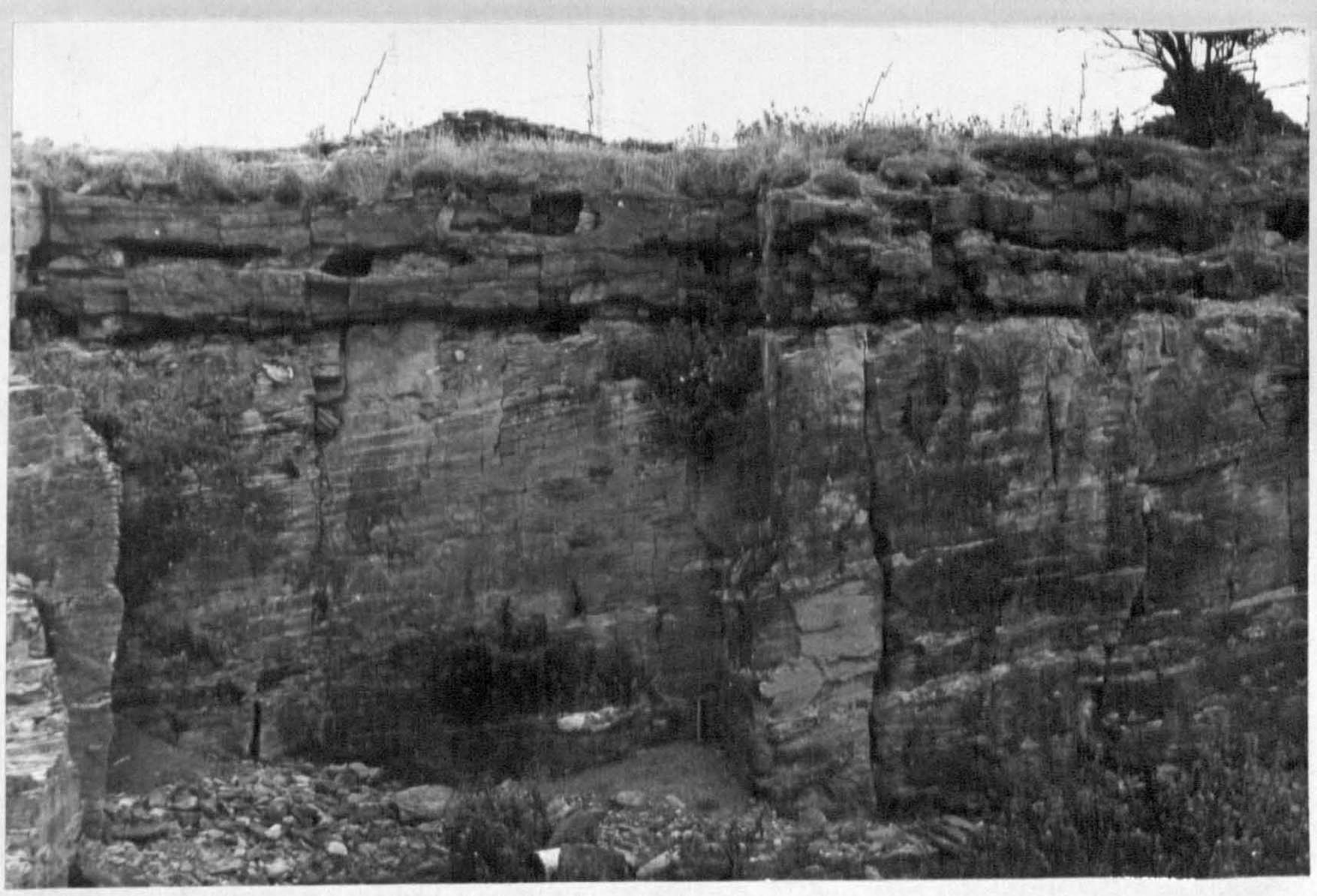


PLATE 15 A

The Richmond Chert Series in the quarry on Middleham Low Moor (115874). 4' of platy cherts rest on inclined detrital limestone with lenses of chert.

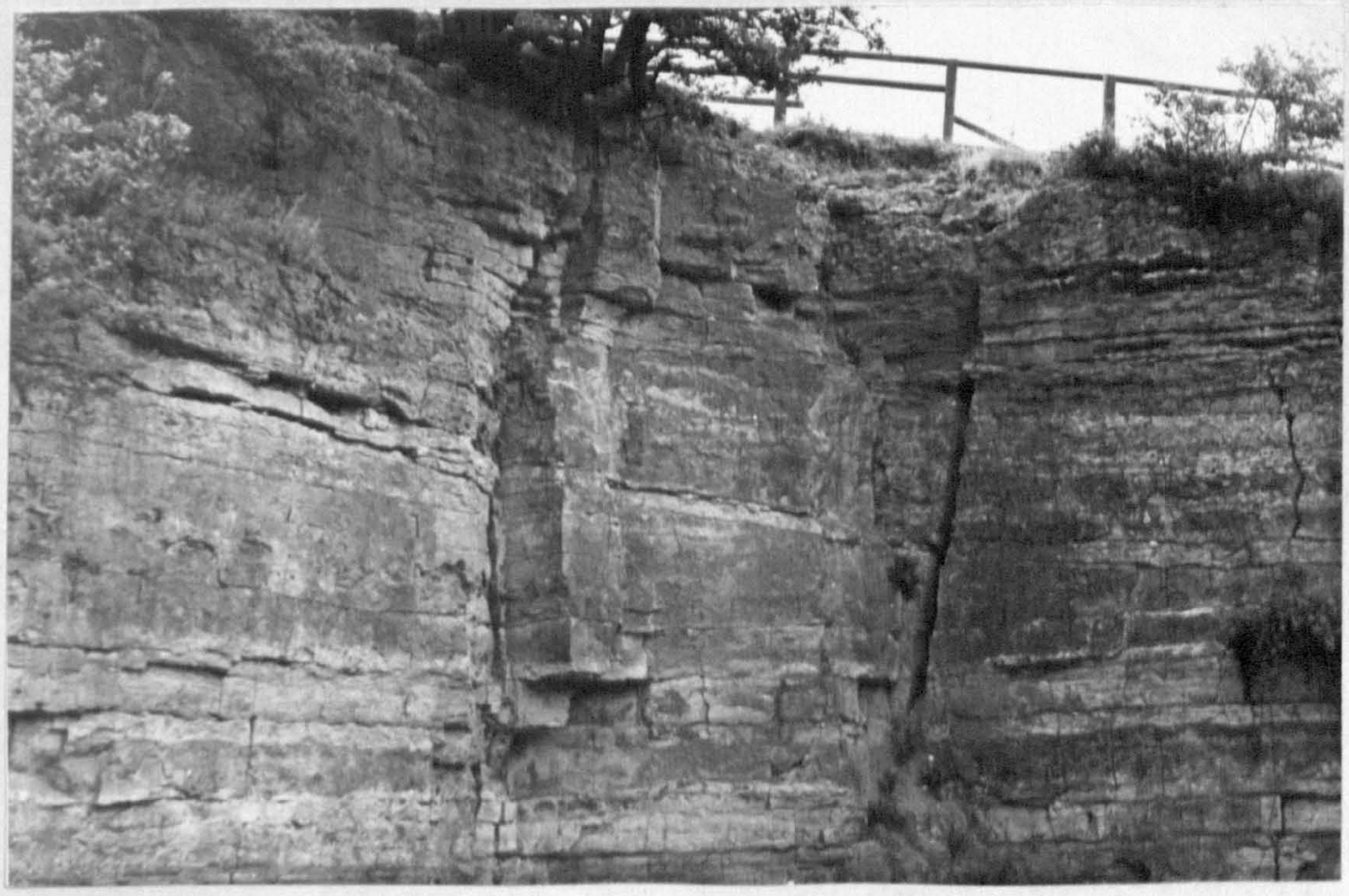


PLATE 15 B

The Richmond Chert Series in Ever Bank Quarry (114870). Excellent joint faces are developed , on which the irregular weathering characteristic of these beds is seen. The cross-cutting relations of the strata are also well shown.

this horizon which has been recognised over a large area by Rowell (1953), Wells (1955a) and Scanlon (1955). Wells measured the sections at Thupton and Howden Gills in the present ground and suggested, by analogy with other exposures that he had examined, that the Little Limestone occurred at the base of the Richmond Chert Series (Wells' own term for the cherty beds above the Little Limestone) in these sections. He did not find the Pipe Bed however and was thus not able to confirm his identification. A band of glassy chert 40' above the base of the Richmond Chert Series in these sections was tentatively correlated with the Marske Chert Bed of the Middleton Tyas-Sleightholme anticline.

Stratigraphy- The Little Limestone Pipe Bed has been recognised at six points in Coverdale and Waldendale. It consists of a stratum intersected by vertical pipes about 1' long and under 1" wide. Their cherty infilling contains some glauconite. None of the pipes which were seen showed an undoubted U shape, but it seems likely that they are annelid borings similar to those seen in sandstones below the Middle Limestone of Morpeth Scar and below the Main Limestone of Raven Scar, Waldendale, (and here referred to cf. Arenicolites sp.). The cherty substance of the pipes joins with a rim of cherty limestone forming the top of the stratum in which the borings occur. In all the respects outlined the Pipe Bed resembles that described by previous authors in ground to the north. The discovery of the Pipe Bed confirms the belief of Wells that the Little Limestone occurs at the base of the cherty series. The Little Limestone invariably overlies the Main Limestone in the present ground except where the beds above the intra-E_1 erosion surface have transgressed over all the chert

series and rest directly on the Main. The strata above the Little Limestone are called the Richmond Chert Series, following Wells (1955a).

Whilst the Pipe Bed is the distinctive top of the Little Limestone, the base is more difficult to define. Though Wells (1955a, b) believes that there is an erosion surface at the base, it exceedingly difficult to point out the exact lower limit of this horizon. This is due to the lithological similarity of the Little and Main Limestone and the lack of any conspicuous bedding plane dividing the two horizons. It appears that the base of the Little Limestone is a few feet only below the Pipe Bed. On the basis of the occurrence of the Pipe Bed and of a feature at this horizon in the north of the ground, it is possible to fix the base of the Little Limestone correct to the nearest few feet. In the south of the area, in upper Coverdale and upper Waldendale the Pipe Bed is not seen and the base of the Chert Series shows a more gradational appearance than to the north. In upper Waldendale coarsely crinoidal beds occur at the top of the Main Limestone which closely resemble similar ones within the Richmond Chert Series further north. It seems probable that these are the equivalents of the Little Limestone to the north, deposited on top of the Main Limestone without a break. In upper Coverdale the base of the Chert Series is indistinct. It is possible that the junction of the Chert Series and the Main Limestone has been obscured by secondary chertification at the top of the Main Limestone. If this is correct, some of the beds referred to as Richmond Chert Series in the text and diagrams may be chertified Main

Limestone.

The Richmond Chert Series which overlie the Pipe Bed are variable in both thickness and lithology. Wells showed that these beds attain a maximum thickness of over 130' near Richmond. The present work shows that on the N.W. slopes of Penhill, below Flamstone Pin and at East Witton the cherts are about 125' thick, and therefore almost as thick as at Richmond. The mapping of the Geological Survey at Leyburn suggests that the cherts are there about 60' thick. It seems likely therefore that there are separate areas of maximum thickness at Richmond and in lower Coverdale, whilst at Leyburn the beds are relatively thin. South of the zone of greatest thickness the Chert Series thins rapidly up Coverdale to 50'-70', a thickness maintained over a large area in the middle of this valley. In the upper dale the beds thin rapidly again and are absent owing to intra-E_1 erosion in upper Coverdale and in Nidderdale. Except in the N.E. of the ground where higher beds of Yoredale facies are present, the intra-E_1 erosion surface rests directly on the Richmond Chert Series. The southerly thinning is at least in part due to overstep on to lower horizons by this surface which ultimately comes to rest on the Three Yard Limestone in Nidderdale. Wells (1955a, b) showed that thinning took place rapidly away from the area of maximum thickness of the Chert Series at Richmond. It seems possible that some of the southerly thinning in the present ground is due to normal stratigraphic thinning and some to overstep at the level of the intra-E_1 erosion surface. Since there is no widespread horizon which can be mapped within the Chert Series it is not possible to assess the relative roles which

these two factors played in this change in thickness.

A horizon of glassy chert noted by Wells (1955a) in Thupton and Howden Gills was found by the present author to have a fairly wide distribution in mid-Coverdale. It can be found 40' above the Pipe Bed in several sections. Wells suggested that this horizon might be equivalent to the Marske Chert Bed which can be mapped over 30 square miles of country to the W. of Richmond. The Marske Chert Bed of the type locality at Marske Quarry occurs 65' above the top of the Little Limestone and is yet higher in the sequence at Whitcliffe Scar. It seems more likely that the representative of this horizon in the present ground is a pale, flinty chert with crinoid ossicles weathering as voids which forms a feature on Dovescar Moss at White Hill and North Tarn Hills. This horizon appears to be higher in the sequence than the lower band of flinty chert seen in Howden Gill and elsewhere and by virtue of its position, about 60' above the Little Limestone, it seems to be a more likely equivalent of the Marske Chert Bed. This same horizon appears to be absent at Howden Gill, probably as a result of intra-E_1 erosion, because the Chert Series is there thinner than on Dovescar Moss to the S.W.

Two persistent lithological types are readily distinguished in the Richmond Chert Series. The first are blocky, well bedded and well jointed cherts which commonly show cross-cutting bedding, with small, but markedly angular unconformities (Plate 15B). These contrast somewhat with pale grey crinoidal limestones which appear in the series at all levels and are markedly lenticular. Frequently they consist entirely of crinoid remains which are either



PLATE 16 A

The Main and Underset Limestones in Walden Beck, looking up-valley. The scree below the upper cliff, in the Main Limestone largely obscures the shales of the Underset cyclothem.



PLATE 16 B

Wray Gill , near Fleensop, Coverdale. The lower half of the cliff is in the Main Limestone which is overlain by the Richmond Chert Series which form the darker, more strongly jointed beds in the upper part of the cliff. The valley bottom is in sandstone and shale which is not exposed.

large stems and ossicles (Plate 17B) or very minute ossicles. The latter type makes a white, incoherent, granular-looking rock seldom affected by secondary chertification. Fossils are fairly abundant in some of the flinty cherts, but are rare or absent in those blocky cherts which show a streaky internal structure. Hyalostelia mooring ropes and small productids are the most common records.

Details - exposures are considered in sequence from Waldendale, proceeding down-dale and Coverdale going up-dale.

Walden Head to Penhill - Whilst there is little certainty, it appears probable, or at least possible, that the Richmond Chert Series extends to the head of Waldendale. Limestone with unusually large crinoid ossicles is developed in the upper part of Raven Scar (978786) (Plate 13) and in a pot hole N.N.E. of the scar. Whilst there is no distinct dividing line between the typical Main Limestone and these crinoidal beds, it is evident that this development resembles that seen in the Richmond Chert Series to the north where horizons rich in crinoid remains are frequent records, and it is therefore tentatively referred to these beds.

Further north these crinoid beds are seen in the cliff at Crag Brea where they are partly secondarily chertified and are at least 18' thick, but with fewer large ossicles in the upper than in the lower beds (Plate 13). Exposures of the lower part of the Richmond Chert Series are not seen in a northward direction until Dove Scar is reached (016826) (Plate 13). The section here seen is:

2'	gingerbready chert chips
22'	granular, incoherent weathering grey limestone
-	limestone with secondary chert bands (Main Limestone)

The granular beds are taken to be the lowest part of the Richmond Chert Series. Below Harland Hill (022841) (Plate 13) the base of the Richmond Chert Series is marked by a limestone stratum carrying vertical cherty tubes (the Little Limestone Pipe Bed). A short distance above this horizon are seen both crinoidal limestones and blocky cherts, the two characteristic lithologies in the Richmond Chert Series. The entire Chert Series is not here exposed. It appears to be about 68' thick, but this is possibly and over-estimate; this is much thicker than the development which is tentatively referred to these beds at the head of Waldendale (Plates 21B, 14B illustrate this variation). The section in Thupton Gill (Plate 13) gave 56' of beds by levelling; these are largely blocky cherts with no evidence for a basal 'pipe bed' (Wells, 1955b, reaches the same conclusion).

The northern outcrop: Dove Scar to Williams Hill - Scattered old stone pits and blocks in the soil on Dovescar Plain indicate that the Chert Series is here pre-eminently a granular limestone composed chiefly of small crinoid ossicles. A 6 degree dip recorded in an old quarry at 034869 runs counter to the regional one and therefore may be an original depositional dip; 14' of granular weathering limestone beds at 036867 is almost certainly derived from the upper part of the Richmond Chert Series, at a higher horizon than the granular facies, here forming the bulk of the series. The granular limestones are seen at almost all the exposures in the Richmond Chert Series N.W. of Black Scar, but to the E. the cherty facies is more strongly developed. The feature on Dovescar Plain delimiting the base of the Richmond Chert Series is weak and often dies out, but to the E. gains height, and can be

followed continuously for $2\frac{1}{2}$ miles along the north side of Penhill, and down its eastern spur to Black Plantation. Exposures on the N. side of Flint Lane in scars and old stone pits on the face of this strong feature are in blocky cherts which locally carry a band of chertified lithostrotionoid corals. The section in the feature at 057874 shows the most complete section (Plate 13) in blocky cherts, some of which are platy, others gingerbready weathering. At a higher level in this section a small outcrop in granular, grey unchertified limestone may be equivalent to part of the granular development which predominates in the Richmond Chert Series further west. Lone Slack quarry is an exposure in 14' of similar beds in the upper part of the Richmond Chert Series. In this neighbourhood the Chert Series is is very thick. Though exposure is incomplete, it appears that these beds are over 125' thick at Flint Lane, and there is no indication that beds higher than the Richmond Chert Series are present on the slopes of Penhill below the intra-R_1 unconformity. The mapping indicates that the whole division has thickened rapidly to the east from Dovescar Plain where it has an estimated thickness of 60' (Plate 14B summarises information regarding thickness of beds at this horizon).

The feature on the lower part of the Richmond Chert Series persists past Penhill Park and shows scattered exposures of blocky cherts along its length. The feature dies abruptly at Black Plantation, but there is no evidence for a fault; for half a mile E. of this point the exact base of the Richmond Chert Series is hard to fix, due to the complete absence of a feature and paucity of exposure. Between Naylors Hill and Middleham Low Moor the lowest

beds of the Richmond Chert Series are platy and occasionally form a lecture. Old stone pits in platy cherts occur on the edge of Middleham Low Moor, 15' being the most that is seen in any one section. In this area a large number of outcrops occur in the middle of the Chert Series, here a pale grey, often granular crinoidal limestone resembling those on Dovescar Plain to the west. Original dips of deposition, directed in an easterly direction, are often developed.

An old quarry on Middleham Low Moor (115874) shows an extensive section in the middle beds of the Richmond Chert Series. The floor and capping rock in the quarry are blocky, streaky cherts. These are bedded parallel to each other, in the base and the lip of the excavation, but the intervening beds are pale grey limestones made up of crinoid debris forming a unit consistently 15' thick. This, however, shows depositional dips of between 10 and 15 degrees in an easterly direction for 150 yards, the length of the quarry face. In this distance the upper cherts transgress 20' of incline-bedded limestone. (Plate 15A). Secondary chertification has taken place along bedding planes, but it is noteworthy that it is restricted to the lower half of these beds and is entirely absent in the upper part. The siliceous fluids probably migrated upwards, but not downwards, since there is no sign of chertification near the upper chert-limestone contact and for 7' below it.

At Ever Bank Quarry (116872) (Plate 15B) the lowest 27' of the Chert Series is seen lying on the Little Limestone Pipe Bed. The beds are conspicuous because of their cross-cutting relationships,

a common feature of the blocky cherts. The section on Plate 13 for Middleham Low Moor is compounded from the records of the two above named quarries, with the additional help of levelling to the top of the Main limestone on the N. side of Middleham Low Moor.

A gap occurs in the outcrops to the E. till Williams Hill is (125873) is reached; here, blocks of platy chert and shale chips are seen. It appears that the beds have been disturbed by faulting, though it is possible that they were tilted during the construction of the defensive site on which they occur.

N.W. side of Coverdale from Ever Bank to Downs Gill - Exposures of platy cherts are numerous along the outcrop in a westerly direction from Ever Bank Quarry. Imperfect sections N. of Cotescue Park show crinoidal limestones and platy cherts which appear to be interbedded in a complex manner. The thickest exposure of blocky cherts shows 15' of these beds in a quarry E. of Ash Gill (095869). At Griff Head, Melmerby (074856) (Plate 13), the Little Limestone Pipe Bed is exposed and is overlain by blocky cherts which show cross-cutting bedding similar to that seen in Ever Bank Quarry. The characteristic features of the Pipe Bed are well seen. The pipes, which are about 1' long, decend from a rib of cherty limestone forming the upper part of the grey limestone stratum in which the pipes occur. The 1" wide pipes, which show irregular margins, weather out from the surrounding rock and appear to be siliceous; scattered green grains, presumably of glauconite, occur in them.

Parts of the Richmond Chert Series are exposed in Cat Gill and Hollin Gill, but a more complete section is seen in Howden Gill



PLATE 17 A

The Main Limestone of Dove Scar , Penhill. The line of workings , right of centre is in a sandstone of the Underset cyclothem which were probably for roofing tiles. The distant hill is Buckden Pike, with Waldendale in the middle distance.

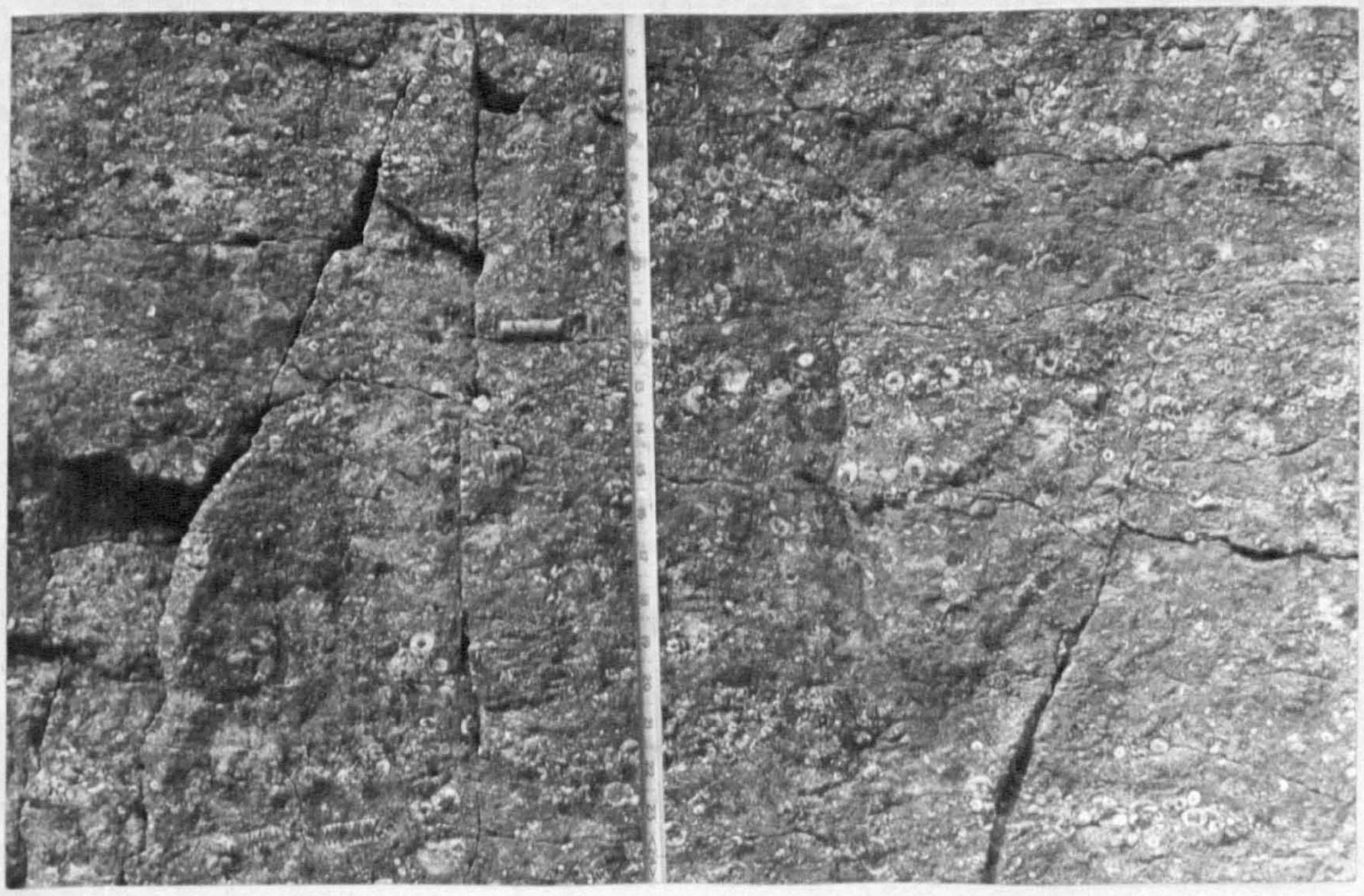


PLATE 17 B

The Richmond Chert Series, Cumma Gill, Coverdale (031832). The rock consists largely of crinoid debris , much of which is still articulated in the original stems. The ruler is graduated in inches.

(045846) (Plate 13). The base of the Little Limestone is difficult to locate exactly in this latter section owing to the absence of 'pipes'. The Chert Series here includes blocky cherts and granular unchertified limestones; some of these latter horizons show secondary chertification which takes the form of lenses of chert in the host rock. In the upper part of the series a horizon of glassy chert occurs, which tends to weather to a gingerbready consistency owing to the leaching out of calcite forming crinoid ossicles. This horizon was noted as a possible equivalent of the Marske Chert Band by Wells (1955a) when he measured the above section. It is evident that the Richmond Chert Series is here much thinner than to the N.N.E.; this is probably due at least in part to intra-E_1 erosion prior to the deposition of the Grassington Grit Group.

Below Carlton Moor periodic exposures occur in the lower part of the Chert Series, here chiefly blocky cherts. An exposure S.E. of Mount Pleasant (046838) (Plate 13) shows that the Pipe Bed is present and overlain by blocky cherts. The Pipe Bed is again seen in Cumma Gill (031832) (Plate 13) where only a few tubes are developed. The lower part of the Chert Series is a crinoidal limestone with abundant ossicles, some of which exceed $\frac{1}{2}$" in diameter, together with some articulated stems, reminiscent of the crinoid biostromes in the upper Middle Limestone (Plate 17A). Some of these crinoidal beds have been secondarily chertified, but the beds in the photograph are entirely free from chertification. The development of a crinoidal facies at the base of the Chert Series was also noted at Dove Scar to the E. of Cumma Gill (see ante).

Ray Gill (030825) (Plate 13) also shows a clear section in

the lower part of the Chert Series. The Pipe Bed is well developed, but the exact base of the Little Limestone is difficult to fix. The overlying beds are chiefly blocky cherts (Plate 16B). A horizon of white, glassy chert with crinoid ossicles weathering as voids is seen in a similar position to a like band in Howden Gill.

The Pipe Bed was not noted in Fleensop Grain where the lowest two thirds of the Richmond Chert Series consist of an alternation of platy cherts with wispy structures, pale grey blocky cherts and gingerbready-weathering cherts with crinoid ossicles represented by voids leached of calcite. A white, glassy chert 40' from the base of the Little Limestone resembles closely a similar horizon in Ray Gill and Howden Gill which appears to occur at a persistent level. A horizon-for-horizon comparison of the beds below this level at the three localities named in this paragraph is unrewarding however and it is evident that there is much variation in the lower part of the Richmond Chert Series. The higher beds of the Chert Series are seen on Dovescar Moss, close to the horizon of the intra-E_1 unconformity and include a horizon of glassy chert with large ossicles which weather as voids. These beds form a feature at White Hill and W. of North Tarn Hills. They appear to be over 50' above the base of the Little Limestone and seem to lie at a higher level than the cherts seen in Ray Gill and elsewhere, which closely resemble them in lithology. Since these latter beds are only about 10' below the base of the Grassington Grit Group in Howden Gill it follows that the level of the unconformity has lifted

slightly to the south to expose higher beds of the Richmond Chert Series sequence at Dovescar Moss. Cherty beds at a somewhat lower level are seen in the quarries on Petticoat Rake; these are highly crinoidal limestones lithologically similar to those seen at Cumma Gill.

Horsehouse Moor is ill-exposed, and the most complete section is in a stream draining the S.E. face of this spur. (036808). The lower beds of the Richmond Chert Series are blocky cherts; a glassy chert horizon is seen 32' above the base which is at a somewhat lower level than a similar development seen in Fleemis Gill and elsewhere to the N. No trace of the Pipe Bed is seen here, nor was this horizon noted at exposures further up the dale.

In Fall Gill (015800) it appears that the Richmond Chert Series is much thinner than to the N. Whilst the Pipe Bed was not noted, the base of the platy development of the Chert Series is well defined; the total thickness of cherty beds is 6' which is much smaller than that seen further to the N., owing to intra-E_1 erosion. In West Gill the Chert Series is entirely cut out by channelling at the base of the Grassington Grit Group. A thin cherty development is seen in Downs Gill (004788) (Plate 13) where 3' of platy beds overlie the Main Limestone (the full thickness here is perhaps about 7', but cannot exceed this figure). This is the furthest point up the western side of Coverdale that the Richmond Chert Series have been recognised.

S.W. side of Coverdale from Cover Scar to Burn Gill - the lowest 50' of the Richmond Chert Series is exposed in steep cliffs at Cover Scar. They consist of blocky cherts showing cross-cutting

relationships; the base is twice seen and varies somewhat. In the easterly section (127865) the lower beds are developed as follows:

30'	limestone with cherty layers
6"	shale
6'	platy chert
2'	shale (taken as the base of the Little Limestone and Richmond Chert Series)
-	unchertified Main Limestone.

Further E. (124864) there is no shale at the base of the Chert Series which rests on an unchertified limestone (probably the Main). No record of the Pipe Bed was made from the above sections, though it is possible that a search might reveal it. E. of Cover Scar exposures occur in cherty limestones which are probably higher in the succession than the beds in the scar. Platy chert and crinoidal limestones occur in close association in a field N. of East Witton, in quarries near East Witton Lodge and adjacent to Braithwaite Hall. Also, tips of lead workings N. and W.S.W. of Braithwaite Hall show both crinoidal limestone and cherty 'Plate'. All these facts taken together combined with the mapping evidence, indicate that the Richmond Chert Series is about 150' thick here. This is comparable with its development on the N.E. slopes of Penhill and it consists, as is usual, of blocky cherts with lenticular crinoidal limestones.

In a westerly direction little is seen of the Chert Series on Hanghow Pastures, but the lower beds are again well seen in a feature N.E. of Elm Gill where the principal rocks are blocky cherts. At the level of the blocky cherts a quarry in 26' of massive, unchertified grey limestone with a band of lithostrotionoid

corals is seen in this same feature (097854). A rapid facies change appears to have taken place southwards here in the lower beds of the Richmond Chert Series. A similar facies change back to cherts occurs to the S., since the lower beds are again blocky cherts in Elm Gill, 400 yd S.S.W. of this point. Below Flamstone Pin the upper part of the Richmond Chert Series is not exposed. A feature mapped on Caldbergh Pasture and above Hanghow Pastures agrees well in position with the top of the Richmond Chert Series, on the assumption that these beds are about 150' thick, which is consistent with the known, large thickness on the N.E. slopes of Fenhill and in the country N. of Braithwaite Moor. This is supported by the presence of chert in tips of old lead shafts located 40' above the base of this feature, which agrees well with the presence of the Chert Series immediately below the feature.

The sections in Elm Gill (096851) and Thorow Gill (085840) both show a development of compact, blocky streaky textured cherts in the lower part of the Richmond Chert Series (Plate 18A is a polished specimen from Thorow Gill). In Lead Up Gill (073825) a long section which is almost complete can be measured (Plate 13). It consists very largely of blocky cherts and contains no thick development of unchertified limestone. The Chert Series is here about 66' thick, of which 62' are exposed. It is evident from the mapping that a thinning of the Chert Series occurs southwards. It is probable that this is at least in part due to intra-E_1 erosion prior to the deposition of the Grassington Grit Group.

Exposures of cherty beds occur near Swineside, largely in quarries for wall stone. In Hindlethwaite Gill (056809) (Plate 13)

a clear section of the lower part of the Richmond Chert Series is seen. An alternation of platy chert and shale partings in the lower beds is overlain by 20' of unchertified crinoidal limestone, reminiscent of a similar development in the quarry N.N.E. of Elm Gill (see ante). The entire thickness of the Chert Series is about 62' here, but the upper beds are not exposed, excepting for the uppermost portion which are platy cherts directly underlying a sandstone of the Grassington Grit Group.

18' of blocky cherts are seen in Arkleside Gill. The lower 42' of the Chert Series are partially seen in Harkera Gill (040795) where they include blocky cherts and granular, crinoidal limestone. There is no trace of a Pipe Bed. At the top of the visible section the chert is quite glassy; it seems possible that this is the horizon which appears to persist over an area round Fleensop to the N.W. (see ante). The full thickness of the Chert Series is perhaps about 58'. In the streams draining to Low Pasture indications of cherts are frequent; fairly complete exposure occurs in Lords Gill where the Chert Series is about 28' thick, indicating a progressive decrease in thickness up-dale. The Chert Series is finally cut out by intra-E_1 erosion N. of Burn Gill and is not seen up-valley from this point.

Beds of the Little cyclothem above the Richmond Chert Series; the Crow Limestone

The sandstone of the Little cyclothem was first named the 'White Grit' by Phillips (1836). Subsequently the Geological Survey (Dakyns et al. 1891) employed the old miners' term 'Ten Fathom Grit', which is the current usage. Scanlon (1955)

has divided up this horizon into two parts separated by a local marine band, the Faraday House Marine Band, not represented in the present area, where the Ten Fathom Grit consists only of one leaf. The limestone above this horizon was named the 'Crow' by Phillips. Both of these horizons are only known from the northern part of the Askrigg Block and are absent owing to intra-E_1 erosion to the south. Scanlon and the present author provide details of their southern limit (Plate 20).

The strata of the Little cyclothem above the Richmond Chert Series and the Crow Limestone appear somewhat abruptly in the N.E. of the ground. Evidence from tips of old mine shafts suggests that they are entirely absent below Flamstone Pin on Caldbergh Pasture. No trace of these beds is seen below Braithwaite Banks, but they appear in full force in Red Beck Gill. This is conceivably due to there being a low scarp on the intra-E_1 erosion surface which caused a large thickness (about 50') of beds to come in rapidly below the Grassington Grit Group. The Crow Limestone can be traced for over $1\frac{1}{2}$ miles along the outcrop and appears to very little in thickness, though it may thicken to the east from 20' to about 30'. The Ten Fathom Grit underlying the limestone appears to thin eastwards from 18' to a few feet. The underlying shales also thin slightly in that direction.

Details - The Crow Limestone and the beds which immediately underlie it are exposed only in the extreme N.E. of the present ground. The only complete section of the limestone is in Red Beck Gill, but no full section of the beds below the limestone occurs, but it is probable that the exposures in Red

Beck Gill are nearly complete. The section in the gill is as follows:

1'	ganisteroid sandstone (Grassington Grit Group)
-	slight gap
14'	yellowish limestone
4'	partly chertified grey limestone
2'	grey limestone (total Crow Limestone is 20' thick)
18'	compact, flaggy limonite-spotted sandstone with silty partings near the base (Ten Fathom Grit)
4'	micaceous shale with silty partings
17'	micaceous shale (base not seen)

A fault through Braithwaite Wood shifts the outcrop of the Crow Limestone downhill. 4' of limestone with cherty layers seen 200' yards downstream from the above exposure appear to be a repetition of this horizon. Over 8' of flaggy sandstone seen at a lower level in the section are assumed to be the Ten Fathom Grit 10' of which is also exposed in the lip of a nearby shaft (120858).

A feature at the base of the shales of the Grassington Grit Group can be mapped from Red Beck Gill eastwards to East Witton. S.E. of this village it dies out owing to its being mantled with boulder clay. This feature overlooks a platform in the Crow Limestone. Below Braithwaite Lane the measures of the Little cyclothem above the Richmond Chert Series form a feature which is 20' high at East Witton Lodge. The Ten Fathom Grit is seen just below the Crow Limestone at this point. It is only a few feet thick and therefore much thinner than in Red Beck Gill, to the west. The limestone is about the same thickness as in the gill section and does not exceed 25'. East Witton is built on a platform of Crow Limestone which here forms a wide outcrop. Phillips (1836) records a sinking in

the villare which penetrated 7 yards of limestone. The possible total is here about 70' and the horizon appears, therefore to be thicker than it is to the west.

The petrography of the Richmond Chert Series and the problem of its origin

The chief work on the cherts in beds of Yoredale facies on the Askrigg Block was carried out by Sargent (1929) and Wells (1955). Both agreed that the bulk of the cherts which they studied originated as primary gels. A paper by Hey (1950) on the Crow Cherts gave a somewhat different interpretation. Whereas Sargent and Wells considered that the cherts were largely deposited as silica gels, Hey believed that many of the siliceous rocks which he studied owed their origin to silicification of calcitic sediment soon after deposition; he also recognised a minority of cherts as being probably primary in the strict sense.

There are three fairly distinct types of rock represented in the Richmond Chert Series of the present ground (the divisions closely resemble those of Wells, 1955 a, b)

1. <u>Streaky, blocky cherts</u> - these are typically compact, grey, blocky weathering and distinctly jointed cherts. A platy form of weathering is common. In some cases the weathering is of a porous nature due to the leaching of calcite, leaving a siliceous sponge. Bedding planes affected in this way show a cavernous surface (Plate 15).

In thin section the rock consists of isotropic, pale brown silica intermixed with finely divided calcite, scattered shell fragments and sponge spicules preserved in calcite. The organic

debris tend to show some parallelism along the planes of sedimentation. The fabric of the rock is characteristically streaky and very complex. Numerous dark pods and lenses occur in a lighter ground mass of grey or dirty buff colour. The more readily recognisable markings are cusp-shaped structures (for instance, see Wells, 1955b, Plate 14, Fig. 4). In thin section the fabric of these structures is identical with that of the parent rock and includes shell fragments preserved in calcite. On that account an algal origin for these organisms is rejected, since they are merely a redistributed matrix. Some of these bodies are remarkably planar (those figured by Wells, for instance), but the bulk are of irregular shape. In view of the fact that these structures may cross each other and are commonly of irregular shape it is considered that they are most probably the product of the passage of annelids through the rock when it was soft. It is also possible that the pod-like fabric of the streaky cherts in general may be due to the flattening out of tubular markings made by the passage of large numbers of annelids which lived in the mud. (Plate 18A shows both cusp shaped and streaky structures in a chert).

2. <u>Flinty Cherts</u> - these are commonly of a pale grey colour and occur principally at horizons 40' and 60' above the base of the Richmond Chert Series. Joints are placed close together and the rock tends to break up into small pieces. In thin section they consist primarily of colourless chalcedony, which often takes the form of fibrous, radial aggregates. Disrupted remains of crinoid ossicles occur in the chalcedony groundmass and show markedly irregular borders due to the marginal replacement of

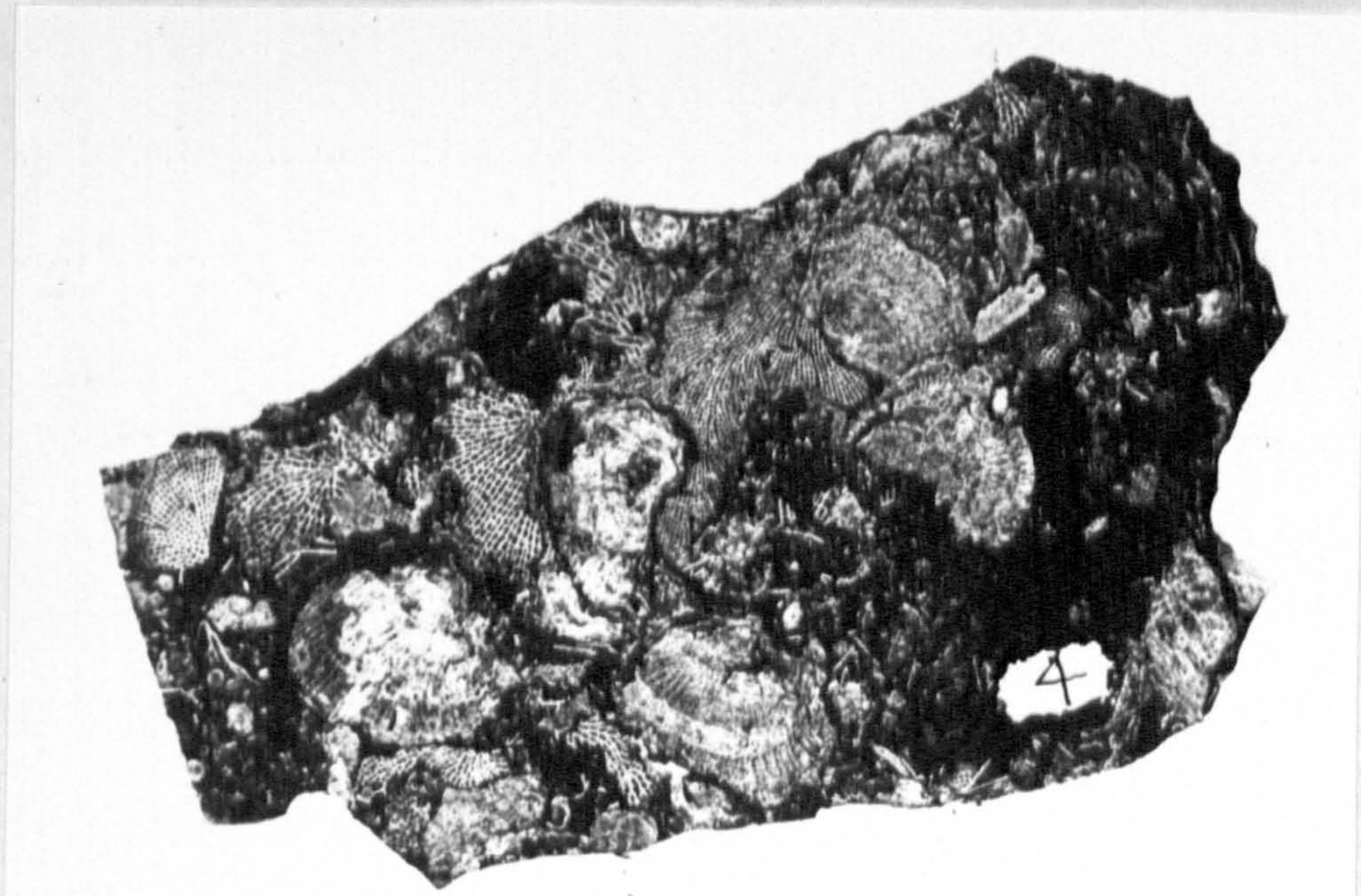


PLATE 18 A

Fenestella haemisphaerica M'Coy and Productus (Productus) productus preserved in large numbers on a bedding plane in silicified 'plate' below the Underset Limestone of Low Dove Scar, Penhill.
Natural size.

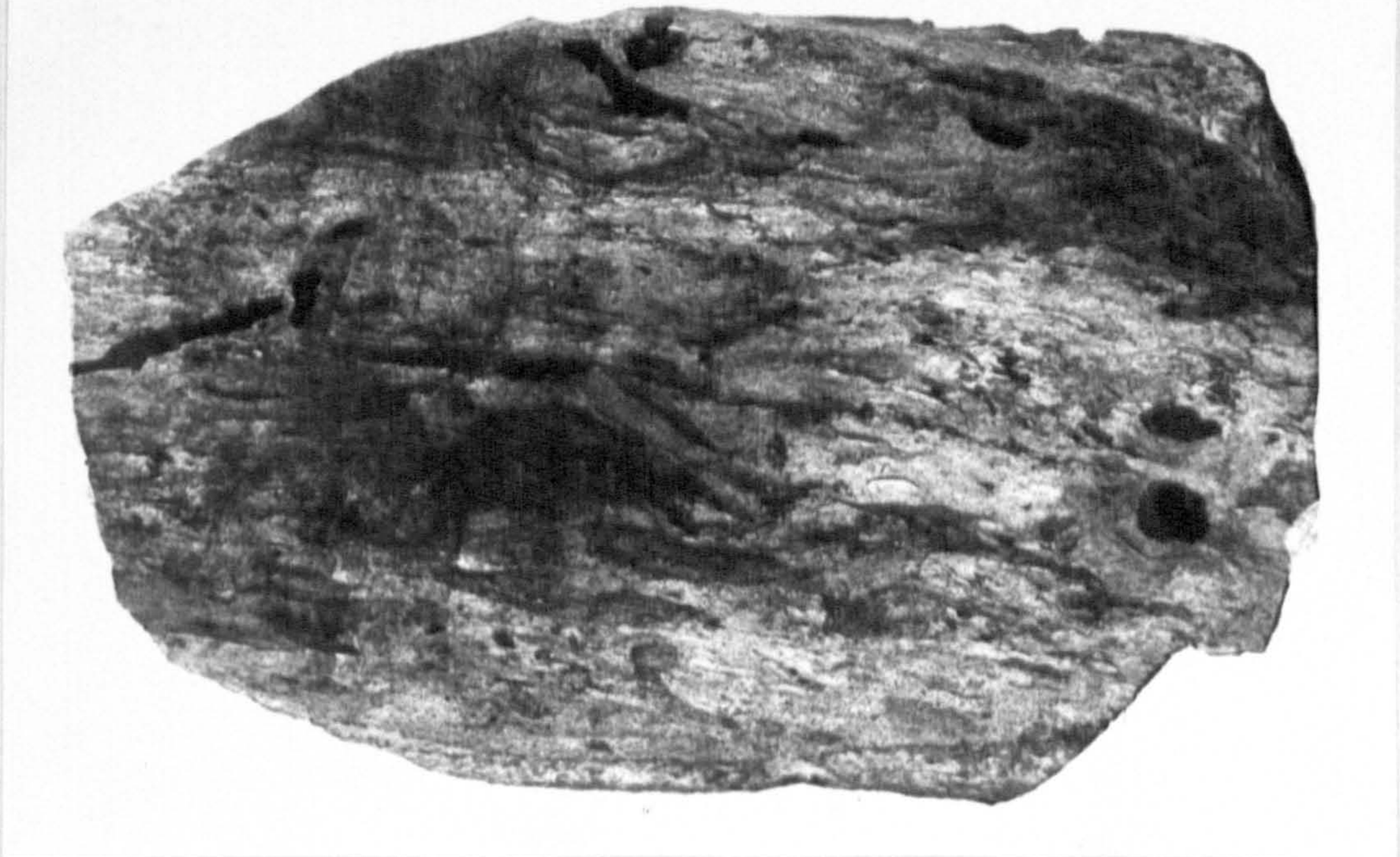


PLATE 18 B

Wispy , bedded chert from the Richmond Chert Series of Thorow Gill, Coverdale. The structure is extremely complex and discontinuous. The dark streaks are possibly due to annelids or algae and show cuspoidal markings , the clearest of which are seen top, centre. In thin section the rock is composed of finely crystalline silica.
Natural size.

the calcite by secondary chalcedony. Scattered carbonate rhombs occur in the secondary chalcedony. In hand specimen such cherts often show large crinoid ossicles, often exceeding $\frac{1}{2}$" in diameter which were not replaced by chalcedony and were subsequently leached of calcite, leaving a void. Highly porous cherts occur with large numbers of voids faithfully reproducing the shape of crinoid ossicles leached of calcite. The secondary chert shown in Plate 50A, replacing calcite mud is also glassy. In thin section it is a chalcedony showing radial aggregates.

3. Crinoidal limestones - these are of two distinct types. The first is made up of large ossicles, some of which are articulated (Plate 17B) and the second is an incoherent pale grey rock composed entirely of minute polygonal ossicles without interstitial cement. Both of these developments are lenticular and occur at all levels in the Chert Series. In some instances they show original dips of deposition. These are especially well seen in the quarry on Middleham Low Moor (Plate 15A). On the N.E. slopes of Penhill beds of the crinoidal facies replace the bulk of the blocky cherts in the lower half of the Chert Series; it seems likely that rocks of the two facies were being deposited simultaneously. The crinoids probably built up a mound on the sea bed, round which the siliceous sediments were forming. The glassy cherts described in the previous section are in many cases secondary after the streaky varieties.

Whilst it seems certain that some of the cherts are undoubtedly secondary, the streaky cherts especially show such such an intimate admixture of silica and calcite that it seems likely

that they are primary deposits. The principal alternatives to a primary hypothesis of the origin of cherts are the introduction of siliceous solutions at the plane of the intra-E_1 unconformity and silicification soon after deposition by silicifying agents on the sea-bed. The first hypothesis is attractive because there is good evidence for its validity at the level of the Three Yard and Five Yard cyclothems in Nidderdale (see Chapter 5). The sudden cessation of cherts in a downward direction at the level of the Little Limestone Pipe Bed is strong evidence against this view, since it is excessively unlikely that the chertifying solutions would stop percolating downwards at the identical level over an area of many square miles, especially in view of the fact that the Main Limestone includes a high proportion of calcite mud which elsewhere seems to be more readily chertified than crinoid ossicles.

Further evidence against secondary chertification is to be found in the quarry on Middleham Low Moor where the lip and floor is made up of streaky cherts between which is a cake 15' thick of almost unchertified crinoidal limestone (Plate 15A). The only signs of chertification are flinty cherts in nodules and pods parallel to the bedding, but only in the lower part of the limestone. The restriction of secondary replacements to the lower part of the limestone strongly suggests that the chertifying solutions were travelling upwards. The contact between the streaky cherts and the limestone which is largely chert-free is very sharp and is difficult to explain by any hypothesis of selective secondary replacement. It is however noteworthy that streaky structures, such are typical of certain cherts here considered as probably

primary, are also found occasionally in calcite mudstones. The writer visited an exposure of the Cockleshell Limestone at Trout Beck, Westmoreland, in which the streaky and cusp shaped patterns characteristic of streaky cherts were seen preserved in a calcite mudstone. There is thus a faint possibility that the streaky cherts are secondary after calcite muds. Reasons have already been given for rejecting the theory that the silica came from the plane of the intra-E_1 erosion surface in this case, though a penecontemporaneous silicification of the type outlined by Hey does not seem to be ruled out. In short, the present author does not consider that the petrographic evidence presented by Wells (1955,b) amounts to final proof that the bulk of cherts in the Richmond Chert Series were deposited as gels, as distinct from calcitic sediments which were altered soon after deposition. From an experimental standpoint and for want of present day analogues the gel hypothesis also has some weaknesses. On this account it is held that the views of Hey may apply to some extent at least to the Richmond Chert Series; primary precipitation remains a possibility. Chertification at the plane of the intra-E_1 unconformity appears to be chiefly in the beds of the Three Yard and Five Yard cyclothems in Nidderdale. Many, if not all of the flinty cherts seem to be of secondary origin as is shown by their tendency to marginally replace crinoid ossicles as well as the matrix which is usually wholly made over to chalcedony. The exact date of this secondary alteration is unknown; it may be penecontemporaneous, or it may have taken place at the time of intra-E_1 erosion.

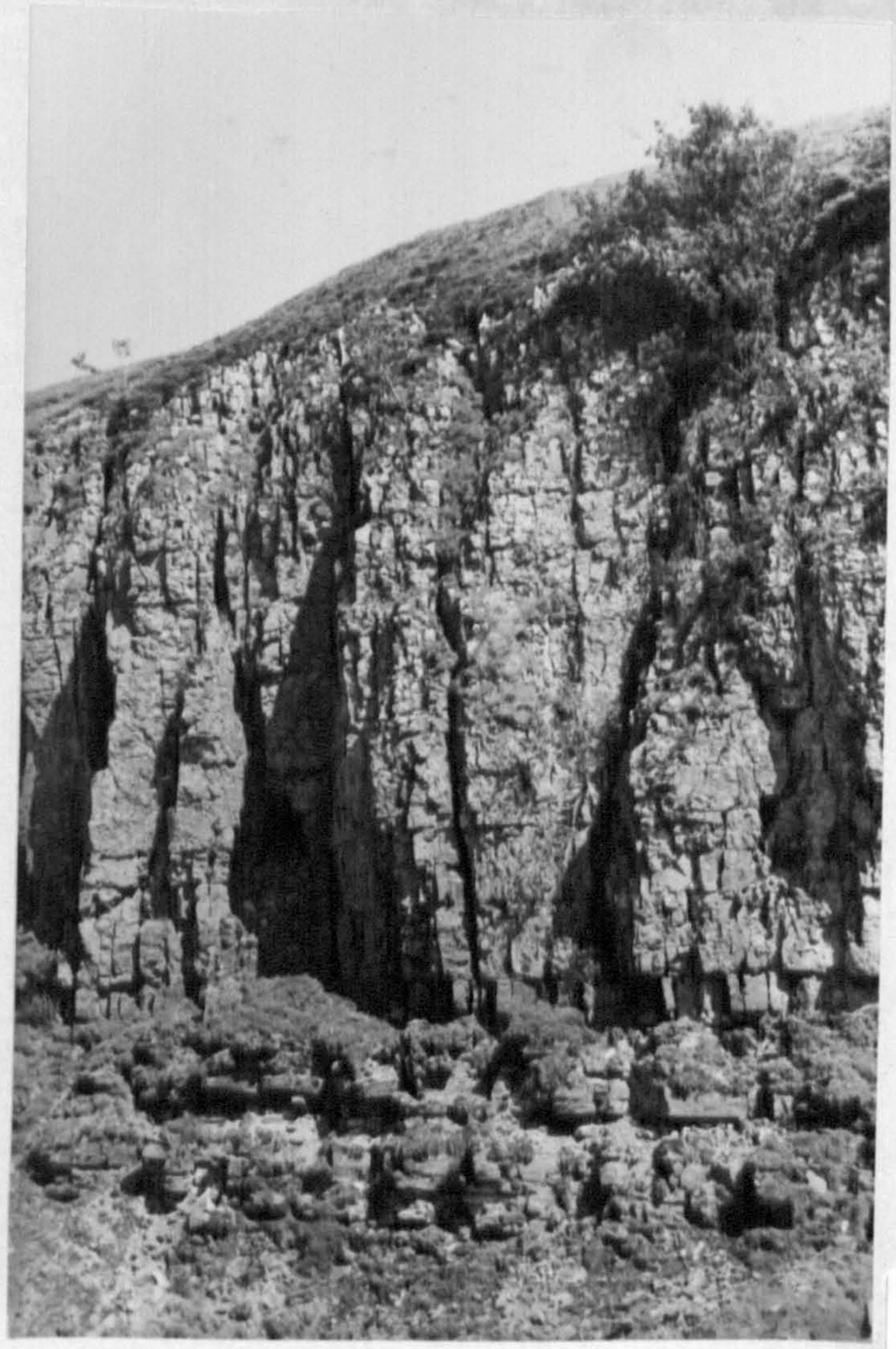


PLATE 19 A

The Main Limestone at Walden Head (978787). The basal beds are sandstones of the Underset cyclothem which are here flaggy and are overlain by the well jointed Main Limestone.



PLATE 19 B

The Richmond Chert Series in Fleemis Gill, looking down-stream from 022818. The gorge is in blocky cherts which overlie the Main Limestone in the bed of the valley. These latter beds are characterised by rounded, as distinct from angular weathering forms.

Palaeontology

The Main Limestone of the present ground is only sparsely fossiliferous and appears to yield a smaller fauna than in upper Wensleydale and on the Gilling dome. The bulk of the present records are from a richly fossiliferous band at Lock Gill in Coverdale with a large quantity of shelly debris set in pale grey calcite mud. The forms include large Schellwienella and excellently preserved Phricodothyris lineata. The corals and foraminifera recorded from the Main Limestone are chiefly long ranged forms, though Chaetetes depressus and Zaphrentis curvilinea have not been recorded from any other level in the present ground.

The fauna of the Richmond Chert Series is chiefly restricted to the limestones. Streaky cherts appear to be without fossils other than cusp shaped and lenticular markings referred tentatively to the annelids. The Pipe Bed is presumed to be the product of a colony of lugworms operating over a large intertidal area during a period of minimal deposition. These are referred to cf. Arenicolites sp. and resemble borings in the sandstones of the Simonstone and Underset cyclothems elsewhere in the area. The brachiopod fauna is chiefly found in the limestones which yield small forms, especially Eomarginifera. Hyalostelia is a characteristic fossil, also recorded in numbers at this level by Wells (1955a); it is chiefly developed in the Richmond Chert Series.

Faunal Lists

Main Limestone

?Bevocastria sp., 1
Cirvanella sp., 1
"Organism∝" Johnson ms., 1

Ammodiscus incertus (d'Orbigny), 2
Archaediscus karreri Brady, 1
Calcisphaera Johnson ms., 1, ?2
Endothyra sp., 1, 2
Orobias ornata Brady, 1
Tetrataxis decurrens (Brady), 1
Textulariid, 1

Aulophyllum fungites (Fleming), 1, 3
Caninia sp., 1
Chaetetes depressus Fleming, 3
Dibunophyllum bipartitum bipartitum (McCoy), 3
Diphyphyllum lateseptatum McCoy, 3
Heterophyllum sp., 1
Hexaphyllum sp., 1
Konickophyllum sp. ?echinatum (Thomson), 1

Archaeocidarid spine, 1, 2

Crinoid ossicles, 1

Cryptostome indet., 2

?Actinoconchus sp., 1
Brachythyris decora (Phillips), 1,3
Phricodothyris lineata (Martin), 1
Productus (Buxtonia) scrabiculus (Martin), 1
--------- (Echinoconchus) punctatus (Martin), 1
--------- (----------) cf. subelegans Thomas, 1
--------- (Lomarginifera) lobatus J. Sowerby, 1
--------- (----------) praecursor Muir-Wood, 1
Schellwienella cf. crenistria (Phillips), 1
Schizophoria resupinata (Martin), 1
Spirifer bisulcatus J. Sowerby group, 1

Ostracods, 1,2

Vertebrate crushing tooth, 1

Index of localities for the above

1.	Lock Gill, Coverdale (includes thin section)	995782
2.	Hindlethwaite Gill, Coverdale (thin section)	056809
3.	Dove Scar, Penhill	035874

Richmond Chert Series

Archaediscus karreri Brady, 1

Endothyra sp., 1
Tetrataxis decurrens Brady, 1

Hyalostelia smithii Young and Young, 3
Sponge spicules, 2,4

Archaeocidarid spine, 1

Crinoid ossicles, 1, 2, 3, 4

Cryptostome indet., 3
Fenestella sp., 4
Rhombopora sp., 1

cf. Arenicolites sp., 5, 6, 7, 8, 9, 10

Cleiothyridina sp., 4
Productus (Echinoconchus) elegans McCoy, 4
--------- (Lomarginifera) longispinus J. Sowerby, 2, 3, 4
--------- (Productus) sp., 4

?Fish tooth

Index of localities for the above

1.	Hindlethwaite Gill, Coverdale (thin section)	056809
2.	Dumps from old lead shaft, Fleensop Moor	012814
3.	Dovescar Plain, N. of Penhill	043872
4.	Thorow Gill, Coverdale	085839
5.	W. side of Harland Hill, Waldendale	022841
6.	Ever Bank Quarry, Coverdale	116872
7.	Griff Head, Melmerby	074856
8.	S.E. of Mount Pleasant, Coverdale	046838
9.	Cumma Gill, Coverdale	031832
10.	Ray Gill, Coverdale	030825

CHAPTER 8

THE SUB-GRASSINGTON GRIT GROUP UNCONFORMITY

Movements prior to the mid E_1 times

Phillips (1836) drew attention to the fact that there was a pronounced thinning of measures between the limestones of Yoredale facies towards the S.E. of the Askrigg Block. This fact was later emphasised by Chubb and Hudson (1925) who give comparative sections for upper Wensleydale and Kettlewell in Wharfedale. The work of Moore (1955) and the present thesis provides details of this thinning which strongly affects the shales and sandstones of all cyclothems excepting the Underset. It is evident that deposition was minimal in the Kettlewell area though the thickness of the limestones varied little. The sediments of the Gayle, Hardraw (fide Chubb and Hudson, 1925), Middle, Five Yard, Three Yard and Main cyclothems all thin towards Coverdale and Nidderdale. It appears that the S.E. of the Askrigg Block was a positive area in P_2 times during which the deposition of terrigenous sediments was minimal. In low E_1 times during the deposition of the shales and sandstones of the Underset cyclothem subsidence appears to have gone on fairly evenly over the Block and these sediments are everywhere about 90' thick in the present ground, except locally in lower Coverdale (this excepting the area where they have been removed by intra-E_1 erosion).

Wells (1955, a, b) showed that the shales and sandstones of the Main cyclothem thin greatly to the south. They are cut out completely in the latitude of Leyburn, leaving a large area in the

S.E. of the Askrigg Block where they are absent. It is evident that the positive movements causing, as Wells maintains, an unconformity below the Little Limestone, were more widespread than the earlier positive effects in the S.E. corner of the Askrigg Block. This is because they affect a larger portion of the relevant cyclothem over a larger area than in the case of underlying rhythmic units. The shales and sandstones of the Crow cyclothem are also appreciably thinner in the present area than to the N., though an accurate evaluation of this thinning is not possible due to diachronism as the top of the Richmond Chert Series (fide Wells, 1955b).

Hudson (1930, 1944) and Black (1950) described pre-E_1 overlaps by the Upper Bowland Shales from the Malham and Grassington areas. The details of these have been summarised by Rayner (1953). It is evident that they antedate the present unconformity which progressively cuts across beds which range from mid-E_1 (Stonesdale cyclothem) to D_1 (Great Scar Limestone). There is no evidence to show that more than one phase of denudation was involved and hence the pre-Grassington Grit Group unconformity is referred to one date, near the middle of E_1 times.

The intra-E_1 unconformity

The earliest work on the character of the base of the Grassington Grit Group was that of Phillips (1836) who recognised that the Main Limestone in Coverdale was locally cut out by transgression at this level. Dakyns had constructed a section (according to Chubb and Hudson, 1925) which showed an unconformity at this level. The papers of 1891, 1892 do not specifically state

this however and appear to attribute the dying out of several horizons of Yoredale facies to the fact that they thinned rather than that they had been eroded.

The work of Chubb and Hudson (1925) involved mapping the Yoredale sediments and the base of the Grassington Grit Group along the outcrop from Starbotton in Wharfedale to Greenhow. It was then shown by mapping that the Grassington Grit Group came to rest on successively lower horizons to the south, since it lay on the Main Limestone in the extreme north and ultimately on D_1 beds of the Great Scar Limestone in the Greenhow area. On the basis of a field reconnaisance it was also stated that the highest beds to emerge from under this unconformity to the north were the sediments of the 'Fell Top' (i.e. Stonesdale) cyclothem. Later, Anderson (1928), Dunham and Stubblefield (1945), Black (1952), Black and Bond (1952) and Joysey (1955) mapped portions of the outcrop previously studied by Chubb and Hudson and added details to the previous work. Rowell (1954) summarised the knowledge relating to the unconformity north of Grassington and drew a section, chiefly from Chubb and Hudson's and Geological Survey data. This is in several respects inaccurate and has been corrected in details by the work of Scanlon (1955), Wells (1955a) and the present author. The chief value of this diagram is the correlation of the Mirk Fell Ganister with the Grassington Grit Group of the Grassington area on the basis of the occurrence of Cravenoceras cowlingense in the Mirk Fell Ironstones, overlying the Mirk Fell Ganister (Hudson, 1941) and in the Cockhill marine Band of Greenhow (Dunham and Stubblefield, 1945) which overlies

the Grassington Grit Group. Scanlon (1955) added detailed information about the overstep by sandstones of the Stonesdale and Crow Limestones of the Shunner Fell area in a southerly direction, He showed that the Mirk Fell Ganister and the Lower Howgate Edge Grit were identical horizons from a mapping point of view, a fact which had not hitherto been realised by Chubb and Hudson (1925), or Rowell (1954).

The above work has shown that eleven cyclothems of beds of Yoredale facies are transgressed in a southerly direction by the Grassington Grit Group. This group was deposited on an erosion surface which appears to have covered the southern part of the Askrigg Block, with the maximum erosional effect in the S.E. corner, culminating near Greenhow with the exposure of beds of D_1 age. The total thickness of sediments affected is about 750'.

The present work confirms that the Grassington Grit Group rests on progressively lower horizons in a south easterly direction. In the north of the area round East Witton the Crow Limestone and Ten Fathom Grits are present, but elsewhere in the north, in lower Coverdale and on the north slopes of Penhill, the Grassington Grit Group rests directly on the Richmond Chert Series, These latter beds thin progressively up Coverdale under the unconformity so that in the upper dale the Grassington Grit Group rests immediately on the Main Limestone. The Main Limestone is completely cut out on the S.E. side of the dale under Little Whernside and is locally much attenuated on the N.W. side of the valley, but is again thick near Coverhead (Plate 20). The local

dying out of the Main Limestone in Coverdale appears on mapping evidence to be due to channelling at the base of the Grassington Grit Group and not to flexuring and subsequent erosion of these beds. The Main Limestone is rapidly cut out by the Grassington Grit Group N. of Caseker Scar. It seems probable that a low scarp stood on the sea bottom at the time, since the base of the Grits appears to descend below the level of the limestone to the south in such a manner as to suggest that the latter beds stood as a low scarp facing in a southerly direction. The erosion at the foot of this low escarpment appears to be reflected in a greater thickening of the Grassington Grit Group to the S. of it.

In Upper Nidderdale it has been shown in the present work that the base of the Grassington Grit Group rests on the Three Yard Limestone and, locally at the head of the dale, probably on the Underset Limestone. Whilst Tonks (1925) realised the extent of the overstep of beds in Nidderdale, the reader will appreciate that the re-naming of the beds lessens the discrepancy between the level of the unconformity in Coverdale, N.W. of Little Whernside and that in Nidderdale. A problem still exists however, since the base of the Grassington Grit Group in mid-Coverdale stands about 40'-60' above the base of the Richmond Chert Series, with only a slight downstepping to the south on to lower horizons in the cherts. In contrast, in upper Nidderdale over a comparably large area the base of the Grassington Grit Group is at the level of the Three Yard and Underset (?) Limestones, with only a small change in stratigraphic level, similar in magnitude to that seen in the case of the Richmond Chert Series in mid-Coverdale.

Between these two areas the unconformity changes in horizon through 140' of strata under a ridge (that of Little Whernside) only 1/2 miles wide, and with an effective length of two miles (insofar as it affects the existing exposures showing the varying levels at which the unconformity stands in Coverdale and Nidderdale.) It is well known from the work of Chubb and Hudson (1925), as amended by Hudson (1933), and the present author that a comparable overstep is achieved in two miles, E. of Kettlewell, but this appears to be in part due to the formation of a pre-E_1 scarp south of which there is a thickening of the Grassington Grit Group. Whilst the possibility of a scarp underneath Little Whernside aligned with the long axis of that mountain is attractive, it must be stated that there is no evidence for thickening of the Grassington Grit Group below such a hypothetical scarp in upper Nidderdale. On the contrary, most of the sediments at that level in upper Nidderdale are shales and the sequence is thinner here than in other places in the dale, or in upper Coverdale and Waldendale. The alternative to a scarp is a flexure aligned with the axis of Little Whernside. Whether the explanation be a slight flexure or a low scarp, it is evident that 80' of the 140' of the sediments cut out rapidly to the south are relatively soft shales which would readily yield to erosion.

Summary

It appears that the early positive tendency affecting the thickness of sediments in the S.E. corner of the Askrigg Block in P_2 and early E_1 times was followed by a period of emergence some time after the formation of the Stonesdales Limestones. Erosion

affecting a maximum of 750' of sediments took place with its greatest effect at Greenhow. The influx of deltaic sediments of the Grassington Grit Group over this land surface appears to have been relatively sudden. Beds of Millstone Grit facies therefore lay above progressively lower horizons to the south. Over much of the centre and S.W. of the Block the formations under the unconformity were the Richmond Chert Series and Main Limestone, but to the north, and largely to the N. of Wensleydale, higher beds appear from under the erosion surface, namely strata of the Crow and Stonesdales cyclothems. Whilst the present outliers on the Askrigg Block at Pen-y-Ghent, Fountains Fell and round the heads of Wharfedale show that the Grassington Grit Group does not rest at lower levels than the Main Limestone, there was pronounced erosion in the S.E. corner of the Block which led to overstep on to low levels, culminating with a local transgression on to D_1 beds at Greenhow.

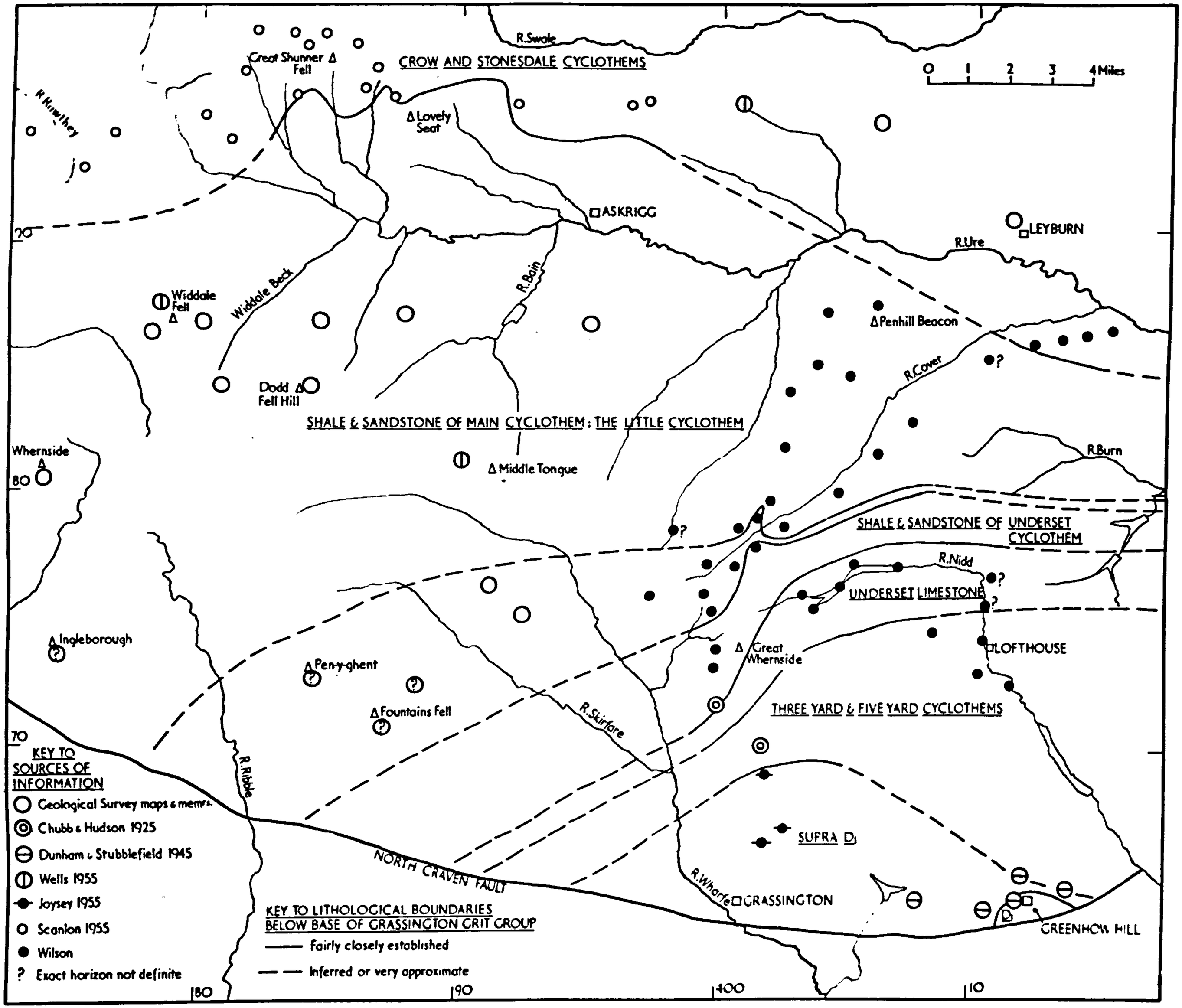
Though there is good evidence of channelling at the base of the Grassington Grit Group in upper Coverdale, the present author cannot agree with the contention of Joysey (1955) that the overstep may be due to scour off the face of a delta. This is because of the extent of the surface and the fact that coals are abundant in the Grassington Grit Group, even in the lowest beds (which are locally fireclays), indicating conditions of repeated emergence which do not appear to be likely to be the immediate sequel of a supposed period of delta-front scour.

PLATE 20

Map showing the beds exposed beneath the plane of the intra-E_1 unconformity.

PLATE 21

Diagram to show facies and thickness changes from the base of the Middle Limestone to the Cockhill Marine Band. The upper section shows clearly the effect of the intra-E_1 unconformity.
In each case the Cockhill Marine Band has been used as datum. Information is compiled from measured sections, the localities of the chief of which are written above the section.


CROW AND STONESDALE CYCLOTHEMS
0 1 2 3 4 Miles
R. Swale
Great Shunner Fell
Kirkby
Lovely Seat
ASKRIGG
LEYBURN
R. Ure
Widdale Fell
Widdale Beck
R. Bain
Penhill Beacon
R. Cover
Dodd Fell Hill
SHALE & SANDSTONE OF MAIN CYCLOTHEM: THE LITTLE CYCLOTHEM
Middle Tongue
R. Burn
Whernside
SHALE & SANDSTONE OF UNDERSET CYCLOTHEM
R. Nidd
UNDERSET LIMESTONE
Ingleborough
Pen-y-ghent
Fountains Fell
Great Whernside
LOFTHOUSE
R. Skirfare
THREE YARD & FIVE YARD CYCLOTHEMS
R. Ribble
SUFRA D1
NORTH CRAVEN FAULT
R. Wharfe
GRASSINGTON
GREENHOW HILL
KEY TO SOURCES OF INFORMATION
Geological Survey maps & memrs.
Chubb & Hudson 1925
Dunham & Stubblefield 1945
Wells 1955
Joysey 1955
Scanlon 1955
Wilson
? Exact horizon not definite
KEY TO LITHOLOGICAL BOUNDARIES BELOW BASE OF GRASSINGTON GRIT GROUP
Fairly closely established
Inferred or very approximate
80
70
180
190
400
10

Providence Mine | Park Gill Beck | Slape Gill | Lords Gill | Harkera Gill | Arkleside Gill | Hindlethwaite Gill | Lead Up Gill | Caldbergh Gill | Braithwaite Hall

A

HORIZON OF COCKHILL MARINE BAND

B

G.G.

C

R

M

U

T

F

M

Walden Beck | Dales Barn | Ashes Farm | Fleensop Cram | Scar Folds | Thupton Gill | Long Ing Wood | Low Dove Scar

C

HORIZON OF COCKHILL MARINE BAND

D

G.G.

P.R

M

U

T

T

F

M

200 Feet Vertical Scale – in addition the ends of Horizontal Sections are graduated at 100 Ft. intervals

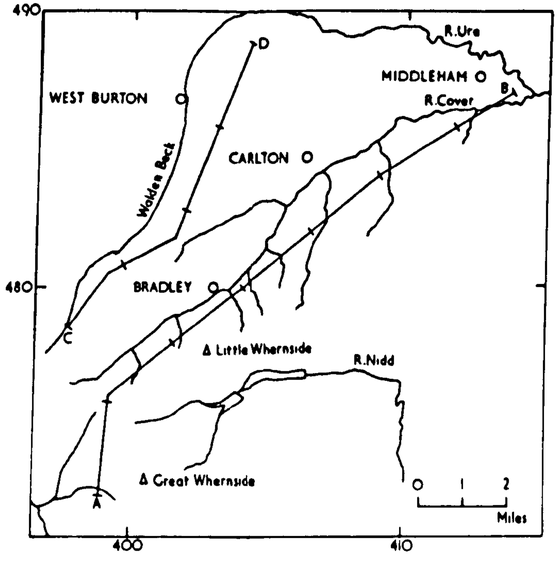
100

0

1

2 Miles Horizontal Scale

Lines of Sections are graduated at 2 Mile intervals.
All principal streams giving data for Horizontal Sections are named above the Sections & their courses shown on the Key Map.



KEY

- COAL on FIRECLAY
- SANDSTONE
- LIMESTONE
- Gigantoproductus LIMESTONE
- CHERT & CHERTY LIMESTONE
- CHERT
- SHALE

G.G Grassington Grits & its equivalents
C Crow Limestone
R Richmond Chert Series
M Main Limestone
U Underset Lst
T Three Yard Limestone
F Five Yard Lst.
M Middle Lst
→ Denotes Horizon of Unconformity



PLATE 22 A

Little Whernside from East Stone Gill. The scar in the foreground is in the shale of the Underset cyclothem which overlies the Underset Limestone of the scar downstream. The black area on the hillside on the far side of Coverdale is the outcrop of the Grassington Grit , forming Fox Stones. Little Whernside is capped by the Lower Follifoot Grit, with steep slopes on the Nar Hill Beds. The feature seen on the sky-line at the right end of the hill is in the Red Scar Grit.

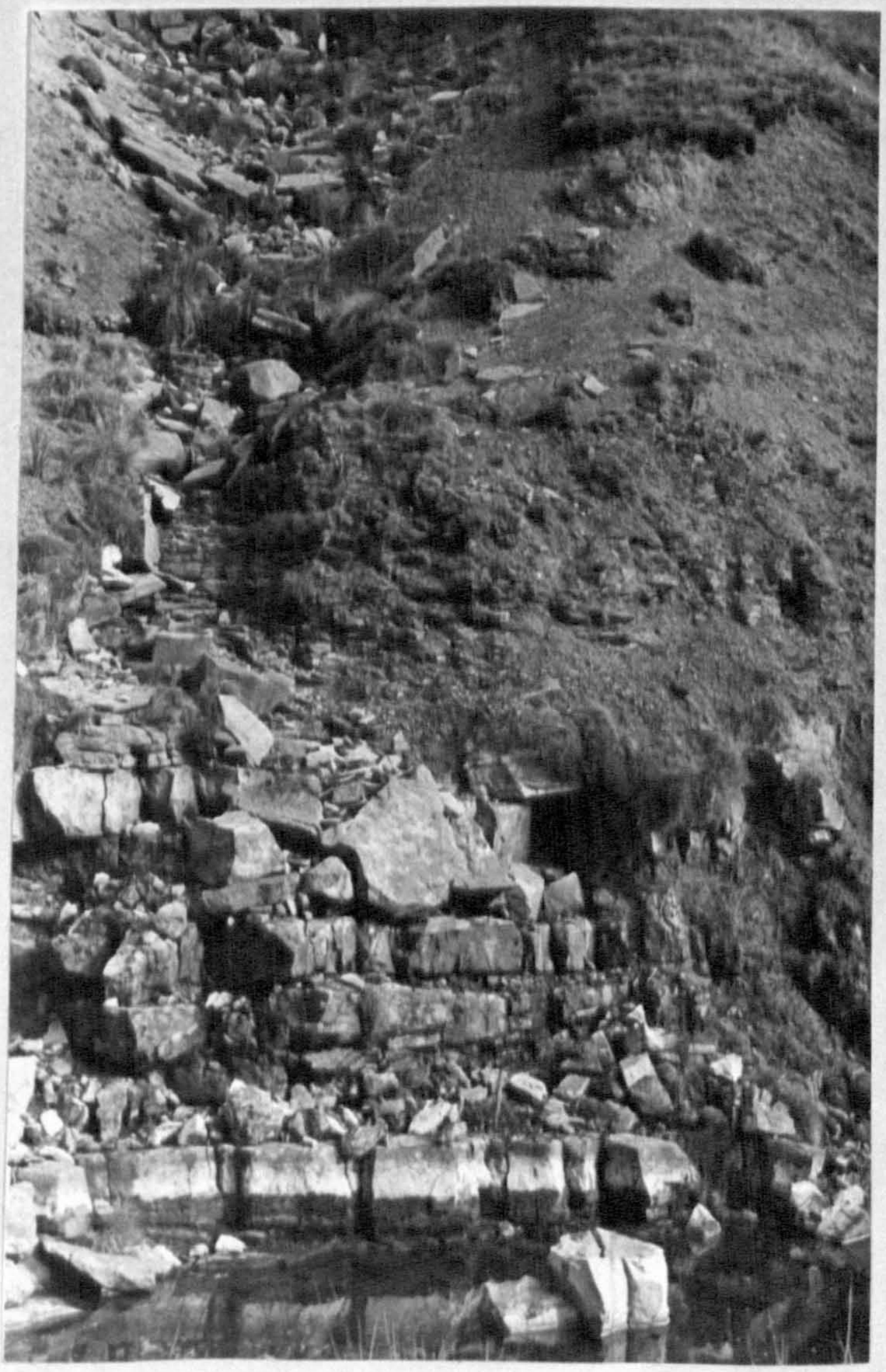


PLATE 22 B

The plane of the intra-E_1 unconformity in Nidderdale, at Stone Beck (034753). The limestone seen below the hammer is probably the Underset Limestone, overlain by sandstones and shales which are equivalent to the Grassington Grits. This is the only point in upper Nidderdale where the contact is now visible.

CHAPTER 9

THE GRASSINGTON GRIT GROUP

The term 'Grits of Grassington Moor' was coined by the officers of the Geological Survey for arenaceous beds with some shale overlying the strata of Yoredale facies in the country between Grassington and upper Coverdale. This term was used in the key of Sheet 97 S.E. (New. Ser. 51) which covers the present area. Since this date Bisat (1914) and Tonks (1925) reverted to the old miners' name 'Basement or Bearing Grit'. The present author prefers a nomenclature that does not stress the arenacous beds because the bulk of the sandstones at this level do not persist in the north of the ground here described. For this reason the term Grassington Grit Group (following Hudson, 1939) is employed.

The earliest record of the variations at the level of the Grassington Grit Group was by Dakyns (1891, 1892). He noted that a deterioration of the sandstone members set in down Coverdale and Waldendale so that in the lower reaches of these valleys they are represented by a predominantly shaly sequence. Bisat (1914) noted that the coarse sandstone development was well seen in Howstean Beck, Nidderdale and held that the maximum thickness of these beds was in a N.-S. line under Great Whernside. Tonks (1925) also noted these changes and mentioned that the lower sandstones were the most persistent.

Stratigraphy

The Grassington Grit Group comprises all strata between the

intra-E_1 unconformity and the Cockhill Marine Band. The thickness of the beds varies from at least 200' (probably 220') to about 125'. The thinning takes place in a northerly direction and appears to occur largely at the point of change from a predominantly arenaceous to a predominantly shaley facies. In the Great Whernside area and in Howstean Beck the beds are largely coarse, massive current bedded sandstones with layers of pebbles often developed in the lower half of the division. Here the thickness is at its maximum; it probably exceeds 200' locally and is always about this figure. The sandstones show current bedding predominantly from the N.N.W. and are characteristically feldspathic. Occasional shale partings occur and are in some instances mappable. One such parting outcrops on the S.W. flank of Great Whernside and in Howstean Beck; at both localities it carries a coal seam (Plate 23). Whilst exposures in the upper part of the Grassington Grit Group are incomplete, the evidence from Providence Mine and elsewhere suggests that it contains several shale partings and that the beds of sandstone are less coarse than in the lower part of the division.

In upper Waldendale, upper Coverdale and in Nidderdale above Angram Reservoir there is a strong suggestion of rapid facies change in a northerly direction accompanied by rapid thinning of sediments from 200' to 160'. Further north the Grassington Grit Group appears to thin still further to about 125', but this decrease in thickness does not appear to be linked with any facies change. The thinning at the line of facies change appears to be largely due to the rapid lensing out of the massive, coarse sand-

stones in the lower half of the group. It appears to take place along a distinct line which can be traced from Waldendale into Coverdale and thence into upper Nidderdale. The line then must run under Kay Head Allotment and across the Nidd again E. of the Scar House Dam (the section in the dam trench is in the predominantly shaly development) (see Plate 20 in which the line of facies change is shown). The result of this facies change is that thick developments of coarse sandstones at this level occur only in the south of the area, in upper Waldendale, upper Coverdale, Nidderdale around Lofthouse and the How Stean Valley, whilst a portion of the beds of massive sandstone facies are also seen in the R. Nidd above the Angram Dam.

In the area where the predominantly shaly facies occurs, coals are more frequent than in the ground where sandstone predominates. These are accompanied by fireclays and ganisters which attain their maximum development in the lower part of the sequence. Sandstones are thin and are chiefly fine grained, but also include coarse types similar to those developed where the sandstones are thick. Exceptionally, thicker sandstones occur as on the N.E. slopes of Penhill and on the S.W. slopes of Harland Hill. In no instance is it possible to map a sandstone with any degree of confidence in these beds and there appears to be rapid variation which is in fact seen in the sections of the Angram dam trench. Shales of the Grassington Grit Group have yielded Lingula sp. at three widely separated localities in Coverdale, indicating a periodic influx of salt or brackish water into the area; generally speaking however, fossils apart from plant remains are absent.

The cause of the rapid facies change in the Grassington Grit Group is not clear. The interpretation given on Plate 21 is based on facies change. This seems to be the most likely explanation, but the possibility of a partial overlap cannot be overlooked since the coarse sandstones appear to die out to the north in such a fashion that the lowest beds are the last to thin out, which would be the condition brought about by erosion followed by overlap. The evidence in upper Nidderdale in which several of the sandstones in the shaly development are coarse suggests a lateral passage. If this explanation is correct a reason must be found for the rapid replacement of a thick series of sandstones by a comparable, but slightly smaller thickness of shales, with impersistent sandstones and several coal seams. The bar fingers of the bird foot delta of the Mississippi (Fisk et al., 1954) appear to provide a good analogy since the thick development of sandstones in the Grassington Grit Group in the south of the area is a similar, thick pile of arenaceous sediment, differing only in the detail of grain size (coarse, as opposed to fine). The deposits into which the sandstones pass are chiefly shales with several coals which were on this explanation formed in interdistributary swamps subject to long periods of inundation. Occasional crevassing of the levees of the main river channel lead to the influx of occasional sheets of coarse sediment which contrast with the predominantly fine sandstones interleaved with the shales at this level.

The directions of current bedding which were measured show a maximum in the direction N.N.W. This direction is parallel to

the edge of the postulated channel, marked by the facies change to shaley beds in the north. The incision into the Main Limestone of Coverdale which can be picked up on both sides of the dale also shows alignment in this direction. It has steep sides after the fashion of a channel which has been scoured out. The present author maintains that it is possible that this represents the early stages in the formation of the channel which later built up a bar finger when the preliminary erosive period was followed by one of deposition. The major objection to this view is that already expressed by Walker (1952) who considered that coarse and fine sandstones are the products of differing sedimentational environments. The difficulties associated with Walker's scheme are more fully dealt with in Chapter 23. In the present case however both coarse and fine grained sandstones occur in close proximity in the shaley development of the Grassington Grit Group. It is therefore difficult to conceive that they are the product of differing sedimentational environments, namely the fan-spread and the bird-foot delta.

Details

Exposures are described in sequence from Waldendale, Coverdale and Nidderdale.

<u>East side of Waldendale from Walden Head to Penhill</u> - The upper part of Waldendale, on the N.W. slopes of Brown Haw shows a thick sandstone in the lower part of the Grassington Grit Group which can be seen resting on limestone in a sink at Walden Head (980789). The lowest 80' at least of the group appears to be wholly sandstone and forms a well defined platform above

Crag Brea. The upper beds are not exposed though they are probably alternations of sandstone and shale of the type shown in Plate 21B. The uppermost strata are seen in a gulley section at 989799 where the following section is exposed:

-	Cockhill Marine Band
7'	gap
1'	flaggy sandstone
18'	shale, getting silty upwards

At Brownhaw Holes (998805) the following beds are seen:

-	shale chips (probably just below the horizon of the Cockhill Marine Band)
1'6"	sandstone
30'	shale

It is evident from these two sections that the highest 35' or 40' of the Grassington Grit Group are predominantly shales on the W. slopes of Brown Haw. Beds which appear to be at a slightly lower level still in the sequence are exposed in the vicinity and include 8' of shale.

N.E. of Brownhaw Holes the platform on the arenacous lower half of the Grassington Grit Group rapidly looses definition, which is no doubt due to the dying out of the arenaceous beds in the manner shown in Plate 21B. The additional discovery of the Cockhill Marine Band on the N. slopes of Fell Pot is important as it shows that the Grassington Grit Group has thinned northwards at the point where the sandy beds die out. Below the exposure of the marine band on the slopes of Brown Haw the Grassington Grit Group is about 195' thick (the feature on the sandstones in the lower part of the beds is here strongly developed) whilst below Fell Pot it is about 165' thick. The available evidence suggests a further northerly thinning

towards Dovescar Moss (the feature on the sandstones is absent W. of Fell Pot and to the north). A sandstone a short distance below the Cockhill Marine Bend at Fell Pot can be mapped on the basis of a feature for a mile; a maximum of 15' of flaggy sandstone is exposed at this level.

Back Dike (021815) shows a section in the lower half of the Grassington Grit Group which may be interrupted by faulting. When this is taken in conjunction with that seen in Coal Gill (025817) (Plate 23) the section is seen to be composed chiefly of shaley beds with the development of thick fireclays with coals. This forms a strong contrast to the sandstone developed at this level in the platform on the W. slopes of Great Haw.

North of this point the Grassington Grit Group has been removed by erosion on Dovescar Moss, a plateau on the Richmond Chert Series, except probably at North Tarn Hills and South Tarn Hill where sandstone blocks in the soil together with features point to the presence of outliers.

The S.W. slopes of Harland Hill are not well exposed, but show features with much scree developed on them which indicate a fairly strong development of sandstones at this point. Plate 23 gives the result of the levelling of these features with the apparent geology indicated. It seems probable that the Grassington Grit Group is about 150' thick here, which is rather thinner than the development of these beds at Fell Pot. Whilst some of the sandy bands persist along the W. slopes of Harland Hill there is no evidence for their presence N. of Chance Hill and when seen in Thupton Gill, the lowest 13'

of beds in the sequence are shales. A horizon 40' above these shales has been worked for roofing tiles, and it is probably the same bed which was worked for this purpose on the N. slopes of Penhill. The extensive development of sandstone boulders at Buckstones and Foundations indicates the presence of a sandstone, mapped tentatively as the same horizon as the highest sandstone of the Grassington Grit Group on Harland Hill; boulders at Buckstones show wavy bedding.

<u>North slopes of Penhill to Coverhead on the W. side of the dale</u>.

On the N. slopes of Penhill the chief indications are at the level of the roofing tile workings about 60' above the base of the group. These are flaggy fine grained micaceous sandstones (of grain size about 200 microns) with some feldspar and many flecks of carbon which have been worked in open cut and levels; the horizon is perhaps about 6' thick. The old pony track ascending Penhill E. of Black Scar shows some shale chips at higher levels than the roofing tile horizon and also some sandstone boulders, here tentatively taken as representative of a sandstone horizon which is extended round the hillside in the direction of Foundations on slight evidence. The Grassington Grit Group appears to be less than 150' thick here because the Cockhill limestone was found in the debris of the Black Scar landslip, the top of which is 150' above the base of the Grassington Grit Group. Since the horizon of the limestone does not appear to occur in the actual scar of the slip it must lie between 150' and 50' (its actual level of occurrence in the debris of the slip) above the base of the Grassington Grit Group. The records from

Howden Gill 1 mile to the south strongly suggests from mapping evidence that the Cockhill Marine Band is about 125' above the base of the Grassington Grit Group which is therefore thinner than it is further south (compared with a probable thickness of 150' at Harland Hill and 195' at Brown Haw).

On the N.E. spur of Penhill the Grassington Grit Group is never exposed, but appears to include a strong arenaceous development in its upper part, where a feature is developed at Little Penhill with abundant sandstone blocks on the surface of the ground. This horizon has been tentatively mapped as the same as that exposed at Foundations and elsewhere. An old level below Little Penhill shows shale in its tip derived from a horizon lower in the sequence than the sandstone of Little Penhill. This latter sandstone appears to die out rapidly to the south because of the loss of definition of the feature which it forms. At about the level of this shale a coal has been worked in Hodge Holes Colliery. In Rams Gill several sections occur in chiefly shaley beds. The sections include 17' of flaggy mudstone. Some of the lowest strata are seen in a sink hole S.W. of Rams Gill (049852) where 1' of black shale with Lingula are exposed.

Howden Gill shows a few feet of shale low in the sequence and a few exposures at higher levels. The beds a short distance below the Cockhill Marine Band are chiefly shales, with thin bands of flaggy sandstone. On the S.E. slopes of Penhill, below Slantgate and on the S.E. slopes of Harland Hill sandstone bands are developed which appear to belong to a horizon just below the Cockhill Marine Band.

On Horsehouse Moor there are several small exposures in the

lower beds of the sequence which appear to be largely shales for the lowest 70'. These are overlain by a medium grained sandstone which has been worked in an old stone pit. The section in Fall Gill (015801) (Plate 23) contrasts with that seen on Horsehouse Moor and that in Coal Gill due to the presence of about 30' of current bedded highly feldspathic medium grained sandstone in the lower part of the beds. This sandstone overlies 13' of measures which appear to be all shaley and include a coal seam, once worked in the vicinity. The current bedded sandstone is overlain by shales with sandstone bands and a thin coal seam; the uppermost beds are not exposed, but are presumed to be chiefly shales.

West Gill (007792) shows a much stronger development of sandstones in the lower part of the beds. Here are seen 60' of massive, coarse current bedded sandstone with layers of quartz pebbles. All further sections on the N.W. side of Coverdale in an up-dale direction show a thick development of current bedded sandstones with no shale partings in the lower part of the group; exposures in the upper beds are very poor however and it is presumed that they consist of sandstones and shales. A coal is developed low in the Grassington Grit Group in upper Coverdale. It is seen to be 1'6" thick in a pot hole (985768) and overlies 2' of deeply weathered coarse sandstone, which probably rests almost directly on the top of the Main Limestone. The coal persists across Great Hunters Sleets where it has been extensively worked in shafts. A pot hole on this ground shows the lowest beds of the Grassington Grit Group, here 3' of very coarse pebbly sandstone.

Providence lead mine to East Witton along the E. side of Coverdale - Dakyns (1892) gives a section for the Providence lead mine which appears to be an almost complete section in the Grassington Grit Group. There is no evidence for the presence of the Cockhill Limestone in these records and it is assumed that since it was known from the country further south it would not have been missed by the miners. The fact that this limestone does not seem to appear in the section means that the Grassington Grit Group is probably here thicker than elsewhere in the area. The mapping evidence based on a feature on the side of Great Whernside supports this view. The surface geology in the vicinity of Providence Mine bears out the main details of the section given by Dakyns. There is a thick development of sandstones in the lower part of the group since shafts sunk into these beds below the horizon of the main coal seam show only sandstone in the tips. The surface mapping shows that a feature may be mapped for a mile south of the mine (this is outside the bounds of the appended geological map). The crest of the feature is in a coarse current-bedded sandstone which is appreciably more arenaceous than the beds recorded by the miners at this level (though this may be due to facies change near the mine). The feature itself is in shales; this is apparent since a coal has been worked intermittently along its length, both south of the mine and north of it, where the feature again appears. The highest beds are not exposed, but occur in a sloping peat covered platform, penetrated by a shaft which shows shale with plants and ganister in the tip (999725) and probably penetrated the upper coal quoted by Dakyns. This

shaft occurs near the base of a large, but vague feature. Experience in Nidderdale showed that a similar feature tends to occur at the level of the Cockhill Marine Band and thus it is assumed that this horizon is just above the top of Dakyns' measured section.

The lowest 70' of the Grassington Grit Group are seen at Caseker Crag where they are entirely current bedded sandstones without any shaly partings. East of Coverhead exposures are poor, but further north at Hem Gill Beck and Fox Stones (998767) the lower 100' of the beds are chiefly, or perhaps wholly, sandstones, because prominent lines of crags in current bedded sandstone are developed at intervals. It seems likely that the whole of the beds are 200' thick here and may include a proportion of shaly beds in the upper part (Plate 21A gives an interpretation of the available evidence). Between Slape Gill and Burn Gill (014781) the base of the Grassington Grit Group appears to cut through the Main Limestone into the sandstone and shales below it; exposures in Crab Gill indicate that the filling of this channel is predominantly and probably entirely sandstone.

Exposures of the Cockhill Limestone on the N.W. slopes of Little Whernside indicate that N. of Pally hut the total thickness of beds is 200', which thin to 170' in the direction of Lords Gill. The section in Lords Gill (020783) is incomplete, but the exposures seen are chiefly in shales. The uppermost one shows the following beds:

-	shale chips
6"	black, brittle shale with <u>Lingula</u>

6"	impure coal
6"	gap
-	ganister

By comparison with the section already enumerated it is evident that the line of facies change from persistent sandstones to shales with thin sandstones has been crossed and this is reflected here, as it is on the opposite side of the dale and in Waldendale by a northwards thinning at the point of facies change from predominant sandstones to predominant shales. The Cockhill Marine Band exposures on the N.W. slopes of Little Whernside occur at the base of a feature which can be mapped to the N.W. to High Pasture. This feature appears to die out when its base is only 110' above the bottom of the Grassington Grit Group and it seems probable that these beds have thinned rapidly. This agrees moderately well with their known, smaller thickness in the north of the area. 5' of shale with nodules of limestone occur in the lowest beds in Side Gill (036792) and are followed upstream by 3' of platy, sulphurous flaggy sandstones. A feature with sandstone boulders occurs at a slightly higher level in this vicinity and further blocks occur in the steep stream course in Harkera Gill. Arkleside Gill (049798) shows 25' of current-bedded fine grained sandstone in the lower part of the series at the level where shale occurs further up the dale in Lords Gill and Side Gill.

In Hindlethwaite Gill there is a good section in the lower part of the Grassington Grit Group (Plate 23). At the S. end of Hindlethwaite Gill Plantation the lowest beds include 20' of ganisters and fireclays with a 1' coal seam, not shown on the figured section

due to the rapid facies changes within the limits of the exposures. A section at 057808, further upstream, shows platy cherts which are apparently the uppermost beds of the Richmond Chert Series. They are here overlain by shales and sandstone with a thin coal, but with very little fireclay, in strong contrast to the section at this level 100 yards away. A calcareous sandstone 3' thick, and 1' from the base carries unidentifiable shelly debris and crinoid stems; this is not seen elsewhere at this level. Higher beds are chiefly shales which have yielded Lingula sp. They include sandstones which vary much in thickness and show ripple markings. A fireclay and thin coals occur at this level in the sequence giving a section similar to that in Back Dike and Coal Gill on the W. side of Coverdale. The several coal seams which outcrop in Hindlethwaite Gill have been worked in the vicinity, but do not appear to persist along the outcrop since the workings are localised.

The strata seen in Lead Up Gill are exposed in such a disjointed section that measurement is not possible. It is evident however that the lowest 20' or so of beds are shales with limestone nodules. They are followed upstream by ganisters with shales; these beds occur up to a thickness of 12' in a single exposure. In one of the exposures a tilted sandstone is transgressed by a fire-clay which appears to rest on an erosion surface. North of this point sections are not seen till Caldbergh Pasture is reached. There, a series of old shafts (101851) show shale and chert fragments on the tips. The shale is from the Grassington Grit Group and the shafts appear to have also penetrated the Richmond Chert Series. The mapping evidence suggests that the entire Grassington Grit Group

may be only 100' thick here since no trace of the Cockhill Marine Band is seen in a gulley section whose base is 100' above the top of the Richmond Chert Series. On the north side of Castle Steads shales occur at three levels on the hillside. They are more completely exposed in Red Beck Gill (121855) (Plate 23). The lower beds of the sequence are principally shales, here interrupted by a fault which brings in shales with two sandstones. These latter beds may belong to the lower part of the Nidderdale Shales or to the upper part of the Grassington Grit Group. Since the field evidence suggests that the fault involves the omission of 50' of beds from the section, it is perhaps more consistent with the supposition that the Grassington Grit Group is 100' thick to consider them as part of the Nidderdale Shales.

Whilst exposures of the Grassington Grit Group do not occur on Witton Banks, shale chips are abundant since the hillside is drift-free. Some fossiliferous blocks found on Witton Banks (see Chapter 10) may belong to the Cockhill Marine Band, but this cannot be proved. If this is the case however, the Grassington Grit Group is here about 100' thick, a figure which agrees well with the evidence from elsewhere. A coal seam which has been worked on Witton Banks is perhaps in the lower part of the Nidderdale Shales, though in the absence of firm evidence it has been placed in the upper part of the Grassington Grit Group in Plate 21A.

Nidderdale, from above Angram to Howstean Beck - The section in the R. Nidd above Angram Dam (018758) includes a large proportion of coarse, pebbly sandstone in the lower part of the Grassington Group. The upper 90' of these beds are not here seen. 5' of coarse sandstone near the base of the Grassington Grit Group are

seen near the bottom of Long Hill Sike (021760). In Crook Dike, further east, a dearth of sandstones is apparent and it seems that the feather edge of the massive sandstone development lies between Long Hill Sike and Crook Dike. This transition is considered to be the same as that observed in Waldendale and Coverdale. The succession is similar to that in Hindlethwaite Gill and Coal Gill, Coverdale because of the abundance of fireclays, coals and dark shales. The highest beds in the section are not fully exposed but include two sandstones, the lowest of which is micro-current bedded and is a fine grained, slightly feldspathic sandstone with carbonaceous flecks; the upper sandstone is medium grained. The total thickness of the Grassington Grit Group does not appear to exceed 150', which is a good average for the shaly development of these beds in mid-Coverdale and in Waldendale (Plate 23).

The section in Stone Beck is sufficiently extensive at some levels to trace thickness variations. The basal 7' of sandstone which overlies the intra-E_1 unconformity is a fine grained sandstone with little feldspar and with occasional green grains which are probably glauconite (Plate 22B). The beds above this horizon are variable, but are predominantly shales (Plate 23) which include a medium grained feldspathic sandstone varying in thickness from 25' to 11'. Maiden Gill Beck and Haw Gill Sike are incomplete sections in dominantly shaly beds with sandstones.

Wising Gill Sike (042759) (Plate 23) is fairly completely exposed and shows a strong development of sandstones. It appears likely that this section lies on the transition line between predominant sandstones and dominant shales. Two of the chief beds in the section are fine grained feldspathic sandstones. Other

bands are coarser; one contains both quartz and shale pebbles. The Angram dam trench cut through the lower part of the Grassington Grit Group. The strata encountered in the trench were very variable. This is apparent in the section quoted by Tonks (1925, Plate xvii) which shows a basal sandstone which dies out within the limits of the section. The northerly direction in which this sandstone dies out, from 40' to nil is the same as that of the thinning of the sandy facies, seen elsewhere in Nidderdale and in the country to the N.W. It seems probable that this is the visible expression of this thinning in the Angram trench.

In Wench Gill (043770) (Plate 23) there is a good section in the middle beds of the sequence, here predominantly shales. In thin section one of the sandstone bands in these shales was a coarse grained highly feldspathic sandstone with a high percentage of microcline. Trows Beck is not completely exposed, but shows coarse sandstones at about the same level as at Wench Gill. Exposures are scanty in these beds down-dale from Lodge, but the Scar House dam trench penetrated a predominantly shaly sequence (Plate 23). Tonks (1925) records Limipecten dissimilis and Leiopteria from an impersistent band in this trench 75' above the base of the Grassington Grits and Shales. Whilst the Cockhill Marine Band was not seen in the trench it was exposed in the vicinity and occurs a little higher in the sequence than the sediments of the trench.

Full sections are absent between Scar House reservoir and Lofthouse, but there are several exposures in the lower beds and few in the upper ones. These lower beds are predominantly massive, coarse and current bedded sandstones which contrast with the predominantly shaly sequence seen in the Scar House Dam trench. It

appears that the line of transition from predominating sandstones to a shaly sequence crosses the Nidd valley a little to the E. of Scar House, indicating a swing in the direction of the zone of facies change from a N.N.W.-S.S.E. course to a probable W.S.W.-E.N.E. trend. The upper beds, here chiefly shales are exposed in Foggy-shaw Gill (093766):

-	Cockhill Marine Band
7'	shale
18'	blocky mudstone
3'6"	sandstone
15'	mudstone and flaggy mudstone (base not seen)

Shales occur at approximately the same level in Woo Gill and Turnacar Gill, but their exact relation to the Cockhill Marine Band is not clear though they appear to be in the upper 50' of the Grassington Grit Group.

The bed of the R. Nidd in the vicinity of Low Woodale shows coarse sandstones developed near the base of the Grassington Grit Group. Some shales with flaggy bands occur, but the predominant beds are coarse sandstones which are also seen in the Nidd near New Houses and in the vicinity of Thwaite House and Limley. A long section is seen in the R. Nidd upstream from Sampsons Wood. It appears that the lowest 40' of beds are here entirely made up of coarse sandstone which is very massive and current bedded. The basal stratum is exposed in Sampsons Wood (099742) where it is a fine grained sandstone with no feldspar and carrying a high proportion of calcite cement with many grains of glauconite.

Backstone Gill (110735) shows an incomplete section in which coarse sandstones are dominant in the lower beds, though it seems

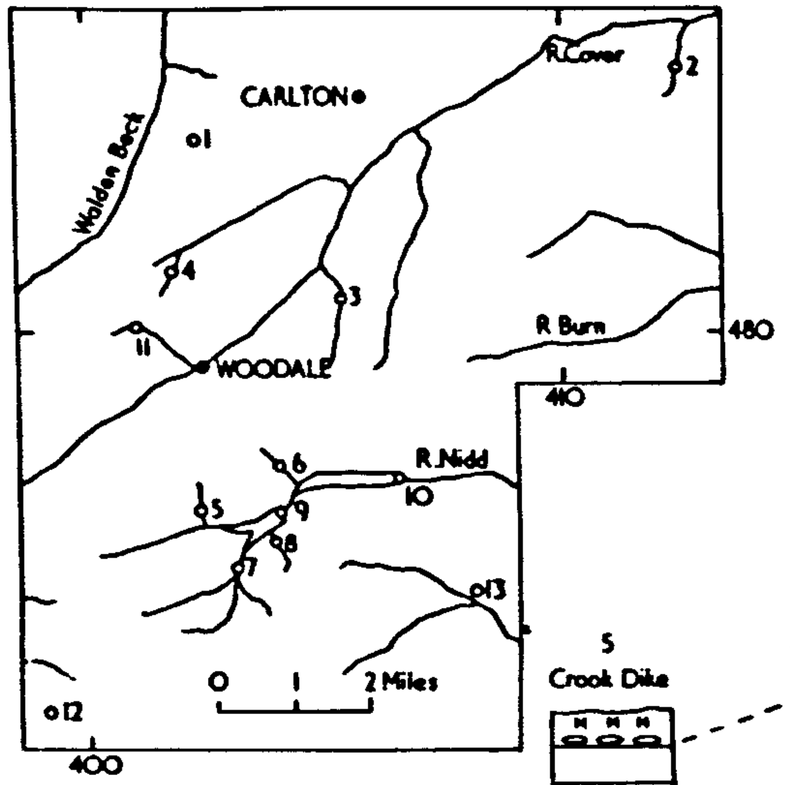
that near the top of the Grassington Grit Group there are several shale partings, including one of silty shales about 10' thick. A coal 5" thick was also seen in the section. A traverse made up Blayshaw Gill indicated that the lowest 60' or so of the Grassington Grit Group consists of coarse, massive current bedded sandstones. Shafts for lead on the adjoining country near Moor House show coaly shale in the tips pointing to the presence of a shale parting in the upper part of the beds, which may be the same horizon that has yielded shale chips below Hard Gap Lane (087730). This horizon has been tentatively mapped as part of a shale parting 17' thick, known to occur high up the Howstean valley and which has yielded obscure marine fossils. A coal at this horizon is apparently impersistent, but has been worked at Ruscoe Beck and is also seen in place in Howstean Beck at one point.

A gorge is excavated in the lower part of the Grassington Grit Group in Howstean which is flanked by cliffs for a long distance. In them are seen up to 40' of massive coarse, current bedded sandstones, part of a sandstone development 100' thick. These beds are only measurable at Ruscoe Beck, though by far the most extensive outcrops are in the gorge of Howstean.

PLATE 23

Comparative sections in the Grassington Grit Group together with the Cockhill Marine Band.

60 Feet
40
20
0



KEY

- Sandstone
- Siltstone
- Shale with bands of Sandstone
- Ganister
- Coal on Fireclay
- Shale
- Marine Shales with Limestone Nodules
- Gap in Section - probable geology indicated only in 1 & 13

1
Harland Hill

2
Red Beck Gill

3
Hindlethwaite Gill

4
Coal Gill & Back Dike

5
Crook Dike

6
Wench Gill

7
Stone Beck

8
Wising Gill

9
Angram Dam Trench

10
Scar House Dam Trench

COCKHILL MARINE BAND

11
Foll Gill

12
Providence Mine

13
Ruscoe Beck & Howstean Beck

CHAPTER 10

THE COCKHILL MARINE BAND

The Cravenoceras cowlingense fauna which characterises this horizon has not hitherto been found in situ in the present area, but one exposure of the Cockhill Marine Band was discovered in Forcryshaw Gill, Nidderdale, by Tonks (1925) which did not yield any goniatites at the time. Tonks regarded this horizon as the probable equivalent of the Top Limestone of Phillips (1836) and the Gate Up Limestone of Dakyns. Specimens Zh 4223-28 in the Geological Survey Collection in London were found by Hudson in the River Nidd between Limley and Lofthouse as loose blocks, which no doubt originated at an exposure described subsequently (Exposure No. 10 in the text). The blocks collected by Hudson yielded C. cowlingense preserved as 'solids' in blue calcite mudstone.

Outside the limits of the present ground, the Cockhill Limestone has long been recognised, having been recorded by Phillips, who quotes Newbold's section at Greenhow. Dakyns, in surveying Sheet 116, in the latter half of the Nineteenth Century, found "calcareous shale with fossils" in Gate Up Gill, a record confirmed by Dunham and Stubblefield (1945) who also re-examined the adits at Greenhow from which the limestone was originally recorded. These authors renamed the Top Limestone of Newbold and Phillips, the Cockhill Limestone, after Cockhill Adit where it was discovered (Dunham and Stubblefield, 1945). These same authors recorded for the first time the Cravenoceras cowlingense fauna from the southern part of the Askrigg Block. A record

from Deep Gill in the Beamsley area, south of the Craven Faults, cited by T.W. Jones (1943) is discounted by Hudson (discussion in Dunham and Stubblefield 1945), who claims that this is the Colsterdale Marine Series and not the equivalent of the Cockhill Marine Band as Jones had maintained.

The term 'Cockhill Limestone', is modified to 'Cockhill Marine Band' in the present treatment, since here the limestone is not the dominant member of these marine beds as it is at the type locality of Cockhill Adit.

Stratigraphy

The Cockhill Marine Band appears to persist throughout the area and is known from several outcrops in upper Nidderdale, in Coverdale and in Waldendale, together with an occurrence in the debris of the landslip at Black Scar, Penhill. Exposures are not found on the east side of Coverdale, north of Arkleside, or on the south side of Wensleydale, east of the River Cover.

The full thickness of the marine band is usually not seen, owing to incomplete exposure, but it is known to attain a maximum of 6 Feet, locally. The horizon appears to be somewhat varisble with the development of a discontinuous limestone, set in a soft, calcareous, highly carbonaceous shale. The limestone occurs in blocks which were apparently always of nodular shape. These are usually about 9 inches in diameter and consist of blue calcite mudstone containing a little quartz sand; septarian cracks infilled with calcite occur commonly, whilst cone-in-cone structure, poorly developed, is seen in a few instances. The limestone often contains scattered goniatites, all the identifiable

ones being Cravenoceras cowlingense Bisat, preserved as 'solids' (as in the case of those recorded from the Cockhill Limestone of Greenhow by Dunham and Stubblefield, 1945). The limestone is absent from several sections and is not regarded as characteristic of the horizon within the area mapped, but appears to be a more persistent feature in the Greenhow area.

The shales of the Cockhill Marine Band occur chiefly above the limestone, where a thickness of 3'-3'6" is usually seen. These shales are typically compact, brittle, black, finely micaceous shales which yield a fauna of Cravenoceras and pelecypods, chiefly posidonids. Below the limestone the shales are sometimes fossiliferous for about a foot, but locally up to 3' of shale of marine aspect, without fossils, occurs.

Variants of the limestone - shale facies occur on the slopes of Brown Haw, Waldendale where a fossiliferous sandstone and a fossiliferous, black, finely laminated shale are seen, but there is no trace of a limestone.

The Cockhill Marine Band has been mapped through most of the area on the evidence of scattered outcrops. Sometimes the band occurs at the foot of a large, indistinctly defined feature on the Nidderdale Shales, as in the country around Angram, and on the western slopes of Great Whernside and Little Whernside. Complete exposures of this horizon are infrequent, owing to peat cover and the lack of dissection of the landscape at the topographic level where the outcrop of the band might be expected.

Details

Since the records set out in the following pages are nearly

all new ones, they have been detailed at length and the exposures are numbered.

South Side of Nidderdale.-

1. The stream draining into Scar House Reservoir which drains parallel to Scar House Gill, and 50 Yards to the East of it (064765), shows the following section:

15'	unfossiliferous shales
3'	black, brittle, fissile shale with well preserved Posidonia membranacea
1'6"	black mudstone with Posidonia vetusta and Productus (Productus) sp. and containing nodules of about 9" diameter showing cone-in-cone and septarian structures, with an infilling of calcite in the cracks. The nodules weather yellow and have yielded orthocone nautiloids and zaphrentid corals, but no goniatites
1'	black mudstone with Posidonia sp.
1'	soft, pale grey, unfossiliferous shale
5'	unfossiliferous mudstone (with impure limestone nodules in the upper part)
2'	sandstone seen

2. Scar House Gill (063765) shows a less complete section which is essentially similar, being only 50 Yards away from the section detailed above.

-	unfossiliferous shale
8'	gap
1'6"	brittle, black shale with goniatite 'ghosts'
1'	approx. nodular limestone with goniatites
-	soft shale with goniatites
4'	gap
5'6"	current bedded sandstone

3. The stream draining Haden Carr Pasture (051765) shows:

-	unfossiliferous shales
1'	brittle, black shale (probably the top of the Cockhill Marine Band)

4. Wising Gill Beck (044757). Here the Cockhill Marine Band is somewhat thinner than usual and poor in fossils. The section seen is:

-	gap
2'	micaceous, coarse black shale with septarian nodules of blue limestone
6"	zone of nodules of blue calcite mudstone
6"	black shale
2'	siltstone passing down into 2' sandstone

5. An unnamed tributary of Stone Beck (034750) shows a section disturbed by hill creep, with beds of Cockhill lithology at two levels close to each other. In reality there is probably only one horizon and the most complete exposure appears to show the following beds:

4'	unfossiliferous mudstone
3'6"	black, brittle shale
1'	approx. gap
2'	greenish, micaceous flaggy sandstone

Traces of goniatites occur in a very rotten, black mudstone at a slightly higher level uphill, from whence the section detailed above appears to have slipped en bloc.

North side of Nidderdale

6. Crook Dike (025764) shows the most fossiliferous development seen in the Cookhill Limestone of the present area. The section shows:

3'6"	black, blocky weathering ferruginous shale with small carbonaceous nodules and occasional Productus (Productus) sp. and palaeoniscid scales. (top not seen)
1'	horizon with nodules of blue calcite mudstone in shale. The centre of the nodules contain a 2" layer with profuse 'solid' specimens of Cravenoceras cowlingense Bisat. Cracks in the limestone carry infillings of calcite and barite.
5'	gap
-	mudstone

The stream draining past High House Lathe into Angram Dam (037766) shows an excellent exposure at this horizon which is here detailed:

-	unfossiliferous mudstone
3'6"	black, blocky shale with Posidonia sp. and Cravenoceras sp.
1'	layer of subspherical, blue calcite mudstone nodules in a zone of carbonaceous, rotten mudstone. The nodules show commonly the development of the most perfect septarian structure, with a polygonal mesh of calcite infilled cracks intersecting the rounded surface. 'Solid' specimens of Cravenoceras cowlingense Bisat occur scattered sparsely through many of the nodules, but although the exposure is extensive, no nodules showed goniatites in the profusion seen in Crook Dike. Cone-in-cone structure is also developed
3'	black, carbonaceous, blocky mudstone with no fossils recorded
-	grey mudstone

8. Wench Gill (041772) - The section here is involved in landslips and only part of the thickness of the marine band appears to have been preserved. 1' of black, brittle shale with Productus (Productus) sp. and Lingula occur, which is very similar to shales seen above the Cockhill Limestone in Crook Dike.

9. Near the North end of the Scar House Dam (067773), a scree in shale has yielded a pelecypod fragment which is almost certainly at the horizon of the Cockhill marine Band (in this connection it is here stated that the horizon yielding traces of marine fossils in the Scar House Reservoir trench, believed by Tonks to be a possible correlate of the (Cockhill) marine band at Foggyshaw Gill is certainly at a lower stratigraphic level than this band).

10. An exposure in the right bank of the River Nidd $\frac{1}{4}$ Mile upstream from New Houses (091769), shows large nodules of blue calcite mudstone up to 2' in diameter with 'solid' goniatites together with septarian cracks infilled with calcite, and cone-in-cone structure. The large nodules weather orange, but show smaller nodules within the main ones, which weather grey.

11. An outcrop on the hill slopes above the Nidd in the same area as the previous exposure is separated from it by a branch of the Limley fault which has here shifted the Cockhill limestone in an upward direction on its south side. The exposure (092768) is disturbed by the tectonics but shows limestone nodules together with shale containing badly preserved goniatites and specimens of Posidonia sp. Owing to the disturbed nature of the beds the detailed relations are difficult to determine.

12. A third and topographically higher outcrop occurs in Foggyshaw Gill (093767), the only locality mentioned by Tonks (1925). Our sections agree in the fact that no limestone was recorded at this point, but my record of the thickness of the fossiliferous shales is substantially in excess of the figure quoted by Tonks.

The section here shows:

-	unfossiliferous shales
5'	fossiliferous mudstone; brittle, black and blocky weathering with heavy limonite staining on the joints. The upper beds are compact and yield Productus (Productus) sp., whilst the lower beds are more fissile.
7'	shale without fossils
18'	blocky mudstones
3'6"	sandstone

It is considered that the previous three exposures, which lie at differing topographic levels within 350 Yards of each other, belong to the Cockhill Marine Band since they all show some of the characteristics of this horizon and there is no known duplication of marine horizons at this level.

Coverdale.- Several important sections occur, but none are complete.

13. A gulley 400 Yards north of Pally Hut (015774), shows the following section:

1'6" nodular weathering, tough highly ferruginous shale with Posidonia sp.
1' yellow clay (probably deeply weathered Cockhill Limestone)

The tough shales in the upper part of the Cockhill Marine Band are characteristic of several of the Nidderdale exposures of this horizon.

14. Lords Gill Shaw (021780) shows the following section:

6" micaceous mudstone
6" compact, black, brittle shale
1'6" black, fissile shale with Posidonia sp.
6" fossiliferous shale. (no base seen; the section is incomplete

15. A gulley, also on the northern slopes of Little Whernside (022782), shows the following incomplete exposure:

1' black, brittle shale (approx.)
3' gap with orange debris, which may be deeply weathered Cockhill limestone
1' black, soapy shale with a possible Posidonia sp.
1'6" pale grey, soapy shale (no fossils seen)
1' flaggy mudstone.

In all the three aforementioned exposures on the northern slopes of Little Whernside, the total thickness of the Cockhill Marine Band appears to be about 5' and therefore comparable with that commonly observed in Nidderdale.

16. In Howden Gill (038849), a crinoidal limestone 6" in thickness resting on a weathered shale is seen, but unfortunately no further beds are visible. In thin section the limestone is a calcite mudstone with angular quartz grains of 50-100 microns scattered through the calcite, together with numerous crinoid ossicles, showing the original cellular internal structure. The hand specimen yields a brachiopod comparable with Actinoconchus

planosulcatus (Phillips). A little of the Cockhill Limestone from the Black Scar Landslip develops a crinoidal phase which resembles this rock from Howden Gill, but this development in the Cockhill limestone is certainly not typical. In view of its stratigraphic position and such fauna as it contains this exposure is referred to the Cockhill Marine Band.

Waldendale and Wensleydale.

17. The scar left by a bog-burst on the west slopes of Brown Haw in Waldendale shows an incomplete, but unusual, exposure (989799):

-	unexposed.
2'	blue shale chips
6"	shale chips with chips of chalybite nodules
6"	zone of incoherent, limonite stained, medium grained sandstone blocks
6"	orange mud (possibly a decayed limestone)
6"	medium grained sandstone with shale pebbles and with casts of Productus (?Eomarginifera sp.) and Dielasma hastata
7'	gap
1'	flaggy sandstone
-	silty shales

This exposure is apparently at the level of the Cockhill Limestone and differs in lithology, rather than fauna, from certain other occurrences of this horizon (The fauna from the Penhill landslip is similar in general respects to the present one, except for the lack of goniatites at the exposure here described).

18. A further exposure on the slopes of Brown Haw, in Waldendale, but situated further north (011812) has yielded about 1' of brittle shale similar to that which usually occurs above the Cockhill Limestone. This has yielded Productus (Productus) sp. and crinoid ossicles. A black, finely laminated, papery shale appears to underlie it, chips of which occur with minute, thin

shelled pelecypods. No rock similar to this shale in lithology has been seen in place elsewhere at this horizon.

19. The debris of the Black Scar Landslip, Penhill (042869) yield limestone blocks with Cravenoceras cowlingense. The occurrence in the Penhill area of the C. cowlingense fauna brings the record of this fossil to a point geographically mid-way between Mirk Fell Gill and Greenhow from where it has been previously described on the Askrigg Block.

The blocks of limestone which occur in the debris of the slip are of about 1' diameter, rounded in shape and consist of a blue calcite mudstone, showing a distinct, fine layering on the weathered surface. Other features seen are cone-in-cone (also seen at several localities in Nidderdale) and nodules within the main nodules, weathering grey in contrast to the orange of the main nodules (seen also at the exposure No. 10, in the Nidd near New Houses.) In a fresh section of this limestone these inner nodules are of almost the same shade of blue as the surrounding limestone, but they contain goniatites in larger numbers, preserved as 'solids', one of which was readily determinable as C. cowlingense Bisat. The fauna of the limestone of the larger nodules is chiefly one of brachiopods, comprising Productus (Productus) sp. and athyrids. C. cowlingense occasionally occurs, but is concentrated in the inner nodules which weather grey, though it is never very prolific, and extraction of specimens was difficult. A little weathered shale in the landslip debris appears to be of the fossiliferous variety. The bulk of the shale in the landslip is unfossiliferous.

20. A spring above Braithwaite Lane (132857) has yielded a block of fossiliferous, arenaceous rottenstone accompanied by similar blocks with no organic remains visible. Since this occurrence is close to a drift-free patch and the exposure is at approximately the right stratigraphic level for an outcrop of the Cockhill Marine Band, it is at any rate possible that these blocks are derived from this horizon and fine their parallels in the fossiliferous sandstones of the southern exposure on Brown Haw.

Palaeontology

Whilst the C. cowlingense fauna has not been found in situ in the present area by previous workers, several important records of this form exist. The type specimen was described from an erratic block in Keighley Churchyard by Bisat (1932) and was subsequently found in the Mirk Fell Ironstones of Mirk Fell Gill by Hudson (1941). This locality (Plate 2) is of great importance since the record from Mirk Fell Gill is the sole one of an E zone goniatite from the north part of the Askrigg Block. At the time it was found, it was the only record from the whole of the Block. The discovery of C.cowlingense at Greenhow by Dunham and Stubblefield (1945) demonstrated that the C. cowlingense fauna was more widespread than had hitherto been thought. Hudson and Cotton (1945) recorded the C. cowlingense group from Edale. It is seen in their lists to occur in E_{2a} and E_{2b}. Ct. nitidus, the form characteristic of the Colsterdale Limestone of the present area was only recorded from E_{2b} and may in a sense be said to succeed C. cowlingense, as was definitely shown to be the

case at Greenhow. Moseley (1954) provides concrete evidence of the C. cowlingense horizon and publishes detailed lists, corroborating Dunham and Stubblefield's conclusion that C. cowlingense occurs substantially lower in the sequence than Ct. nitidus. The Edge Marine Band of Rombalds Moor (with Eumorphoceras bisulcatum Girty and Cravenoceras sp., Stephens et al., 1953) and the Werley Wise Marine Band (with forms referred tentatively to C. cowlingense by Stubblefield, in Dunham and Stubblefield, 1945) are regarded as approximate correlates of the Cockhill Marine Band by Dunham and Stubblefield (1945).

The Cockhill Marine Band of the present area is characterised by C. cowlingense Bisat which is recorded from several localities. It is usually found in the Cockhill Limestone and more rarely in the shales which overlie the limestone. The forms found vary little from the type specimens in respect of shape, dimensions, suture and the shape and spacing of the ornament. The umbilical edge is a little less acute than in the specimens described by Hudson from Mirk Fell, and in this respect they agree better with the type material from Keighley Churchyard. The specimen from the Penhill landslip is more finely lirate than usual; 7 lirae per mm. occur at 8 mm. diameter at the centre of the venter; however the suture and shape (sub-sphaerocone) correspond well with that of the type specimens. A specimen from Wench Gill has a diameter of 1.1 mm. with 4 lirae per mm. on the centre of the venter, which corresponds with the type material.

The fauna accompanying the characteristic goniatite in the present area is chiefly of thin shelled pelcypods and nautiloids.

These records compare in many respects with those of other authors. Posidonia vetusta is seen at several localities in the shales above the Cockhill Limestone; this characteristically strongly ornamented form does not occur in higher marine bands in the present area apart from a doubtful record referred to P. aff. vetusta in the Colsterdale Marine Series. Posidonia cf. membranacea is a common fossil in the section west of Scar House Gill and elsewhere but is not recorded at Greenhow.

Comparison of the records from the present area with those from Greenhow shows similarities, especially in the records of C. cowlingense and forms near P. vetusta; these two fossils may be taken as the most typical forms found in the present area. Moseley (1953) describes a fauna from the Tarnbrook Wyre Marine Band of the Lancaster Fells. The goniatite records, C. cowlingense Bisat and Dimorphoceras sp. are similar, whilst other fossils listed in common are the species Posidonia cf. corrugata, P. cf. membranacea and P. vetusta (Moseley actually gives, P. corrugata, P. membranacea and P. ?vetusta). Pseudamusium fibrillosum, orthocone nautiloids and crinoid columnals are further joint records and serve to stress the considerable faunal similarity, which is a little remarkable in view of the large distance separating the two localities. Eumorphoceras bisulcatum and Anthracoceras paucilobum were not recorded from the present area, but it is interesting to note that they figure in the records from this horizon of Moseley and Dunham and Stubblefield.

Brachiopods are a feature of the fauna of the Cockhill Marine Band of the present area which have not been considered this far. They are a constant element in the shales above the limestone in

Nidderdale and Coverdale and also occur in the limestone itself in the debris of the Penhill landslip. The bulk of the specimens are brachial valves of Productus (Productus) sp. The actual species is difficult to determine owing to the dearth of pedicle valves, but P. carbonarius appears to be most likely. Several other brachiopods, chiefly anthyrids and terebratulid forms, make up the majority of the rarer remaining records. The bulk of these latter specimens come from the north of the present area, where brachiopods appear to be dominant, whilst farther south, in Nidderdale, they are restricted to the shales above the Cockhill Limestone and are absent at Greenhow and in the Lancaster Fells.

The fauna of the Mirk Fell Beds corresponds only partially with that from the present area, though the records of C. cowlingense, Zaphrentis and Productus (Eomarginifera) sp. are held in common. The remainder of the Mirk Fell fauna with nuculids, Glabrocingulum sp. and several species of cephalopods corresponds most closely with that of the nuculid-gastropod beds developed at the base of the Colsterdale Marine Series of the present area which lie at a substantially higher horizon, but contain a similar faunal assemblage.

The brachiopod fauna from the Cockhill Marine Band corresponds more strongly with that of the Lad Gill Limestone (Scanlon, 1955) which contains Dielasma hastata, Eomarginifera sp. and Isogramma sp. (given as Semenewia by Scanlon), orthocone nautiloids and fish teeth. On the basis of the correlation of the Mirk Fell horizon containing C. cowlingense with the Cockhill Marine Band, the Lad Gill Limestone is at a higher level than the Cockhill Marine Band and only resembles it in faunal phase.

It seems likely that the area in which the Mirk Fell Ironstones was laid down was isolated, since there is so little resemblance in the fauna between this locality and that of the area here described. In contrast, the conditions which gave rise to the fauna of the Cockhill Marine Band in the south of the present ground must have been constant over a wide area to explain the strong faunal resemblances between the records from the Lancaster Fells, Greenhow and the present region.

Faunal List

Cockhill Marine Band

'L' denotes fossil preserved in limestone, unlettered numbers denote preservation in shale, 's' denotes preservation in sandstone.

carbonised wood, 2s, 7

crinoid ossicles, 2s, 3, 4L, 5L, 6, 8, 9

zaphrentoid coral indet., 4L

cf. Actinoconchus planosulcatus (Phillips), 6L
Crurithyris sp., ?2s, ?3, 4
Dielasma cf. hastata (J. Sowerby), 2s
cf. Isogramma sp., 7
Lingula mytiloides J. Sowerby, 3
?Phricodothyris sp., 5L
Productus (?Eomarginifera) sp., 2s
Productus (Productus) carbonarius de. Koninck, ?4, 5L, 8, 9, 10
--------- (---------)sp., 1, 3

Aviculopecten cf. losseni (von Koenen), 4
Cypricardella cf. concentrica Hind, 4
Leiopteria longirostris Hind, 4
Palaeolima sp., 4
Posidonia cf. corrugata (R. Etheridge jun.) 1, 3, ?7, 9, 10
--------- cf. membranacea (McCoy) 3, 4, 7
Posidonia vetusta (J. Sowerby), ?1, 4, 7
Posidoniella laevis (Brown), 1s
---------- minor (Brown), 7

Posidoniella cf. minor(Brown), 4
---------- cf. trapezoedra Ruprecht, 1
---------- cf. wapanuckensis (Girty), 7
Pseudamusium fibrillosum Salter, 4

Cravenoceras cowlingense Bisat 4, 4L, 5L, 7L, 9L
---------- sp., indet. 1, 7L, ?10
Dimorphoceras sp., ?1, ?4L, 7
Dolorthoceras sp. (finely lirate), 4L
Orthocone nautiloid indet., 1, 4L, 7

Palaeoniscid scale, 4, 9
?Rhadinicthys sp., (scale), 4

Index of localities for the above

1.	400 yd. N. of Pally Hut, Coverdale	015774
2.	Westerly slopes of Brown Haw, Waldendale, S. exposure	989799
3.	Westerly slopes of Brown Haw, Waldendale, N. exposure	011812
4.	Un-named gill 50 yd. E. of Scar House Gill, Nidderdale	064765
5.	Debris of landslip, Black Scar, Penhill	042869
6.	Howden Gill, Coverdale	038849
7.	Un-named gill draining past High House Lathe, Nidderdale	037766
8.	Wench Gill, Nidderdale	041772
9.	Crook Dike, Nidderdale	025764
10.	Foggyshaw Gill, Nidderdale	093767

CHAPTER 11

THE NIDDERDALE SHALES

Phillips (1836) named the strata between the base of the Grassington Grit Group and the base of the Red Scar Grit the Nidderdale Shales. This definition has been restricted during the present work to include only those beds which are predominantly shales i.e. the beds between the Cockhill Marine Band and the Red Scar Grit. Dakyns (1892) gave no name to these beds, but named a sandstone within them after Pinlow Pike, an eminence on Great Whernside which cannot now be located. Bisat (1914) called these beds the Barren Shales, a term which would have been retained by the present writer, had it been uniform with the application of local names to the entire system of nomenclature of Millstone Grit facies sediments used in the present work and comparable works. Bisat, in common with Tonks (1925) gives a predominantly shaly sequence at this level in his tabulated section. Tonks mentions the Priest Tarn Grit however (named by Dakyns from Priest Tarn, south of the present area), which is the approximate equivalent of the sandstone in Stone Beck, Nidderdale (this may also be equivalent to the Pinlow Pike Grit).

The records from Simonseat (Hudson, 1939) and Greenhow (Dunham and Stubblefield, 1945) are of interest since these beds show a lower shaly portion and the chief sandstones occur in the upper beds as in the present area. Bands of limestone recorded at Greenhow are parallelled in the present area, where they are not so numerous.

Stratigraphy

The Nidderdale Shales are a persistent group of beds of lower

Arnsbergian age lying between the Cockhill Marine Band and the base of the Red Scar Grit. The total thickness varies from 270' to 200', with the maximum in the Great Whernside area. East and north of this area the beds appear to thin to 200' so that in the country around Lofthouse and Penhill and in the slopes above East Witton the smaller thickness is usual.

As the name used for the division implies, this series consists chiefly of shales which carry several impersistent sandstones which are locally abundant near the top of the series. The lowest 100' of beds are almost always shales, though a higher sandstone appears to transgress down into these beds on the N. face of Little Whernside. A sandstone appears to occur at a similar low level in the vicinity of Lodge hamlet in Nidderdale. Fine grained sandstones, rarely over 20' thick, are mapped at several horizons in upper Nidderdale where these beds are best exposed. A sandstone which has been mapped 110' below the Red Scar Grit in Stone Beck, Nidderdale has also been mapped tentatively into a sandstone at the same level on the N. slopes of Great Whernside and on the N. and W. sides of Little Whernside; it is possible that this is the Pinlow Pike Grit of Dakyns. On the basis of a feature on the N. slopes of Little Whernside this sandstone has been mapped as descending in the succession until it comes to within 50' of the Cockhill Marine band, amongst beds where sandstone partings are rare occurrences.

In the middle part of the Nidderdale Shales at several localities impure silty limestones are developed which show rounded weathering and contain imperfect plant remains. None of these

horizons can be mapped as persistent and they do not appear to be so common as in the sections at Greenhow.

The upper 100' of the Nidderdale Shales shows the greatest lithological variation. In some sections in upper Nidderdale (How Gill, Scar House Gill) and in mid Coverdale (Arkleside Gill and environs) these beds are virtually all shale; elsewhere they show a sandstone about 30' below the Red Scar Grit (as at Thrope Edge landslip scar, Woodale Scar and elsewhere in the Scar House area. At other localities shales with several thin sandstones occur (Greystone Gill, Coverdale and Black Scar, Penhill), whilst locally sandstones are developed to a thickness of 60' or more. These thick sandstones are fine to medium grained and lense out rapidly. The sections in Birk Gill, Colsterdale (Plate 24) and Penhill Crags (Plate 24, 32) show lateral facies change of a predominantly shaly sequence to one composed entirely of sandstones. The nature of these arenaceous thickenings is not clear. The best exposed section of 60' of sandstone in Penhill Crags does not appear to be a washout lens; in fact the shales which lie to the east of the sandstone appear to bear a washout relation themselves to this thick arenaceous development, which is possibly a levee deposit, terminated laterally by crevassing of the type described from the Mississippi delta by Fisk et al. (1954).

The mapping of the Nidderdale shales is aided by the frequent presence of a feature on the Red Scar Grit forming the upper limit of these beds. The lower limit, the Cockhill Marine Band, is less well exposed, but has proved fairly satisfactory except in

the north of the area where the position of the Cockhill Limestone has been put in tentatively on the geological map on the evidence of the section in Howden Gill and of the occurrence in the landslip at Black Scar, Penhill. Complete sections in the Nidderdale Shales are rare, but several stream sections in upper Nidderdale show extensive gulleys in the shaly portions of these beds (Plate 38B). On Penhill the best sections are in the scars of the two great landslips on the N. face of the hill.

Details

Exposures are dealt with in sequence, in Nidderdale, Coverdale and Colsterdale.

Dead Mans Hill to Backstone Gill (N. and E. sides of Nidderdale) - Stand Syke (051776) (Plate 24) shows an incomplete section, chiefly in shales, but with four thin sandstones. The uppermost sandstone with its top 8' below the base of the Red Scar Grit, is associated with blocky, micaceous siltstones with carbonaceous flecks and is seen in this position in several sections in the Scar House area. The lowest arenaceous band in this section is a medium grained feldspathic sandstone,

Tops Gill (056776) is incompletely exposed, but the sandstone which occurs a short distance below the Red Scar Grit is here also seen. A gulley on the slopes of Carle Fell (059774) shows an uninterrupted section in 50' of shales in the lowest part of the Nidderdale Shales, shortly above the horizon of the Cockhill Limestone. A band of rottenstone occurs near the base of the section here and is overlain by shales with poorly preserved plant remains.

Occasional shale debris are seen on the south eastern slopes of Carle Fell. Woo Gill is badly exposed but the beds below the Red Scar Grit are well seen. The section at 080777 shows:

-	Red Scar Grit
10'	shale
15'	flaggy sandstone, passing down into
20'	shale

At a lower level in the section 24' of shale are exposed which probably come shortly above the Cockhill Limestone, not here exposed. In Turnacar Gill the lowest beds of the sequence are also exposed (089775) and include shales with two thin bands of rotten weathering siltstone which probably overlie the Cockhill Marine Band. A shale scree, probably in the lower part of the Nidderdale Shales, is seen near Summerstone Lodge (096772).

At the N. end of Thrope Edge landslip scar (105761) (Plate 24) an excellent section is seen in the upper part of the Nidderdale Shales:

30'-44'	olive coloured silty shales with abundant small muscovite plates (an impersistent blocky, fine grained sandstone occurs near the base)
17'	fine grained, flaggy sandstone with some kaolinised feldspars and scattered carbonaceous spots
24'	siltstone with a flaggy parting and carrying carbonaceous lenses in the lower part
4'	fine grained, loosely cemented sandstone with a little kaolinised feldspar, scattered muscovite plates and flecks of carbonaceous material
70'	dark blue shale with fine mica plates; siltstone bands occur in the upper part - these vary from 4" to 2' in thickness and are composed of micaceous silt with a calcite cement causing the rock to weather into rounded shapes

A section in the landslip near above High Thrope (105759) shows:

30'	flaggy mudstone
9'	sandstone
6'	flaggy mudstone
10'	medium grained sandstone

The top of this section is at approximately the same level as the base of the section detailed above from the landslip scar, though there may be slight overlap between the sections.

A stream section S.E. of High Thrope shows 15' of mudstone and flaggy mudstone at a horizon which is probably shortly above the Cockhill Marine Band. In the side of the track ascending Trapping Hill two sandstones are seen in the upper beds of the series in conjunction with shales. The section in Backstone Gill is very incomplete but shows 6' ganisteroid sandstone overlying 15' of shales in the lower part of the series.

Woodale Scar gives an excellent section in the upper beds of the Nidderdale Shales. These include a persistent band of sandstone which forms a cliff along part of the length of the scar. The section measured near the centre of the scar (080765) shows the following beds (Plate 24):

-	Red Scar Grit
5'6"	pale olive flaggy mudstone
1'6"	blocky, soft orange sandstone with carbonaceous flecks
9'	blue, micaceous, ferruginous shale
21'	soft blocky sandstone with carbonaceous flecks, becoming more compact downwards. The lower portion of this horizon is a well sorted fine grained quartz sandstone with occasional feldspars and with flecks of limonite and carbon together with a little muscovite. This sandstone persists along the length of the scar
5'	alternating flaggy sandstone and flaggy mudstone
5'	shale

The position of the sandstone above is similar to that seen in the landslip scar on Thrope Edge (see ante).

The south slopes of Rainstang show exceedingly few exposures in the Nidderdale Shales, though limited outcrops occur on the E. side in Northside Head Plantation and in How Gill where shales with a band of sandstone and siltstone are exposed. The section

in Foggyshaw Gill is incomplete, but shows several scars in shale, in the upper and lower part of the Nidderdale Shales.

The section in the side of the track ascending Scar House Pasture from Scar House (068764) is as follows (Plate 24):

-	Red Scar Grit
10'	mudstone and flaggy mudstone
50'	shales

The sandstone which forms a persistent feature along Woodale Scar is absent in this section, though beds of sandstone occur at this approximate horizon further up the dale.

The sections on the south side of Kay Head Allotment are never complete, but provide additional evidence about this group. In Armathwaite Gill the upper 70' of beds are partially exposed and form screes below the outcrop of the Red Scar Grit. They are chiefly shales, but a ganisteroid sandstone, of which 7' are seen, occurs about 90' below the base of the Red Scar Grit. Aygill Beck is largely without exposures, except in the middle beds of the Nidderdale shales which outcrop in a gorge (058739) where the section shows:

5'	shale
10'	sandstone, strongly current bedded and coarsening in grain upwards
30'	silty shales passing up into sandstone

Scattered shale exposures occur at lower levels in the section.

Scar House Gill (063762) (Plate 24) provides one of the most complete sections in the present area in which the upper beds are excellently exposed in a deep gulley. The lower beds are not so fully seen, but appear to be almost entirely shales, like the upper ones which are here unusually deficient in arenaceous horizons.

A soft, fine grained, slightly micaceous carbon-flecked sandstone occurs near the top of the section and resembles that which occurs at this level elsewhere in this area, but is absent in the section adjacent to the track ascending Scar House Moss (see ante), which lies a short distance to the E. of Scar House Gill. The shales in the upper part of the Nidderdale Shales carry only occasional sandstone ribs, one of which is calcareous and shows rounded weathering. The lowest bed of the sequence are partially seen in Scar House Gill and in the stream a short distance to the east where all the visible strata are shales.

In a stream at the W. end of Haden Carr Pasture (051764) the lowest beds are exposed in a gulley. About 50' of shales without sandstone follow directly a horizon which is probably the top of the Cockhill Marine Band. The next 40' or so of beds above these shales are ill-exposed but include two thin sandstones. Further upstream a gulley cut through about 25' of shales exposes two bands of calcareous siltstone in the sequence, whilst a higher section in beds about 30' below the Red Scar Grit shows a soft sandstone 13' thick (the possible equivalent of a similar sandstone which occurs at this level locally).

The section in Wising Gill (Plate 24) is complete except for the highest and lowest beds. An excellent section is seen in a gorge excavated in the middle part of the shales which carry occasional arenaceous horizons, always fine grained sandstones with small quantities of feldspar. Occasional bands of calcareous siltstone showing rounded weathering forms occur. These are dark grey, highly carbonaceous siltstones with flecks of mica and some obscure plant fossils. The highest sandstone in the section

is perhaps equivalent to one at a similar horizon in the stream on Haden Carr Pasture, described above.

The sections in Haw Gill Sike and Maiden Gill are incomplete, but show shales at several levels and also a sandstone 6' thick, here mapped as continuous with a similar one in the lower part of the Nidderdale Shales of Wising Gill. This sandstone appears to die out rapidly to the S.W. since it is absent in the un-named stream draining into Stone Beck (035749) where the lower half of the Nidderdale Shales is fairly well exposed. All the visible beds are shales, which include a calcareous siltstone band.

An excellent section is seen in the middle beds of the Nidderdale Shales of East Gill Dike (Plate 24). A sandstone occurs at approximately the same level as the lowest sandstone of Maiden Gill Beck and Wising Gill Sike. It is here at least 10' thick, being a fine grained feldspathic sandstone with rootlets. The overlying beds are almost entirely shales, which carry several bands of siltstone at a restricted level, followed by a soft, grey sandstone 5'6" thick which has been mapped into the sandstone of Wising Gill Sike in a north easterly direction on scant evidence. West Gill Dike shows along its length a large number of shale scars in the lower and middle parts of the Nidderdale Shales which are here virtually devoid of arenaceous horizons. A 2' band of flaggy sandstone which lenses out in the stream section has been tentatively mapped into the 10' sandstone of East Gill Dike. The upper part of the Nidderdale Shales has been involved in a series of landslips on the hill side overlooking Stone Beck. These beds are exposed below Red Scar where a big scree in shale is seen below the outcrop of the Red Scar Grit.

Sections at the head of Stone Beck are particularly extensive (Plate 24) and show that the upper 110' of the Nidderdale Shales are exclusively shales. These overlie a current-bedded fine grained, moderately feldspathic sandstone 16' thick, forming a waterfall in Stone Beck. Below the sandstone there is a further thickness of shales devoid of sandstone beds. On the spur below Blackfell Scar there is a large arcuate landslip in which are seen sections in canted shales without traces of sandstone partings. At a lower level a scar shows about 50' of shale in an un-named stream at 019752.

A large number of scattered exposures occur north of the headwaters of the Nidd around 010758 where the Nidderdale Shales are involved in an extensive landslip whose boundaries are virtually impossible to map since the slip is superficial and of irregular shape. Shales exposed in gulleys above this slipped area include arenaceous horizons which have tentatively been mapped as continuous with the sandstone in Stone Beck and with that developed on the northern slopes of Great Whernside at this level. At this point the sandstone seen is only 3' thick, though it is probably thicker.

In Long Hill Sike (015765) and nearby the lowest 100' of the Nidderdale Shales are excellently exposed in gulley sections and consist entirely of shales. A gulley above the slip (016767) shows the highest beds visible in this vicinity which include an impersistent band 1' thick which is appreciably more calcareous than the calcareous siltstones sporadically developed in these beds in Nidderdale. The rock is lithologically not unlike a goniatite bearing limestone since it is a blue calcite mudstone

showing rounded weathering, effervescing with dilute HCl and with a well developed pattern of septarian cracks in calcite.

The lowest beds of the Nidderdale Shales are excellently exposed in Crook Dike (025766). They are entirely shales seen to a thickness of about 90' and are overlain by flaggy sandstone blocks taken to be derived from the same horizon as is seen in Stone Beck and elsewhere at the N. end of Great Whernside. The section in the stream draining past High House Lathe (037766) is very similar to that seen in Crook Dike. A continuous section is seen in 90' of shales above the Cockhill Marine Band. They are overlain by a sandstone which is probably over 10' thick, since blocks of it are common on the nearby hillside. Whilst this sandstone cannot be connected by mapping with that mapped at Crook Dike, owing to the presence of an intermediate exposure of shale at this level, it was evidently deposited at about the same time as the sandstone of Stone Beck and elsewhere.

In Wench Gill and Trows Gill the lower beds of the sequence are fairly well seen, but are affected by faulting in the latter section. Beds of sandstone appear to occur low in the sequence at a level where only shale is recorded in exposures around Long Hill Sike, further up the valley. The thickest of these sandstones is 20' thick and appears to occur only 50' above the Cockhill Limestone. This is at the same stratigraphic level as a sandstone which forms a boulder-strewn feature on the north slopes of Little Whernside. The upper beds of the Nidderdale Shales are excellently seen in How Gill (039779), tributary to Trows Gill, where a deep gulley shows the upper 100' of the Nidderdale shales to be almost entirely in shales (Plate 24), as in Stone Beck. At

this same level however, a sandstone 4' thick is developed in Shaw Gill, whilst the sandstone which locally occurs above the Cockhill Limestone is also seen in this section.

W. slope of Great Whernside and the E. slopes of Coverdale to Flamstone Pin and Sowden Beck - The Nidderdale shales of the outcrop edge of the main body of rocks of Millstone Grit facies in the present area are not usually well exposed. The outcrops are dealt with in sequence.

Exposures are rare on the W. side of Great Whernside, but extensive landslips indicate that the Nidderdale Shales are chiefly shaly here. On the N. slopes of Great Whernside (007765) a sandstone which is possibly nearly 20' thick forms a local feature. It is possible that this is the type locality of the Pinlow Pike Grit of Dakyns (1892), but the absence of the name on the available topographic maps leaves this in doubt. This bed is at the same level as that in Stone Beck and is mapped as part of the same horizon. In the vicinity of Lords Gill Shaw (020779) the lowest 50' or so of the Nidderdale Shales forms a feature often intersected by gulleys in which there are a sufficiently large number of exposures to show that these beds are exclusively shales, overlying the Cockhill Marine Band which is exposed at three points in the gulley sections. Above this feature which is developed S.W. and N.E. of Lords Gill Shaw is a gently inclined platform at which level no sandstone occurs; it is probably on shale like the gulleys further down hill. A somewhat discontinuous feature overlooks this platform and carries on it sandstone blocks which are especially abundant on High Pasture (034787); here there is little doubt that the arenaceous band is over 10' thick. Sandstone blocks also occur in the old stone pit S.S.W. of Pally Hut which is probably

in the same bed as that seen on the N. flank of Great Whernside. A yet higher feature is mapped fairly continuously on the northern and south western flanks of Little Whernside; it never carries large numbers of sandstone boulders, nor is any similar horizon developed in the entirely shaly sequence on the south slopes of the mountain. It therefore seems possible that this feature is developed on beds of different hardness within a shaly series.

The section in Harkers Gill (042789) shows clearly the upper beds of the sequence, which appear to be almost entirely shale for 100' below the Red Scar Grit. A black rottenstone nodule, weathering yellow at the edges, collected a few feet below the base of the Red Scar Grit yielded a single gastropod referred to Naticopsis sp. in conjunction with other possible organic fragments. This is the only record of a fossil, other than indeterminate plants, from the Nidderdale Shales of the present area. Sections in the middle beds of the Nidderdale shales are less complete and include alternations of sandstone and shale, whilst the lowest beds are entirely obscured by drift.

Arkleside Gill (050790) shows exposures only in the upper beds of this division which are excellently seen in a deep gulley showing the following beds (Plate 24):

-	Red Scar Grit
16'	shale
7'	flaggy mudstone
50'	shale

This exposure closely resembles similar exposures to the S.S.W. in Nidderdale, as at How Gill. Intermittent exposures in the middle beds of the Nidderdale shales of Arkleside Gill include flaggy sandstone. A gulley on Arkleside Moor (053795) shows 70' of beds

underlying the Red Scar Grit, in a section closely resembling that in Arkleside Gill. Exposures are lacking on the barren spur of Hindlethwaite Moor and in the head waters of Lead Up Gill.

The upper 65' of the series is well seen in Greystone Gill (075818) (Plate 24) where they are chiefly shales, but apparently more silty than in exposures to the S.W. They include several thin sandstones the thickest of which is 8' thick, occurring at a horizon comparable with arenaceous beds in the Scar House area of upper Nidderdale. This sandstone shows wavy bedding and mild slump structures which are also found at a similar horizon in Black Scar, Penhill.

Exposures in Ulfers Gill and to the west indicate that the upper 125' of the Nidderdale Shales includes a high proportion of shale, though arenaceous horizons alternate with the shales in the uppermost beds which are exposed in a waterfall in the gill (097830).

North of Ulfers Gill the slopes of Caldbergh Moor are without exposure, but below Flamstone Pin (002851) 52' of beds are seen in a gulley which appears to be cut into the lower part of the Nidderdale Shales, the following section being seen:

-	Red Scar Grit outcrop
100'	approx. unexposed, except for 10' of flaggy mudstone in the centre of these beds
3'	shale
0-1'	impersistent impure limestone, altering laterally to mudstone
6'6"	mudstone
1'6"	flaggy mudstone
15'	shale - this horizon probably almost directly overlies the Cockhill Marine Band which is not exposed on the E. side of lower Coverdale, but is probably present

In a small scar overlooking the Castle Steads overflow channel (005853) 15' of shale are seen, overlain by flaggy sandstone. These

beds are probably equivalent to the higher strata of the scar below Flamstone Pin. The Nidderdale Shales are exposed sporadically in Red Beck Gill where all the visible beds are shales. They are never seen on the N. slopes of Witton Fell, except for a small exposure on Sowden Beck Road where some flaggy mudstone and an old stone pit for flagstone are seen in the uppermost beds of the series. All outcrops to the east of this point are entirely unexposed and are largely covered by the drift from the Wensleydale ice sheet.

Brown Haw, Harland Hill and Penhill - outliers on the W. side of Coverdale - Sections in the slopes of these hills are chiefly in the scars of landslips or in gulleys and are never complete for the whole series.

Brown Haw, Fellpot - the exposed on Brown Haw are in a number of gulleys in the lower part of the Nidderdale Shales for 100' above the Cockhill Marine Band which is exposed on the N.W. face of the hill at two points (Plate 24). On the S.E. side of the hill the Cockhill Marine Band is unexposed and it is difficult to know if the sandstone forming a feature on Cranshaw Ridge (804020) is in the lowest part of the Nidderdale Shales or in the highest part of the Grassington Grits and shales. The beds in the feature are an impersistent feldspathic fine grained flaggy sandstone at least 8' thick. About 50' higher in the sequence a second feature can be mapped almost persistently into the feature in the upper slopes of Brown Haw. This feature keeps a fairly constant height above the top of the sandstone

of the Grassington Grit Group which decreases in thickness to the N. It thus descends to a progressively lower level in this direction in relation to the top of the beds of Yoredale lithology, a phenomenon which appears to be repeated on the north slopes of Little Whernside. The mapping of the higher horizons in the Nidderdale Shales of Brown Haw and of Great Fell Pot is unsatisfactory and the interpretation put forward on the map is based on a few features and very few exposures. The abundance of sandstone blocks, as in the stone circle at Precious Hull (003805) and on the top of Brown Haw, suggests that a sandstone is strongly developed at a level similar to that of the cap rock of Harland Hill to the N.N.E.

Harland Hill - sections are very poor, but the approximate base of the series is probably marked by an indistinct, but major change of slope on the W. slopes of the hill. An exposure in the lower beds of the group is seen in a gulley on the N. slopes of the hill, where shales with a thin sandstone are exposed through a thickness of about 20'. A small feature with sandstone blocks occurs on the S.E. slopes of the hill, but does not appear to be persistent. The numerous sandstone blocks on the summit of the hill appear to indicate the presence of a sandstone capping, probably equivalent to that on Fell Pot. It may also be the same as the sandstone mapped at this level on Penhill. It seems likely that 35' of shale in a gulley on the col between Harland Hill and Penhill (033850) is in the $b_a$sal part of the Nidderdale Shales, but no trace is seen of the Cockhill Marine

Band, though the mapping in Howden Gill to the E. suggests that it almost immediately underlies the beds in this section.

Penhill - the chief exposures are on the N. side of the hill in two large landslip scars with excellent sections in the upper and middle beds of this group. On the southerly sides of the hill exposure is poor and the geological lines on the map are somewhat approximate. It appears that an arenaceous horizon can be mapped from Burton Outstray, on the S. side of the hill past Slantgate to Rams Gill (048859). Exposures are rare, but sandstone chips occur at several points and also small exposures are found above Slantgate and Rams Gill where it is probable that this horizon consists of 20' of flaggy sandstone, only partially exposed. This horizon has been mapped into the sandstone forming the landslip scar at Hodge Holes (052862) which is more massive and at least 45' thick, but which appears to die out entirely to the N.N.E. since the available exposures below Penhill Beacon suggest that the succession is here largely of shale. This is confirmed in the E. end of Penhill Crags, further West. The lower beds of the Nidderdale Shales are partially exposed in Ramsgill where they are chiefly shales with a few thin sandstones, in all 78' thick.

The section in Penhill Crags (052868) is excellent in the upper part of the Nidderdale shales which form a cliff capped along its length by the Red Scar Grit (Plates 24, 32). The chief feature of the section is a lens shaped development of sandstone whose base is not seen, but which probably rests almost

directly on shales (hence the enormous landslips under the crags). The main body of the sandstone attains 60' in thickness; a specimen collected from the lateral part of the lens was of a fine grained slightly feldspathic quartz sandstone. The bulk of the thickness of the sandstone appears to be gradually cut out by the uppermost stratum of this lens which sweeps down to the E. across the lower beds, leaving only a very attenuated representative of the thick sandstone at the E. end of the cliff. It seems therefore that this thick sandstone does not appear to be a washout, but has itself suffered by being washed out and is hence attenuated on the E. side. The bulk of the filling of the excavation in the sandstone on its E. side is shale, with thin sandstones (Plate 32 is taken from a distant view of the Crags and shows the relations in this section). The same beds appear to persist to the E. round the base of Penhill Beacon, but are replaced by sandstones closely resembling those of Penhill Crags in the vicinity of Hodge Holes.

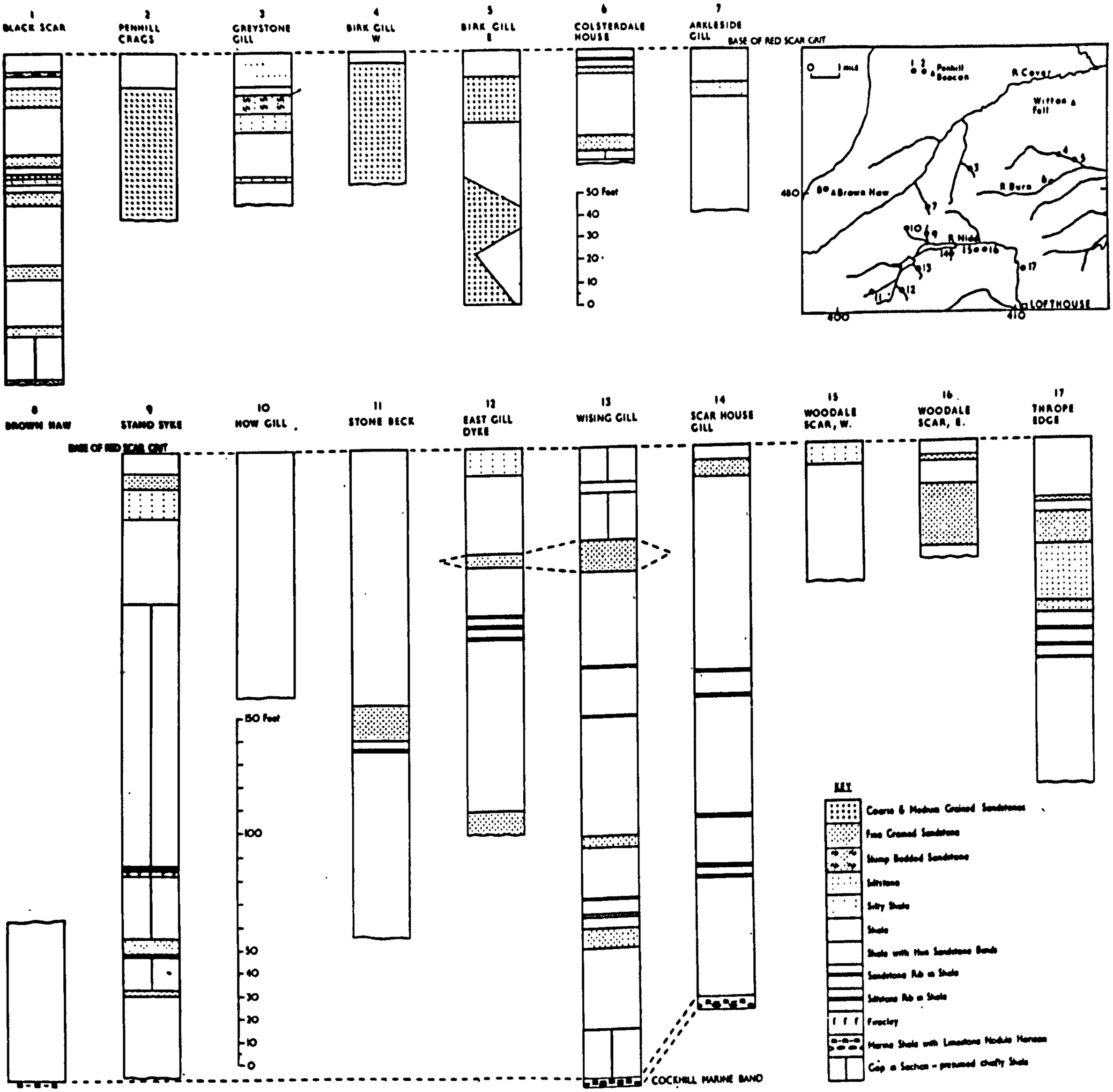
Colsterdale inlier - exposures are restricted to a boomerang shaped inlier in Birk Gill and the valley of the R. Burn. The most extensive section is in Birk Gill Wood, in a long line of scars on the banks of Birk Gill (Plate 24). Rapid facies changes are seen in the section. Near 133819, current-bedded sandstones and thick shale partings are seen dipping down stream. Lower beds appear up-stream and the lowest visible beds are 36' of dark micaceous shale with thin bands of siltstone, the middle part of which is replaced up-stream by flaggy sandstone in a picturesque waterfall (128821). Above the waterfall the equivalents of the

shale with sandstones further down stream are entirely flaggy sandstones, forming a series of cliffs. Arenaceous beds persist to the base of the Red Scar Grit. In the cliff sections where alternations of shale and sandstone are seen, rapid facies changes are common and transitions from sandstone to silty shales are frequent. It is plain that no single horizon in these beds may be mapped with confidence. It seems that the bedding planes in the series do not run parallel to those in the Red Scar Grit and the appearance of lower and lower beds coming in upstream does not imply that the section is located further and further below the Red Scar Grit. Despite the appearance of successive lower beds coming into the section, in actual fact the thalweg of the stream runs almost parallel to the outcrop of the Red Scar Grit further up the hill side. It is concluded, therefore, that the beds were either deposited on inclined surfaces, or acquired a component of their dip as a result of compaction before the Red Scar Grit was laid down. In hand specimen the sandstone members usually show a flaggy parting and are fine grained with shreds of mica; feldspar is not common. A single band of impure grey limestone with detrital quartz was seen at 137815, but it does not persist farther N.W. in the principal section in Birk Gill.

Sections in the R. Burn near Colsterdale House yielded a section shown on Plate 24 which is a composite of several exposures. The Red Scar Grit is underlain by a predominantly shaly series which contrasts with the development of sandstones at this level in the sections in Birk Gill.

PLATE 24

Comparative sections in the Nidderdale Shales, together with the Cockhill Marine Band.


1 BLACK SCAR
2 PENHILL CRAGS
3 GREYSTONE GILL
4 BIRK GILL W
5 BIRK GILL E
6 COLSTERDALE HOUSE
7 ARKLESIDE GILL
BASE OF RED SCAR CAVT
50 Feet
40
30
20
10
0
0 1 mile
Penhill Beacon
R Cover
Witton & Fell
R Burn
Brown Haw
R Nidd
LOFTHOUSE
480
400
410
8 BROWN HAW
9 STAND SYKE
10 HOW GILL
11 STONE BECK
12 EAST GILL DYKE
13 WISING GILL
14 SCAR HOUSE GILL
15 WOODALE SCAR, W.
16 WOODALE SCAR, E.
17 THROPE EDGE
BASE OF RED SCAR CAVT
150 Feet
100
50
40
30
20
10
0
COCKHILL MARINE BAND
KEY
Coarse & Medium Grained Sandstones
Fine Grained Sandstone
Slump Bedded Sandstone
Siltstone
Silty Shale
Shale
Shale with Thin Sandstone Bands
Sandstone Rib in Shale
Siltstone Rib in Shale
Fireclay
Marine Shale with Limestone Nodule Horizon
Coal in Section - presumed shelly Shale

CHAPTER 12

THE RED SCAR GRIT

The Red Scar Grit was so named by Dakyns (1891) owing to its tendency to form "Red scars". This name is now in general use and is here adhered to, though it was antedated by the name 'Sandgill Grit', quoted by Phillips (1836) from Newbold (Mss.)

This horizon has been widely recognised by workers subsequent to Phillips (1836) who recorded a coal horizon in the Grit at several localities. Dakyns (1890, 1892) recognised a feldspathic lower leaf of Grit, a ganisteroid upper leaf and a coal in between the two, whilst the Survey maps, for which Dakyns was in part responsible, show this grit with an intermittent coal within it, which was termed the Woogill Coal by Dakyns (1892)). Bisat (1924) confirmed the conclusions of Dakyns, but appeared to draw the base of his Colsterdale Marine Series at the horizon of the Woogill Coal; since the term 'Red Scar Grit' has priority, this nomenclature is not here retained, and the base of the Colsterdale Marine Series is taken at the top of the Red Scar Grit. Tonks (1925) added no new information about this horizon.

Stratigraphy

The Red Scar Grit is a fine to coarse grained sandstone, varying from quartz sandstone to arkose, carrying an impersistent coal which locally divides it into an upper and a lower leaf. When the coal is absent, this subdivision of

of the Red Scar Grit is not normally possible; this situation obtains chiefly in the south part of the area. Normally when the Grit is split into two leaves the lower leaf is a feldspathic, coarse, massive sandstone with well developed current bedding, whilst the upper leaf varies from a coarse quartz sandstone to a compact, medium or fine grained siliceous sandstone which is usually somewhat ganisteroid. Current bedding on a very large scale with units of 20' or more in height occurs locally in the upper leaf. The presence of this unusual development can usually be correlated with a local, abnormal thickening of the upper leaf of the Grit (normally about 7' thick) (Plate 26 is an information diagram incorporating 26 measured sections of this horizon, which will be found useful in following the changes which take place at this stratigraphic level.) When the large scale current bedding is developed, there are rapid changes of grain size. Marine fossils have been found at several localities in the Upper Red Scar Grit, both in the thick and thin developments of this horizon, chiefly in the north of the present area.

The Woogill Coal is an impersistent horizon which has been extensively worked in the past in Coverdale, Nidderdale and Colsterdale. It occurs in a parting 3 to 17' in thickness between the Upper and Lower Red Scar Grits, consisting of fire-clays, ganisters, a tough, highly carbonaceous platy black siltstone and dark, brittle shales with Lingula sp., pelecypods and gastropods, together with unfossiliferous shales. The Woogill Coal is seldom recorded to be thicker than 1'4", which means that about 2' of unproductive measures were worked in conjunction with

the actual extraction of the coal; these beds are chiefly fireclay, as is shown by examination of the tips of levels working the coal.

In localities where the Woogill Coal is absent, the Red Scar Grit is not usually divisible into its component leaves and is then a single feldspathic sandstone with no development of ganisteroid beds.

Outcrops of the Red Scar Grit were mapped in Colsterdale (a valley inlier of complex shape), Nidderdale, the W. slopes of Great Whernside and Coverdale. The cap of Penhill is an outlier on these beds, whilst the remainder of the oucrops occur within the main outcrop of the Millstone Grit. Frequent scars mark the outcrop of the Red Scar Grit, and a rather indistinct feature is usually seen, with its base some distance below the base of the Grit. Landslips are frequent on the Nidderdale shales, below the Red Scar Grit and the base of the Red Scar Grit and the upper edges of the landslip bodies are often close to each other for long distances. The Grit is everywhere overlain by marine shales of the Colsterdale Marine Series which locally form a marshy hillside notch with a spring line at the top of the Grit, a valuable aid to mapping.

Details

<u>The Colsterdale inlier</u> - An inlier of complex shape occurs in the valleys of Birk Gill, Spruce Gill and the River Burn in Colsterdale. The Woogill Coal occurs over much of this area and hence the Red Scar Grit is everywhere divisible into two leaves, though in Barnley Beck below Long Side, the coal is not

exposed and has not been worked. It is however seen again in the section high up Barnley Beck and further to the west in Ulfers Gill, a tributary valley of Coverdale.

The section in Barnley Beck above its junction with Scale Gill (108825) is interrupted by faulting, but the succession can be pieced together as follows:

3'	Medium grained quartz sandstone with scattered grains of glauconite. Poorly preserved organic fragments include crinoid ossicles and a probable chonetid which occur in kaolinite filled voids.
2'	ganisteroid sandstone with rootlets (the total Upper Red Scar Grit is probably not much in excess of the indicated thickness of 5')
-	possible gap
2'	yellow fireclay
1'6"	soapy grey shale without fossils
7"	coal - the Woogill Coal
6"	ganister
4'6"	grey fireclay
5'	silty, coaly shale
6"	carbonaceous siltstone
-	small gap (probably sandstone)
30'	coarse feldspathic sandstone (no base seen) - Lower Red Scar Grit

In the lower part of Barnley Beck, the Lower Red Scar Grit frequently exposed in the stream course and from the mapping of features appears to be over 60' thick. Near Colliers Stile (116823) the Lower Red Scar Grit includes a 3' ganister, unusual at this horizon. The lower portion of the Lower Red Scar Grit is seen further downstream at 120823 where 25' of current bedded coarse sandstones are seen. These rest immediately upon sandstones of the Nidderdale Shale group, which are distinguished from the Red Scar Grit by their thinner bedding and finer grain size.

Backstone Gill (123823) shows an intermittent section in a thick development of the Lower Red Scar Grit which is here typically

massive. East of this point in Birk Gill there is little trace of the Lower Red Scar Grit, and this horizon cannot be more than 50' thick near the junction of Brown Beck and Birk Gill.

The Upper Red Scar Grit is recognisable in lower Birk Gill, owing to the presence of the Woogill Coal which has been worked in numerous drifts from the outcrop. The Upper Grit has thicknened greatly in comparison with the thin development in upper Barnley Beck. Measurement above a coal adit in Brown Beck (134819) showed a thickness of over 55' of Upper Red Scar Grit at this locality. On the south side of Birk Gill (136815) over 40' of Upper Red Scar Grit is seen above the line of levels in the Woogill Coal (Plate 26). Large scale current bedding in units of up to 33' thick is excellently seen. The grain size is extremely variable and includes coarse quartz sandstone with crinoid ossicles and fine grained ganisteroid quartz sandstone in which are found occasional fossiliferous pockets yielding a small brachiopod-pelecypod fauna similar in composition to that of the Cayton Gill Shell Bed.

At 136817 on the north side of Birk Gill, cliffs are seen in 20' of very massive sandstone with current bedding and undulose slump structures. These are rapidly replaced in 50 yards to the east by a ganisteroid sandstone of which 20' are seen at the head of an adit working in the Woogill Coal. A number of sandstone boulders below Low Houses (138814) are inferred to belong to the Lower Red Scar Grit. The outcrop of the Grit on the north side of the dale is covered by numerous boulders of sandstone and lines of workings in the Woogill Coal, below which are extensive tips of the fireclay. The Upper Red Scar Grit is seen in the bed of the

R. Burn at Gollinglith Foot and appears to have thinned greatly to the east since its outcrop in the valley is here so restricted. Trial holes sunk in this vicinity by Leeds Corporation proved 12' of Upper Red Scar Grit, but the top of the bed was not seen, though it is unlikely that it was much thicker than 12'. The Lower Red Scar Grit was 55' thick in the trial hole, a substantially greater thickness than that seen near Colsterdale House at this horizon. (See Plate 26).

In Spruce Gill, exposures of the Upper Red Scar Grit occur at intervals in the valley bottom, but no more than 10' are seen anywhere. At one point shale lenses are seen below sandstones in the stream bank and it is possible that locally the stream cuts down low enough to expose the parting containing the Woogill Coal, to which these shales may belong. In lower Spruce Gill the Upper Red Scar Grit is fossiliferous. The section seen at 148806 shows:

9"	compact, medium grained sandstone
6"	sandstone with rootlets.
3'	gingerbready medium grained sandstone with numerous fragmentary organic remains including crinoid ossicles preserved as voids leached of the original calcite.
1'	white ganister with rootlets.

The Red Scar Grit can be traced on the N. side of the spur N. of Spruce Gill by means of numerous boulders and scars, and is seen to be always massive and never ganisteroid. At 147813, 2 5' of Lower Red Scar Grit are seen; this is not the full thickness which is probably about 40', being intermediate between the 29' seen near Colsterdale House and 55' recorded from the trial hole at Gollinglith Foot.

The Lower Red Scar Grit exposed in a cascade in the right bank of the R. Burn at 123805, is 29' thick, inclusive of a flaggy

development at the base (Plate 26). Adits in the Woogill coal in the area round Colsterdale House show a roof in variable strata which often shows original dips of sedimentation, up to an inclination of 30 degrees. A maximum of 24' of Upper Red Scar Grit is seen in cliffs above the Woogill Coal outcrop, and though the lithology is usually a massive medium grained sandstone, in an up-valley direction ganisteroid beds become increasingly common.

Upstream from Colsterdale House the Lower Red Scar Grit forms many exposures in the bed of the R. Burn for over a mile. It is always a massive, current bedded, coarse grained sandstone. At several points it is markedly pebbly and a specimen from the waterfall immediately above the bridge over the R. Burn at Colsterdale House was a very coarse, slightly feldspathic sandstone of grain size 1000 microns, with pebbles of quartz up to 9 mm. in diameter.

The Upper Red Scar Grit is seen above the entries of several levels upstream from Colsterdale House, and also in Slee House Gill. The horizon is frequently current bedded on a large scale and tends to be ganisteroid in the lower part and coarser in grain and less ganisteroid in the upper part. The cliff section on the right bank of the River Burn at 118802 shows 10' massive sandstone becoming less ganisteroid upwards, resting on 6' flaggy, ganisteroid sandstone.

Near the confluence of Thorny Grane Gill and the R. Burn some silty shales appear in the bed of the R. Burn. Since shale partings do not usually occur in the Lower Red Scar Grit, they are interpreted as being beds below the Grit, forming a small inlier. This gives the lower Red Scar Grit a thickness of 26' up to the

level of an adit in the Woogill Coal. Upstream from this point the Lower Red Scar Grits are seen in the bed of the R. Burn as far as Dawson House and also near the bottom of Thorny Grane Gill in a series of cascades (15' of massive sandstone are seen in the latter exposure). The section in the R. Burn above Dawson House (103799) Plate 26) in an excellent exposure in the Upper Red Scar Grit and Woogill Coal;

31'	approx. medium grained sandstone, partly ganisteroid and quite massive in its lower part, with large scale current bedding in the lowest 15' of strata
9"	fireclay
1'	coaly shale
3'	highly carbonaceous black, coarse quartz sandstone
1'8"	black, finely micaceous, carbonaceous shale with obscure plant remains, and becoming more brittle downwards
2"	coal
3"	greenish ganister - probable top of the Lower Red Scar Grit which is again seen 20 yd. downstream where the section shows:
3'	medium grained sandstone with rootlets (overlain by shale chips)
2'	ganisteroid sandstone

Since the upper portion of the Upper Red Scar Grit is rarely satisfactorily exposed in Colsterdale, it has not been possible to verify the occurrence of the thin coal recorded from the log of West Pit and Brown Beck Pit. An exposure in Thorny Grane Gill (112798) is thought to belong to a horizon higher in the succession than the Woogill Coal. A 2" coal is seen resting on sandstone and is overlain by 6" shale and a 1' grey ganister which may possibly be equivalent to the 'capon hardstone' of the coal pits north of Colsterdale.

North side of upper Nidderdale - outcrops are described from W. to E. from Dead Mans Hill to Bull Brae, between which points the Red Scar Grit forms a fairly continuous, but poorly defined feature.

The section seen in Stand Syke (051778) is as follows (see

also Plate 26):

-	Colsterdale Marine Beds
6'	unexposed (probably upper Red Scar Grit)
1'	soft, medium grained sandstone
1'	fireclay
10'	compact, pale, well bedded, ganisteroid, very fine grained sandstone with a little mica on planes of parting and carrying appossible shell cast resembling Myalina sp.
4'	gap (probable horizon of the Woogill Coal, if this horizon is present)
2'	coarse, compact quartz sandstone with a somewhat ganisteroid texture.
3'	gap - probably coarse sandstone.
5'	coarse sandstone, with layers of varying grain size.
3'	grey, feldspathic, medium grained sandstone, poorly sorted with grains up to 2 mm. in diameter. In thin section interstitial silt is abundant and the rock approximates to a subgreywacke in composition.
-	micaceous mudstone of Nidderdale Shales.

The outcrop may be followed by means of a feature, eastwards to Tops Gill, with an exposure of 7' current bedded sandstone at 053777.

Tops Gill shows a section similar to Stand Syke but the Lower Red Scar Grit is not seen (057776):

-	Colsterdale Marine Series
5'	current bedded coarse quartz sandstone with scattered feldspar grains and containing crinoid ossicles, preserved in calcite and weathering out as voids of characteristic shape. The ossicles are scattered through the rock and may be presumed to have been swept into place from a source outside the present area
6'	unexposed
1'6"	grey fireclay
3'	unexposed (probable horizon of the Woogill Coal, if present)
2'6"	compact fine grained, pale ganister, intersected by carbonaceous traces of rootlets. (base not seen)

150 yd. E. of Tops Gill the outcrop of the Red Scar Grit is marked by sandstone rubble. At 061774 a symbol on the topographic map suggests that the Woogill Coal was once worked by a level, but this place is now overlain by tips from the Scar House Quarries.

Firth Plantation (076775) shows a feature with sandstone rubble on the Lower Red Scar Grit, whilst the ground above the plantation is interpreted as being, in part, a dip-slope on the upper beds of the Red Scar Grit.

The section in Woo Gill is informative (075782) (Plate 26):

-	Colsterdale Marine Series (chips of soapy shale)
7'6"	fine or medium grained fairly compact, massive sandstone with shale pebbles in the lower part and carrying scattered glauconite grains. The base of this bed shows U shaped worm burrows referred to cf. Arenicolites sp. which have an infilling of sandstone, but descend 2 cm. into the shale beneath.
1'	unfossiliferous shale
5'	measures with Woo Gill Coal which include grey, brittle fossiliferous shales which probably overlie the coal. The shale contains Lingula sp., pelecypods and gastropods. This material occurs in tips from coal adits.
45'	Medium grained, current bedded sandstone consisting in thin section of medium grained quartz, a little oligoclase, hydrobiotite and interstitial silt, with clay minerals. (no base seen, thoug the indicated thickness is probably close to the total)

The Upper Red Scar Grit of Woo Gill is approximately the same thickness as in the exposures previously detailed on the south flanks of Carle Fell, but the Lower Grit is appreciably thicker here than in the exposures further west.

At 079777, on the E. side of Woo Gill, the lowest beds of the Red Scar Grit are seen in scars which appear to have been involved in slips on the valley side. The Woo Gill coal is here present on the N.E. side of Woo Gill and has been worked in a closely spaced line of drifts, at the head of one of which blocks of Upper Red Scar Grit occur (it is likely that this horizon is thin in this area).

The section at the head of the Bull Brae landslip (084776) is similar to that given for the upper part of Woo Gill:

-	Colsterdale Marine Series
5'	porous weathering medium grained sandstone
-	parting with Woogill Coal (thickness not correctly measurable.)
35'	Lower Red Scar Grit (no base seen)

East of Bull Brae the Red Scar Grit is seen rarely. 100 yd. E. of Summerstone Lodge the lowest 5' is seen and at Brown Ridge Plantation the lowest 15' is exposed.

<u>East Nidderdale south of the Limley Fault</u> - The Red Scar Grit forms a feature on Bleasefield and is seen again in the landslip scar on Thrope Edge where its outcrop is disturbed by two faults. This section shows rapid lithological variation at this horizon within a distance of 200 yds. The north end of the cliff above the landslip shows 17' of coarse sandstone with no visible top; no coal is seen either, but it has been worked immediately to the north of this point on Bleasefield. In hand specimen the Red Scar Grit is here a coarse grained feldspathic sandstone with pebbles up to 5 mm. in length. The centre of the cliff (105761) shows 1' coal resting on 9' coarse sandstone, the beds above the coal being unexposed. The section at the S. end of the cliff shows:

2'	sandstone - Upper Red Scar Grit
2'	pale grey soapy s hale
1'6"	ganister
1'6"	black, carbonaceous, blocky siltstone
4'	ganister
-	coal smut
6'	fireclay
4'	coarse sandstone - Lower Red Scar Grit
-	mudstone (Nidderdale Shales)

This section shows that very rapid deterioration of the Red Scar Grit takes place laterally. The measures with the Woogill Coal, which is here represented only by a smut, contain rocks of the several lithologies which are typical of this parting, namely fireclay, ganister and black, blocky siltstone. The soapy shales are

here without fossils, but are at a horizon which has yielded a lingulid fauna elsewhere at scattered localities.

The section at the S. end of the cliff shows:

-	Colsterdale Marine Series
1'	weathered, coarse sandstone
18'	pale cream very fine grained compact, blocky quartz sandstone of ganisteroid appearance (possibly the Upper Red Scar Grit)
3'6"	coarse indurated sandstone (possibly the Lower Red Scar Grit)
"	shales (Nidderdale Shales)

This section is a further illustration of the extremely rapid lateral variation in facies in this small area, since the three exposures quoted above are each within 100 yds. of each other. (refer to Plate 26).

South of Thrope Edge the Grit is seen in the side of the track at Trapping Hill (107738) and in a cliff in Sandscar Wood (110738) where 32' of massive, coarse sandstone are seen. The Grit is also exposed in Sandscar Wood in a stream course and at Fox $Cr_{a}g$. The Grit is here in a single leaf, however, and consists of a coarse sandstone with a quantity of interstitial material of silt grade.

Rainstang - The Red Scar Grit makes a feature on the S. side of Rainstang and an intermittent one on the E. side, but exposures of this horizon are rare. Cross Lane Plantation Quarry shows 15' of massive, coarse grained sandstone and partial exposures of the Red Scar Grit are seen in Northside Head Plantation and How Gill. The total thickness of the Grit on the S. side of Rainstang is probably about 40' and there is no evidence of the presence of the Woogill Coal.

In the vicinity of Foggyshaw Gill, the Woogill Coal has been worked and the tips of the adits are principally in coaly shale.

The section in Foggyshaw Gill (091763) is difficult to measure owing to the considerable dip of the strata. The lower leaf of the Grit is here ganisteroid in part and the Woogill coal is exposed partially and is seen to be at least 1' thick, with a central parting of fireclay. The upper leaf of the Red Scar Grit is over 8' thick.

The sections in the E. end of Woogill Scar indicate that the Red Scar Grit is here a single sandstone, 25' thick, without a coal seam (083765, 081765). The Grit is a coarse, sometimes pebbly, feldspathic, poorly sorted sandstone, tending to weather incoherently and to form rounded surfaces. A specimen collected from the upper part of the Grit was a poorly sorted medium grained sandstone containing some grains up to 2 mm. in diameter, the whole being interspersed with scattered patches of kaolinite, some of which appear to be of rectangular shape and are probably infilled voids once occupied by small crinoid ossicles.

A section west of the centre of Woodale Scar (080765) shows the Woogill Coal, which occurs intermittently on the N. side of Rainstang. The beds seen are as follows:

5'	coarse sandstone, with some kaolinite, apparently interstitial to the quartz grains, and somewhat ganisteroid in its lower part - Upper Red Scar Grit
6"	buff fireclay
1'	impure coal - Woogill Coal
3'	fireclay
4'	carbonaceous siltstone with ganister ribs
6'6"	coarse sandstone showing rounded, incoherent weathering - Lower Red Scar Grit
2'6"	shale
3'	flaggy, fine grained, micaceous sandstone with abundant flat shale pebbles and carbonised plants, including Stigmaria sp. A few grains of glauconite occur and also kaolinite, which is in part secondary after feldspars - Lower Red Scar Grit

The section E. of the track from Middlesmoor to Scar House (071765) is a similar one, but in all likelihood the Upper Red Scar Grit is much thicker than in the section above, as is also the Lower Red Scar Grit, which is illustrative of the rapid thickness variation to which this horizon is subject. The section here seen is (see also plate 26):

-	Colsterdale Marine Series
32'	massive sandstone, curre nt bedded in huge foresets throughout - Upper Red Scar Grit
2'6"	coal
6"	black, soapy shale
9"	coal - Woogill Coal
1'	fireclay
8'	coarse sandstone - Lower Red Scar Grit
5'	gap(probably sandstone)
18'	coarse sandstone with a flaggy mudstone parting - L. Red Scar Grit
-	Nidderdale Shales

The measures with the Woogill Coal in the last two sections cited show the general similarity of lithological features outlined in the introductory remarks on stratigraphy of the Red Scar Grit. The same basic types of sediment accompany the coal, namely fireclay, black carbonaceous siltstone and soapy shale. The total thickness of the Woogill Coal cited above, 3'3", is considerably thicker than that seen at any other exposure in the present area, and should be compared with that recorded from the section on Woogill Scar, namely 1', which again illustrates the rapid thickness variation at the Red Scar Grit horizon, where all beds vary in thickness in very short distances.

West of the Middlesmoor - Scar House track the Red Scar Grit forms a line of scars in which are seen a maximum of 32' of sandstone overlying the Nidderdale shales with a sharp base (066763). There

is no trace of the Woogill Coal in the visible section, but the top of the Red Scar Grit is not seen.

Kay Head Allotment - The Red Scar Grits form extensive dip slopes on the interfluve between the Nidd and How Stean drainage. Clack Gill Beck (060751) shows a prdonged section in the Red Scar Grit which is not readily measurable. The lower leaf of the Grit outcrops in the stream and its upper most beds are ganisteroid, with rootlets and are overlain by at least 5' of shale in which no trace of the Woogill Coal is seen, though it is probable that these shales are at the level of the parting in the Grit which usually carries the coal. The Upper Red Scar Grit which overlies these shales is partially ganisteroid and partially a normal sandstone. At several points on Kay Head Allotment there are blocks of sandstone visible under the peat and these are usually of the two litholigical types which seem to belong the the upper part of the Red Scar Grit, which is thus considered to be the hard horizon responsible for the monotonous dip slope.

Between Clack Gill Beck and Aygill Beck the Lower Red Scar Grit forms an outcrop marked by scattered boulders and occasional obscure features. In Aygill Beck (054743) (see also Plate 2 6) the Lower Red Scar Grit is seen to be 12' thick and rests with a markedly transgressive base on the underlying shales. The measures above the Lower Red Scar Grit are fireclays, ganisters and coaly shales, beds usually associated with the Woogill Coal, which is here only represented by the coaly shales. Occasional exposures high up Agill Beck show coarse sandstones with the local development of pebbles, which belong to horizons high in the Red Scar Grit.

Scar House Gill to Blackfell Scar - The section in Scar House

Gill (063762) is informative since the Lower Red Scar Grit is here only 11'6" thick, whilst in the section seen 500 yd. to the E. there are at least 32' of sandstone without a shale parting, illustrating yet again the rapid facies and thickness changes at this horizon. The beds seen are (Plate 26):

15'	blocky, slightly ganisteroid, medium grained quartz sandstone with numerous muscovite flakes on bedding planes. Occasional crinoid ossicles, preserved in calcite and weathering as voids occur, together with doubtful shell fragments and scattered grains of glauconite
-	Upper Red Scar Grit
6'	shale, unfossiliferous and not of soapy texture
2'3"	compact, blocky weathering, black carbonaceous, micaceous siltstone without fossils
3'	brittle, black shale with Lingula sp., in the lowest 1'
2"	coal with pyrite veining (attenuated representative of the Woogill Coal)
2'	grey fireclay
1'6"	very coarse grained quartz sandstone with welded grains, due to ganisterisation
2'	industrated fireclay
9'	coarse grained, very feldspathic sandstone intersected by carbonaceous strings which are relicts of a rootlet system, and with thin partings of plant bearing carbonaceous shale
2'6"	coarse grained, blocky sandstone with an uneven base, terminating in a slump roll 5' in height, with shale pebbles in the nose of the roll
-	shale (Nidderdale Shales)

West of Scar House Gill the Grit is occasionally seen and outcrops intermittently in Wising Gill Sike. A feature occurs on the Grit to the N.E. and S.W. of Wising Gill Sike. In Maiden Gill Crags (039749) 35' massive sandstone are seen without any trace of parting, but an exposure at 037748 shows 5' ganister overlying 8' coarse sandstone and it is possible that these ganister beds are the local equivalent of the Upper Red Scar Grit of the ground where the Woogill Coal is developed. In East Gill Dike (037744) 42' of massive, coarse grained sandstone with some current

bedding is seen resting on shales belonging to the Nidderdale Shales. Exposures further to the S.W. also show no trace of the parting with the Woogill Coal - instead there are cliffs in a homogeneous, massive coarse grained sandstone which weathers into soft rounded forms in Blowing Gill Dike and Red Scar Dike. Grit scars with associated landslips on the Nidderdale Shales occur intermittently between Red Scar Dike and Stone Beck.

The section in Stone Beck indicates the presence of the Woogill Coal, which has not however, been recorded on the S. side of Nidderdale between this point and Scar House Gill. The upper section (013742) (Plate 26) shows:

5'	sandstone - Upper Red Scar Grit
3'	gap
2'6"	unfossiliferous shale
1'	shaly coal
1'6"	ganister
24'	coarse grained, soft weathering sandstone (no base seen) = Lower Red Scar Grit.

Further downstream the coal is absent and the section shows:

15'	ganisteroid sandstone - presumed Upper Red Scar Grit
12'	coarse sandstone - presumed Lower Red Scar Grit

This section is only 160 yd. from the section previously detailed.

Intermittent exposures and a strong feature overlooking the Hurders Edge landslip continue along the outcrop to Blackfell Scar, where (012748) the following section is seen:

-	Colsterdale Marine Series
5'	blocky, tough coarse grained sandstone
35'	massive, coarse grained sandstone, showing rounded weathering forms and the softness which is characteristic of the coarser beds of this grit in upper Nidderdale (no base seen, but total thickness is probably not in excess of 30')

It is possible that the top 5' of beds in the above section are the equivalents of the Upper Red Scar Grit of the localities where the

coal is present, but this cannot be proved.

Outcrops on the northern and W. slopes of Great Whernside - N.W. of Blackfell scar the feature on the Red Scar Grit dies out, but the top of the horizon is demarcated by springs issuing from the Colsterdale Marine Series - Blackfell spring and Nidd Head Spring are such springs. The Grit forms a feature on Nidd Head Allotment, overlooking a landslip where 12' of coarse sandstone are seen, this being only a partial exposure at this horizon. Features and sandstone boulders mark the outcrop of the Grit round the N. end of the Great Whernside massif. On the N.W. slopes of the mountain a section (002760) shows 3' ganister resting on coarse sandstone, 33' of which are visible. It is possible that this upper bed of ganister is equivalent to the Upper Red Scar Grit of localities where the Woogill Coal is present. On the western slopes of Great Whernside, the Grit forms a fairly continuous feature with sandstone blocks scattered along it and with occasional good exposures, the best of which are at 997747 where 24' coarse sandstone are seen and at 003724 where 20' of sandstone are exposed. The total thickness of the Grit on the W. and N.W. slopes of Great Whernside is never seen, but it appears to outcrop as a single leaf without a coal seam, totalling about 40' in thickness.

Little Whernside to Greystone Gill - The Red Scar Grit forms an outcrop ringing Little Whernside, which is poorly exposed except for the lower beds which are seen at the head of several streams draining into the R. Nidd. These lower beds are massive, medium or coarse grained sandstones visible to a thickness of about 10', whilst the upper beds of the Grit form a sloping platform on High Pasture and on the col between Little Whernside and Dead

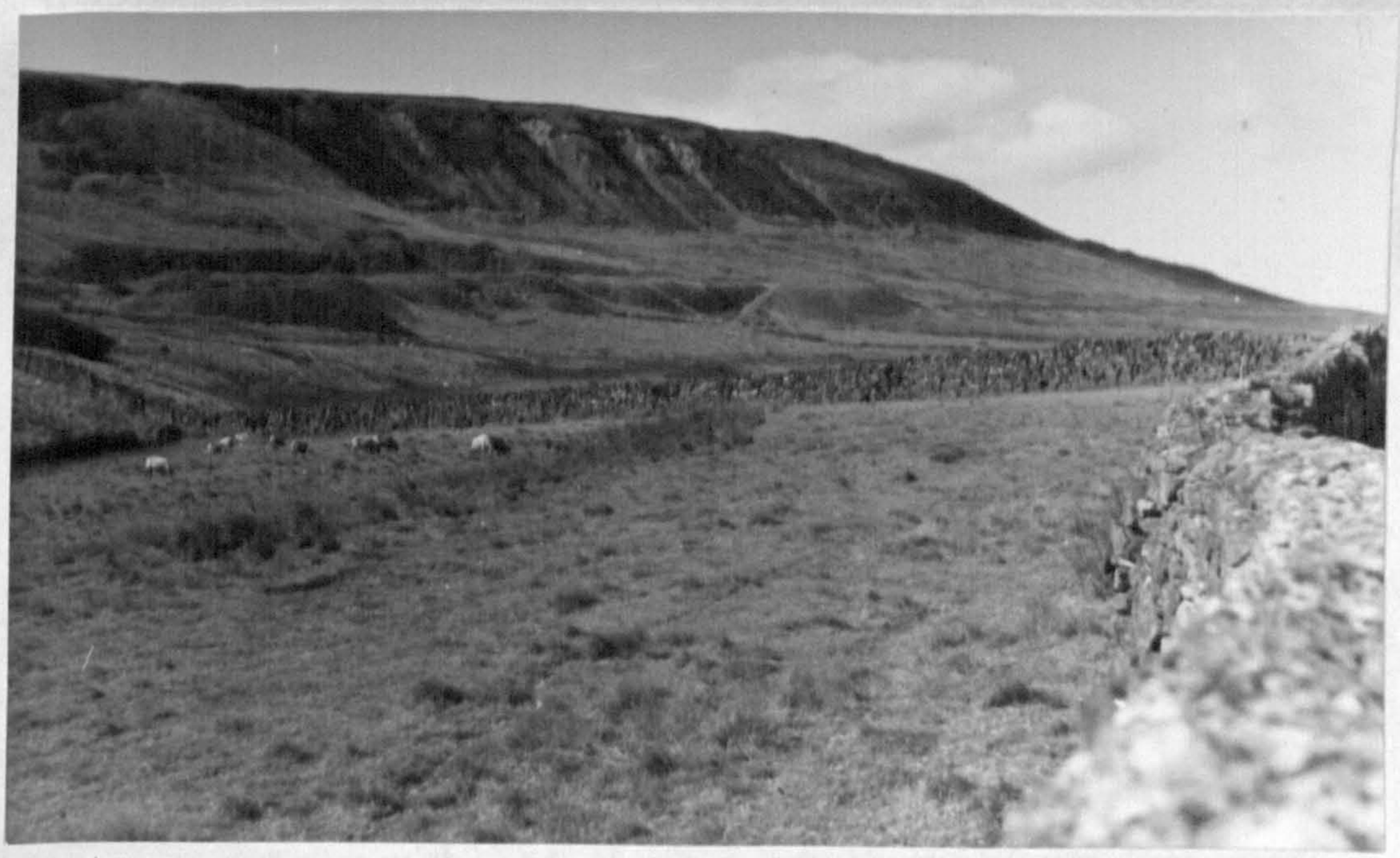


PLATE 25 A

Black Scar, Penhill viewed from Flint Lane. The flat ground in the foreground is on the Richmond Chert Series, overlain by Grassington Grits which are here chiefly replaced by shales with a flaggy sandstone which has been worked in open-cut and levels in the middle distance, with extensive tips in the reject stone. Black Scar is in the Nidderdale Shales, with thin sandstones, overlain by the Red Scar Grit which forms the cap of Penhill on the skyline. The irregular hummocks of the Black Scar landslip are also seen on the skyline (right).



PLATE 25 B

Carle Fell from Horse House, looking eastwards across Coverdale. On the skyline is the summit of Carle Fell in Lower Follifoot Grit, which forms a line of scars below the summit plateau. The strong feature with Grit scars which dies out towards the left is in the Lower Red Scar Grit, overlying Nidderdale Shales, 70' of which are seen in the gulley, top right. Four pale patches, top left, are tips of adits working the Woogill Coal. The foreground is in Yoredale facies sediments chiefly concealed by a mantle of drift.

Mans Hill. On the N. side of the hill the Grit is seldom exposed, but occurs as a feature, as it also does on the S. side.

Harkera Gill (042786) shows 6' rotten weathering, massive coarse sandstone overlying shales belonging to the Nidderdale Shales. At a higher horizon a small quarry adjacent to the road from Arkleside to Scar House (044786) shows 4' medium grained, compact, white quartz sandstone with a little muscovite which is probably equivalent to the Upper Red Scar Grit of areas with the Woogill coal. Some 330 yds. E.S.E. of this point, blocks of sandstone of this lithology occur uphill from an exposure of the coarse sandstone typical of the lower beds of the Red Scar Grit.

The Woogill Coal has been worked in shafts and levels near the headwaters of Arkleside Gill and here the parting with the coal carries fireclay, ganister and carbonaceous shale which are seen in the tips of the workings in the seam (this is a characteristic assemblage of rocks at the level of the measures with the Woogill Coal.) The lowest 8' of the Grit are seen in Arkleside Gill (050790). A prominent feature occurs on the Grit on Arkleside Moor which can be traced N.E. from Arkleside Gill (see Plate 26). Scars along this feature show up to 18' of sandstone directly overlying the Nidderdale Shales.

The Woogill Coal has been worked at two places on Hindlethwaite Moor where workings show shale on the tips and sandstone blocks occur at the heads of adits at 064802, indicative of the presence of the Upper Red Scar Grit. The upper beds of the Grit are seen in Lead Up Gill (065797) where they are massive medium grained sandstones. It is probable that the Woogill Coal is absent in

the valley bottom, but it has been locally worked on the valley side. North of Lead Up Gill blocks of Red Scar Grit occur along an ill defined edge which runs in the direction of Greystone Gill.

Greystone Gill to Jervaulx - The section in Greystone Gill (076818) (Plate 26) shows the Red Scar Grit to be locally very improverished. The upper leaf is a compact massive stratum, 7' in thickness, and the Woogill coal shows two thin leaves split by fireclay (this double coal seam is seen elsewhere and is a common occurrence in mine records, though it cannot have made extraction of the coal other than difficult). The beds which occur with the coal here are fireclays and ganisters. The Lower Red Scar Grit is impoverished and consists of flaggy sandstones with a shale parting.

Below Roova Plain the Woogill coal has been worked for a distance along the hillside (see Plate 27A) and is here overlain by a thin, but persistent Upper Red Scar Grit which weathers very massive and forms a line of scars. At 077820 the Upper Red Scar Grit is a compact, medium grained, somewhat ganisteroid quartz sandstone with a little muscovite and hydrobiotite and weathers into massive blocks. Small surfaces of the rock are covered in a mineral resembling kaolinite and are probably shelly remains in a poor state of preservation.

On the spur W. of Ulfers Gill the coal has not been worked, but in the Gill itself, adits have been driven into it. Here (096828) the Lower Red Scar Grit is about 40' thick and is a massive medium grained sandstone, thicker and coarser than its equivalent in Greystone Gill. The Lower Red Scar Grit probably thickens gradually between Greystone Gill and Ulfers Gill because

the indications of this horizon on the spur to the W. of Ulfers Gill suggest that it is fairly thick there. The parting with the Woogill Coal in Ulfers Gill is not completely seen, but includes fireclays and ganisters and is overlain by at least 4' of ganisteroid sandstone equivalent to the Upper Red Scar Grit (see Plate 26). The full thickness of this leaf is hard to estimate but is probably about 6'. This thickness agrees well with that seen below Roova Plain and in Barnley Beck and it is probable that the Upper Red Scar Grit maintains a constant thickness of about 7' over a large area on the E. slopes of lower Coverdale and in uppermost Colsterdale, but thins in middle Colsterdale and on Kay Head Allotment, Nidderdale (see Plate 26, which indicates areas of abnormal thickness of the Upper and Red Scar Grit).

The Lower Red Scar Grit forms a prominent line of scars at Ulfers Crags where it is seen as a line of massive, huge boulders of coarse sandstone, little displaced from the line of outcrop. The Red Scar Grit forms a weak edge on the slopes of Flamstone Pin, but is poorly exposed, and appears to be displaced by a fault.

The Lower Red Scar Grit is exposed in a quarry on Crundell Hill (110853) where 18' of current bedded, feldspathic coarse sandstone occur, but the full thickness is not seen. This horizon is also seen in a relict waterfall at the E. end of the Crundell Hill overflow channel.

The Woo Gill Coal has been worked in levels to the E. of Crundell Hill and the Upper Red Scar Grit, though not fully exposed, was seen to a thickness of 5'. Old records from the levels

record 'limestone' from as little as 3' above the base of the Upper Red Scar Grit, and it is thought probable that the crinoidal variety of the Upper Red Scar Grit is present here, though it was not seen in place. The presence of crinoidal sandstone on Braithwaite Moor was verified in the tip of an old shaft which yielded a block of very coarse quartz sandstone with crinoid ossicles preserved in calcite making up 29% of the rock (micrometer stage reading).

Red Beck Gill (119852) shows exposures in the Red Scar Grit which have been involved in faulting and the rock is in consequence much jointed; it is not clear whether the visible sandstones occur above or below the Woogill Coal, which is most probably here present in view of its extensive development on Braithwaite Moor where it has been worked in numerous shafts and a few levels. The Red Scar Grit forms a feature on the slopes of Witton Fell which has been emphasised by a meltwater channel marginal to the Wenslydale ice. Occasional exposures occur, but no sections are seen which give a comprehensive notion of the succession within the Red Scar Grit which does however appear to be thick below Witton Fell and probably in the vicinity of 70'.

Deep Gill Beck (149845) provides exposures in which 39' of sandstone are seen, the lowest 24' of which forms a picturesque waterfall in exceedingly massive, coarse grained, feldspathic sandstone. The beds above the waterfall are current bedded, fine grained and micaceous. Further exposures occur upstream and a portion of these beds may be stratigraphically higher than the 39' of strata seen at the waterfall. No trace of the parting

carrying the Woogill Coal was seen.

East to Deep Gill Beck the Red Scar Grit forms a pronounced feature blanketed by drift whose base is emphasised by a periglacial spillway and becomes weaker as it looses height in the direction of Jervaulx, in the direction of the regional dip along which the strata gradually fall from W. to E.

Penhill Outlier - The monotonously flat top of Penhill (040860) which is largely peat covered, is in a capping of Red Scar Grit. Features occur on the S.E. side of the hill on the base of the Red Scar Grit and good exposures occur in the top of Penhill Crags and Black Scar. A maximum of 15' of coarse grained sandstone with interstitial kaolinite, which may be secondary after feldspars, occurs in Penhill Scar. A thin section of a specimen from 5' above the base of the Grit in Penhill Crags was of a coarse grained, poorly sorted quartz sandstone; this is one of the few records of a quartz sandstone, as distinct from a feldspathic sandstone, from the lower part of the Red Scar Grit.

Palaeontology

The first record of fossils in the Red Scar Grit was by Dakyns (1892) who recorded a supposed northerly facies change of the Colsterdale Limestone to a crinoidal limestone, current bedded from the N.E. This supposed northerly facies change has been, unfortunately, quoted since as evidence in support of certain views on sedimentational problems (Jones, 1943, Walker, 1952) and is in fact based on a miscorrelation of the Upper Red Scar Grit with the Colsterdale Limestone since the crinoidal phase cited

is shown in the present work to be at the horizon of the Upper Red Scar Grit.

Bisat (1914) records a considerable fauna from Woo Gill which is from the horizon of the beds with the Woogill Coal, below the Upper Red Scar Grit - this he terms part of the Colsterdale Marine Band. The term 'Red Scar Grit', in the middle of which these shales occur, has priority over Bisat's definition of the Colsterdale Marine Series and in any case the Red Scar Grit forms a mapping unit which locally does not show an upper and a lower leaf and thus it is not logical to split this horizon in such a manner. The fact that Dakyns (1892) had mistakenly correlated portions of the Upper Red Scar Grit of Colsterdale with the Colsterdale Limestone does not invalidate his general definition of the Red Scar Grit as a horizon locally showing two leaves separated by a coal seam which he called the Woogill Coal.

It is implicit in the text of Bisat's paper that he recognised the upper Red Scar Grit as fossiliferous, since he says that the "grit and ganister .... seem to have fossiliferous layers" and includes these beds on this account in his Colsterdale Marine Band. The present author is able to confirm the records of fossils in the Upper Red Scar Grit, which has yielded a considerable fauna.

The shales with the Woogill Coal, which is itself only a localised horizon, are occasionally of a fossiliferous variety. At two localities they yield a fauna of moderate proportions. The shales from tips of adits in Woo Gill, working the Woogill Coal have yielded a lingulid-pelecypod-gastropod fauna with some of the fossils preserved in pyrite and the remainder as impressions in a compact grey shale, which here probably immediately overlies the

Woogill Coal. This fauna is in many respects similar to the nuculid-gastropod fauna recorded from the Colsterdale Marine Series of Colsterdale (see Chapter 13). The chief forms - lingulids, nuculids, bellerophontids and palaeoniscid scales are common to both, though pleurotomariids which figure in the nuculid gastropod beds here appear to be absent and the pelecypod fauna of the Woogill locality is more strongly developed than that of the nuculid-gastropod beds. The fauna recorded by Bisat (1914) is in most respects similar to my own, but he obtains some additional forms the most interesting of which was a queried goniatite discovery, which is the only one which has come to light at this horizon. The presence of a lingulid fauna usually seems to preclude the abundant presence of goniatites, especially the lirate forms - this is the conclusion one reaches in investigating the Namurian faunas of the present area. Whilst the bulk of forms at Woogill are lying flat on the bedding planes, some of the lingulids appear to transgress several of the bedding laminae and it is quite possible that they grew in place, by burrowing in the mud and were twisted into a subhorizontal position by the compression of the sediment.

A fauna was also recorded during the present work from Scar House Gill where it is more restricted and consists of Lingula mytiloides and palaeoniscid scales preserved in a black, brittle, fissile shale which is darker and therefore more typically a linguliferous shale than the grey shales of Woo Gill. This horizon extends through 1' of shale immediately above the Woogill Coal.

No further records of fossils in situ exist at this level, though at a few localities some soapy shale occurs, but is apparently unfossiliferous. At two localities in Colsterdale fragmentary

fossils are recorded from black shales in the tips of levels and these are included in the list in view of the paucity of fossil records at this horizon. Since the material in these tips was moved to extract the Woogill Coal it is assumed that the fossiliferous shales are adjacent to the coal and by analogy with the known exposure this is probably immediately above the coal.

Fragmentary fossils in a poor state of preservation occur at several localities in the Upper Red Scar Grit, the most common records being of crinoid ossicles which have locally been observed to make up as much as 29% of the rock, this presumably being the origin of the term 'limestone' used by the old coal miners in describing portions of the Upper Red Scar Grit on the moors north of Colsterdale. Both the thin and thick developments of the Upper Red Scar Grit have yielded fossils and both may locally develop a crinoidal phase. Only two localities have yielded a list of appreciable length, however. One exposure on the south side of Birk Gill, near Colsterdale hamlet (136816) has yielded fossils from two levels in an exposure of the Upper Red Scar Grit which is here current bedded on a major scale and shows both fine grained ganisteroid and medium grained sandstone variants. The lower fine grained beds are fossiliferous in very restricted patches which yielded a brachiopod-pelecypod fauna consisting chiefly of forms which occur in the R_1 shell beds of the present area. The higher medium grained beds yielded only crinoid ossicles.

A second important record is from Woogill Scar, Nidderdale

(082765) where lenses of very fissile soapy grey shale yield a fauna totally unlike that of the Colsterdale Marine Beds which here directly overlie the Red Scar Grit, a single sandstone with no trace of the Woogill Coal. The faunal assemblage is somewhat similar to that of the R_1 shell beds of the area, but also has features in common with that from the parting with the Woogill Coal. Since the single leaf of the Red Scar Grit is coarse and feldspathic and more nearly resembles the Lower than the Upper Red Scar Grit the possibility must not be overlooked that this fauna is coeval with that overlying the Woogill $Co_{A}l$ and was swept in here during an episode of re-sorting of the underlying sands which now make up the Red Scar Grit. However this view is hard to prove and these fossils are quite possibly a good deal later and synchronous with the Upper Red Scar Grit faunas.

Whilst it is quite probable that the fauna above the Woogill coal of Woogill is indigenous (note the previous remark on the position of the fossilised lingulids) it is at least improbable that the fauna preserved in the sandstone of Birk Gill is an immediately local one, since it is difficult to envisage a fauna building itself up on the steep foreset face of what must have been a small deltaic cone. It is possible, however, in view of the fact that some of the crinoid ossicles are still articulated into their component stems, that the fauna flourished on top of the delta which was being built some distance out at sea by the force of occasional floods which did little toupset the generally high salinity of the water. The quantity of ossicles locally seen in the Upper Red Scar Grit is indicative of the considerable colonial growth of these animals, at some locality not far removed

from the present area. The purely secondary origin of the ossicles from an already existing deposit must not overlooked, but this explanation is difficult to prove or disprove.

Faunal Lists

Measures with the Woogill $Co_a l$

Lingula mytiloides J. Sowerby, 1

Lingula cf. squamiformis Phillips, 1,2,

cf. Allorisma sulcata (Fleming), 1

Aviculopecten cf. plicatus (J. Sowerby), 1
Limatulina occidentalis (Meek and Worthen), 1
Modiola sp., 1
Myalina peralata de Koninck, 1
Nucula laevirostris, 1
Unidentified pelecypod, 3

Bellerephon sp., 1

Palaeoniscid scales, 1,2

Unidentified organic fragments, 4

In addition W.S. Bisat (1914) records:

Leda stilla (McCoy), 1
Leiopteria sp., 1
Nuculopsis aequalis (J. Sowerby,) 1
Posidoniella Laevis (Brown), 1
Schizodus antiquus Hind, 1

Index of localities for the above:

1.	Tip of old adit, Woogill, Nidderdale	075782
2.	Scar House Gill, Nidderdale	062761
3.	Tip of old coal level, Colsterdale	114800
4.	Tip of old coal level, Colsterdale	104799

Upper Red Scar Grit('s' denotes shale preservation).

Crinoid arms, 2
crinoid ossicles, 1s, 2, 4, 5, 6, 9, 11

Camaratoechia pleurodon (Phillips), 2
Chonetes sp., 1s, ?5
Productus (Productus) carbonarius de Koninck, 1s, 2
Schizophoria sp., 1s
Spirifer bisulcatus J. Sowerby group, 1s

Allorisma sulcata (Fleming), 1s
Amusium concentricum Hind, 1s
?Aviculopecten sp. 1s, 2
?Limatulina sp, 1s
Myalina peralata de Koninck, 2, ?8?Schizodus sp., 2
?Schizodus sp., 2
?Spathella sp., 2

Euphemites urei (Fleming), 2

indeterminate shelly fragments, 7, 10

cf. Arenicolites sp., 3

Index of localities for the above:

1.	Woodale Scar, Nidderdale	082765
2.	Birk Gill, Colsterdale	136816
3.	Coal adit, Woo Gill, Nidderdale	075782
4.	Tip of old coal shaft, Braithwaite Moor	115847
5.	Upthrow side of fault, Barnley Beck, Colsterdale	10[illegible]825
6.	Left bank of Spruce Gill, Colsterdale	148806
7.	Pony track to Scrafton Colliery, Coverdale	077820
8.	Stand Sike, Nidderdale	051779
9.	Scar House Gill, Nidderdale	062761
10.	Tip of Brown Beck Pit, Colsterdale	133827
11.	Tops Gill, Nidderdale	056776

PLATE 26

Information and sections diagram for the Red Scar Grit.

KEY

N.W. face of Great Whernside (incomplete section)	996767
Blackfell Scar	012750
Stone Beck (W.) (incomplete section)	013743
Stone Beck (E.) (incomplete section)	014743
East Gill Dike	037735
Penhill Scar (incomplete section)	051868
Tops Gill and Stand Syke	052779
Aygill Beck (incomplete section)	054743
Scar House Gill (incomplete section)	062763
Scar House Pasture	069764
Greystone Gill	075819
Woo Gill (incomplete section)	076780
Woodale Scar	078766
Ulfers Gill	096829
Thrope Edge landslip (N.) scar	104760
Thrope Edge landslip scar -central	104759
Thrope Edge landslip scar (S.)	104758
Barnley Beck (incomplete section)	108825
Sandscar Wood	110738
River Burn , near Dawson House	111800
Jemmy Scar, Colsterdale	123806
West Pit (mine record- top part only)	124846
Brown Beck Colliery (mine record- top part only)	134826
Birk Gill (incomplete section)	136815
Deep Gill Beck (incomplete section)	152850
Gollinglith Foot trial borehole (Leeds Corporation) (incomplete section)	152810

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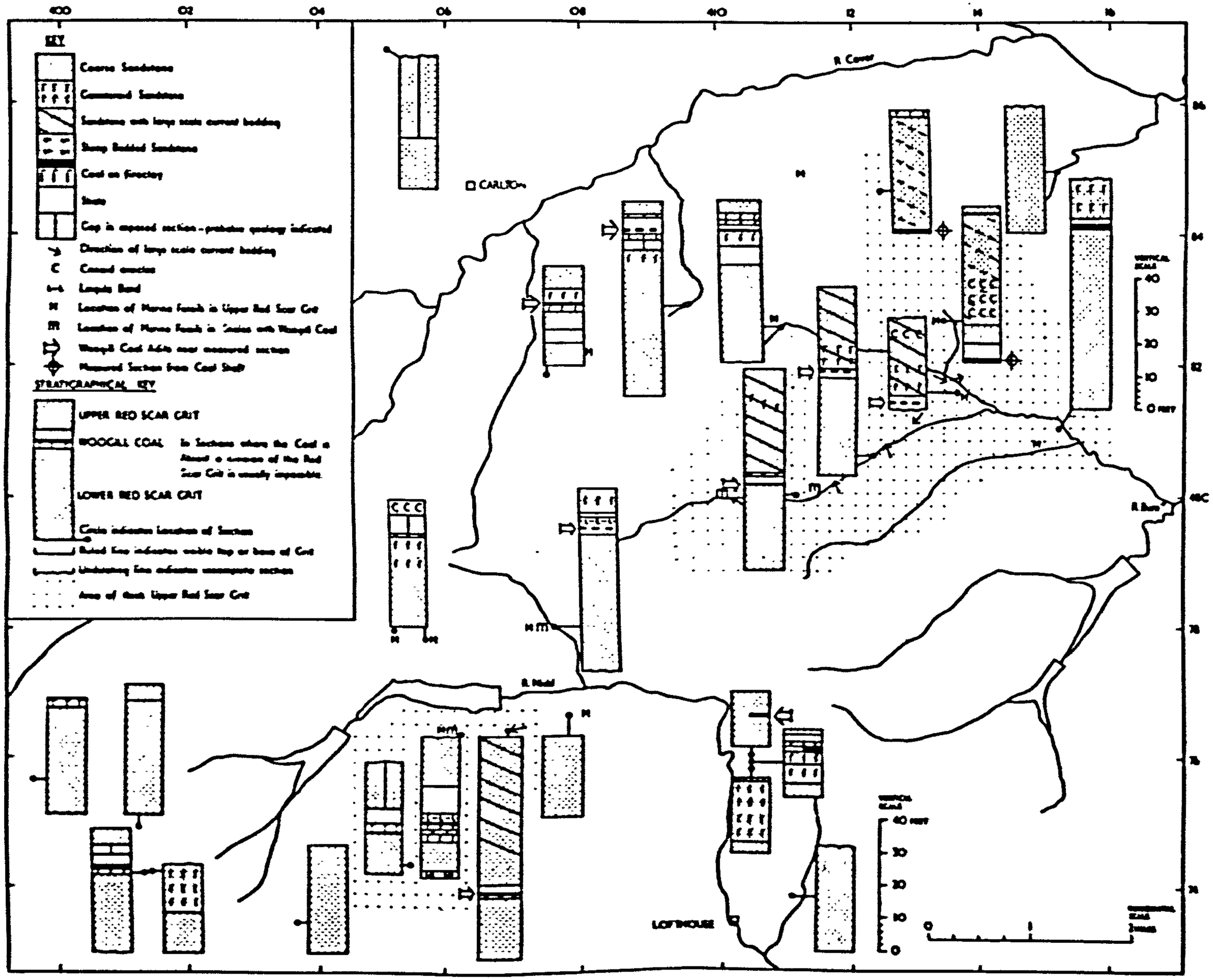
KEY
Coarse Sandstone
Cemented Sandstone
Sandstone with large scale current bedding
Slump Bedded Sandstone
Coal on fireclay
Shale
Gap in exposed section - probable geology indicated
Direction of large scale current bedding
Conoid anticline
Lingula Band
Location of Marine Fossils in Upper Red Scar Grit
Location of Marine Fossils in Shales with Woogill Coal
Woogill Coal Adits near measured section
Measured Section from Coal Shaft
STRATIGRAPHICAL KEY
UPPER RED SCAR GRIT
WOOGILL COAL
In Sections where the Coal is Absent a division of the Red Scar Grit is usually impossible.
LOWER RED SCAR GRIT
Circle indicates Location of Section
Ruled line indicates visible top or base of Grit
Undulating line indicates incomplete section
Area of thick Upper Red Scar Grit
R. Cover
CARLTON
R. Burn
R. Nidd
LOFTHOUSE
VERTICAL SCALE
40
30
20
10
0 FEET
0
1
2 MILES