DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

MEMOIRS OF THE GEOLOGICAL SURVEY ENGLAND & WALES

EXPLANATION OF SHEET 77

The Geology of the Country around Huddersfield and Halifax

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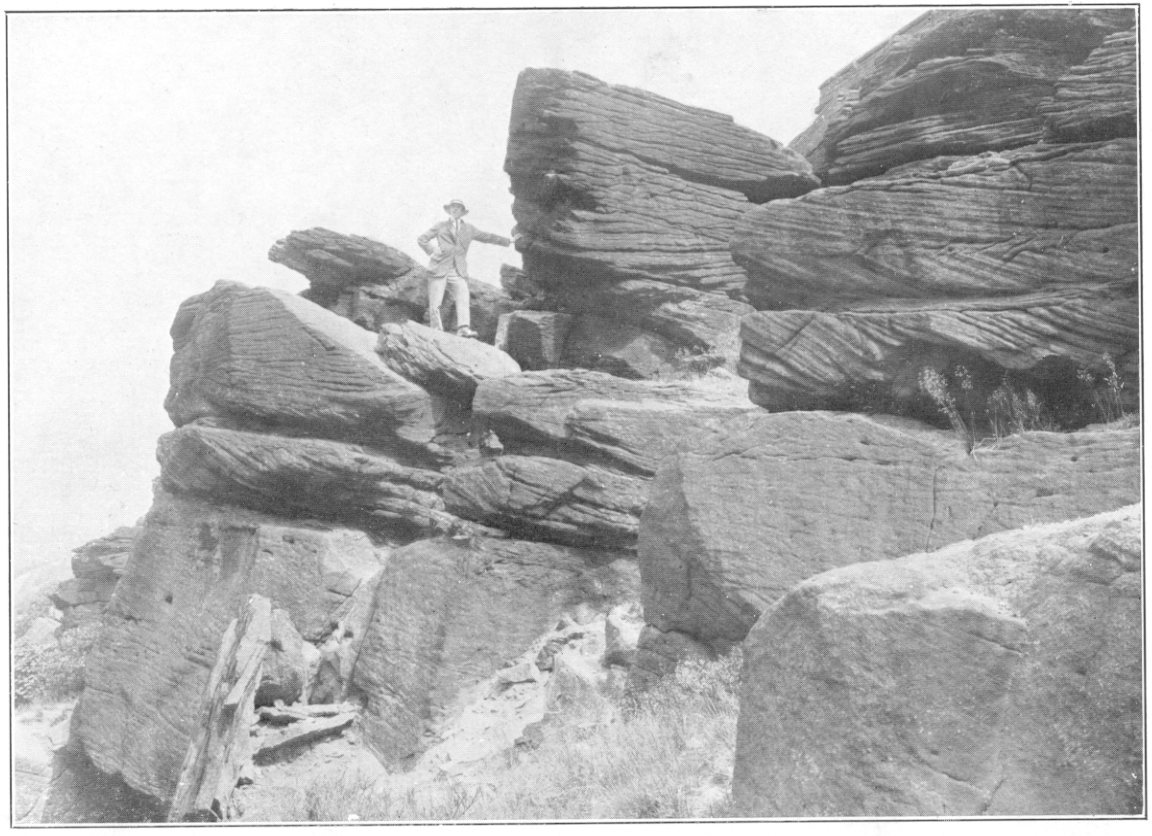
To face p. 1.



ROUGH ROCK CRAGS WEST OF HALIFAX

PREFACE

The area comprised in the New Series Huddersfield Sheet, described in this memoir, was originally surveyed on the six-inch scale by A. H. Green, C. Fox-Strangways, J. C. Ward, J. R. Dakyns, E. Hull and R. Russell, and was published at various dates between 1868 and 1875. Brief accounts of most of this country appeared in short memoirs on the quarter-sheets of the Old Series one-inch Sheet 88. These memoirs are now out of print and the maps are superseded. A general description of the Yorkshire Coalfield was given in A. H. Green's Geology of the Yorkshire Coalfield (1878).

The re-survey under Mr. C. E. N. Bromehead was begun in 1923. He has been assisted by Dr. D. A. Wray, Mr. J. V. Stephens and Mr. W. N. Edwards and the new six-inch and one-inch maps were published in 1926–1928. The part taken by each of these geologists in the revision will be understood from the list of six-inch maps given on p.vi of this memoir. Each officer has supplied notes on the area he surveyed, and Mr. Bromehead has acted as editor besides having superintendence of the field work. Dr. Wray has put together the chapters on the Superficial Deposits, the Geological Structure and the Palaeontology; he had previously worked in the adjoining area on the west and his knowledge of the Millstone Grits was invaluable to his colleagues. Dr. Crookall has collaborated with Mr. Bromehead in the section on the fossil plants.

Much assistance has been received from scientists who are not members of the Survey Staff. Special mention must be made of Mr. W. S. Bisat who has identified many goniatites, and Professor D. M. S. Watson and Dr. J. W. Jackson who have named fishes and lamellibranchs. Dr. T. W. Woodhead of Huddersfield Museum has provided much valuable information and placed his intimate knowledge of the district very freely at our disposal.

Our thanks are due to many firms who have furnished details of shafts and borings; without exception the colliery companies and firms working fireclay, building-stone, etc., have given fully all information desired. Special mention may be made of Messrs. T. Matthews of Pendleton and Messrs. C. Isler & Co., Ltd. of Leeds and London for providing records of borings. We have also received much valuable information and assistance from the Waterworks Department of the Wakefield Corporation.

A comparison of the New Series with the Old Series maps will show that our knowledge of the Coal Measures and the subjacent rocks has been enormously increased since the first survey of the district.

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Director.

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14th November, 1929.

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List of Six-Inch Maps.

The following is a list of the revised six-inch geological maps included in the one-inch map, Sheet 77, with the initials of the surveyors and dates of survey. The names of the officers are as follows :—C. N. Bromehead, W. N. Edwards, W. Lloyd, J. V. Stephens, R. L. Sherlock, and D. A. Wray. All those which include an appreciable area of Coal Measures have been published. The remainder, marked with an asterisk, are available for public reference only in MS. form at the head office of the Geological Survey. Copies of these MS. maps can be supplied at the cost of drawing and colouring.

Yorkshire

*214 N.E.	Walshaw Dean	W.L.	1921.
*214 S.E.	Heptonstall	W.L.	1921.
*215 N.W.	Oxenhope	J.V.S.	1923.
215 N.E.	Denholme	J.V.S.	1924, 1925.
*215 S.W.	Pecket Well	J.V.S.	1923.
215 S.E.	Ogden	J.V.S.	1923, 1924.
216 N.W.	Thornton	J.V.S.	1924.
216 N.E.	Bradford	J.V.S.	1925.
216 S.W.	Queensbury	J.V.S.	1924.
216 S.E.	Wibsey	J.V.S.	1924, 1925.
217 N.W.	Laisterdyke	J.V.S.	1925.
217 N.E.	Armley	W.N.E.	1925.
217 S.W.	Westgate Hill	J.V.S.	1925.
217 S.E.	Gildersome	W.N.E.	1924, 1925.
*229 N.E	Eastwood	W.L.	1921.
*229 S.E.	Todmorden	W.L. & R.L.S.	1921.
*230 N.W.	Hebden Bridge	C.N.B.	1923.
*230 N.E.	Luddenden	C.N.B.	1923.
*230 S.W.	Cragg	C.N.B.	1923.
*230 S.E.	Sowerby Bridge	C.N.B.	1923.
231 N.W.	Halifax (North)	W.N.E.	1924.
231 N.E.	Wyke	W.N.E.	1924.
231 S.W.	Halifax (South)	C.N.B.	1924.
231 S.E.	Brighouse	C.N.B.	1924.
232 N.W.	Gomersal	W.N.E.	1924.
232 N.E.	Morley	W.N.E.	1924, 1925.
232 S.W.	Heckmondwike	C.N.B.	1925.
232 S.E.	Batley Carr	W.N.E.	1925.
*244 N.E.	Soyland Moor	D.A.W.	1921.
*244 S.E.	Blackstone Edge	D.A.W.	1921.
*245 N.W.	Manshead End	D.A.W.	1924.
245 N.E.	Barkisland	D.A.W.	1924.
*245 S.W.	Rishworth Moor	D.A.W.	1923.
*245 S.E.	Rishworth	D.A.W.	1925.
246 N.W.	Elland	D.A.W.	1924, 1925.
246 N.E.	Bradley	C.N.B.	1924.
246 S.W.	Lindley	D.A.W.	1924.
246 S.E.	Huddersfield	D.A.W.	1925.
247 N.W.	Mirfield	C.N.B.	1925.
247 N.E.	Dewsbury	C.N.B.	1925.
247 S.W.	Kirkheaton	D.A.W.	1925.
247 S.E.	Thornhill	D.A.W.	1925.
*258 N.E.	Bleakedgate Moor	D.A.W.	1921.
*259 N.W.	Buckstones Moss	D.A.W.	1925.
*259 N.E.	Slaithwaite	D.A.W.	1925.
*260 N.W.	Linthwaite	D.A.W.	1925.
260 N.E.	Farnley Tyas	D.A.W.	1925.
261 N.W.	Kirkburton	D.A.W.	1925.
261 N.E.	Flockton	D.A.W.	1925.

THE GEOLOGY OF THE COUNTRY AROUND HUDDERSFIELD & HALIFAX

CHAPTER I

INTRODUCTION

The area represented on Sheet 77 and described in the present memoir embraces in a general way that part of the West Riding of Yorkshire known as Calderdale, together with its several tributary valleys ; it extends from Wadsworth and Blackstone Edge Moors on the west to Morley, Dewsbury and Emley on the east. The principal towns are the county boroughs of Huddersfield, Halifax and Dewsbury, and the borough of Batley, while other important centres are Hebden Bridge, Mytholmroyd, Queensbury, Sowerby Bridge, Elland, Brighouse and Mirfield. It also includes the thickly populated areas in the Spen Valley and in the upper part of the Colne and Holme valleys, the southern part of the city of Bradford and some of the outer suburbs of Leeds. With the exception of a very narrow strip of moorland along the south-western margin of the Sheet belonging to Lancashire the whole area lies within the West Riding of Yorkshire.

In the west the area consists of high and somewhat bleak moorland forming part of the so-called Pennine Range ; much of the ground lies above the thousand foot contour, the highest point Blackstone Edge, quaintly referred to as the English Andes by Defoe, attaining a height of 1,553 ft. above sea-level. From these elevated moorlands the ground slopes away gently to the east ; along the eastern margin of the Sheet the highest ground is below the 600-ft. contour, while the floor of the Calder valley is little more than 100-ft. above sea-level.

The greater part of the area is drained by the River Calder and its several tributaries, but a small part of the southern slopes of Airedale is included in the north-east, the watershed running eastwards from Ovenden Moor through Queensbury and Birkenshaw towards Morley. At the south-eastern corner there is a small area around Flockton and Emley which drains south-eastwards into the Dearne valley.

The River Calder flowing from west to east is a dip or consequent stream ; the valley, however, meanders on a large scale, while there are numerous minor meanders of the river itself within its valley, notably around Elland, Mirfield and Dewsbury. The tributaries on the left or north bank of the Calder flow as a general rule along the strike of the rocks, and are therefore subsequent streams. From west to east they are the Hebden Water, the Lud, the Hebble, the Spen and the Batley Beck. On the right or south bank of the Calder the principal tributary is the Colne, which is, in the main, a consequent stream ; at Lockwood it is joined by a subsequent

stream, the Holme, which flows along the base of the Coal Measures, from south to north; this direction is followed by the united waters which, however, take the name of the Colne to the confluence with

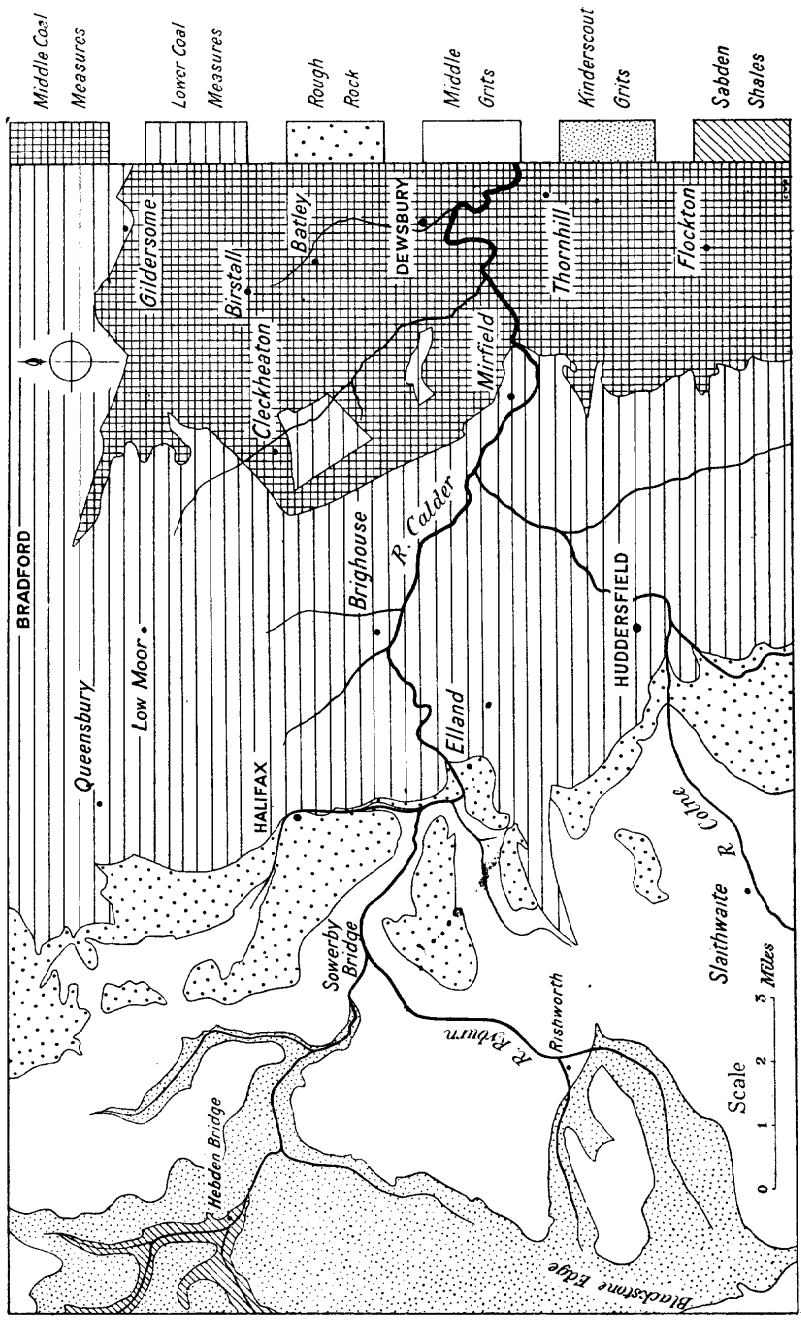


Fig. 1.—*Sketch Map of the Geology of the Huddersfield and Halifax area.*

the Calder. The remaining tributaries along the south bank of the Calder from west to east are the Cragg and Turvin Brooks, the Ryburn and Booth Dean Beck, the Blackbrook, and the Burton, Lees, or Thunderbridge Beck. With the exception of the upper parts of the Cragg, Ryburn, Booth Dean, and Blackbrook streams they are in the main subsequent streams.

The geological structure of the area is on the whole remarkably simple, though somewhat complicated in detail by extensive faulting. The main axis of the Pennines lies just beyond the western margin of the map to the north, but enters it at Blackstone Edge and trends southwards across Bleakedgate Moor. Practically the whole area, therefore, forms part of the easterly dip-slope; it is diversified only by small subsidiary folds (Fig. 2). The lowest beds are exposed near the axis, and successively higher beds crop out at lower altitudes towards the east. The rocks, with the exception of the superficial deposits, all belong to the Upper Carboniferous formation, the subdivisions represented being the Millstone Grits and the Lower and Middle Coal Measures. Their general distribution is shown in the sketch map (Fig. 1).

The whole series consists of an alternation of grit, sandstone or flagstone with soft shale or mudstone. The main beds of grit

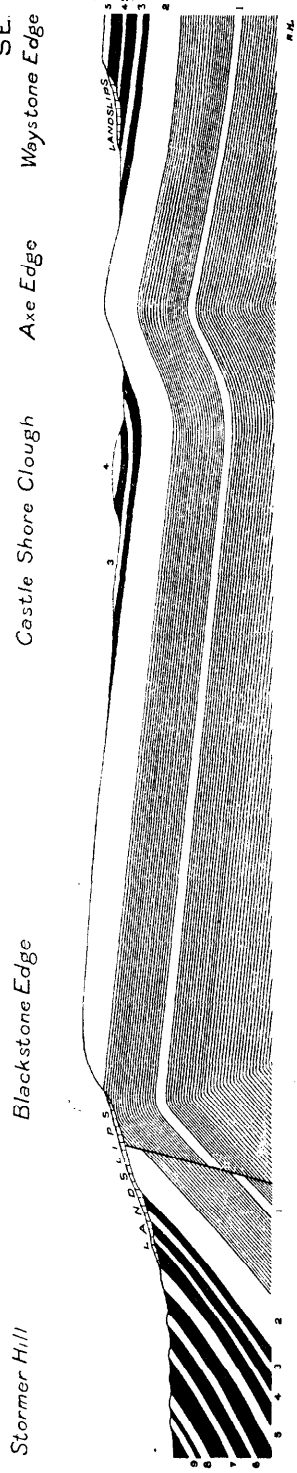


Fig. 2.—*Generalized Section across the Pennine Anticline at Blackstone Edge.*

1. Todmorden Grit. 2. Lower Kinderscout Grit. 3. Upper Kinderscout Grit. 4. Readycon Dean Flags. 5. Gorpley or Pule Hill Grit. 6. Hazelgreave Grit (Beacon Hill Flags). 7. Holcombe Brook Grit (Huddersfield White Rock). 8. Rough Rock. 9. Woodhead Hill Rock.

or sandstone are almost invariably overlain by fireclay together with a thin seam of coal. As a general rule, the several beds of grit or sandstone, locally referred to in this area as ' rocks,' become relatively less numerous and important from the base towards the top of the succession ; in the Millstone Grits they constitute about one half of the total thickness of strata, but less than one quarter of the Middle Coal Measures. In the Millstone Grits the main beds of grit persist over the entire area of the Sheet. With the exception of the Elland Flags this feature is less marked in the Lower Coal Measures, while the sandstones of the Middle Coal Measures are developed only over limited areas and exhibit abrupt lateral changes in both thickness and character. On the other hand, the coals become relatively thicker and more frequent in the higher measures, clearly indicating that a gradual retardation of the subsidence of the area of deposition was taking place.

The frequent alternation of hard and soft beds, combined with the low uniform easterly dip, gives rise to a characteristic type of scenery, which at once catches the eye when seen from any elevated view-point (see Plate IVA). Each bed of sandstone tends to form a long dip-slope falling gently to the east and bounded on the west by an abrupt escarpment. The face of these scarps is mainly formed by the outcrop of the softer shales or mudstones : the sandstone at the crest may occasionally attain a considerable thickness, though more frequently it is a mere feather-edge. These prominent escarpments, which almost invariably face westwards, are locally known as ' Edges ' : thus Blackstone Edge is formed by the massive Kinderscout Grit ; Waystone Edge and Ringstone Edge are capped with the Middle Grits, Hullenedge and Longwood Edge by the Rough Rock, Elland Edge by the Elland flagstones, and Lepton Edge, Crackenedge and Thornhill Edge by massive sandstones in the Middle Coal Measures. In an area where much bare rock is exposed the terms ' scar ' or ' scout ' are occasionally employed, as at Woodhouse Scar west of Halifax (Frontispiece) or Hathershelf Scout facing the Calder opposite Mytholmroyd ; Scar is more frequent in the fell country to the north-west of our area and Scout to the south.

The concave slope near the foot of an escarpment for which there appears to be no corresponding physiographical term is known throughout the uplands as a ' slack ' ; it frequently appears in place names such as Catherine Slack between Queensbury and Holmfield, Slack Side near Wibsey, Dick Slack near Blackstone Edge and Badger Slack on Rishworth Moors. A ' slack ' corresponds to the outcrop of a band of soft shale or mudstone, and is usually a marshy tract often constituting the headwaters of incipient subsequent streams.

The broad upland plateaux or long uniform dip-slopes which form such a distinctive feature within the present area are described as ' moors ' or ' mosses.' On the latter drainage is deficient and they are consequently wet and peaty and largely covered with cotton grass (*Eriophorum*). The heather moors, on the other hand

are sandy and dry, while the peat is thinner and well-drained. A greater number of plant species accompany the heather, including the cloudberry and bilberry. Dr. T. W. Woodhead has pointed out that the geographical distribution of the terms ' moss ' and ' moor ' has a striking significance and is clearly determined by altitude and rainfall. Thus in the area above the height of 1,200 ft. where the average rainfall is from 50 to 56 inches there are 62 ' mosses ' and 9 ' moors ' ; while at altitudes ranging from 700 to 1,200 ft. where the rainfall is from 40 to 42 inches there are 6 ' mosses ' and 39 ' moors.' [1] On the Coal Measures the term ' moor ' only is met with and is usually applied to the flat-topped hills formed by the sandstones.

The extensive gritstone plateaux are dissected by numerous streams, which have cut narrow steep-sided valleys ; the sandstones form a line of crags, while the shale-slopes below are encumbered by large masses of tumbled rocks, occasionally the effect of landslips. Waterfalls are frequent, occurring wherever a stream passes from a hard sandstone or grit to the more readily eroded shales below (Plate IIIA).

The narrower and smaller valleys where the streams abruptly descend from the edge of the gritstone plateau are locally termed ' cloughs ', while the larger and broader valleys are more commonly spoken of as ' deans ' or ' dens,' such as Booth Dean, Crimsworth Dean and Luddenden Dean.[2]

Another feature of the physical geography of the Millstone Grit moorlands is reflected in such place names as High Stones, Cat Stones, Joiner Stones or Buckstones. The massive and coarse-grained beds of gritstone which have been long exposed to the weather exhibit all stages of erosion and in places form groups or stacks of isolated rock, often of fantastic shape. The felspar which they contain also shows all stages of decomposition down to an ultimate point when the grit becomes a very porous quartzose sandstone. Some of the less decomposed masses, coarse in grain and still containing quartz, felspar and mica, may readily be mistaken for granite, and it was doubtless this resemblance which led the novelist Charlotte Brontë to describe the rocks of her native moors in the north-western part of our area as granite.

Erosion by rain and frost, combined with the sand-blast action of the loose quartz grains on the weathered faces and stacks of grit, etches out the current-bedding and forms rain channels and pot holes, while in some places loose blocks of grit have become Rocking Stones ; a fine example is seen on Rishworth Moors (see p. 28). It should be noted that the term ' stones ' invariably indicates a natural exposure, whereas an artificial section or quarry in this district is not infrequently a ' delph,' a term that is occasionally met with as part of a place name.

[1] Woodhead, T. W., ' The Scenery of Huddersfield and its Significance,' Huddersfield, (1923), p. 14.

[2] ' Luddenden Dean ' is a double tautology ; the original name of the stream is the Ludd ; ence Luddenden, now the name of the village, is ' Ludd Dean Dean.'

The predominantly shaly nature of the Coal Measures produces a gentler type of scenery than that of the Millstone Grits, but the general arrangement is similar and the more prominent beds of sandstone repeat in a lesser degree the features of the gritstone moorlands. The more important sandstones are the Elland Flags and the Grenoside, Birstall, and Thornhill Rocks which produce prominent scarp features at Elland Edge, Highburton, Batley and Thornhill Edge respectively.

With the exception of the peat, the Superficial Deposits occupy only a small proportion of the area; spreads of boulder-clay occur in the north along the Aire and Calder watershed; otherwise the drifts are practically confined to the valleys. The alluvium of the Calder forms fairly wide spreads where the underlying rock is shale, but only narrow strips where the river flows in gorges through the sandstones. This alluvium is underlain by a coarse gravel considered to be of fluvio-glacial origin.

Landslips are frequent wherever a prominent scarp of grit overlies a thick mass of shale. Probably most of them were formed in Glacial times or during the succeeding phase when the fluvio-glacial gravel was laid down. The larger and better defined landslips are shown on the map.

INDUSTRIES

The diversity of physical feature is accompanied by a corresponding variety of economic interest, and by conspicuous inequality in the distribution of the population. The elevated and peat-covered moorlands to the west are now almost exclusively employed as gathering grounds for the extensive gravitational water-supply systems which serve the industrial centres on the plains or foothills. They are sparsely populated, and all the moorland parishes record a gradually dwindling population, due in part to the desire to preserve the water-gathering grounds from contamination.

All the principal industries in the valleys or on the lowlands are dependent, directly or indirectly, on the geology. The quarrying of building stone and flags has long been an important industry in this area, and some of the larger quarries still export considerable quantities of stone, flagstone or artificial products prepared from the waste. Coal mining has also for several centuries employed a large proportion of the population. It probably attained its maximum importance in the latter half of last century, and the larger mines now working are close to the eastern margin of the Sheet. The working of fireclay is also an important industry in the country around Elland and between Halifax and Huddersfield. The bedded ironstones in the Coal Measures have also been extensively worked in the past, the Low Moor district being especially notable. The ironstones in the Coal Measures to the south of the River Calder have, however, not been worked since mediaeval times.

The predominant industry of the present area is the production of woollen cloths; this, together with the allied trades of dyeing and specialised engineering find employment for the bulk of the population in Lower Calderdale and the adjoining Spen and Colne valleys. The twin towns of Dewsbury and Batley, together with the Spen valley, constitute the so-called Heavy Woollen District; Huddersfield is pre-eminent for fine worsteds and dye products, Halifax for worsted yarn and carpets, while coarser textiles are distinctive of the Colne valley.

The larger towns are situated in the lower parts of the main valleys, especially at or near the confluence of the principal streams. They developed in the first instance as meeting places or markets at the convergence of the several routes from the uplands. The origin of Hebden Bridge, Sowerby Bridge and Brighouse is clearly indicated by their names.

The woollen industry was at first supplementary to agriculture. Sheep were raised on the small holdings on the Pennine uplands, where the pastures were ill-suited for arable farming, and the wool was woven at home on hand-looms. This ancient industry, illustrated by the unique collections of textile machinery in the municipal museums at Halifax and Huddersfield, is reflected in the highly characteristic architecture of the weavers' cottages. Nearly all the older houses in the country villages and hamlets show this peculiarity: for the working of the looms ample light was essential; consequently windows, separated only by narrow stone mullions, occupy practically the whole of the wall space. The next stage in the development was the employment of water power. The streams descending abruptly from the moors supplied this, and mills were established; several of these older mills high up in the valleys are still at work, but steam has largely replaced water and many have been abandoned owing to the cost of transporting coal and are in ruins. The modern growth and concentration of the woollen industry in this district has been mainly due to two factors, the presence of an important coalfield and the fact that the moorlands of the almost lime-free Millstone Grits furnish a copious supply of soft and pure water well adapted for the various processes of washing, scouring, etc., entailed in the production of textiles. In the eastern part of the district many deep borings have been made into the Millstone Grits within recent years and have usually been successful in tapping this water.

Soils, Agriculture, Vegetation

Comparatively speaking, agriculture is not an important industry, and the proportion of arable land is small. The high Millstone Grit plateaux offer little reward to the agriculturist and remain as bleak moorland. Here there are large areas which have never been reclaimed. On the lower ground milk production for the neighbouring towns is the mainstay of the farms, particularly on the

Coal Measures; on the Millstone Grits large numbers of sheep are raised, and in both cases enough oats for their own use are often grown. In former times larger areas were cultivated than now, and on the edge of the moors derelict farms are often to be seen; their abandonment is in part due to the appropriation of the ground by the several public water-supply corporations and in part to the decay of the hand-loom industry. The soils throughout are deficient in lime and of an acid character. Lime was formerly imported in large quantities, mainly by pack-horse from Derbyshire in the south or the Skipton area in the north, but this practice has long been abandoned owing to its prohibitive cost: Limers Gate remains as the name of a pack-horse track across Wadsworth Moors. Within recent years poultry-farming has extensively developed on the poorer soils of the Millstone Grits, mainly on account of their proximity to somewhat densely populated industrial areas. Most of the hill pastures consist of grassy heaths, and in the absence of grazing rapidly revert to moorland. Gorse and heath (*Erica*) followed by bilberry and rushes, and at a later stage by ling (*Calluna*) soon invade the uncultivated areas.

The same conditions apply to the Coal Measure districts, except that moorland plants are rare, bracken and grasses predominating.

A somewhat unusual agricultural feature on the lowlands in the eastern part of the area is the extensive cultivation of rhubarb. This is especially distinctive of the shale areas of the Coal Measures more particularly around Mirfield and to the north of the Calder valley. The plant was first introduced into Yorkshire at the end of the eighteenth century and large quantities are grown for medicinal and export purposes, including the production of cheap 'champagne.' The central market is Leeds.

The intimate relationship between the vegetation and the geology was originally pointed out by Phillips, and was subsequently described in some detail by Davis, Lees and other Yorkshire naturalists.[1] Woodland is naturally more abundant on the more shaly and less elevated Coal Measure tracts than on the Millstone Grit moorlands, while the wooded appearance of the former is further enhanced by the hedgerows dotted with trees; these stand out in striking contrast to the loose stone walls which divide the pastures of the bleak and almost treeless Millstone Grit moorlands. On the argillaceous soils, oak is generally the dominant tree, but is being to some extent replaced by mixed plantations. On the drier and sandy patches birch is usually present, and sometimes predominates; it has been somewhat depleted for the manufacture of clogs, still much worn in the district. On the Coal Measure tracts many of the older houses are half-timbered, whereas the mansions and farmsteads on the Millstone Grit moorlands are built exclusively of

[1] See especially, Davis, J. W. and F. A. Lees, 'West Yorkshire: an Account of its Geology, Physical Geography, Climatology, and Botany.' London, 1878. One of the earliest and most admirable works on the ecology of the district is that by Messrs. W. B. Crump and C. Crossland entitled 'The Flora of the Parish of Halifax,' Published at Halifax in 1904.

the massive grits and roofed with slabs of the more fissile finer-grained grits.

The moorlands present on the whole a grey and austere aspect. The more exposed areas are treeless and clothed only with cotton grass, heather or bracken according to the drainage. This sombre aspect is greatly accentuated by the general smokiness of the atmosphere which doubtless exercises a deleterious effect on trees of all kinds. The prevalent wind is from the south-west and in that direction lies the industrial area of south and east Lancashire. In the cloughs and sheltered places birch, hawthorn and mountain ash are found at considerable heights, but the greater part of the open moors is clothed with a uniform bed of peat usually about 8 ft. thick, formed by cotton grass. This peat seems to have begun to develop in Neolithic times at the expense of the birch forest (Plate VB), but is now almost everywhere recessive, being cut through by innumerable streams, and in dry weather further disintegrated by the wind. The almost complete absence of lime has been mentioned above, but there are occasional thin calcareous bands in the shales; along the sides of the cloughs hard water drips from them, and gives rise to colonies of lime-loving mosses, otherwise completely absent from the district.

Table of Formations

The following table summarizes the geological formations and their subdivisions which are represented on the map. The thicknesses are generalized from data collected in various parts of the area. On the map the shales and sandstones of the Lower and Middle Coal Measures are distinguished by colour, and the more important sandstones and coals are individually indicated by letter. In the Millstone Grits the shales are coloured uniformly throughout, but the grits and sandstones are shown by three colours for the main groups, viz.: The Rough Rock Series, The Middle Grits, and the Kinderscout Grits. These again are individually distinguished by letter.

Superficial Formations

Recent :—	Alluvium Peat Brickearth of Valleys
Pleistocene :—	River Gravel Fluvio-glacial Gravel Boulder Clay

Solid Formations

Upper Carboniferous :—

Middle Coal Measures :—(top of division not present).

Measures, mainly shale with bed of sandstone ... up to	70 ft.
Gawthorpe Coal	
Measures with thin coals and Horbury Rock	200 ft.
Top Haigh Moor Coal	
Measures, with thin sandstone ... ... up to	50 ft.
Low Haigh Moor Coal	
Measures with thin irregular coals and Thornhill Rock ...	250 ft.
Joan Coal	
Measures with Tankersley Ironstone	70 ft.
Flockton Thick or Adwalton Stone Coal	
Measures with Emley Rock	48 ft.
Flockton Thin Coal or Adwalton Black Bed	
Measures with thin coals and Birstall Rock	90 ft.
Old Hards, Parkgate or Brown Metal Coals	
Measures with Lepton Edge Rock	60 ft.
Green Lane or Middleton Little Coal	
Measures, mostly shale with thin lenticular sandstones ...	60 ft.
New Hards or Middleton Main Coal	
Measures	60 ft.
Middleton Eleven Yard Coal (to north of Calder valley only)	
Measures	
Wheatley Lime, Cromwell or Three Quarters Coal	
Measures with Falhouse Rock	80 ft.
Blocking (or Silkstone) Coal	

Lower Coal Measures :—

Measures with Trub, Top Lousey, Low Lousey and thin irregular coals	200 ft.
Beeston, Shertcliffe or Black Band, and Whinmoor Coals	
Measures with Clifton Rock	120 ft.
Measures, mostly shale with 32-Yard & 22-Yard Coals	40 ft.
Crow or Grenoside Sandstone Coal	
Measures with Grenoside Rock	40 ft.
Black Bed Coal	
Measures with Thick Stone	120 ft.
Better Bed Coal	
Elland Flagstones	250 ft.
Measures with 80-Yard, 48-Yard Coals and thin sandstones	150 ft.
36-Yard and Hard Bed Band Coals, Fireclays and Rocks	
Measures, mostly shale	100 ft.
Hard Bed Coal	
Measures, mainly shale	36 ft.
Middle Band Coal	
Measures with Middle Band Rock	30 ft.
Soft Bed Coal	
Measures with Soft Bed Flags	80 ft.
Thin or Pot Clay Coal	

Millstone Grits :—

(base not seen).

	Rough Rock	80 ft.
	Rough Rock Flags ... ... up to	80 ft.
	Shales, with Moorside Flags and thin coal...	160 ft.
	UPPER MELTHAM COAL	
Middle Grits	Warley Rock, Huddersfield White Rock and Barkisland Flags	60 ft.
	Shales...	60 ft.
	Nab End Sandstone and Beacon Hill Flags	35 ft.
	Shales...	50 ft.
	Midgley or Pule Hill Grit	60 ft.
	Shales...	80 ft.
	Scotland Flags or Readycon Dean Series	50 ft.
	Shales...	60 ft.
	Upper Kinderscout Grit	40 ft.
	Shales...	30 ft.
	Lower Kinderscout Grits, in two or three beds	150 ft.
	Upper Sabden Shales with two or more bands of grit ...	250 ft.+

The total thickness of solid rocks exposed at the surface is 3,750 feet. All the deep borings that have been made are situated in the eastern part of the area and consequently begin comparatively high up in the column of strata. Nothing whatever is known directly of the nature of any rocks older than those exposed in the inlier of Sabden Shales at Crimsworth Dean.

CHAPTER II

MILLSTONE GRITS

INTRODUCTORY

On the south-western section of William Smith's geological map of Yorkshire is a 'Table of Strata of Yorkshire in succession, dipping eastward'; one of the divisions is called 'Moorstone or Millstone Grit'; below it is the 'Mountain or Metalliferous Limestone' and above 'Clay' followed by 'Flagstone':[1] from the explanatory notes it is clear that the flagstone is the Elland Flags, and the clay may therefore be taken to represent the strata between that horizon and the base of the Coal Measures; the Millstone Grit would then extend from the top of the Rough Rock to the Carboniferous Limestone.

In 1836 Phillips introduced the term 'Yoredale Beds' for strata intermediate between the Mountain Limestone and the Millstone Grits.[2] These beds have a wide development in Yoredale or Wensleydale, and at the time of the original survey of the Central Pennine area by Hull and Green, they were regarded as the equivalents in age of the beds immediately succeeding the Carboniferous Limestone in North Derbyshire. The massive bed of gritstone which was taken as the base of the Millstone Grits was named by Green the Kinderscout Grit, owing to the fact that it caps the high tableland of Kinder Scout in the Peak Country.[3] This classification was adopted in all subsequent Survey Memoirs, and also employed by Davis and Lees,[4] Spencer,[5] and other local geologists. The late Dr. Wheelton Hind, however, pointed out that the so-called Yoredale Beds of Derbyshire were newer in age than those of the type area in Wensleydale,[6] but no satisfactory alternative nomenclature was suggested.

It had been recognised by Green on lithological grounds that it would be better to include the 'Yoredale Rocks' of the present area in the Millstone Grits.[7] Palaeontological work has steadily tended to confirm this view. Wheelton Hind (*op. cit.*) showed that the beds here dealt with were allied to the Millstone Grits, the true Yoredales to the Carboniferous Limestone, the same being true of the

[1] Sheppard, T., 'William Smith: his Maps and Memoirs,' *Proc. Yorks. Geol. Soc.*, vol. xix, 1917, pp. 75—253.

[2] 'Illustrations of the Geology of Yorkshire' Part II. 'The Mountain Limestone District,' London, 1836, p. 37.

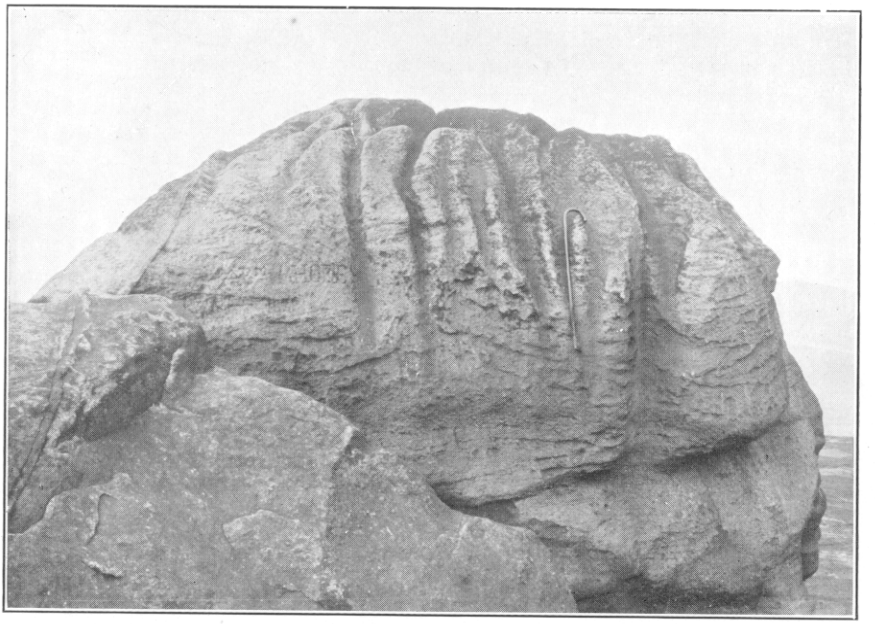
[3] Hull, E., 'The Geology of the Country around Oldham' (*Mem. Geol. Surv.*), 1864, p. 11.

[4] 'West Yorkshire,' London, 1878; 2nd Ed., 1880.

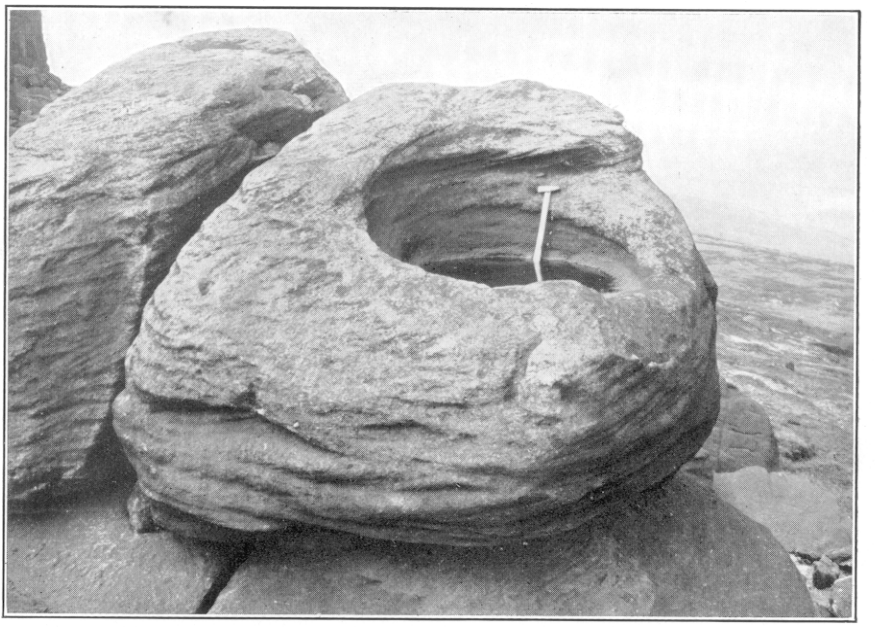
[5] 'Yoredale and Millstone Grit Rocks of the Upper Calder Valley,' *Proc. Yorks. Geol. and Polytech. Soc.*, vol. xiii, 1899, pp. 375—394, etc.

[6] See, for instance, 'Sub-divisions of the Carboniferous Series in Great Britain, and the True Position of the Beds Mapped as Yoredale Series,' *Geol. Mag.*, 1899, pp. 91, 159—169, 205—213.

[7] 'Geology of the Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1878, p. 33.



A.—VERTICAL EROSION CHANNELS IN KINDERSCOUT GRIT, BLACKSTONE EDGE



B.—POT-HOLE WEATHERING IN KINDERSCOUT GRIT, BLACKSTONE EDGE

To face p. 13.

'Shales with Limestone' of Derbyshire which appear to be older than any beds exposed in the area covered by our map. Mr. Bisat[1] has shown that the so-called Yoredale Beds of Derbyshire are the equivalent of the Sabden Shales, and in the adjoining area to the west the beds below the Kinderscout Grit have been shown by the marine bands they contain to belong to the upper part of the Sabden Shales.[2] Mr. Bisat's researches prove that these beds are closely allied to the Millstone Grit by their fauna; and also that the base of the Kinderscout Grit, though it locally makes an admirable line of sub-division, does not represent any palaeontological break. In fact no such break is met with until some distance below the base of the Sabden Shales. Consequently the whole of the beds in our area below the base of the Coal Measures is here referred to the Millstone Grit Series, the former 'Yoredales' being named the Sabden Shales.

The upper limit of the Millstone Grit Series has always been taken at the top of the Rough Rock. This rock is the most uniform member, in character and thickness, of the Millstone Grits; throughout the present area it is succeeded by a band of fireclay, usually with a thin seam of coal, and a thick series of shales. A marine band immediately overlies the coal, and this horizon is therefore readily recognisable. The fauna of the marine band however shows that there is no palaeontological break at this horizon, whereas the marine band immediately overlying the uppermost of the Middle Grit Series, the Warley or Huddersfield White Rock marks a distinct faunal change. At that horizon the genus *Gastrioceras* first becomes dominant, while *Reticuloceras*, a form dominant throughout the greater part of the Millstone Grit Series of the present area, disappears. This line in fact is taken by Mr. Bisat as the division between two major palaeontological zones characterized respectively by *Reticuloceras* and *Gastrioceras*.[3] It is of interest to note that this line of subdivision was adopted by Binney as long ago as 1839; he took the upper limit of the Millstone Grits at the top of the 'Third Grits' and placed the Holcombe Brook coals, which correspond with the Meltham Coals of our district (see page 20), at the base of the Coal Measures.[4] The top of the Rough Rock forms however a particularly well-marked horizon of lithological change in West Yorkshire and is readily identifiable, both in the field and in borings. The additional fact that it is an horizon with which geologists and mining men have long been familiar, renders it by far the most suitable datum-line to adopt as the upper limit of the Millstone Grit Series.

The Millstone Grit Series of the present area, thus defined, has been subdivided in various ways. The more distinctive members

[1] Bisat, W. S., 'Goniatite Zones in the Middle Carboniferous,' *Rep. Brit. Assoc.*, 1922, p. 366.

[2] 'The Geology of the Rossendale Anticline' (*Mem. Geol. Surv.*), 1927, p. 15.

[3] Bisat, W. S., 'The Carboniferous Goniatites of the North of England and their Zones,' *Proc. Yorks. Geol. Soc.*, vol. xx, 1924, pp. 40—124.

[4] Binney, E. W., 'The Lancashire and Cheshire Coalfield,' *Trans. Geol. Soc., Manchester*, vol. i, 1839, p. 78.

are the Rough Rock and the Kinderscout Grits, the latter consisting of at least two, and in the southern part of the area of several separate beds of grit, usually coarse. Between these two is a variable series of shales and mudstones, flags, sandstones and grits called the ' Middle ' or ' Third Grits ', the ' second grit ' of the latter classification being the flags which in our district lie immediately beneath the Rough Rock and are known as Rough Rock Flags.

The beds below the Kinderscout Grits, discussed above, occupy only small areas and are seldom well exposed. They consist mainly of sandy mudstones in which lenticular masses of coarse grit are locally developed. They contain two marine bands.

The correlation of the goniatite succession in the beds below the Kinderscout Grit in the Edale and Mam Tor area with those of Crimsworth Dean and the Vale of Todmorden just mentioned has been made by Dr. J. W. Jackson.[1] His work shows that the ' Kinderscout Grit ' of our area is a true local representative of that of the type area in North Derbyshire ; consequently the name has been retained. The Kinderscout Grits can always be divided into an Upper and Lower part. The Upper in the north contains a thin parting of mudstone with a coal and fireclay ; the Lower may consist of a single thick bed or of several separated by considerable thicknesses of shale. In the Hebden Bridge area a marine band occurs between the Upper and the Lower Kinderscout Grits, but in the south it appears to be represented by a *Lingula* band (p. 29).

Since the name ' Second Grits ' seems unnecessary for beds that are hardly separable from the Rough Rock, we have preferred the term ' Middle Grits ' in place of ' Third Grits ' for the measures next above the Kinderscout. These have been further subdivided, separate beds of grit or sandstone being lettered A B C and D from the top downwards and the shales taking the letter of the underlying rock.[2] Though this scheme has been adopted by several writers in the district, it has led to a good deal of confusion, especially as in the eastern part of the area the same letters were used from the bottom upwards.[3] We have therefore given names, taken from localities within the area where each bed is prominently developed, to the four successive grits and sandstones included in the Middle Grits. On the map a colour different from those of the Kinderscout Grits and of the Rough Rock is adopted for these beds, which are individually indicated by initial letters.

The name ' Rough Rock ' is descriptive of the lithology and universally known : we have therefore retained it ; to the underlying flaggy beds we give the name ' Rough Rock Flags ' which has been largely used in other parts of Yorkshire. The two are distinguished on the map by the letters R and R.F.

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[1] Jackson, J. W., ' The Goniatite Zones below the Kinderscout Grit in North Derbyshire,' *Naturalist.*, July, 1926, p. 205 ; also *Journ. Manchester Geol. Soc.*, vol. 1, 1927, pp. 15—32.
[2] ' Geology of the Burnley Coalfield ' (*Mem. Geol. Surv.*), 1875, p. 98.
[3] ' Geology of Dewsbury, Huddersfield and Halifax ' (*Mem. Geol. Surv.*), 1871, p. 4.

The researches of Sorby,[1] Gilligan [2] and others suggest that the Millstone Grits Series originated as the large deltaic deposit of some ancient river or river-system; it is therefore only to be expected that individual rock bands should vary in character and even in places die out within the small area here dealt with: stratigraphical continuity is frequently interrupted by faulting, and therefore such changes cannot always be followed at the surface; still less can beds be identified by their lithology when encountered in a boring at a distance from any outcrop. A satisfactory key to the succession has, however, been found in the marine bands which occur at intervals; the goniatites of these bands have been studied in detail by Mr. Bisat [3] and afford a ready means of identification; certain problems in this connexion are discussed below, and in greater detail in Chapter VII (pages 141—153). Their wide distribution has enabled a precise correlation of the Millstone Grits to be made, not only for the area here described but also throughout the Central Pennine Area.[4] The several zones established by Mr. Bisat within the area of the present one-inch map are as follows:—

Zone	Subzone	Strata
G	*G. circumnodosum* & *G. listeri* ...	Lower Coal Measures
	G. subcrenatum	
	G. crenulatum & *G. cumbriense*	Rough Rock
	G. cancellatum	Shales
R_2	*R. reticulatum*, mut. γ	Middle Grits and intervening shales
	R. reticulatum, mut. β ...	
	R. reticulatum, mut. α	
R_1	*R. reticulatum*, type	Kinderscout Grit (and lower beds)

G.—*Gastrioceras*. R.—*Reticuloceras*.

General Stratigraphy

The lowest beds exposed within our area in Crimsworth Dean belong to the upper part of Zone R 1, several marine bands occurring below and between the divisions of the Kinderscout Grit. A few feet above the Upper Kinderscout a band with *Reticuloceras reticulatum*, mut. α is well developed and is taken as the dividing line between the Kinderscout and the Middle Grits; to the south-west of Rishworth Moors, Scammonden and Slaithwaite this marine band yields a distinctive form referred to by Mr. Bisat as 'late mutation α.' This appears however to be merely a local variant of the typical mutation α (see page 145).

The Lower Kinderscout Grit is a single bed of conglomeratic sandstone around Hebden Bridge but is split up by shale partings both to the north and south of that area. Between Rishworth and Blackstone Edge there are three beds, but in the intervening shales no fossils other than fragmentary plant remains have been found. Between the Upper and the Lower Grits the shales may be 150 ft.

[1] Sorby, H. C., 'Structure and Origin of the Millstone Grit in South Yorkshire,' *Proc. Geol. and Polytech. Soc. W. Riding Yorks.*, vol. iii, 1859, p. 669.

[2] Gilligan, Prof. A., 'Petrography of the Millstone Grit of Yorkshire,' *Quart. Journ. Geol. Soc.*, vol. lxxv, 1920, pp. 251—294.

[3] Bisat, W. S., 'Carboniferous Goniatites of the North of England and their Zones,' *Proc. Yorks. Geol. Soc.*, vol. xx, 1924, pp. 40—124.

[4] Wray, D. A., 'The Carboniferous Succession in the Central Pennine Area,' *Proc. Yorks. Geol. Soc.*, vol. xxi, 1929, pp. 228—287.

thick or more; at their base in Crimsworth Dean is a marine band with *Reticuloceras reticulatum* (type) and other fossils, but further south this is apparently represented by a *Lingula* band with lamellibranchs but no goniatites, about 5 ft. above a thin coal lying on the top of the Lower Kinderscout Grit.

At the surface this band has been found only in the Rishworth district, but it has a wide development around Marsden, just beyond the southern margin of the present one-inch map. It has also been observed between the Lower and Upper Kinderscout Grits in a deep boring at Mold Green (see page 189) where the intervening shales are less than 10 ft. thick.

The Upper Kinderscout Grit in the north is usually divisible into two leaves separated by a fireclay, coal and mudstone band, the latter yielding *Lingula*; in the west, from near Pecket Well to Keelam this parting is near the base of the grit, but at Cat i' th' Well Clough near Wainstalls (Plate IIIB) it is near the top. In the south the grit forms a single bed with a fireclay and coal on the top.

The succeeding shales and mudstones contain a marine band 5 to 30 ft. above the surface of the grit. The shales of this band are usually crowded with goniatite impressions, the characteristic and predominant form being *Reticuloceras reticulatum*, mut. α Bisat.[1] This marine horizon has been found as far north as the Worth valley, near Keighley, to the south along the border of Derbyshire and Yorkshire and to the west in the Blackburn district. It is therefore of widespread occurrence, but the examination by Mr. Bisat of material collected during the survey from a large number of localities within this area has revealed the fact that lateral variations in fauna are recognisable at this horizon. *Reticuloceras reticulatum* type form and mutation α both occur together in the Mold Green boring, Huddersfield; mutation α alone occurs in the Luddenden valley and around Rishworth and Slaithwaite, while to the west of these localities a form described by Mr. Bisat as 'late mut. α' occurs to the exclusion of the typical 'mutation α.' In the boring at Mold Green, marine fossils were found to occur throughout 23 ft. of shale commencing 3 ft. above the coal that overlies the Upper Kinderscout Grit; 3 to 5 ft. above the base the type form of *Reticuloceras reticulatum* was abundant but in the remainder, the form *Reticuloceras reticulatum*, mut. α became predominant. Three miles west of Mold Green, a second deep boring at Quarmby Clough, Longwood (see page 191) showed only 8 ft. of shale with marine fossils overlying the Upper Kinderscout Grit; the type form of *Reticuloceras reticulatum* was rare, the 'mutation α' predominating. Still further west in Merry Dale Clough, Slaithwaite (see page 33) *R. reticulatum*, mut. α occurred to the exclusion of other forms at this horizon; while in the numerous cloughs on Buckstones Moor,

[1] A description of the diagnostic characters of these mutations of *Reticuloceras reticulatum* is given by Mr. W. S. Bisat in his paper 'The Carboniferous Goniatites of the North of England and their Zones,' *Proc. Yorks. Geol. Soc.*, vol. xx, 1924, pp. 40—124. A summary of these results so far as they affect the present area is given in Chapter vii (page 141).

the form *Reticuloceras reticulatum*, late mut. α alone occurs in this marine band.

The shales with the 'mut. α' marine band near their base vary from about 60 to 140 ft. in thickness; in the south-west they locally contain a second marine band, about 30 ft. above the first, characterized by a goniatite described as *Reticuloceras reticulatum*, 'early mut. β.'

The Middle Grits.—The lowest member of the Middle Grits is called in the north the 'Scotland Flags,' the name being taken from Scotland Quarries, Midgley, where about 100 ft. of flagstones, the lower part of great commercial value, occurs. Northwards this bed of flagstones is traceable to our northern margin near Wadsworth Moor, where it is about 60 ft. thick, but to the south it splits up and passes to sandy shales, becoming unmappable at Cragg, three miles from Midgley. Further south these beds are found to be of a very variable nature including bands of flagstones, tilestones, and ganister rock. They have been termed the Readycon Dean Series [1] owing to their typical development in that valley.

The Scotland Flags or Readycon Dean Series are usually the 'Grit D' of the older writers on this district, though in some cases, as at Hathershelf Scout near Mytholmroyd, the Upper Kinderscout Grit has been called Grit D.[2]

Near the base of the succeeding group of shales is a marine band with *Reticuloceras reticulatum*, mut. β, a form which was originally described as *Goniatites bilinguis* by J. W. Salter[3]; other goniatites occurring with it are *Homoceratoides divaricatum* (Hind) and *Dimorphoceras sp.* The band has been detected, wherever the horizon is exposed, over a large area including the whole of that here described, but it differs from the usual type of greasy black shales: the fossils mostly occur in small nodules embedded in soft grey mudstones.

About 60 ft. above this 'mut. β' horizon is an important grit sometimes referred to as the 'Main Third' or 'Main Middle Grit.' It is well developed and extensively exposed on Midgley Moor and is here termed the 'Midgley Grit.' Normally it is about 80 ft. thick and is a true grit, though rather less coarse than the Kinderscout Grits or the Rough Rock; it forms the surface of the plateau between the valleys of the Calder and the Ryburn on which Sowerby village is built. In the south it is referred to as the 'Pule Hill Grit,' as it crowns that prominent feature; at several localities, for example Waystone Edge and Manshead, it forms well-marked escarpments. In the upper part there is usually a shale parting which, around Slaithwaite, is 20 ft. thick and yields *Lingula*, *Orbiculoidea*, *Naticopsis*, and *Nucula aequalis* J. de C. Sow., though goniatites and *Pterinopecten* are absent. This grit is the bed C of most writers, B in the Old Series sheet memoir on the eastern part of

[1] 'Summary of Progress' for 1922 (*Mem. Geol. Surv.*), 1923, p. 50.
[2] Spencer, J., 'Yoredale and Millstone Grit Rocks of the Upper Calder Valley,' *Proc. Yorks. Geol. and Polytech. Soc.*, vol. xiii, 1899, p. 382.
[3] 'The Geology of the Country around Oldham' (*Mem. Geol. Surv.*), 1864, p. 60.

this district,[1] and is known in the Todmorden district as the Gorpley Grit.[2] A fireclay and thin coal overlie it.

The shales which overlie the Midgley or Pule Hill Grit constitute a readily-recognizable horizon throughout the greater part of the present area; for they contain a thick marine band yielding forms which range from the typical *Reticuloceras reticulatum*, mut. β of Mr. Bisat to 'late mut. β,' and in some parts forms which are referred to as 'early mut. γ' by Dr. W. B. Wright.[3] All forms may be present, though the typical mut. β is confined to the lower part of the band and early mut. γ is typical of the upper; for the most part, however, late mut. β is the dominant form. In the Longwood boring (p. 191) and in the Rishworth and Colne valley districts, forms referable to late mut. β are dominant, while early mut. γ is apparently unrepresented; but in the Mold Green boring (p. 189) early mut. γ occurred to the exclusion of other forms. North of the Calder valley this marine band appears to die out; at Sowerby Bridge it is still present, but poorly developed, being seen in the railway cutting east of the station about 24 ft. above the top of the Midgley Grit; it was nowhere detected in the Luddenden valley, though the horizon is exposed in several little cloughs joining the brook on the right bank; but at the head of the Dean and in Bare Clough a band with *Lingula mytiloides* J. Sow. occurs in this position.

Overlying these shales a variable sandy series is found, to which we have given the names 'Nab End Sandstone' in the north and 'Beacon Hill Flags' in the south; the name first used, 'Long Edge Flags'[4] has been dropped as there are several localities in the district with that name and the rock exposed is not always stratigraphically the same. Nab End is the northern extremity of Blackwood Common, 1 mile south of Mytholmroyd; the beds here have been extensively quarried and are still exploited on a small scale. They are about 50 ft. in thickness and consist of medium to fine grained sandstone, mostly in thin beds. The lower part is frequently flaggy and the upper a grit occasionally pebbly. At Deep Clough, Castle Carr, the flaggy part is about 60 ft. thick with a few feet of grit above; it has been quarried for flags and building stone, and 'numerous fossil plants occur, such as *Lepidodendron obovatum*, *L. aculeatum*, *Sternbergia* (*Artisia*), *Sigillaria tessellata*, *Halonia regularis*, ferns, *Cauleopteris*, *Stigmaria ficoides*, numerous fruitstones, Calamites, etc.'[5] The eastern part of the railway cutting east of Sowerby Bridge Station shows a similar rock, though further south these beds are largely represented by thinly laminated flagstones, the Beacon Hill Flags.[6] The Beacon Hill Flags cover large

[1] 'Geology of the Neighbourhood of Dewsbury, Huddersfield and Halifax' (*Mem. Geol. Surv.*), 1871, p. 4.
[2] 'Geology of the Rossendale Anticline' (*Mem. Geol. Surv.*), 1927, p. 12.
[3] Wright, W. B., 'New Goniatites from the Millstone Grit of Lancashire,' Appendix VII in 'Summary of Progress' for 1925 (*Mem. Geol. Surv.*), 1926, pp. 192—199, and Plate XII.
[4] 'Summary of Progress' for 1923 (*Mem. Geol. Surv.*), 1924, p. 52.
[5] Spencer, J., 'Yoredale and Millstone Grit Rocks of the Upper Calder Valley and their fossils,' *Proc. Yorks. Geol. and Polytech. Soc.*, vol. xiii, 1898, p. 383.
[6] Green, A. H., 'The Geology of the Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1878, p. 61.

areas around Flints, Soyland and Ripponden, and they also give rise to a prominent scarp feature along the eastern slopes of the Ryburn valley. On the Slaithwaite Moors they form the prominent hills known as Cupwith Hill and Goat Hill, while in the Colne valley they include an important bed of ganister rock in their upper part. They are also invariably succeeded by a band of fireclay and coal, known in the country to the south as the Lower Meltham Coal.

The shales above the Nab End Sandstone or Beacon Hill Flags vary from 100 ft. or more in the south to 30 ft. in the north. Near the base is a marine band in which the final mutation of *Reticuloceras reticulatum*, mutation γ, is dominant, accompanied by *Homoceras proteum* (Brown), *Homoceratoides divaricatum* (Hind), and species of *Lingula, Orthoceras, Bellerophon, Dimorphoceras, Gastrioceras* and *Pterinopecten.* This band has been found at several localities in the Luddenden valley, one of which is near the head. South of the Calder it has been observed wherever the shales overlying the Lower Meltham Coal are well exposed. In this area a second marine band has been found, 2 to 10 ft. above the first, characterized by *Gastrioceras ? sigma* Wright.[1] Both bands are present around Rishworth, Barkisland, and Golcar, but in the two deep borings near Huddersfield neither was found, suggesting that both die out eastwards. The '*sigma*' band appears to die out northwards also, but in Cat i' th' Well Clough, Wainstalls, a bed with *Lingula mytiloides* J. Sow. has been found near the top of the shales, and may represent it. It is noteworthy that in the country to the west the 'γ' band passes into a *Lingula* band on the north side of Todmorden and the '*sigma*' band also disappears farther north.[2]

The shales just described are followed by the last member of the Middle Grits, the 'Warley' or 'Huddersfield White Rock' or 'Barkisland Flags,' the A Grit of the usual alphabetical scheme. In the north this is a coarse massive grit, pinkish to white, current-bedded in parts. It "has a greater surface range than any of the other Third Grits. It forms the surface rock of Warley and Saltonstall Moors, and thence runs round the head of Luddenden valley to the upper end of Wadsworth Moor. . . . This grit, like all the other Third Grits, is liable to thin away and deteriorate into rag and shale. It is a typical grit on Warley Moor, but in Wheatley valley, a mile and a half to the south-east, it has become a mass of bedded rag and shale."[3] On the eastern side of the Luddenden valley the lower part is flaggy. Further south, in the Rishworth and Barkisland districts, the same bed locally referred to as the Barkisland Flags, is a thinly laminated flagstone exhibiting rapid local variations. To the south of Barkisland and Stainland it gives rise to several wide flat-topped moors known as Outlane, Pole Moor, Bolster Moor and Golcar Flat; here it is a fine-grained sandstone, sometimes flaggy, and has been somewhat extensively

[1] Wright, W. B., 'New Goniatites from the Millstone Grit of Lancashire,' 'Summary of Progress' for 1925 (*Mem. Geol. Surv.*), 1926, p. 197.

[2] 'Geology of the Rossendale Anticline' (*Mem. Geol. Surv.*), 1927, p. 116.

[3] Spencer, J., 'Yoredale and Millstone Grit Rocks of the Upper Calder Valley,' *Proc. Yorks. Geol. and Polytech. Soc.*, vol. xiii, 1899, p. 383.

quarried. In the immediate neighbourhood of Huddersfield this bed is commonly known as the White Rock; in the Longwood boring (p. 191) it was found to consist of fine-grained flaggy sandstone over 100 ft. thick, but in that at Mold Green (p. 189), three miles to the east, it forms two beds of flaggy sandstone not more than 25 ft. thick in all. A constant feature of this division is a hard ganister or ganisteroid sandstone at the top, overlain by a thick bed of fireclay with a thin coal, ranging in places up to 18 in. thick. This coal, which has occasionally been worked, is the Upper Meltham Coal of the area to the south [1] and corresponds to the Holcombe Brook Coal of east Lancashire. A full detailed section of the Middle Grits of the Huddersfield district has been published by one of the authors of the present memoir.[2]

The Rough Rock Series.—In the shales above the Warley Grit or Huddersfield White Rock, a well-marked marine band occurs in which species referable to the genus *Gastrioceras* first become the predominant members of the goniatite fauna. Earlier forms such as *Gastrioceras ? sigma* and *Gastrioceras lineatum* Wright[3] occur at a lower horizon but they are never the dominant forms. The line of subdivision between the Middle Grits and the Rough Rock Series thus constitutes the most important palaeontological break in the Millstone Grits of our area, and is adopted by Mr. Bisat as the dividing line between his two main palaeontological zones characterized respectively by the genera *Reticuloceras* and *Gastrioceras*.

The marine band found in the shales overlying the Warley Grit or Huddersfield White Rock is characterized by *Gastrioceras cancellatum* Bisat, and occurs over a very wide area. In the north the '*cancellatum*' marine band is a considerable distance above the top of the grit: about 50 ft. above the coal that immediately overlies the Grit is a second coal, usually only 2 to 3 in. thick, well seen west of Ogden Reservoir; the marine band is 20 to 30 ft. above this coal, and yields *Reticuloceras reticulatum*, mut. γ, as well as *Gastrioceras cancellatum*. A further 30 ft. up is a second marine horizon in which *Gastrioceras cumbriense* Bisat is dominant; *Gastrioceras crenulatum* Bisat, of which *cumbriense* was at first called a variety, is common to both, as are *Homoceratoides divaricatum* (Hind), *Dimorphoceras sp.*, *Orthoceras sp.* and various lamellibranchs; a peculiar form of *Aviculopecten*, first noticed from Bigrigg, Cumberland, seems to be confined to the upper zone. Both these marine bands are of widespread occurrence and have been found throughout our area, but the position relative to the top of the Warley Rock varies slightly. West of Halifax the presence of both marine bands was noticed many years ago by Spencer;[4] the total thickness of the shales, to the base of the Rough Rock Flags, is about 150 ft., with the Cancellatum band about 30 and Cumbriense about 60 ft. up. South of the Calder, near

[1] 'Geology of the Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1878, p. 61.

[2] Wray, D. A., 'The Carboniferous Succession in the Central Pennine Area.' *Proc. Yorks. Geol. Soc.*, vol. xxi, 1929, p. 249.

[3] 'Summary of Progress' for 1925 (*Mem. Geol. Surv.*), 1926, pp. 196, 197.

[4] 'Additional Notes on the Millstone Grit of Halifax,' *Trans. Manchester Geol. Soc.*, vol. xiii, 1874, pp. 103—114.

Norland, the shales are 90 to 100 ft. with the marine bands the same distance from the base as before. In the Huddersfield district the Cancellatum band is 15 to 25 ft. above the Upper Meltham Coal, the intervening shales yielding occasional impressions of *Lingula* and *Modiola*. In the lowest marine shales *Reticuloceras reticulatum*, mut. γ is found at some localities and in the upper part of the same band a form of *Gastrioceras crenulatum* closely approximating to *cumbriense*. In the Mold Green boring (p. 189) the section from the Rough Rock was alternating flags and sandy shale 58 ft., Cumbriense band 2, shale 92, Cancellatum band 3, shale 30, Upper Meltham Coal. At Longwood 96 ft. of dark shale separated the marine bands from one another and 23 ft. of black shale with occasional *Lingula* intervened between the Cancellatum band and the Upper Meltham Coal. Between Greetland and Barkisland a thin group of flagstones, termed the 'Moorside Flags,' is found between the two marine horizons. This is the only representative in our area of the Lower Haslingden Flags, an important group in East Lancashire.[1]

The Rough Rock series above the shales just described, which are associated with it for palaeontological reasons, is here divided into two parts, the Rough Rock proper and the underlying Rough Rock Flags; the two are separated by a parting of mudstone usually about 5 ft. thick, but where they disappear beneath the Lower Coal Measures at Elland the parting has disappeared and the lithological distinction implied by the names is lost. In a boring at Brookfoot, near Brighouse (p. 193), no division can be made. On the original survey[2] the flags were classed as the 'Second Grit,' the Rough Rock proper being the First and the Middle Grits the Third; these divisions had been carried on from the south and west, the flags being regarded as the equivalent of the Upper Haslingden Flags. Spencer showed clearly that they are essentially part of a single series with the Rough Rock,[3] and in a later memoir it is stated that between the Calder valley and Illingworth it was found impossible to trace a line of division between the flags and the grit.[4] On the Survey map of the country to the north[5] they were shown as passing into one another, the letters R and R F being used to distinguish them, where possible, as on the present map. Whether the Rough Rock Flags of this area were really continuous with the Upper Haslingden Flags it is impossible to say, nor is the point of any importance; both lie between the Cumbriense marine band and the base of the Rough Rock, of which the top at any rate is a constant horizon, as shown by the overlying coal and marine band (p. 49). The passage to the flags from the underlying shale is gradual, and thin partings of mudstone are found locally throughout the thickness of the flags.

[1] 'Geology of the Rossendale Anticline' (*Mem. Geol. Surv.*), 1927, pp. 22—23.
[2] Old Series one-inch map, Sheet 88 N.W., 1870.
[3] *Op. cit.*
[4] 'Geology of the Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1878, p. 63.
[5] Old Series one-inch map, Sheet 92 S.E., 1878; also 'Geology of Bradford and Skipton' (*Mem. Geol. Surv.*), 1879, pp. 8 and 9.

Ovenden Moor, Hunter Hill and the northern part of Highroad Well Moor are formed by the flagstones, the Rough Rock coming on over the southern part of the last. In the scarps stretching from Ogden and Tower Hill to the north and south ends of Halifax respectively the parting between the two divisions is a bed of grey shaly mudstone 9 to 4 ft. thick. At Exley this parting thins out, the flags become coarser in grain and less laminated, the lower part of the Rough Rock finer in grain and thinner bedded, so that the distinction disappears. On the south of the Calder the flags are well developed, being 80 to 100 ft. thick in North Dean, opposite Copley. Between Norland and Greetland they are known as the ' Flatstone ' and are over 100 ft. thick ; they are largely quarried on Greetland Moor. In less than a mile to the south, however, they rapidly diminish in thickness and around Longwood are probably not more than 20 ft. thick. In places a local unconformity exists between them and the overlying Rough Rock. Around Slaithwaite they exhibit rapid local variations, in part due to the overlying grit resting unconformably upon them.

The Rough Rock is the most constant and uniform of all the Millstone Grits and always constitutes a readily recognizable horizon. Normally it is coarse-grained and massive, though often crumbling where exposed owing to the decomposition of the large amount of felspar it contains. It forms craggy scarps, such as that south-west of Halifax, the enlargement of joints and differential weathering of the beds giving rise to isolated blocks, on which the false-bedding particularly of the lower part, is rendered conspicuous (Frontispiece). In the north the Rough Rock is about 60 ft. thick. In Halifax it may be as much as 120 ft., but the dividing line between it and the flags just described is difficult to place in a boring ; the two together are 170 to 190 ft. thick. Farther east, beneath the covering of Lower Coal Measures, the thickness at the Brookfoot boring was only 72 ft.

Around Elland, the Rough Rock has been proved in several borings to be at least 140 ft. thick. No definite line can be drawn between it and the underlying Rough Rock Flags. At Hullenedge and to the north of Stainland, the Rough Rock forms a fine escarpment. At Stainland the continuity of its outcrop is interrupted by the prominent Rishworth-Stainland fractures.

From Lindley Moor to Blackmoorfoot the Rough Rock gives rise to a continuous and conspicuous escarpment, breached by the River Colne to the west of Lockwood. The Rough Rock escarpment largely dominates the landscape to the west of Huddersfield giving rise to marked features at Longwood Edge and along the western slopes of Crosland Moor. Wholestone Moor consists of an outlier of these beds. Here the lower beds are flaggy, and an outlier of these flaggy beds caps the conspicuous knoll of Worts Hill on Slaithwaite Moors. The Rough Rock covers a wide expanse at Crosland Moor, and it is here quarried extensively for building

stone; the majority of buildings in Huddersfield and its suburbs are built of this stone (pp. 184).

Palaeontology

In the above account of the stratigraphy of the Millstone Grits the position of the Goniatite Zones has been indicated; fuller details of the palaeontology together with complete lists of forms recorded are given in Chapter VII (page 141).

A few fish remains, mostly very poor, have been found and submitted to Dr. Wellburn, but they do not add to the information on the subject already published by him. A complete list is given in Chapter VII (page 157). The usual forms are *Acanthodes wardi* Egerton and *Elonichthys aitkeni* Traquair, which he has recorded from a number of localities in the shales above the Upper Kinderscout Grit; the latter is also found beneath the Lower Kinderscout in Crimsworth Dean, in the shales above the Scotland Flags and the Midgley Grit and in the Rough Rock Series. Other fish are *Cladodus mirabilis* Agassiz, *Orodus elongatus* Davis, *Strepsodus sulcidens* Hancock and Atthey, *Rhadinichthys monensis* Egerton, *Elonichthys obliquus* Wellburn and *Acrolepis hopkinsi* M'Coy.[1]

Worm castings and tracks on ripple-marked sandstone are frequent, more particularly in the Scotland Flags; it was apparently to this rock and also to the Nab End Sandstone that Spencer gave the name Arenicolite Beds, though his sections are not easy to correlate.[2]

Plants are of constant occurrence but are nearly always fragmentary and badly preserved; practically none were collected during the survey, and the old lists, mentioning localities where *Lepidodendron, Calamites* and *Sigillaria* have been found, are not of any great value. Dr. J. W. Jackson has recorded *Calamites* (*Calamitina*) *goepperti*, from the 'Striolatum' marine band in Crimsworth Dean (see page 27), from a locality just beyond the western margin of the present one-inch map. This is a well-known Westphalian species, and has been recorded from the Elland Flags of Northowram.[3] The late Dr. Kidston also records the occurrence of *Mariopteris nervosa* from the Middle Grits at Cold Edge, Luddenden, and Sowerby Bridge.[4]

The Composition and Origin of the Millstone Grits

In a general way the Millstone Grits of this area consist of some four or five principal beds of grit or sandstone separated by shales or mudstones of varying thicknesses. The several beds of which it is composed show rapid lateral variations in thickness and character; yet it is a striking feature that the total thickness of the Millstone Grit Series above the Kinderscout Grit in the Todmorden and

[1] Wellburn, E. D., 'Fossil Fishes of Carboniferous of Yorkshire,' *Proc. Yorks. Geol. Soc.*, vol. xvi, 1907, pp. 199—204, and previous papers there tabulated.
[2] *Trans. Manchester Geol. Soc.*, vol. xiii, 1876, pp. 203—225.
[3] *Naturalist*, 1923, pp. 233—235.
[4] Kidston, R., 'Fossil Plants of the Carboniferous Rocks of Great Britain' (*Mem. Geol. Surv., Palaeontology*), vol. ii, pt. 6, 1925, p. 622.

Rochdale districts at the extreme western margin of the sheet is practically identical with that recorded in a deep boring at Mold Green (see page 189) in the south-east of our area. During the deposition of the grits the area must have been undergoing depression with minor oscillations; the great lateral variations in the sediments indicate deposition in shallow waters, probably with constantly changing currents. These conditions are in complete accordance with those originally postulated by Sorby,[1] and subsequently confirmed by Gilligan[2]: an extensive deltaic deposit of a former river system occupying this area in Millstone Grit times. Sorby's investigations were made in the Sheffield district, while those of Gilligan were confined to localities to the north of the present area; both these observers are in agreement that the original source of the material was an ancient land mass of granite and granitoid gneiss which lay to the north and north east, stretching from northern Scotland to Scandinavia.[3] No detailed petrographic examination of the Millstone Grits of the present area has been made, but quartz, felspar and mica are invariably abundant; pebbles of chert and microperthite have been occasionally found in the coarser grained grits, while in many of the cores of the coarser grained grit from the deep borings at Longwood and Mold Green (see pages 189-191) grains of garnet are abundant at several horizons. They have also been observed in some of the massive grits on Blackstone Edge and Bleakedgate Moors.

Certain of the sandstones occasionally show a peculiar structure which is indicative of the direction of current at the time of formation. In many quarries occur structures known to the workmen as 'mare's balls': sometimes these are the spherical concretions with rusty concentric layers due to the oxidization of ferrous carbonate, but the name is also used for elongated pillows which may reach 20 ft. or more in length and a diameter of 3 or 4 ft. These show no chemical difference from the sandstone of adjoining layers in which the circular bedding planes are absent, and they occur at a definite horizon or horizons for that particular sandstone. They appear to be due to a rolling action at the front of an advancing sand bar in the estuary. Somewhat similar structures have been described by Dr. Bernard Smith, who attributes them to current action on a sloping floor.[4]

Another feature of interest in the stratigraphy of the Millstone Grits is the fairly constant alternation in successive order of grit, fireclay, coal, marine band, shale or mudstone, and flagstone. These cycles of sedimentation, though not always so complete, represent a series of oscillations and breaks in the depression and sedimentation. It appears that subsidence was not continuous but took place in a series of jerks; as an immediate result of such movement an invasion

[1] Sorby, H. C., *Proc. Yorks. Geol. and Polytech. Soc.*, vol. iii, 1859, pp. 669—675.
[2] Gilligan, A., *Quart. Journ. Geol. Soc.*, vol. lxxxv, 1920, pp. 251—294.
[3] Sorby, H. C., Presidential Address *Royal Microscopical Society*, 1877, p. 20; Gilligan A., *op. cit.*, p. 275.
[4] 'Ball or Pillow-form Structures in Sandstones,' *Geol. Mag.*, 1916, pp. 146—156.

of the sea resulted in the formation of a bed with marine fossils; sedimentation then overtook the downward movement, leading eventually to the formation of a sandstone and finally a coarse gritstone, subsequently followed in several instances by that of a coal seam.

A further interesting feature is that although many of the marine bands are very persistent and widespread, others exhibit lateral variations. In some cases bands crowded with goniatites pass laterally into *Lingula* or lamellibranch bands, in which goniatites are absent. Lateral variations within the fauna of the marine bands themselves have also been observed, and these are described in some detail on pages 141—152. As far as our information goes within the limits of the present one-inch sheet, these changes appear on the whole to take place most rapidly in a south-westerly direction.

Economics

The economic products of the Millstone Grits are dealt with in a later chapter; the majority of the grits have been worked either as building or paving stones. The coarser-grained massive beds have been widely employed for reservoir embankment work, while the Middle Grits yield building stone in several places. The Rough Rock Flags are also worked while the quarrying of the Rough Rock as a building stone at Crosland Moor, near Huddersfield, still constitutes an important industry (see page 184). As a source of underground water-supply the Grits are also extensively drawn upon in the principal towns. The fireclays and ganister-rock which overlie several of the Middle Grits have been occasionally worked in the past. The ganister-rock overlying the Huddersfield White Rock and the Beacon Hill Flags becomes of economic importance along the southern margin of the map.

Several of the coal seams have also been worked on a small scale. The coal in the Kinderscout Grit on the west and south sides of Midgley Moor was worked, mainly by bell pits, round about 1840. In a similar manner the coal overlying the Upper Kinderscout Grit was formerly worked near Scammonden in the Deanhead valley. At Barkisland the coal overlying the Pule Hill Grit has been worked along the outcrop in the Blackbrook valley.

One of the more important coals is the Upper Meltham Coal which overlies the Huddersfield White Rock; this has been extensively worked on Pole Moor and to the north of Worts Hill. The old workings are however now completely overgrown.

Details

Sabden Shales

The beds below the Kinderscout Grit, now correlated with the Sabden Shales, are best exposed in Crimsworth Dean. The succession there and in the neighbouring country to the west has recently been described by Messrs. Lloyd and Stephens, who re-surveyed the area.[1] The following account is

[1] 'Stratigraphical Succession below the Kinderscout Grit in the Todmorden District,' *Proc. Yorks. Geol. Soc.*, vol. xxi, 1927, pp. 47—58.

taken almost verbatim from this paper. The stream-level both in Crimsworth Dean, the valley running north and south on the west of Pecket Well, and in the lower part of the Hebden valley is rarely more than 275 ft. below the base of the Kinderscout Grit, and the valley-floor appears to be subject to small longitudinal faults obscuring the exact relations of the beds to one another. A cliff-section in the right bank of the stream at Black Scouts shows the lowest beds in the exposed sequence :—

	Ft.	in.
Grey flaggy siltstone grading down into next	20	0
Grey shale (unfossiliferous)	10	0
Grey shale with occasional fragments of goniatites ...	1	6
Coaly layer, very thin and impersistent	—	—
Shale with occasional goniatite fragments...	2	0
Coaly layer, 1/16 to 1/8 in. thick	—	—
Soft grey shale	—	2
Dark blue-grey mudstone with obscure plant-impressions	—	4
Grey shale with occasional goniatites and lamellibranchs...	2	9
Marine band: black carbonaceous shale (*Reticuloceras reticulatum, Homoceras striolatum, Eumorphoceras ornatum*)	—	4
Grey shale with occasional goniatites and lamellibranchs	2	6
Layer of limestone nodules, weathered to a brown umber-like material, containing goniatites	—	—
Grey shale with band of " pectens " at top	3	0
Layer of nodules	—	—
Grey shale with few plant-impressions	4	6
Grey micaceous rubbly shale with " pecten " band 1 ft. from top	8	0
Coaly layer	—	—
Marine band; carbonaceous shale (*R. reticulatum, H. striolatum*)	—	4
Grey shale	3	0
Layer of nodules	—	—
Grey to grey-black shale with a " pecten " band 10 ft. from top	13	0
Scree to level of stream	9	0

The top of this section ends in beds which are becoming progressively more sandy as traced upwards and both the lithology and the profile of the ground point to the existence, though it is not actually visible, of a strong sandstone or grit bed about 45 to 50 ft. above the upper marine band—the representative of the Todmorden Grit.[1] This grit is from 15 to 30 ft. thick, and is exposed or forms a feature at several places along the sides of the valley. Higher up the valley, 200 yards south of Wet Ing Bridge, a group of small faults throws the Todmorden Grit down below stream-level, but with a southerly dip, so that the grit reappears a hundred yards farther north. It is here coarse-grained and current-bedded. Thirty feet above it is a marine band, well exposed 420 yards above the bridge, almost one mile above the junction with the Hebden Water: it here consists of a band of limestone nodules or ' bullions,' often packed with uncrushed specimens of goniatites, succeeded by 6 ft. of black shale containing many crushed specimens of the same species. The species found here are *Reticuloceras reticulatum* and *Homoceras striolatum* and also the " old age " form *Reticuloceras davisi*. It is from the bullions of this locality that the majority of the specimens collected in the past, and usually labelled ' Crimsworth Dean ' or ' Horsebridge Clough,' have come.

The lower part of the 70 ft. of beds between this marine band and the base of the Kinderscout Grit is obscured, but the top 40 ft. are well exposed farther

[1] Geology of the Rossendale Anticline ' (*Mem. Geol. Surv.*), 1927, p. 16, *et. seq.*

upstream, consisting of barren grey shales with bands of thin grey calcareous siltstones. cf. Hey Slacks Clough

At Lumb Falls (Plate IIIA) the Kinderscout Grit reaches stream-level and occupies the stream bed thence to Jack Bridge, 100 yards north of the boundary of the map, where the top of the main bed of the grit is reached, and 100 yards farther on a marine band containing *R. reticulatum* is exposed in the left bank of the stream. This is the highest horizon from which the type form of *R. reticulatum* has been obtained.

The succession in Crimsworth Dean may be conveniently summarized as follows :—

	Ft.
Marine band ; *R. reticulatum* (type form)	—
Shale	6
Lower Kinderscout Grit (main body)	175-200
Shale	70
Marine band ; *R. reticulatum, H. striolatum, R. davisi* ...	—
Shale	30
Todmorden Grit	15-30
Shale	45-50
Marine band ; *R. reticulatum, H. striolatum, E. ornatum*	—
Shale	18
Marine band ; *R. reticulatum, H. striolatum*	—
Shale, etc.	80-100

The whole of the exposed succession in Crimsworth Dean, therefore, falls within the R_1 Zone ; the base of the zone is not visible though possibly present.

The valley of the Hebden Water from its junction with Crimsworth Dean is much obscured by slips and screes. The historical locality at High Freen Wood, from which Samuel Gibson obtained many of his specimens, has not been rediscovered. At Walshaw, in Rowshaw Clough, there is an exposure of the *R. reticulatum* band immediately above the Lower Kinderscout Grit, similar to that at Jack Bridge.

On the north side of the Calder valley a section in Dale Clough, just beyond the western border of the area, shows, according to Mr. Lloyd, the normal pebbly base of the Lower Kinderscout Grit, underlain by nearly 300 ft. of strata consisting of sandy shale and sandstone, intercalated with beds of coarse grit, which series has been referred to as the ' Sub-Kinderscout Grit'.[1] This development of Sub-Kinderscout Grit can be traced around the hillside into the Calder and Hebden valleys, where there are exposures of lenticular masses of grit in a predominantly sandy series which extends to the bottom of the valley. In Beaumont Clough, west of Horse Hold, several hundred feet of grit, representing Kinderscout and Sub-Kinderscout Grit, are exposed ; but wherever the Sub-Kinderscout Grit development has been observed, the normal base of the Kinderscout can be traced by a line of pebbly grit crags.

Sandy mudstones belonging to the upper part of the Sabden Shales are exposed below Withens Reservoir and in a small faulted inlier about half a mile south of Cragg Church.

The Kinderscout Grits

The Lower Kinderscout Grit.—The Lower Kinderscout Grit is well seen in Crimsworth Dean. In the upper part it occupies the valley bottom as far down as Lumb Falls (Plate IIIA) where the fall is due to differential erosion of the shales beneath. A thin bed of shale splits the grit into two parts. In Hollin Hall Wood, east of Shackleton, a thin coal, 1¼ in., with a 3½ in. seat, occurs in this shale 10 ft. above the lower part of the grit. To the north and west this shale thins and possibly disappears, but elsewhere it forms a distinct slack between the two shelves of grit, a feature well seen between Pecket Well and Old Town. The picturesque old village of Heptonstall lies on this grit ;

[1] 'Geology of the Rossendale Anticline' (*Mem. Geol. Surv.*), 1927, pp. 16, 36.

about 60 ft. of coarse pebbly current-bedded grit is seen in the crags south-west of the church. Mr. Lloyd notes an unusual feature in that the lower part of the grit in the Colden and Hebden valleys is in places highly calcareous.

Similar grit caps the hills on both sides of the Calder valley at Hebden Bridge, but eastwards it is cut off by a fault just before the base would reach stream-level. Westwards a remarkable local failure of the Lower Kinderscout Grit, evidently referable to the complex conditions of deposition giving rise to a local Sub-Kinderscout Grit, is inferred on the south side of the valley from the evidence of stream sections in the adjoining area to the west.[1] In Beaumont Clough, west of Horse Hold, it is still prominent, but in Parrock Clough, draining the western slope of Edge End Moor, the position of both grits is taken by shales and shaly flagstones, which appear to extend with few gaps to the top of the moor, where a small capping of Upper Kinderscout Grit has been mapped.

Owing to the slight easterly dip very little of the Lower Kinderscout appears in the Luddenden valley. It is confined to a narrow strip rising at Low Bridge, 1,100 yards south of Castle Carr, and running south along the stream bed.

To the south of the Calder valley the grit is largely covered by peat on Turley Holes Moor, but the Cragg Brook has cut a fine gorge in it at the village and for about one mile above.

Numerous sections occur in the massive Lower Kinderscout Grits on Soyland Moors. In the upper part of Turvin Clough these beds consist of massive thick-bedded and conglomeratic grit. Several disused quarries occur alongside the Mytholmroyd-Rochdale main road at Wicken Hill, where its massive and conglomeratic nature is well shown. This region being unglaciated the grit is everywhere overlain by a thick mantle of light grey kaolinised 'head' or rotted grit. In addition large blocks, stacks, and tabular masses of weathered grit occur scattered over the surface of these moorlands. Forming distinctive landmarks on an otherwise featureless moorlands they have received special names such as the Woolpack, Dove Lowe, Holder and Little Holder Stones.

One of the finest natural sections of these massive Lower Kinderscout Grits is seen in the crags constituting Blackstone Edge. Here the rocks have all a gentle and persistent easterly dip. The basal bed of the Kinderscout Grits is exposed here and is of a very coarse-grained, conglomeratic and massive nature.

Many of the outstanding stacks and weathered crags of grit have been carved by wind-erosion into fantastic forms with a fretted surface due to their pebbly nature. In many of these crags and stacks current-bedding is admirably displayed. The upper surfaces of many of the tabular blocks also contain many large pot-holes, due to the weathering out of larger pebbles, and their subsequent gyration in the hollow produced by rain water (Plate II). A line or ridge of coarse tabular blocks forms a second scarp behind the main escarpment, and represents a higher bed of Kinderscout Grit.

To the south of Blackstone Edge and alongside the Rishworth-Oldham main road, about a mile east of the county boundary, the massive Lower Kinderscout Grits form prominent weathered stacks which are known locally as the Rocking Stones.[2] Here extensive undercutting by atmospheric agencies, principally wind erosion, along the main bedding planes and joints has produced a series of isolated tabular masses of conglomeratic grit somewhat resembling perched blocks.

In Booth Dean Clough the Lower Kinderscout Grit, consisting of coarse grit and conglomerate, is more than 150 ft. thick. Current-bedding is so prevalent that no reliable average dip can be obtained, though the slope of the ground indicates a general easterly dip.

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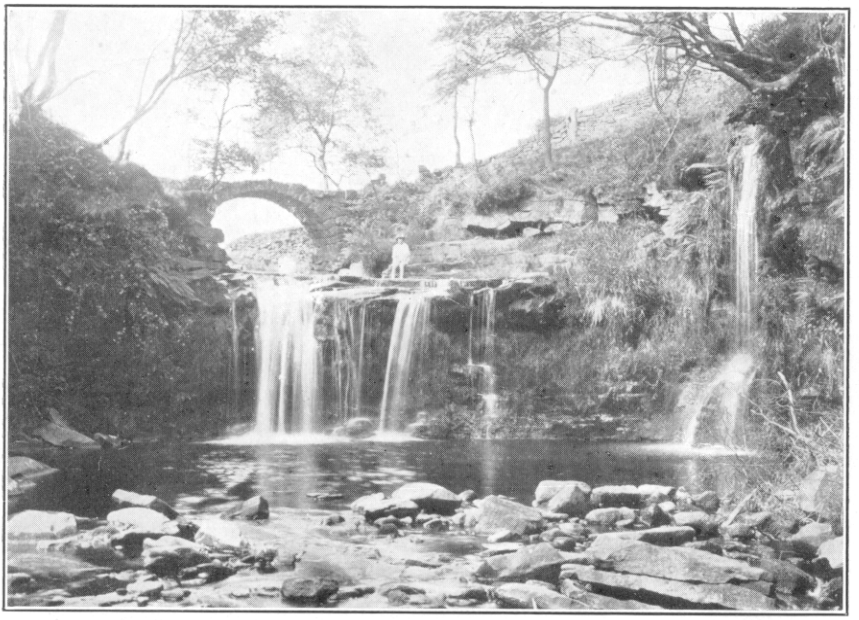
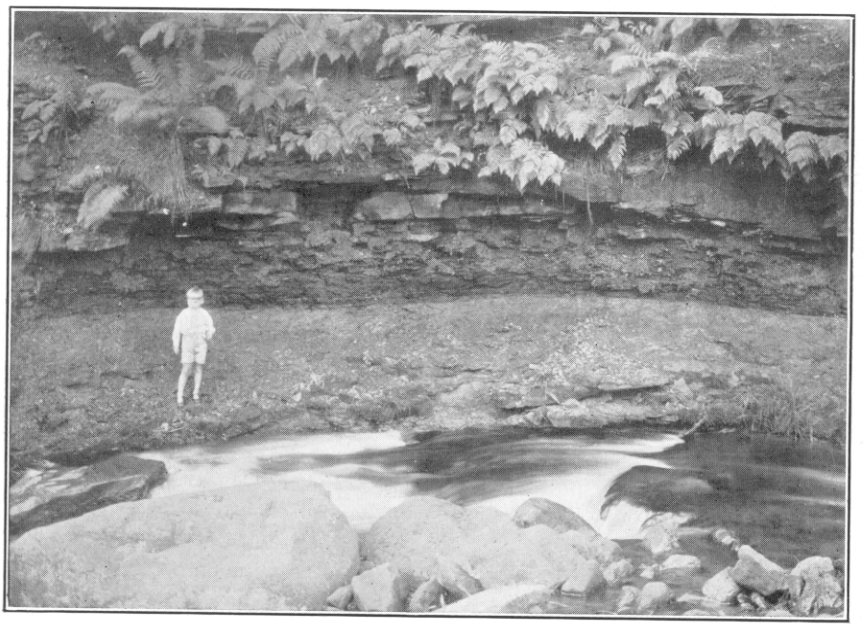
[1] 'Geology of the Rossendale Anticline' (*Mem. Geol. Surv.*), 1927, p. 36.

[2] These were figured by the late Professor Hull and confidently claimed by him to have "been produced by the waves of the old Glacial Sea." *See* 'The Geology of the Country around Oldham' (*Mem. Geol. Surv.*), 1864, p. 7.



A.—BASE OF KINDERSCOUT GRIT, LUMB FALLS, CRIMSWORTH DEAN, HEBDEN BRIDGE



B.—COAL SEAM IN KINDERSCOUT GRIT, GROTTO TERRACE, CAT I' TH' WELL, WAINSTALLS, HALIFAX

To face p. 29.

The main mass of Kinderscout Grits continues in force all the way down Booth Dean Clough, forming at Booth Wood and the Cunning Corner a steep-sided gorge with steep crags of conglomeratic grit over 150 ft. high. At the base of Butts Clough, however, the Kinderscout Grits are abruptly cut off by the prominent Rishworth-Stainland fault (see page 123.) Two trial borings that have been made on behalf of the Wakefield Corporation Waterworks Department in the upper part of the Booth Dean valley are of interest as indicating the probable depth to the base of the Kinderscout Grits in this area. The first was made at the confluence of Oxygrains Beck with Booth Dean, and the second about a mile lower down the valley, 1,000 yards west of Derby Inn. The borings in both cases reached the base of the massive grit at depths of from 50 to 60 ft., and the strata underlying it for a depth of 50 ft. consisted largely of sandy shale.

The beds between the Lower and Upper Kinderscout Grits.— In the north a marine bed occurs just above the top of the Lower Kinderscout. No exposures of this actually come within the area, but it has been seen in two places, one 40 and the other 200 yards north of the edge of the sheet where it cuts Crimsworth Dean Beck. The bed consists of grey shaly mudstone containing crushed but well-preserved goniatites, the zone fossil being *R. reticulatum* (Phill.). This marine band was also encountered in the Halifax water-supply tunnel under Midgley Moor. The tunnel commences in the upper leaf of the Lower Kinderscout Grit just below Pecket Well and comes out in a small clough 200 yards north-west of Low Bridge in Luddenden Dean. The beds passed through by this tunnel and the three shafts on Midgley Moor connected with it give a continuous section from the Midgley Grit down to the Lower Kinderscout Grit. The records were obtained and published by Spencer.[1]

The thick mass of shale separating the Lower from the Upper Kinderscout is 162 ft. 6 in. thick in the tunnel, thus :—

	Ft.	in.
Blue shale, becoming sandy at top...	108	0
Black shale	20	0
Black shale containing goniatites, etc.	7	0
Layer of ironstone nodules with fish-remains		4
Cone-in-cone		2
Hard ganister seat-earth	4	6
Grey shale with white rock	10	6
Blue shale with goniatites, etc.	12	0
Grit [=Lower Kinderscout Grit]	—	—

This thickness is fairly constant. The bed of shale can be traced on either side the length of the Crimsworth valley, and again in Luddenden Dean. Exposures are scarce and the finer divisions, consequently, cannot be differentiated.

In the Calder valley Mr. Lloyd notes that the thickness of strata separating the Lower and Upper Kinderscout Grits increases in an easterly direction from the Pennine Anticline, coincident with the development of upper leaves of Kinderscout Grit. These upper leaves are well exposed in Rowshaw Brook, north of Walshaw. The intervening shales here have yielded *R. reticulatum*, cf. mut. α Bisat.

In both banks of the valley about Mytholmroyd the beds between the Upper and Lower Kinderscout are about 400 ft. thick and consist mainly of shales. In the north bank two thin bands of flaggy sandstone have been mapped out, as they tend to form level platforms on which the farm houses are built. They have not been traced on the south either in the main valley or that of the Cragg Brook, though the beds are exposed in the clough joining the latter on the west from the edge of Erringden Moor ; nor have any fossili-

[1] Spencer J., ' Geology of the Parish of Halifax,' Part III, *Trans. Manchester Geol. Soc* vol. xiii, 1874, pp. 202—225.

ferous bands been detected. Southwards towards Cragg village this series again thins to not more than 100 ft.

The shale series which intervenes between the Lower and Upper Kinderscout Grits forms a prominent slack on either side of the Upper Ryburn valley at Baitings Gate and Schole Carr Moors, and from thence can be traced eastwards towards the village of Rishworth. A prominent bed of fireclay and a thin seam of coal invariably overlies the Lower Kinderscout Grit. These are succeeded by grey micaceous shales and mudstones with impersistent flaggy partings. In Rag Sapling Clough a thin band of fine black shale occurs a few feet above the coal and contains abundant fragmentary fish remains.

On Rishworth Moors, the corresponding shale series are well exposed in Green Withens Clough and here contain a *Lingula* band (together with impressions of *Pterinopecten spp.*) which has been found to have a wide deve opment in the country to the south of the present area. In the constructioln of the Green Withens reservoir embankment an excellent section of the Kinderscout Grit series was exposed (see Fig. 3, page 31). This section also revealed the position of the main Rishworth-Stainland fault (see page 123). To the east of Green Withens there are few sections in the shale series overlying the Lower Kinderscout Grit and they become difficult to trace owing to their being largely obscured by scree and landslip. In London Pasture, however, behind Rishworth Lodge, the top of the Lower Kinderscout Grit is exposed and reveals the following section :—

	Ft.	in.
Grey shaly mudstones with thin flaggy layers ...	10	0
Shaly Coal		6
Bastard fireclay		6
Coal		4
Good yellow fireclay	3	0
Rather massive flaggy grit	15	0+

The Upper Kinderscout Grits.—As a general rule these beds are more flaggy and less massive than the lower or main mass of the Kinderscout Grits. They are liable, however, to rapid variations both in character and texture. In the Hebden Bridge and Mytholmroyd districts they are represented by a grit, medium to fine-grained, split by a thin band of shale containing a small seam or seams of coal. Usually the coal occurs about the middle of the grit, but from a point half a mile north of Peckett Well round to Keelam the lower part of the grit has degenerated into 7 ft. of siltstone with sandy bands, and a 4-in. bed of coarse yellow sandstone, containing flat shale pellets and quartz pebbles, at the base. The beds are traceable the length of the Crimsworth valley, forming marked scarps on both sides, especially along the stretch above Old Town, where the stone has been worked. It is here a massive grit, in places coarse, and occasionally current-bedded.

Though the shale band can be traced all along the outcrop the coal is first seen in a lane 100 yards east of the main road, 600 yards N.N.W. of the Chapel, Pecket Well. Further south at Slack House Lane, 550 yards S. by E. of Pecket Well Chapel, the coal has been worked from an adit and above Old Town shafts have been sunk to the seam. A section measured at Slack House Lane is :—

	Ft.	in.
Black shale with *Lingula mytiloides* J. Sow. ...	—	—
Coal		8
Clay		3
Black Shale	2	3
Coal		6
Grey clay		2
Siltstone		10
Grey shale		—

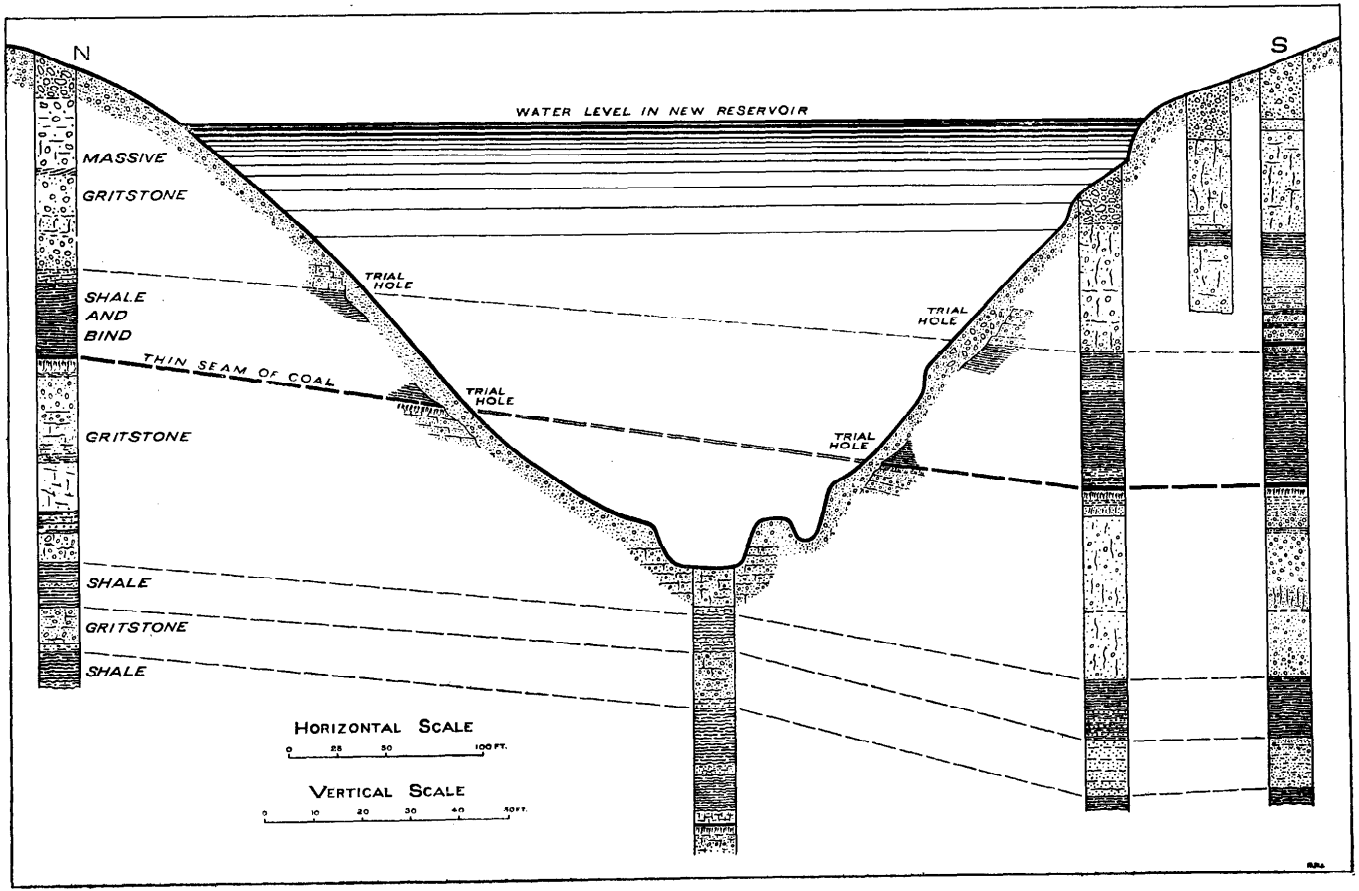


Fig. 3.—*Borings in the Kinderscout Grits for Ryburn Reservoir Dam, Rishworth.*

In No. 2 Shaft of the Midgley Moor Conduit Tunnel, 1,270 yards E. by S. of Pecket Well Chapel, the following section was recorded :—

	Ft.	in.
Sandstone	42	9
Coal		2
Seat-earth	3	0
Blue grit	28	0

West of the Rifle Range a number of bell-pits and small shafts have been sunk to obtain the coal, but presumably it thins eastwards towards Midgley where there is not more than 1 in. with 0 to 3 ft. of fireclay below and 4 ft. of soft shaly mudstone above ; the grit below is here about 15 ft. thick, while that above is seen in the crags of Scout Head to 30 ft., both being coarse and pebbly.

Between Nook and Faugh, that is near the southern end of the rifle range, a shaft and boring has been recorded showing that the coal is here over 1 ft. thick ; the shaft begins 15 ft. above the top of the Upper Kinderscout :—

	Ft.	in.
Shale	15	0
Grit	15	0
Shale	6	0
Coal	1	2
Black Shale	30	0
Coal	0	5
Hard sandstone	27	6
Black Shale	45	0
Quick Sand	4	0
Shale with ironstone bands 1 to 3 in. thick	88	1[1]

In the Luddenden valley the coal appears above stream level just north of Luddenden village and can be traced upwards on both sides, gradually rising in the series until at Caty Wood, in Cat i' th' Well Clough which runs down from Wainstalls, there is only 15 ft. of grit above it (Plate IIIB). Further up the Dean this split in the grit is obscured by slips and the wooded nature of the country, and at Dean Head Reservoirs above Castle Carr the grit itself disappears beneath the surface.

Returning to the south side of the Calder, a wide spread of Upper Kinderscout Grit forms Erringden and Bell House Moors : at the head of the clough between them on their eastern edge the cliff shows 25 ft. of coarse grit containing little lenticles of coal near its base resting on 4 ft. of grey shale, below which is 10 ft. of pebbly grit before the main mass of underlying shale is reached. The total thickness of the grit is probably about 300 ft.

Mr. Lloyd notes that the Upper Kinderscout Grit, in two beds, is well exposed at Stoodley Pike, 2 miles S.W. of Hebden Bridge. The monument stands on the upper bed of grit, which is separated from the lower bed by about 30 ft. of shale, giving rise to a well marked ' slack.'

The lower bed of grit is for the most part fine grained and flaggy and is overlain by a coal seam ; the upper grit is coarser but contains few pebbles.

A short distance south of the monument, a fault crosses the escarpment in an E.S.E. direction, throwing up the Lower Kinderscout Grit in alignment with the Upper, until the Cragg Brook is reached.

Passing down the Cragg valley the Upper Kinderscout Grit crowns the gorge to Hall Bank, east of which are the fine crags of Hathershelf Scout, facing the Calder valley : here the parting between the two leaves consists of as much as 20 ft. of shale with a fireclay and 2 in. coal, with grit above and below : the total thickness is about 200 ft. There are deep railway cuttings in the grit near Luddenden Foot Station and the coal is visible behind the mill at the foot of Boulder Clough. A short distance farther down the valley the beds disappear below the bottom. On Soyland, Rishworth and Buckstones

[1] ' Geology of the Burnley Coalfield ' (*Mem. Geol. Surv.*), 1875, p. 115.

Moors the Upper Kinderscout Grit is usually flaggy and is constantly overlain by a prominent bed of fireclay with a thin seam of coal. The flaggy beds of the Upper Grit are well displayed in Booth Dean, south of Rishworth; excellent sections occur around the Ryburndale Paper Mills and Rishworth. Borings and trial-holes made on the site of the new Ryburn Reservoir dam show that the beds hereabouts contain a good deal of shale (Fig. 3). Below Rishworth Hall the Kinderscout Grits are faulted down to the level of the stream, and at Slithero Bridge, Rishworth the top of the series was formerly exposed, overlain by a thin coal.[1]

Small inliers of these beds occur in the Deanhead valley at Scammonden, and in the lower part of the same valley at Firth House and Penny Hill, Krumlin. In the Colne valley there is also a small faulted inlier in Merry Dale Clough, one mile north-west of Slaithwaite; the overlying coal was noticed below the 'mut. α' marine band.

The Middle Grits

The Kinderscout series is succeeded by shales and mudstones 120 to 150 ft. thick with the mut. α marine band at the base. The shales usually form a wide and gentle concave slope from the grit below to the sandstone beds above. In the north this slope can be traced continuously, save for minor interruptions due to faults, along both sides of Crimsworth Dean, along the north bank of the Calder through Midgley, along both sides of the Luddenden valley as far up as the northernmost reservoir at Castle Carr and along the main valley from Luddenden Foot about half-way to Sowerby Bridge, where the shales disappear below the surface. In this stretch the marine band at the base is visible at 950 ft. above O.D. in Foster Clough, which runs from Midgley Moor to Mytholmroyd; also at several localities in the Luddenden valley:[2] at Caty Wood at 690 ft. above O.D., in the clough draining westwards to Luddenden village at 410 ft. above O.D., and at the same level in Load Clough, a quarter of a mile to the south. Fish have been recorded from this bed at Kiln House Wood opposite Booth,[3] but we did not find the exposure.

In the Midgley Moor Tunnel Shaft No. 2, 136 ft. are recorded, viz:—

	Ft.	in.
Blue bind	60	0
Black shale	20	0
Blue bind	50	0
Seat-earth	6	0

In Shaft No. 3, 750 yards east by south of Pecket Well Chapel, 140 ft. of grey bind containing 30 ft. of black shale in the middle with a 3 to 4 ft. marine band full of goniatites, etc., and several layers of fossiliferous nodules.

This marine band is not exposed elsewhere in the district but was encountered during the construction of Dean Head Reservoir, Castle Carr. Specimens of the goniatites from the puddle-trench of this reservoir have been identified by Mr. Bisat as *R. reticulatum*, mut. α Bisat. The seat-earth at the base of this shale sequence recorded in No. 3 Tunnel Shaft is also exposed in the west bank of the Lower Dean Head Reservoir with here a thin coal in addition.

On the south bank of the Calder the basal marine band was found during the survey in graves in Luddenden Foot Churchyard; it was probably this bed that yielded a fish to Dr. Wellburn in Boulder Clough (*op. cit.*).

The thick shale series which overlies the Upper Kinderscout Grit is well exposed on the southern slopes of Manshead Moor, and with the marine band characterized by *Reticuloceras reticulatum*, mut. α is seen in natural sections in Greenwood, Horse Hey and Clay cloughs. The flaggy Upper Kinderscout Grit is overlain by 3 ft. of rather impure fireclay and a 3 in. coal seam; the

[1] Hull, E., 'Geology of the Burnley Coalfield' (*Mem. Geol. Surv.*), 1875, p. 108.
[2] Bisat, W. S., *Proc. Yorks. Geol. Soc.*, vol. xx, 1924, p. 60.
[3] Wellburn, E. D., *Proc. Yorks. Geol. Soc.*, vol. xvi, 1907, p. 203.

marine band occurs a few feet above. In the upper part of Greenwood Clough it occurs about 1,000 yards north-west of Baitings Farm, and in Horse Hey Clough, 300 yards north-west of the same farmstead. Impressions of *Pterinopecten speciosus* J. W. Jackson, are very abundant, in addition to the zonal fossil. At Rishworth, the same beds are exposed at the foot of Butts Clough, a steep-sided ravine on the eastern side of the Ryburn valley which gives a very complete section of the Middle Grit Series, though somewhat complicated by faulting. There is an excellent section of 'mut. α' band at a point in the clough, 100 yards north-east of Rishworth (Wheelwrights') Mills. The lower part of the marine band contains *Pterinopecten speciosus* exclusively. Overlying this thin band occurs *Reticuloceras reticulatum*, mut. α, together with *Orthoceras* cf. *obtusum* (Brown) and *Posidoniella minor* (Brown).

The same beds are also exposed in the Colne valley to the north-west of Slaithwaite. In Merry Dale Clough, 500 yards west of Clough House Mills, the Upper Kinderscout Grit is overlain by fireclay and a thin seam of coal. In the succeeding dark shales is the thin band crowded with impressions of *Reticuloceras reticulatum*, mut. α. and *Pterinopecten speciosus*. A distinctive feature in the fauna of the marine band here is the occurrence in addition of forms described by Mr. Bisat as *Reticuloceras reticulatum*, late mut. α.

The marine band overlying the Upper Kinderscout Grit to the north and east of the Upper Ryburn valley, Rishworth, Scammonden and Slaithwaite invariably yields forms which Mr. Bisat would regard as typical of his *Reticuloceras reticulatum*, mut. α (see page 144). To the south-west, however, there is an abrupt change and 'late mutation α' occurs to the exclusion of this form. This change is also accompanied by the appearance of a second higher marine band characterized by *Reticuloceras reticulatum*, early mut. β from 10 to 30 ft. above the *Reticuloceras reticulatum*, late mut. α band. These two bands, though invariably present throughout the south-western portion of our area and in the adjoining area in East Lancashire,[1] are, however, quite unrepresented to the north and east. This change is admirably illustrated in the upper part of the Ryburn valley. Thus the marine bands seen in Greenwood, Horse Hey, and Clay cloughs on the southern slopes of Manshead Moors contain *Reticuloceras reticulatum*, mut. α exclusively (see page 144). About one thousand yards to the south and on the opposite slopes of the Upper Ryburn valley the following section is seen in Dry Clough, Warm Withens on Rishworth Moors:—

	Ft.	in.
Thin flags, and flaggy grits with sandy shale partings...	8	0
Soft grey shaly mudstones	20	0
Grey shaly mudstones, concretionary in upper part ...	25	0
Black shales with *Reticuloceras reticulatum*, early mut. β	2	0
Shales and shaly mudstones with *Lingula* &c. ...	15	0
Soft black shales with *Reticuloceras reticulatum*, late mut. α	3	0
Concretionary and ferruginous mudstones	10	0
Coal		2
Fireclay	3	0
Flaggy sandstone and shale (Upper Kinderscout Grit)	—	—

The same beds were also seen on the southern slopes of Rishworth Moors at Green Withens Edge and the marine horizon was located in the banks of the catchwater draining westward into Green Withens Reservoir. A corresponding change in the fauna of the marine band overlying the Upper Kinderscout Grit was also observed in Deanhead Clough, Scammonden. In the neighbourhood of Eastwood Bridge the thin coal overlying the Kinderscout Grit appears to have been worked on a small scale, and on the northern bank of the stream

[1] 'The Geology of the Rossendale Anticline' (*Mem. Geol. Surv.*), 1927, p. 114; see also Wray, D. A., 'The Carboniferous Succession in the Central Pennine Area,' *Proc. Yorks. Geol. Soc.*, vol. xxi, 1929, p. 239.

close to the bridge there is an exposure of black shale which yields typical *Reticuloceras reticulatum*, mut. α, together with *Pterinopecten speciosus*, *Posidoniella minor* and *Dimorphoceras sp.*

One mile higher up the valley the same beds occur on both sides of the Deanhead Reservoir. The Kinderscout Grit with its thin seam of coal on top occurs in the bottom of the valley, while in the succeeding shales both the late mut. α and early mut. β bands can be recognised. At the foot of Great Clough the late mut. α band is well exposed, while the overlying early mut. β band can be examined along both sides of the Reservoir, and also in several places at the foot of Doe Holes Clough.

A similar succession is seen in the lower part of Hard Head Clough at a place known as Shot Scar, to the south-east of Buckstones Moor. Here the lower marine band occurs 15 ft. above the coal; the latter is 13 in. thick, with a thin parting of fireclay in it, resting on 4 ft. of fireclay. The underlying Kinderscout Grit is very hard and ganister-like.

From here the fireclay, coal and marine bands can be traced along the southern slopes of Buckstones Moor, excellent sections being exposed in Broad Rake, Tom, and Dan cloughs.

At the western end of Buckstones Moor and close to Waystone Edge, a fine natural section of the beds on this horizon is seen in Dry and Linsgreave cloughs. The floor of the former clough for the greater part of its length consists of the flaggy ganisteroid Upper Kinderscout Grit, and along both sides the fireclay (3 ft. thick), coal (8 in.) and overlying fossiliferous shales are well exposed (see page 146). A good section of a fault repeating the measures is also well seen in the same clough. To the north of Windy Hill, an excellent natural section of these beds is seen along the sides of Castle Shore Clough. The fireclay, coal and two overlying marine bands occur on the slopes, while the flags and tilestones referable to the Readycon Dean Series constitute the upper part of an extensive section of these beds.

The Scotland Flags and Readycon Dean Series.—In the north the lowest sandy member of the Middle Grits has been called the Scotland Flags; the Scotland Quarries, from which the name is taken, are on the north and north-east of Midgley village. In the deepest of these there is 100 ft. of flaggy sandstone seen, of which the upper 60 ft. is somewhat raggy, but the remainder a first class sandstone, of a pale bluish-grey tint when fresh: some of the upper beds have their surfaces covered with worm or other tracks. Extensive quarries now disused are to be seen at Cock Hill, where the outcrop bends round from the Crimsworth Dean to the Calder valley direction above Mytholmroyd.

At Delf End Quarries, now disused, 800 yards east of Pecket Well the quality of stone is poor, particularly in the upper parts which contain many shale partings. A coal streak with a 7-in. underclay occurs in the sandstone in this quarry.

In No. 2 Shaft, Midgley Moor (see page 33), a thickness of 57 ft. of grit and flags represents these beds.

In Luddenden Dean the Scotland Flags fringe the banks of the Upper Dean Head Reservoir, diverging gradually to form on the west side of the valley the wooded slopes above Castle Carr, and on the east the bare steep hillside bordering the road. In Bare Clough, which runs down to the north-west corner of the Upper Reservoir, 39 ft. of these beds are visible, thus:

	Ft.	in.
Massive sandstone, coarser at base	18	0
Flags	6	0
Shale with thin sandstone bands	10	6
Well-bedded, yellow flagstone, seen to	5	0

In the quarries opposite Castle Carr, variously known as Jubilee Delph, Deep Clough Quarries, etc., 30 ft. of a rather massive sandstone of medium to fine grain, with a grey silty shale parting 1 ft. 6 in. to 4 ft. thick, 20 ft. from the top, are exposed. The shale parting contains fragmentary remains

of plants. The total thickness is not exposed in either of these sections but is probably quite 60 ft.

On the south bank of the Calder there are large quarries in these beds in the river cliff beside the cemetery at Sowerby Bridge, showing about 50 ft. of sandstone, of which parts only are flaggy; other parts show well a tendency, also seen at other localities, for certain beds to form balls and pillows. These appear to be of structural rather than chemical origin, the result of rolling over at the face of an advancing sand-bar (see page 24).

Traced south from the Calder up the Cragg and Ripponden valleys important changes are noticeable. In the former the shale partings gradually increase at the expense of the flags until the series ceases to be recognizable below Aaron Hill. In the latter the beds become more coarse and massive; in the railway cutting north of Triangle Station they are a true grit not unlike parts of the Kinderscout: the horizon is definitely proved by the finding of the marine band immediately above the grit on both sides of the valley at Triangle.

These beds also consist of massive flaggy grits at Kebroyd Bridge to the south of Triangle. From thence to Ripponden they occur as a long narrow inlier at the foot of the Ryburn valley. They are well exposed in cuttings alongside the railway where they consist of rather massive flaggy grits with sandy shale partings. A fault close to Ripponden station again brings in the Kinderscout Grits at the base of the Ryburn valley and the Scotland Flags or Readycon Dean Series form well-marked escarpments on either side of the valley as at Butts Clough, Rishworth. Hereabouts the bed was referred to by Green as the Folly Sandstone or Grit D.[1] At Meg Scar, Rishworth there is a fine natural section of these beds where they consist of alternations of flaggy sandstone and shale. A small faulted inlier of these beds also occurs at the foot of Butts Clough.

At Baitings Pasture on Manshead Moors these beds form broad spreads and consist of an alternating series of flaggy grits, tilestones, and sandy micaceous shales. On the south side of the Ryburn valley the flags referable to this series give rise to an extensive flat-topped and largely peat-covered plateau known as Rishworth Moor.

Around Scammonden and along both sides of the Deanhead valley one or two prominent beds of flagstone occur in the great thickness of sandy shale of about 300 feet from the top of the Kinderscout to the base of the Pule Hill Grit. At the head of Deanhead valley the Scotland Flags or Readycon Dean Series consist of a very variable series of flags and tilestones and closely approximate in character to their development in the type area of Readycon Dean.[2] They also exhibit similar characters on the southern slopes of Buckstones Moor and pass upwards imperceptibly into the overlying Pule Hill Grit. The whole succession is well exposed in the numerous steepsided cloughs draining southwards from Buckstones Moss.

Along the northern slopes of Wholestone Moor there is a fine unbroken succession from the top of the Kinderscout Grit to the Rough Rock. The Readycon Dean Series is here well exposed in the lower parts of Hey and Red Lane cloughs and consists of massive flagstones.

In the Colne valley, the Readycon Dean Series is well developed around Slaithwaite. On the south side of the valley it consists of a single band of massive flags overlain by ganister rock which can be traced from Linthwaite Hall to Lingards Wood. In a disused quarry at the base of Bradley Clough and 150 yards east of Mansergh House the ganister rock is 6 ft. thick and is overlain by black shales with the marine band characterized by *Reticuloceras reticulatum*, mut. β.

Between the Scotland Flags (or the Readycon Dean Series) and the Midgley or Pule Hill (Main Third) Grit is a series of shales of interest mainly because

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[1] Green, A. H., 'The Geology of the Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1878, p. 61.

[2] Wray, D. A. and W. Lloyd in 'The Geology of the Rossendale Anticline' (*Mem. Geol. Surv.*), 1927, p. 37; and 'Summary of Progress' for 1922 (*Mem. Geol. Surv.*), 1923, p. 50.

of the marine band at their base, characterized by *Reticuloceras reticulatum*, mut. β. In the north these shales are 60 to 75 ft., though No. 2 Shaft of the Midgley Moor tunnel (page 33) gives a thickness of 81 ft., a figure in excess of that calculated at any point along the outcrop.

In Crimsworth Dean the only locality for the marine band is above the sandstone in Delf End Quarries, where, however, the fossils are mere 'ghosts' and indeterminable: better examples were found at Nell Nook, near the small reservoir on the south-east of Midgley Moor. Farther up the Luddenden valley are two localities, in the banks of the stream at Cat i' th' Well, 100 yards above the bridge on the lower road from Mount Tabor to Castle Carr,[1] and in the quarry at Upper Saltonstall, less than half a mile farther west.

Two good sections of these beds are exposed in the steep valleys of Bare Clough and Fulshaw Clough; the former draining from the west into the upper reservoir, the latter on the east side, half a mile east of Castle Carr.

In Bare Clough the beds are 66 ft. in thickness, and in Fulshaw Clough about 60 ft. made up as follows:—

		Ft.	in.
Bare Clough	Shale, with a seat-earth at base	9	0
	Flaggy beds and tilestones with many ripple marks and tracks	25	0
	Shale beds	32	0
Fulshaw Clough	Shale	8	0
	Flags and tilestones with ripple marks and tracks	20	0
	Shaly beds ... ... about	30	0

In Cat i' th' Well Clough 150 yards above the bridge, these beds amount to about 57 ft. and are:—

	Shale	20	0
	Soft yellow sandstone, passing into tilestones	22	0
	Shale	15	0

The marine band has been detected on both sides of the Ripponden valley at Triangle, in the railway cutting quarter of a mile north of the station and, in nodules, in the little clough just south of Sowerby Vicarage. Specimens, also in nodules, have been found in the railway cutting east of Sowerby Bridge Station.[2]

In the Rishworth district, this marine band is well exposed in the middle of Pike Clough, to the east of the prominent hill known as Pike End. The goniatites here occur in small nodules and are described by Mr. Bisat as *Reticuloceras reticulatum*, early mut. β, being quite distinct from those of the typical 'mut. β' band overlying the Pule Hill Grit exposed in Butts Clough, on the opposite side of the Ryburn valley. They also appear to be at a somewhat higher stratigraphical horizon than the marine band characterized by *Reticuloceras reticulatum*, early mut. β, which occurs not far above the base of the Kinderscout Grit and has a wide extension in the south-western part of our area (see page 147).

The relationships of the three marine bands which occur between the top of the Kinderscout Grits and the base of the Pule Hill or Main Third Grit are well illustrated by the natural sections exposed in Hard Head Clough and the upper part of the Deanhead valley at the eastern end of Buckstones Moor. The generalized section hereabouts is as follows:—

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[1] Bisat, W. S., 'Carboniferous Goniatites of N. England,' *Proc. Yorks. Geol. Soc.*, vol. xx 1924, p. 60.

[2] Bisat, W. S., *loc. cit.*

	Ft.	in.
12. Massive grit of Buckstones, & Slaithwaite Moors, flaggy at base	50	0
11. Sandy shales and mudstones	60	0
10. Marine band with *Reticuloceras reticulatum*, mut. β Soft shales with goniatite impressions and small nodules with goniatite casts	—	—
9. *Readycon Dean Series.* Alternating bands of ganister rock, tilestones, flags and sandy shale ...	80	0
8. Concretionary shales and mudstones	100	0
7. Marine band with *Reticuloceras reticulatum*, early mut. β. Soft black shale	—	—
6. Soft shaly mudstones with *Lingula*...	20	0
5. Marine band with *Reticuloceras reticulatum*, late mut. α.	—	—
4. Soft Shale	10	0
3. Coal ... ... averaging		6
2. Fireclay	3	0
1. *Upper Kinderscout Grit.* Flaggy grit, upper part ganister-like	—	—

The beds numbered 1 to 9 are described on page 35. The marine band (No. 10) is well exposed in the upper part of Hard Head Clough, 300 yards south of its junction with the main Huddersfield-Oldham road, and also in the upper part of Deanhead clough, 1,000 yards west of the upper end of Deanhead Reservoir (for list of fossils see pages 147, 156). In the Colne valley, the shales overlying the Readycon Dean Series are well exposed in an old ganister quarry close to the southern end of Varley Road, Slaithwaite (see page 182). Immediately overlying the ganister rock the black shales are full of fossils including *Reticuloceras reticulatum*, mut. β (typical), *Posidoniella minor*, and *Pterinopecten speciosus*.

The Midgley or Pule Hill Grit is the most constant member of the Middle Grits and has been referred to as the Main Third Grit; it is usually the Grit C of older writers. It varies from a fine sandstone to a coarse gravelly grit, averaging about 50 ft. thick, sometimes with a ganister top and split into two by a shale parting. This grit borders the east side of Crimsworth Dean and covers a large area of the southern part of Midgley Moor. Occasional quarries along the scarp edge overlooking Crimsworth Dean show a coarse grit, often gravelly.

No. 2 Shaft of the Midgley Moor tunnel (see p. 33) commenced near the top of this grit and went through 47 ft. of it. Round the Luddenden valley there are few sections. In Bare Clough a 55-ft. bed of grit is split by a thin shale band 20 ft. from the top; a section in the lower part in a quarry 600 yards east by north of the clough gives:

	Ft.	in.
Black shales	—	—
Galliard	2	3
Shaly sandstone	1	8
Very coarse sand-rock	9	0
Massive sandstone	12	0

In Cat i' th' Well Clough 20 ft. of massive irregularly jointed coarse grit followed by 25 to 30 ft. of sandstone with shale partings represent the Midgley Grit.

South of the Calder there are large quarries in this grit a quarter of a mile east of Sowerby Church, where 45 ft. is exposed; the lower part is a medium-grained massive sandstone, becoming flaggy and raggy towards the top.

The Pule Hill or Main Third Grit is well developed in the Ripponden and Rishworth districts and forms extensive areas of elevated moorland. At Manshead Moor it gives rise to a prominent escarpment, while it also forms prominent scarp features on both sides of the Ryburn valley. It occupies

the higher parts of Rishworth Moors and caps the prominent hill known as Pike End.

In the lower Ryburn valley there are quarries in the Pule Hill Grit at Lumb, Kebroyd, and Hanging Stones, Ripponden where it consists of a massive somewhat fine-grained grit. It was here referred to as the Foxstones Grit by Green, who estimated it to have a thickness of 85 feet in this district.[1] The same grit forms a long unbroken escarpment overlooking the Booth Dean valley and extending from Buckstones and Waystone Edge to Moselden Height, Pike Law and Krumlin.

At Waystone Edge and on Buckstones Moor, the Pule Hill Grit consists of massive thick-bedded grit, and at the Buckstones gives rise to a prominent line of crags, consisting of massive rectangular blocks of grit due to the very regular system of jointing. It hereabouts rests on a series of flaggy grits and sandstones with no very definite line of subdivision between them. On Slaithwaite Moor, where it covers a large area, many bands of flaggy grit occur within it.

Large quarries occur in this bed on Moselden Height, Pike Law, and at Krumlin. Massive beds of yellow flaggy grit are at present being quarried at the Clock Face quarry on Pike Law (see page 182). At Krumlin are two large quarries along the eastern side of Ringstone Edge reservoir. Here the grit is of a very massive and coarse-grained nature.

On the northern slopes of Outlane Moor the Pule Hill Grit gives rise to a prominent scarp feature overlooking the Blackbrook valley. It here consists of massive grit with bands of flaggy grit.

On the south side of the Deanhead valley the Pule Hill Grit forms a well-marked escarpment extending from Wood Edge to the Slaithwaite Moors. An extensive section in the lane at New Hey Carrs shows that it here consists largely of thin-bedded flaggy grits and alternating sandy shales. It also forms a wide unbroken expanse of peat-covered moorland on Slaithwaite Moors. A fine natural section is exposed in the floor of Drop Clough where it is very flaggy and contains much sandy shale. At the foot of the clough around Slaithwaite Hall there are several large disused quarrieswhere it appears as a thick bedded fine-grained massive grit with only very occasional shale partings. At the head of Bradshaw Dike, however, it exhibits an essentially flaggy and shaly facies showing the rapid variations this bed of grit undergoes in this district.

The Pule Hill Grit is well developed on either side of the Colne valley between Golcar, Linthwaite and Slaithwaite, and throughout this area it consists of a lower bed of massive grit, up to 50 ft. thick, and an upper portion consisting of flags and flaggy grits 20 ft. in thickness, the two being separated by a 20 ft. band of shale which is distinctive in containing a marine band which can be recognised wherever the shale parting is exposed.

The lower part of the grit is being quarried as a building stone on the north side of the Colne valley at Dunnock and Hill Top Quarries, Crimble. It is here 50 ft. thick and overlain by the shale parting referred to above. On the south side of the valley the lower bed of grit has also been extensively quarried at Spring Grove and Hoyle House, Linthwaite. The Pule Hill Grit with its upper shale parting is also well exposed at Holt, Bar House, Shroggs and Sally Bank Quarries to the south of Slaithwaite. The lower 8 ft. of the shale band contains many carbonaceous and indeterminate plant remains, while in the upper part a marine fauna including *Lingula, Orbiculoidea, Naticopsis, Nucula,* &c., occurs, though *Pterinopecten* and goniatites, usually so abundant in marine bands, are apparently absent (see pages 154-157). The corresponding marine band is present in parts of East Lancashire and the upper flaggy parting in places develops into a massive grit.[2]

[1] Green, A. H., 'Geology of the Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1878, pp. 59 and 61.

[2] 'The Geology of the Rossendale Anticline' (*Mem. Geol. Surv.*), 1927, p. 19.

In the north the shales succeeding the Midgley Grit have no peculiar features except that a band at their base contains *Lingula mytiloides* J. Sow. This is seen at the head of Bare Clough and also at the head of Luddenden Dean itself. The total thickness of shale amounts to between 40 and 50 ft.

To the south of the Calder valley, however, the Midgley or Pule Hill Grit is immediately followed by a coal and a marine band with *Reticuloceras reticulatum*, mut. β, which can sometimes be differentiated as 'late mut. β,' and is presumably continuous with the *Lingula* band just mentioned. The most northerly locality at which the marine band has been detected is Sowerby Bridge, where the following section was noted in the railway cutting beside the first road-bridge east of the station :—

	Ft.	in.
Grey shale	—	—
Shale with marine fossils	1	0
Barren shale	3	0
Coal (poor)	—	6
Fireclay	1	0
Flags	4	0
Coal		6
Fireclay	2	0
Shale	10	0
Coal	1	0
Fireclay	2	0
Sandstone (Midgley Grit)	—	—

The coal above the Main Third or Pule Hill Grit is well exposed along the eastern slopes of the Ryburn valley at Rough Hey Scar, 250 yards east of St, John's Church, Triangle. The marine band overlying it could be recognised though the material was too poor for specific identification. The top of the grit here contains bands of ganister rock, the following being a measured section :—

	Ft.	n.
Soft dark grey shales with marine band	3	0
Coal		5
Ganister rock		9
Grey sandy shale	7	0
Ganister rock	1	0
Yellow fireclay	3	0
Ganisteroid grit...	3	0
Massive fine-grained grit (Main Third Grit)... ...	50	0

A short distance to the north, however, the shales overlying the Pule Hill Grit are well exposed in High Lee Clough, and at a point 240 yards north-east of Little Haven Farm the marine band was observed and yielded abundant impressions of *Reticuloceras reticulatum*, mut. β and other fossils (see page 147).

At Butts Clough, Rishworth, there is an excellent exposure of the marine band along the side of the stream, 220 yards south-west of Clough Head Farm; it immediately overlies a thin streak of coal resting on the upper surface of the Pule Hill Grit. The fauna of the bed here appears to be fairly rich, for in addition to the zonal form *Reticuloceras reticulatum*, mut. β, *Posidoniella laevis* (Brown), *P. minor* (Brown), *Posidonomya insignis* J. W. Jackson, *Aviculopecten* cf. *neglectus* (Geinitz), *Lingula mytiloides* J. Sow., *Nuculana stilla* (M'Coy), *Entalis* cf. *meekianum* (Geinitz), and *Chonetes spp.* were obtained.

To the east of Barkisland, the Pule Hill Grit forms the floor of the Blackbrook valley, and alongside Barkisland Mills the thin coal overlying it is 1 ft. thick and has been worked on a small scale along the outcrop. It was, however, of very inferior quality.

On Slaithwaite Moors a small outlier of the Beacon Hill Flags caps Cupwith Hill and on its slopes the soft grey shales overlying the Pule Hill Grit are exposed. Alongside the Huddersfield-Oldham main road and close to the eighth milestone the soft greasy dark grey shales containing *Reticuloceras reticulatum*, late mut. β are exposed in a steep hollow. A prominent bed of fireclay overlies the grit but the coal here becomes reduced to a mere smut. Several forms referred to the genus *Productus* were obtained from the marine band. About a mile to the south-east of Cupwith Hill the same marine band is exposed in Blake Clough, alongside Mean Hey Farm, Slaithwaite and yields a similar fauna.

In the Colne valley the late mut. β band is seen in the upper part of Bradley Clough, Slaithwaite, and in a large disused brickworks at Linthwaite. The section in Bradley Clough is 200 yards north-east of Holt Laithe Farm and here the marine band immediately overlies the upper flaggy portion of the Pule Hill Grit.

The section at Linthwaite is close behind Spring Grove Mills, and the marine band characterized by *Reticuloceras reticulatum*, mut. β occurs a few feet above a prominent bed of fireclay which rests on flaggy grit. The marine band is overlain by about 25 ft. of sandy shale with occasional plant impressions.

The Nab End Sandstone or Beacon Hill Flags.—In the north the sandstone beds which follow cover considerable areas, though they are comparatively thin. On Midgley Moor they extend northwards from High Brown Knoll but are only 20 to 30 ft. thick. The outcrop can be traced along the right bank of Luddenden Dean, the section in Cat i' th' Well Clough showing 30 ft. of massive to thinly bedded sandstone. Where the crop turns eastwards along the Calder valley it widens, and between Sowerby Bridge and Warley Town there are several quarries showing 30 ft. of good sandstone used mainly for setts.

South of the river this sandstone forms Black Wood Common above Mytholmroyd; at the north end of the common are the extensive Nab End quarries, now working only on a small scale. The rock is a thick-bedded medium-grained grit forming a good building stone. There are many small quarries in the outcrops facing the Cragg and Ripponden valleys: at Bowood, half a mile south of Hubberton Green the quarry face shows 35 to 40 ft. of fine rather flaggy sandstone used for road setts and walling. In the railway cutting east of Sowerby Bridge this bed is about 50 ft. thick.

These beds form a well-marked scarp feature along the eastern slopes of the Ryburn valley from Sowerby Bridge through High Lee Wood to Butts Clough, Rishworth. In this district they were originally described by Green as the Beacon Hill Flags.[1]

The Beacon Hill Flags form a wide spread at the Flints to the north of Soyland Moors. They were at one time extensively quarried in Greave Road close to Flints Reservoir for paving stones; they here consist of thinly laminated flags and tilestones. An outlier of the same series of flags caps the flat-topped hill known as Farrer Height, to the west of Soyland village. They also form a prominent shelf at Soyland Town where they consist of well laminated flaggy sandstones. Along the eastern side of the Ryburn valley they are everywhere overlain by a bed of fireclay and a thin seam of coal, known as the Lower Meltham Coal. On Ringstone Edge Moors the Flagstones give rise to a prominent feature at Beacon Hill. To the east of Barkisland and in the Blackbrook valley and in Beestones Wood the Beacon Hill Flags are of a very variable nature and in places contain much shale. At Beestonley Wood there is a large disused quarry where the Beacon Hill Flags were formerly worked for flagstones, paving stones and wallstones. The Lower Meltham Coal is seen in the quarry overlying the flags where the following section is revealed:—

[1] Green, A. H., 'The Geology of the Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1878, p. 61.

	Ft.	in.
Soft black shale	5	0
Fireclay	4	0
Hard band of impure ganister	4	0
Lower Meltham Coal	0	4
Fireclay with bands and lenticles of ganister ...	7	0
Flags, with thin shaly partings	25	0

The strong development of ganister rock here, notably above the coal, is of interest as it is the most northerly occurrence of a band which assumes considerable economic importance in the Meltham district, to the south of the present one-inch map. At Sowood and Sowood Green, two miles south of Greetland, the Beacon Hill Flags have been largely quarried, and consist of 30 ft. of flags with many shale partings; in some sections they exhibit powerful false bedding and in several places the laminae are highly contorted.

Cupwith Hill and Goat Hill on Slaithwaite Moors are capped with Beacon Hill Flags. At Delph Hill, half a mile east of Scammonden there are numerous quarries where they have been worked for roofing slates, setts and walling. About 20 ft. of hard flaggy cross-bedded sandstone is exposed, the lower beds being more massive and in places very hard and ganister-like.

In the Colne valley the Beacon Hill Flags vary considerably. On the north side they consist of thin flags dying out altogether to the east of Golcar. They are, however, strongly developed on the south side of the Colne valley and to the south-west of Linthwaite consist of some 30 to 40 ft. of flags overlain by 10 to 12 ft. of ganister rock which is being quarried.

The succeeding shales, 30 to 50 ft. thick, have near their base the marine band with *Reticuloceras reticulatum*, mut. γ. This band has been found in Cat i' th' Well Clough at 1025 O.D.[1] Impressions, too poor for identification were also found in the shallow excavations, where shale was procured for puddling Dean Head Reservoir, 400 yards S.S.W. of the south corner of Fly Flat Reservoir. *Lingula mytiloides* J. Sow. also occurs in a band near the top of the shale sequence in Cat i' th' Well Clough. The mut. γ band is also exposed near the head of Load Clough, which enters the Luddenden valley from the east between the village and Luddenden Foot.

A complete section of the shale series which separates the Beacon Hill Flags from the Huddersfield White Rock is well exposed at the head of Butts Clough, Rishworth. Ninety yards south-east of Clough Head Farm a 3 ft. band of fireclay overlies the flags, and above it come 45 to 50 ft. of dark shales and shaly mudstones succeeded by the flaggy layers which mark the base of the Huddersfield White Rock. The marine band characterized by *Reticuloceras reticulatum*, mut. γ lies 10 ft. above the fireclay, but impressions of *Lingula* are frequent throughout the lower 10 ft. of shale. The same beds are exposed in Bottomley Clough, Krumlin, to the south of Barkisland. At a point 150 yards E.N.E. of Bottoms Farm the following section is exposed:—

	Ft.	in.
Fine black greasy shales with *Reticuloceras reticulatum*, mut. γ, *Homoceratoides divaricatum*, *Homoceras proteum*, *Posidonomya insignis*, *Gastrioceras lineatum*	2	0
Soft dark shaly mudstones with occasional *Lingula*...	9	0
Lower Meltham coal	0	1
Hard ganister rock	1	0
Reddish yellow fireclay	3	0
Hard flaggy sandstone (Beacon Hill Flags) ...seen to	10	0

Impressions of *Reticuloceras reticulatum*, mut. , some showing sutures admirably developed, are dominant in the lower part of the marine band, while *Gastrioceras lineatum* appeared to be confined to the uppermost part of the bed.

[1]Bisat, W. S., *loc. cit.*

The same succession is seen 600 yards to the south-east in a small gully alongside Clough House Lane. This point, however, is 250 ft. higher than the preceding, so that the fault trending south-easterly from Ripponden Church towards Steel Lane Head must have a throw of at least 200 ft. to the north-east in this district.

A fine section of the shales which overlie the Beacon Hill Flags is exposed alongside the Black Brook at Bowers Mill, Barkisland. Here the Lower Meltham Coal ranges from 12 to 18 in. in thickness and rests on 3 ft. 6in. of fireclay with irregular bands of ganister rock. The marine band, which is separated from the coal by 10 ft. of shales with abundant *Lingula* impressions, is clearly in two beds, though not more than 2 ft. thick in all. In the lower portion typical specimens of *Reticuloceras reticulatum*, mut. γ, are very numerous while the upper part contains casts of *Gastrioceras* to the exclusion of *Reticuloceras*. Though seldom sufficiently well preserved for specific identification, *Gastrioceras lineatum* Wright, and *Gastrioceras ? sigma* Wright could be identified from the upper portion of this marine band. A further section of this bed is seen in the floor of the Black Brook lower down the valley, 400 yards east of Gatehead Mill. Only the upper part of the mut. γ marine band could however be recognised here, the shales being crowded with impressions of *Gastrioceras ? sigma*, *Orthoceras* and *Lingula*.

The shales underlying the Huddersfield White Rock are well exposed in a steep-sided ravine known as Gosport Clough, running northwards from Outlane. Here the marine band characterized by *Reticuloceras reticulatum*, mut. γ is found in three separate sections in proceeding down the valley, the successive sections being due to repeated faulting. The shales beneath the marine band contain abundant impressions of *Lingula mytiloides* J. Sow. and *Lingula squamiformis* Phillips.

A similar section is exposed in Red Lane Dike, a steep clough running northwards from Pole Moor to the Blackbrook valley ; this clough reveals a complete succession of the Middle Grit Series. At a point in the clough, 250 yards north-west of the Royal George Inn, the *Reticuloceras reticulatum*, mut. γ, band is exposed, and here again the upper band characterized by *Gastrioceras lineatum* is also seen (see page 150).

In the Colne valley, the best section of the beds on this horizon is seen in Heath House Clough, Golcar, 600 yards west of St. John's Church. The shales immediately overlying the Beacon Hill Flags contain numerous fish remains and impressions of *Lingula*. The band characterized by *Reticuloceras reticulatum*, mut. γ occurs about 10 ft. above. *Posidonomya insignis*, *Gastrioceras ? sigma* and *Gastrioceras lineatum* occur about 3 ft. above the main marine band. Forms practically indistinguishable from *Gastrioceras crenulatum* Bisat are here not uncommon.

Warley Rock or Huddersfield White Rock.—Overlying this shale is the Warley Rock, which gets its name from its development as a large spread over Warley Moor. It is generally a coarse massive grit, pinkish to white, current-bedded in parts, about 40 ft. thick. The Rocking Stone on Warley Moor is a weathered-out block of this bed.

A small outlying patch of this bed exists 600 yards south of the seventh milestone on the Keighley-Hebden Bridge road. Near Warley Town it is a fine white somewhat flaggy sandstone. A coal, usually 2 to 3 in. thick, occurs on the top of the sandstone.

In the upper part of the valley of the Hebble Brook there are two small outcrops of this rock, both cut off downstream by faults, near the Roman Camp and again between Brookhouse and Mixenden. Near Brookhouse the coal above the rock thickens locally and has at some time been worked. Below the Illingworth fault is a larger inlier extending below Wheatley. Here, however, the rock has become flaggy with many mudstone partings described by Spencer as " a mass of bedded rag and shale ".[1] It is somewhat of the same character under Halifax, as proved by several bores.

[1] 'Yoredale and Millstone Grit Rocks of the Upper Calder Valley,' *Proc. Yorks. Geol. and Polytech. Soc.*, vol. xiii, 1899, p. 383.

On the south of the river there is a wide spread commencing at Long Edge Moor, where it is flaggy and micaceous, becoming more gritty and massive southwards. Above Sowerby Bridge it is becoming more like that seen at Wheatley: a good section is visible in Mapledean Clough below Pickwood Scar; it is described by Spencer (*op. cit.*) as consisting, in the upper part, of raggy stone in beds of from 1 to 2 ft. thick, and in the lower of a mass of thin slaty layers, each three quarters to two inches thick. The Warley or Huddersfield White Rock can readily be traced along the eastern slopes of the Ryburn valley from Norland to High Lee Clough, Ripponden where it gives rise to a prominent escarpment. Hereabouts it consists of somewhat massive flaggy grit, with a thin seam of coal (The Upper Meltham Coal of the country to the south) and fireclay overlying it. High Lee Knowl which forms a conspicuous landmark in the Ripponden district is a small faulted inlier of this rock.

The Huddersfield White Rock consisting largely of massive flags gives rise to the prominent feature known as Ringstone Edge,[1] and forms the well-marked escarpment at Hazelgreave Hill, overlooking the Ryburn Valley. These beds form a wide spread around Krumlin and Barkisland villages where they are locally known as the Barkisland Flags. Here there are numerous large disused quarries where the beds consist almost entirely of flags and were formerly worked for paving stone. Impersistent shale partings occur, however, and the beds are of a very variable nature. Between Barkisland and Stainland the same bed is a massive reddish sandstone forming a fine escarpment at Beestonley overlooking the Blackbrook valley. The rapid variation which the Middle Grits undergo in this area was described by Green.[2]

A tentative correlation was adopted; but the discovery of the mut. γ marine band below and the *Gastrioceras cancellatum* band above the Huddersfield White Rock in this district has enabled us to substantiate in the main the details of Green's original mapping. Around Outlane, Slack, and on Outlane and Pole Moors the Huddersfield White Rock forms a broad upland plateau. It is here a mass of sandstone and rag, false-bedded in places and containing shale bands which become more numerous towards the base; according to Green it reaches a thickness of 150 ft.,[3] though this figure would appear excessive, unless it includes the thick alternations of sandy shale and flagstone that underlie it. In this district the Upper Meltham Coal becomes of some importance and has been worked in the past on Pole Moor, where, however, it was stated seldom to exceed 1 ft. in thickness. Around Worts Hill and Delph Hill there are numerous overgrown crop workings in this coal.

The Huddersfield White Rock covers large areas on both sides of the Colne around Golcar and Linthwaite. South of Pole Moor it constitutes Moorside Edge and Bolster Moor, while a wide spread occurs to the north and east of Golcar, forming Golcar Flat and Leymoor.

Large disused quarries occur at Moorside Edge, Bolster Moor and Golcar, where the rock is a false-bedded yellow gritty sandstone, locally referred to as Golcar Rock.

At Guy Edge and Broad Oak, Linthwaite the Huddersfield White Rock has been worked as a building stone. The Upper Meltham Coal here overlies the rock and in the construction of Blackmoorfoot Reservoir the following section of it was exposed:—

		Ft.	in.
	Black shale	10	0
Upper Meltham Coal	Coal		9
	Fireclay		2
	Coal	1	4
	Hard ganister rock	½ to 1	
	Fireclay	5	6
	Flaggy sandstone (Huddersfield White Rock)	—	—

[1] Referred to by Green as the Ringstone Edge Grit. 'Geology of the Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1878, p. 61.
[2] *Op. cit.*, p. 61.
[3] *Op. cit.*, p. 59.

The Rough Rock Series

The thick shale series succeeding the Warley or Huddersfield White Rock may be conveniently regarded as part of the Rough Rock Series, for it constitutes the lowest portion of the *Gastrioceras* Zone of Bisat (see page 20). The shales varying in thickness from about 130 ft. in the north to 225 ft. in the south contain two marine bands characterized by forms of the genus *Gastrioceras* known respectively as *Gastrioceras cancellatum* Bisat and *G. cumbriense* Bisat. For brevity these bands are referred to as the Cancellatum and Cumbriense bands.

In the north a thin coal has been found about 50 ft. above that capping the Warley Rock; it is visible in Skirden Clough, 400 yards west of the west point of Ogden Reservoir; the Cancellatum marine band is 20 to 30 ft. above this coal and the Cumbriense band a further 30 ft. up.

At Square Mill, on the west side of Hunter Hill, north of Wainstalls a trial excavation for coal turned up shale containing fossils of the lower marine band, and the upper band is exposed in the bank above, where it is a thin, 1 to 2 in., sooty black band of decalcified shale. On the opposite side of Hunter Hill, in Slaughter Gap, 650 yards N.N.W. of the north end of Mixenden Reservoir, both bands are exposed. Elsewhere in the district one or other of the bands is exposed alone. Thus the Cancellatum band can be seen in the two Cloughs, Ogden and Skirden, which feed Ogden Reservoir, and again in the stream below the Golf Club House, Ogden, 600 yards south of the reservoir dam. In Wamesley Scar, a small deep clough at the north end of Hunter Hill, the Cumbriense band is exposed.

A band of shale full of fish scales (*Rhizodopsis sauroides* Will.) was discovered near the top of this shale group, 100 yards south of Upper Height, 900 yards N.W. of Wainstalls Chapel.

In the fine escarpment extending from the west slope of Mount Tabor past Halifax to the junction of the Hebble and Calder no exposures of the marine bands were discovered, but in that facing the Wheatley valley the Cumbriense band is exposed in Dodgson Clough, quarter of a mile north-east of the hospital on High Road Well Moor.

On the south bank of the Calder the same band is visible at Upper Wat Ing, Norland Town, again close to a Small Pox Hospital.

In the thick shale series which intervenes between the Huddersfield White Rock and the Rough Rock Flags at Longley and Upper Greetland a thin but distinct group of flagstones occurs between the Cancellatum and Cumbriense marine bands. These we have termed the Moorside Flags (see page 21). They appear to be a local representative of the great mass of flagstones developed on this horizon in East Lancashire.[1] From Clough Head, Norland, they can be traced to Gallows Pole Hill, and thence eastwards past Greetland Wall Nook towards Greetland village where they gradually die out, being replaced by sandy shale and mudstone. The same band of flags forms a small but distinct shelf on the opposite side of the Blackbrook valley to the north of Stainland.

Around Wholestone Moor and Worts Hill a thick unbroken series of shaly mudstones forms a well marked concave slope between the Rough Rock above and the Huddersfield White Rock which forms the flat plateau known as Outlane Moor and Golcar Flat. They are here 200 ft. thick with the Upper Meltham Coal which has been worked (see page 44) at the base and also contain the two marine bands characterized respectively by *Gastrioceras cancellatum* and *G. cumbriense*. The upper band is only an inch or so thick and is rarely exposed, though the lower band with *G. cancellatum* can generally be recognized throughout the district about 15 ft. above the Upper Meltham Coal. The best natural section is seen in the lower part of a steep ravine in Bonny Wood Clough, Leymoor. The Upper Meltham Coal here rests on a thick fireclay, and a short way above the shales are crowded with impressions of *Gastrioceras cancellatum*. Higher in the clough fossiliferous blocks from the

[1] 'The Geology of the Rossendale Anticline' (*Mem. Geol. Surv.*), 1927.

Cumbriense band occur, though the actual position of the marine band is obscured by extensive screes and slips.

A fine exposure of the shales underlying the Rough Rock is seen in Dean Clough or the 'Big Valley', a steep sided ravine running past the north of Netherton to Armitage Bridge. In the lower part of the valley, 150 yards south-west of Delves House the Cumbriense band occurs about the level of the stream and there are several excellent natural exposures of this marine band.

Rough Rock Flags.—The shales pass up gradually into flaggy sandstones with shale partings, the lowest beds of the Rough Rock Flags. These flags form a large part of Ovenden Moor and the whole of the outlier of Hunter Hill, and also cover a considerable area around Mount Tabor: elsewhere there is only a narrow outcrop below the true Rough Rock: the thickness from Ogden to Halifax is usually about 40 ft. They have been largely quarried at Delph Hill, north-west of Mount Tabor, and at Sentry Edge to the south. Between them and the Rough Rock is a parting of grey shale and mudstone 10 to 4 ft.; this can be traced from Sentry Edge round the west side of Halifax to the Hebble and along both sides of that valley; but on the east below Exley it is not more than 1 ft.; the top part of the Flags is becoming coarse and gritty, and at the western end of Elland railway tunnel no line can be drawn between the Flags and the Rough Rock. In the boring at Brookfoot near Brighouse (page 193) the whole series amounts to 72 ft. with no division.

South of the Calder there is a small outlier of the Flags capping Crow Hill between the Cragg and the Ryburn valleys. On Norland and Greetland Moors, the Rough Rock Flags are separated from the Rough Rock above by a 4 ft. parting of shale with many plant remains At Pickwood Scar 40 ft. of flags are seen, but in North Dean above Copley they swell out to almost 100 ft. in thickness. On the southern edge of Greetland Moor they are less than 50 ft. thick, and are being extensively quarried as 'Greetland Stone' (see page 184).

At Holywell Green and Stainland the Rough Rock Flags have disappeared, the base of the massive Rough Rock resting directly on shaly mudstone.

Along Longwood Edge and at Wholestone Moor the lowest beds of the Rough Rock assume a flaggy nature and have been separately mapped. A small outlier of Rough Rock Flags forms a conspicuous knoll known as Worts Hill to the west of Pole Moor.

In Quarmby Clough, Longwood, an 18 in. shale parting again appears between the massive Rough Rock and the underlying flaggy grits. These flaggy beds are well developed in the gorge of the Colne at Milnsbridge. Along the north-western slopes of Crosland Moor the lower beds of the Rough Rock are flaggy, but the line of demarcation is very indefinite. In the extensive quarries on Crosland Hill (see page 184) the Rough Rock Flags appear to be practically unrepresented.

The Rough Rock.—This rock always consists for the most part of coarse pebbly grit; in a large quarry north of Commercial Road, Halifax and occasionally elsewhere pebbles of hard shale occur as well as of quartz. The outcrop frequently consists of a line of prominent crags, as on the east side of the valley above Mixenden and Wheatley or again on the west of Halifax, as at Scar Wood (frontispiece); in some of these as much as 50 ft. is exposed. The rock has been largely quarried, and is now mainly used for road setts and curbs, as at the quarry in Halifax just mentioned. The grit is well exposed in the railway cuttings between Halifax and the Calder.

Norland and Greetland Moors constitute a large outlier of the Rough Rock with a prominent escarpment to the west overlooking the Ryburn valley. Norland Edge consists largely of crags and stacks of coarse-grained massive grit, one of the more prominent isolated blocks being locally known as the 'Ladstone.'

At Elland, the River Calder flows through a well-marked gorge produced by the Rough Rock, which gives rise to prominent crags on both sides of the valley. It also forms a marked feature at Nab End and Hullen Edge but the

scarp feature ends abruptly at Broad Carr, where it is cut off by faulting. Around Elland the Rough Rock is about 140 ft. thick.

At Stainland and Holywell Green the Rough Rock forms a pronounced feature. There are many large quarries in it along the northern escarpment but they have been long disused. In general it is very massive and coarse in grain. Badly preserved plant remains, especially impressions of *Calamites*, *Sigillaria*, and *Stigmaria* are fairly common.

The prominent hill known as Wholestone Moor consists of an outlier of the Rough Rock, which is still quarried somewhat. Several isolated stacks such as the ' Holestone,' the ' Rocking Stone ' &c., locally regarded as Druidical remains, have been removed within recent years. The Rough Rock forms by far the most conspicuous features in the landscape to the west of Huddersfield. From Lindley Moor past Longwood Edge and along the western slopes of Crosland Moor to Blackmoorfoot, it gives rise to a pronounced escarpment, breached only by the River Colne to the east of Milnsbridge. Usually it is a massive, somewhat incoherent grit and in the railway cuttings at Paddock is intersected by several powerful oblique planes along which the grit is shattered, but along which no apparent displacement has taken place.

At Crosland Moor the Rough Rock is being extensively quarried as a building stone, and the majority of buildings in Huddersfield are built of this stone (see page 184). Stone quarrying in fact still constitutes an important industry in this district. There are also numerous quarries around Netherton but the majority of these are now standing. A fine section of these beds is seen in Beaumont Park, Huddersfield, where a former line of quarries has been laid out as public gardens. The Rough Rock also forms prominent features along both sides of the Holme valley at Armitage Bridge and Berry Brow. In the latter locality plant impressions are not infrequent, and some large tree casts from this rock are to be seen at Berry Brow railway station.

CHAPTER III

LOWER COAL MEASURES

Introductory

In the Lower Coal Measures we have included the beds from the top of the Rough Rock to the Blocking Coal. This coal is known by a variety of names in different parts of the field, of which the most important is the 'Silkstone,' used in South Yorkshire and to some extent in Derbyshire and Nottinghamshire: unfortunately this name has sometimes been used in West Yorkshire for a higher seam here termed the Middleton Main;[1] and, further, there is room for some doubt as to the exact correlation of the West Yorkshire and South Yorkshire Measures. The name Blocking Bed is in use throughout the area here described, and is therefore exclusively employed throughout the present memoir. During the original survey of the district, the Blocking Coal was adopted as the line of subdivision between the Lower and Middle Coal Measures, and this classification has been universally employed in all subsequent descriptions of these measures. Recent researches have however shown that it is doubtful whether this horizon can be strictly correlated with that adopted in the Lancashire and other adjoining North Midland coalfields. A detailed study of the corresponding measures proves that the Arley Mine of Lancashire and the Better Bed coals of Yorkshire are more closely related and would probably make a more suitable line of subdivision between the Lanarkian (or Lower Coal Measures) and the Yorkian[2] Series (or Middle Coal Measures) of Kidston's classification.[3] The Better Bed Coal, however, appears to be unrepresented in parts of South Yorkshire, and consequently such a datum line would be difficult to trace. There is also by no means general agreement as to which line of subdivision should be adopted in North Staffordshire; and here again a purely conventional boundary has been adopted.[4] It seems inadvisable, therefore, in the present state of our knowledge, to make any modification in the existing conventional classification, and especially as it has been extensively employed in the past.

[1] Green, A. H., 'The Geology of the Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1878, p. 247; and Kendall, Prof. P. F., 'Correlation of certain seams in the Yorkshire Coalfield,' *Trans. Inst. Min. Eng.*, vol. liv, 1917, pp. 67–76.

[2] Originally Westphalian. The term Westphalian was first proposed by De Lapparent, and Dr. Kidston's application of it in a different sense is unfortunate. Professor Watts' suggestion to substitute the term *Yorkian* will avoid confusion, and is much to be preferred. See Watts, W. W., *Geol. Mag.*, 1922, p. 238.

[3] Wray, D. A., 'The Carboniferous Succession in the Central Pennine Area,' *Proc. Yorks. Geol. Soc.*, vol. xxi, 1929, pp. 275-285. An abstract of this paper appeared in *Rep. Brit. Assoc.*, 1927, pp. 329, 330.

[4] See especially, Davies, J. H. and A. E. Trueman, 'A Revision of the Non-Marine Lamellibranchs of the Coal Measures and a Discussion of their Zonal Sequence,' *Quart. Journ. Geol. Soc.*, vol. lxxxiii, 1927, p. 254.

The Lower Coal Measures, thus defined as the measures between the top of the Rough Rock and the Blocking Coal attain a thickness of about 1,500 ft. ; in the north it is less, being estimated at 1,170 ft. near Birkenshaw and 1,210 at Farnley where a boring has reached the Rough Rock. At Calder Colliery, south of Ravensthorpe, it is proved by a boring to be 1,500 ft. ; to the south of the River Calder in the Huddersfield district it is approximately the same.

The Elland Flagstones form by far the most conspicuous horizon in the Lower Coal Measures, and they give rise to a fine escarpment which can be traced from Queensbury past Halifax to Elland Edge. To the east and south-east of Huddersfield they form striking features around Almondbury (Plate IVA) and Kirkheaton. The Elland Flags conveniently divide the measures into two groups: below them the fireclays and ganisters are of more importance than the coals, above them the position is reversed. The lower beds are sometimes referred to as the Ganister Group. A complete section of these beds in the Elland district is shown in Fig. 4.

General Stratigraphy

Measures below the Hard Bed Coal.—Immediately on the Rough Rock lies a thick fire-clay with a thin but very persistent seam of coal, the *Thin Coal* of the Halifax district, which is known throughout South Yorkshire as the Pot Clay Coal, owing to the high value of its underlying seat-earth as a refractory fire-clay. The roof of the coal consists of black shales containing abundant fish remains, and about one foot above numerous impressions of *Pterinopecten papyraceus* (J. Sow.) and the goniatites *Gastrioceras subcrenatum* (Schlotheim) and *G. listeri* (Martin). In some localities this shale band contains bullions or concretions enclosing uncrushed goniatite shells.

The next coal is known as the ' Soft Bed ' ; in the north it is separated from the Thin Coal by hardly more than 100 ft. of shale, but around Huddersfield a thick bed of sandstone known as the ' Soft Bed Flags ' immediately underlies it ; these flags may have a maximum thickness of 150 ft. with 30 or 40 ft. of shales below. The Soft Bed Coal is the lowest workable seam in the Coal Measures ; it is also known as the Coking Coal in the district to the south. It is usually about 18 inches thick and has been worked to a considerable extent from the outcrop.

The distance from the Soft Bed to the Hard Bed Coal is 70 to 90 feet ; from the Rough Rock to the Hard Bed is about 175 ft. at Halifax and 115 ft. in the north-east, as shown by the Farnley boring (p. 192). In these measures there is nothing of commercial importance, though there are several features of geological interest. 10 or 12 ft. above the Soft Bed there is invariably a prominent band with *Carbonicola*, which has been traced over a very wide area ; the species found during the re-survey are *Carbonicola acuta* (J. Sow.) and *C. aquilina* (J. de C. Sow.). Another feature is the wide-spread occurrence of a coal usually referred to as the Middle

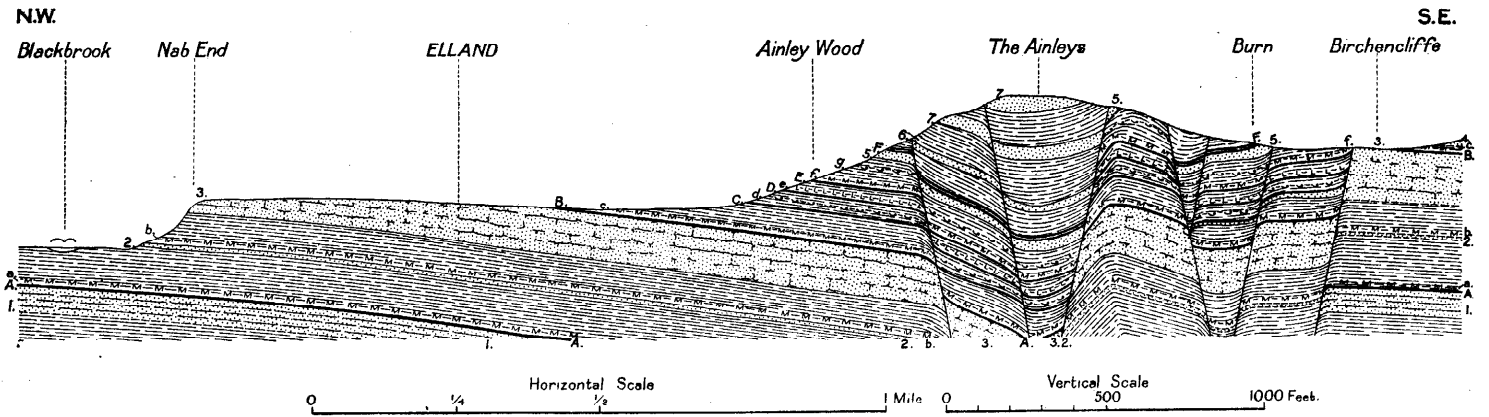


Fig. 4.—*Section through Elland and Birchencliffe to illustrate the effect of the Stainland–Birchencliffe fractures.*

1. Huddersfield White Rock. 2. Moorside Flags. 3. Rough Rock. 4. Soft Bed Flags. 5. Hard Bed Band Rock. 6. 80-Yard Rock. 7. Elland Flags.

A. Upper Meltham Coal. B. Pot Clay Coal. C. Soft Bed Coal. D. Middle Band Coal. E. Hard Bed Coal. F. Hard Bed Band and 36-Yard Coals.

a. Marine Band with *Gastrioceras cancellatum.* b. Marine Band with *Gastrioceras cumbriense.* c. Marine band with *Gastrioceras subcrenatum.* d. '*Carbonicola*' band. e. '*Lingula*' band. f. Marine band with *Gastrioceras carbonarium.* g. '*Carbonicola*' band.

Band, though the name Clay Coal is sometimes used here and is usual to the south ; it is normally 6 to 12 inches thick. Sometimes it rests on a sandstone called the Middle Band Rock, which is prominent in Huddersfield, where it may be as much as 30 ft. thick, the top being almost a ganister ; the rock is only 4 ft. thick near Halifax and is not traceable to the north until Soil Hill [1] is reached ; here the coal has the unusual thickness of 1 ft. 8 in. to 2 ft. 6 in. and has been worked under the name of ' Rattlers', while the rock has also swelled to 8 ft. In the fine black shales which overlie this coal fish scales and teeth are abundant in places, and south of Huddersfield *Lingula* has been found on this horizon.

The Hard Bed Coal.—This important seam is also known as the Halifax Hard Bed and the Ganister Coal. By means of its ganister floor and marine roof it can be identified not only throughout the Yorkshire-Nottinghamshire-Derbyshire coalfield, but also in Lancashire, where it is known as the Bullion Mine, and in North Staffordshire. The ganister has been largely worked in the past, but to-day the fireclay which underlies it is the more important ; where the clay is mined the ganister is often left in as a roof. The Hard Bed seam, being usually of a sulphurous nature, is only an inferior coal, and is mainly employed as an engine coal ; an average section is as follows : Coal 2 ft. 3 in., ganister 8 in., fireclay 4 ft., but the ganister and fireclay are variable, and the former is sometimes absent altogether.

One of the most remarkable features of the Hard Bed Coal is the sporadic occurrence of spherical concretionary masses, known as ' coal balls ' or ' bullions ' within the body of the seam in several districts. The coal-balls or bullions found in the coal seam contain plant remains only, while the roof nodules, or ' baum pots ' as they are sometimes called, yield both plant remains and solid specimens of goniatites and *Pterinopecten*, etc. The coal balls are generally of a calcareous nature, though sometimes dolomitic, pyritous or siliceous ; they enclose fragments of the coal-forming plants in an uncrushed condition, all the delicate plant tissues including even phloem, endodermis, etc., being so perfectly preserved that the complete structure of the plants can be investigated by the microscope. Fifty years ago they were assiduously collected from the Halifax district by enthusiastic local geologists, including Cash and Hick ; and they furnished the material for the classic researches of Williamson, which laid the foundations of the modern science of palaeobotany.

The nature and origin of the coal balls and roof nodules which occur associated with the corresponding seam in East Lancashire, the Bullion Mine, have been closely investigated by Dr. Stopes and Professor Watson.[2] It is clear from their researches that the

[1] Swilling Hill of Old Series map and Swilling or Swill Hill in ' Geology of Yorkshire Coalfield.'

[2] Stopes, M. C., and D. M. S. Watson., ' On the present distribution and Origin of the Calcareous Concretions in Coal Seams known as " Coal Balls ",' *Phil. Trans. Royal Soc.*, Ser. B, vol. cc, 1909, pp. 147-218.

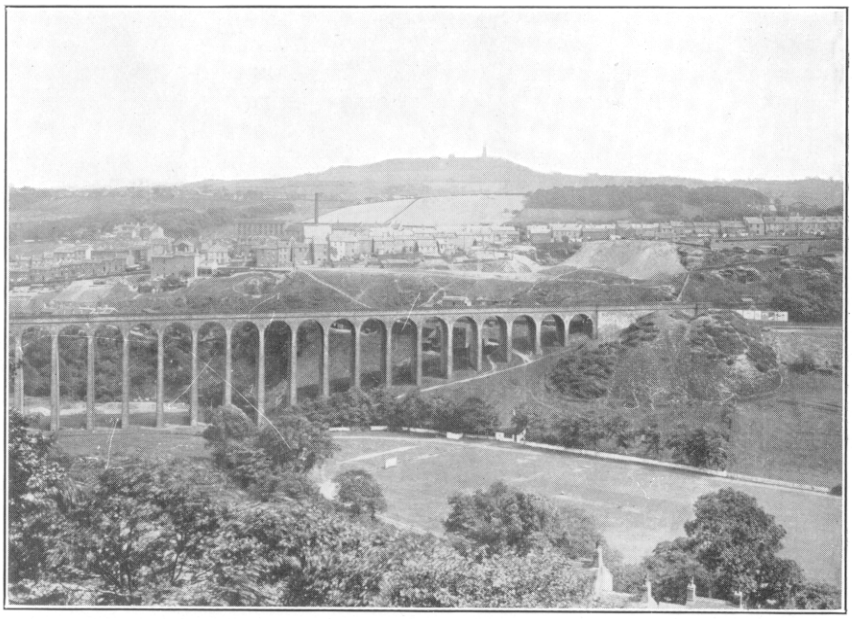
presence of salt water for a prolonged period, as indicated by the marine roof, is essential to the formation of coal-balls. It has recently been suggested that sodium chloride is necessary for the formation of coal itself from vegetable debris,[1] though the Hard Bed, the Thin Coal overlying the Rough Rock, and possibly the Middle Band Coal in some areas, are the only seams here dealt with that can be definitely regarded as having a marine roof.

The shales above the Hard Bed Coal for a distance of about 10 ft. contain abundant marine fossils, notably *Pterinopecten papyraceus* and *Gastrioceras listeri* (see page 153). As in the coal, calcareous and pyritous nodules described as ' baum-pots ' or ' bullions ' are common. In the shale the fossils are crushed flat, but in the nodules they are preserved in their original form; the formation of the nodules must therefore have been almost contemporaneous with the deposition of the mud which forms the shales. The pyritous masses were formerly collected for use in the manufacture of sulphuric acid, but when this by-product ceased to be valuable, the working of the coal in some districts came almost to an end.

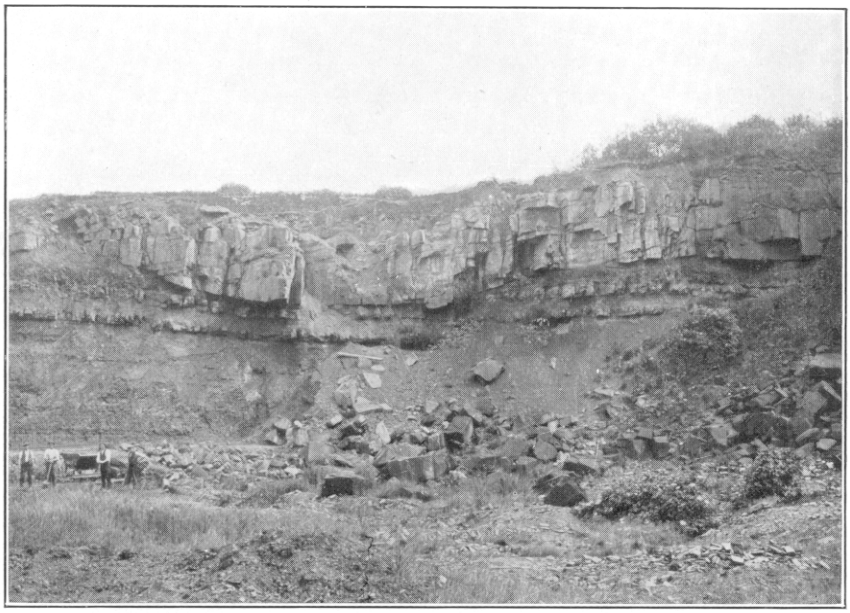
From the Hard Bed Coal to the Elland Flags.—Above the marine band is a series of hard siliceous shales or mudstones 100 to 120 ft. thick which contain a *Carbonicola* band in the upper part. They are followed by a coal seam with a valuable fireclay known as the ' 36 Yard Band ' (from its approximate distance above the Hard Bed), the ' Hard Bed Band,' or simply the ' Band ' Coal. The re-survey has shown that there are really two coals only a few feet apart, but as they do not overlap except for a short distance near Elland (p. 69) they may for practical purposes be regarded as a single seam. The name 36 Yard Band is prevalent to the north and Band Coal to the south of the Calder valley. The fireclay is worked to a considerable extent between Halifax and Brighouse and at Elland. In the north the coal is usually 10 inches, the fireclay round about 4 feet, and below this the mudstone is often so hard and siliceous as to be called a ganister or galliard for as much as 20 feet. In the south the clay below the Band Coal is known as the ' Blue Clay ' in contrast with the ' White Clay ' below the Hard Bed; in some places it is as much as 18 ft. thick. After about 35ft. of shales with some ironstone nodules a thin coal known as the ' 48 Yard ' is found: it seldom exceeds 8 in. and the fireclay is inferior; north of Halifax the coal was worked long ago at Booth Town where the thickness was 10 to 14 in. Further north a sandstone comes in at this horizon; at Soil Hill it forms a thin capping which, when traced north and north-east rapidly develops into a 40 ft. bed of stone called the ' 60 Yard Quarrel,' at the same time cutting out the 48 Yard Coal.

Above this coal is about 80 ft. of dark shale followed by a flaggy sandstone known as the ' 80 Yard ' or ' Upper Band Rock,' the names being taken from the overlying coal which is roughly 80

[1] Taylor, E. McK., ' Base Exchange and the formation of Coal,' *Nature*, vol. cxx, Sept., 1927, pp. 448, 449.



A.—LOWER COAL MEASURE SCENERY; THE HOLME VALLEY, TAYLOR HILL AND CASTLE HILL, HUDDERSFIELD



B.—THE OAKENSHAW OR CLIFTON ROCK, RESTING ON MEASURES WITH THIN COALS (32 YARD, 22 YARD AND CROW COALS) HAYCLIFFE HILL, BRADFORD

To face p. 52.

yards above the Hard Bed Coal. The rock is 12 to 20 ft. thick but in the north is hardly more than rag, though it forms a slight escarpment near Old Dolphin and Stubden Head; it is a flaggy sandstone at Elland Park and Elland Edge and becomes a stronger rock south of Huddersfield at Stirley Hill. The 80 Yard Coal does not exceed 6 in. and may be absent, while the fireclay is 6 ft. in the north and 2 to 4 ft. in the south.

The shales above the 80 Yard Coal pass gradually through sandy shales and alternations of shale with thin flags into the Elland Flagstone; there is no definite boundary, but for convenience 75 to 80 ft. of measures may be reckoned before the base of the flagstone is reached.

The Elland Flags.—The Elland Flags, so named by Green and his colleagues and originally described by Phillips as the Flagstone Rock, constitute a well-marked and clearly defined horizon in the Lower Coal Measures. They give rise to a bold escarpment, and owing to their wide lateral extent can be traced with ease and certainty throughout the coalfield. They are also almost certainly represented by the Wingfield Flagstones in Derbyshire, the Alton Rock in North Staffordshire and the Upholland Flags in Lancashire.[1]

Topographically they form the most conspicuous feature of the present district, since the escarpment which they cap often extends down without a break to the Rough Rock, about 500 or 525 ft. below. Economically they are of importance as yielding a stone which not only makes excellent flags for paving, as the name implies, but can also be obtained in extensive slabs suitable for staircase landings and such purposes which are sent almost all over the country (p. 185). In some places they are thickly bedded and yield a good building stone.

The escarpment capped by the lower part of the Elland Flags runs from near Mountain in the north through Pule Hill, Stump Cross and Bank Top overlooking Halifax; it is breached by the Calder valley, descending through Elland Park to the river at Brighouse; thence by Elland Edge, Fixby, Cowcliffe and Sheepridge to the Colne valley. From Colnbridge to Kirkheaton the flags form a scarp overlooking the Colne and Burton valleys and south of the confluence of those streams they occupy the high ground at Almondbury (Plate IVA).

The beds usually fall into two main divisions separated by about 60 ft. of shale or mudstone; the lower and more important may be 100 to 120 ft. thick and the total thickness about 220 ft. The lower beds have been very extensively quarried and occasionally mined throughout the area, the principal centre of activity being now at Hipperholme (Plate VA); beds of stone are separated by mudstone partings which often contain much carbonaceous matter; some yield good freestone and flags, others being much affected by current-bedding, ripple-marks and 'worm-tracks.' From quarries at Fall Top

[1] Hull, E. and A. H. Green.,' Explanation of Horizontal Sections, Sheet 60' (*Mem. Geol. Surv.*), 1869, p. 3; also Wray, D. A., *op. cit.*, p. 271.

near Queensbury [1] station several large fossil tree-stumps have been obtained.[2] One stump of *Stigmaria ficoides* now in the quadrangle of Manchester University has a height of 3 ft. 9 in. with a maximum diameter of 4 ft. 6 in.; other large specimens are in Horton and Bowling Parks, Bradford.[3]

The beds outcrop in a small area in the north-east between Tong and Gildersome; in the boring at Farnley (p. 192) there are three beds of stone, of which the lowest is about 60 ft. thick, separated by thick bands of shale; the total thickness is 214 ft.

The Better Bed Coal.—Separated from the top of the Elland Flags by a varying thickness of shale is the important seam known as the Better Bed Coal; in the north the shale is about 30 ft. thick at the outcrop near Queensbury and as far south as Stone Chair, 22 ft. at Clayton Heights, 10 ft. near Great Horton and only about 5 ft. at Farnley. In the Calder valley it is almost 80 ft. near Brighouse and at Bradley Park between Bradley and Rastrick, but in the Calder Colliery boring near Ravensthorpe the fireclay seems to be immediately on the top of the flags,[4] as is the case in the south at Fenay Bridge, Rowley and Highburton.

The Better Bed is the most famous of the coal seams occurring in the district. On account of its extreme purity, more particularly the low sulphur content, it has been largely worked for smelting purposes by the Low Moor Iron Works, and is nearing exhaustion (p. 74). Unfortunately, as traced eastward under an increasing cover the seam thins, though the additional value of the underlying fireclay has enabled it to be worked where little more than a foot thick. In the north the coal is 3 ft. thick at the outcrop near Queensbury station, but at Tong, six and a half miles to the east it is only 1 ft. 3 in. The fireclay is of good quality (p. 180) but variable thickness, 6 ft. at Brayshaw Reservoir and only 1 ft. at Horton Bank; it is a little over 2 ft. where worked by the Farnley Iron Co. Between Clifton and Hartshead the coal is usually 1 ft. 5 in. though 2 ft. 5 in. is recorded at Flatts Pit. It is 1 ft. 2 in. at Liversedge, 1 ft. at Ravensthorpe, 10 in. at Batley West End and at Thornhill, but at Shaw Cross east of Dewsbury it is again 1 ft. $3\frac{1}{2}$ in. In the south it is 1 ft. 6 in. at Highburton but dies out immediately south of Kirkburton; the fireclay about 4 ft. 6 in. thick persists.

The structure of the Better Bed Coal was investigated microscopically by Huxley [5] in 1870 and more fully by Wethered in 1886,[6] but the great advances in this method necessitate re-examination; the chemistry is described on p. 176. The roof of the Better Bed Coal is frequently a bone-bed containing many remains of

[1] Queenshead of old map and memoir.

[2] Williamson, W. C., 'Monograph of the Morphology and Histology of *Stigmaria ficoides*,' *Pal. Soc.*, vol. xl. for 1886, 1887.

[3] Adamson, S. A., *Trans. Leeds Geol. Assoc.*, 1885, p. 71.

[4] 'Sections of Strata of the Yorkshire Coalfield,' *Midland Inst. Min. Eng.*, 2nd Ed., 1927, pp. 86, 87.

[5] 'On the Formation of Coal,' *Contemporary Review*, vol. xv, 1870, pp. 618—629.

[6] Structure and Origin of Carboniferous Coal Seams,' *Journ. R. Microscop. Soc.*, vol. v, 1886, pp. 406-420.

fish with some labyrinthodonts (p. 163). This bed is only a quarter to five-eighths of an inch thick and presents the appearance of a brownish-black argillaceous shale easily distinguished from the light-bluish shale above.[1] The late J. W. Davis investigated the fish fauna of this bed and obtained most of his material from the Clifton district.

Between the Better Bed and the Black Bed Coals is about 120 ft. of strata, consisting mainly of shale and mudstone. Around Kirkheaton a band with abundant impressions of *Carbonicola* and *Naiadites* is found a short distance above the Better Bed. In the upper part of this series there is usually a fairly prominent sandstone known as the *Thick Stone*. In the north a thin coal occurs rather below the middle of the section; at Wibsey it is 2 ft. thick and 56 ft. above the Better Bed Coal; round Low Moor, where it is known as the Better Bed Band Coal, it is 45 ft. above that seam; the name '14 Yard Coal' has also been used for this seam, but is more often applied to one higher in the sequence; at the Bowling Iron Works it is only 3 in. thick and is 34 ft. above the Better Bed. At Wibsey the Thick Stone is 35 ft. thick and its top lies 11 ft. below the Black Bed Coal, but eastwards it becomes thinner and nearer to the coal. At Low Moor the Thick Stone is about 27 ft. thick and 27 ft. below the Black Bed. Around Clifton, Bradley, Upper Heaton and Gawthorpe nothing but shale and mudstone is traceable between the Better Bed and the Black Bed Coals, the mudstones being largely worked for brickmaking at Cowmes. At Gawthorpe Green, however, a variable sandstone corresponding to the Thick Stone of the north reappears; the outcrop can be traced past Fenay Bridge to Far Dean, Highburton, where it forms a distinct shelf below the prominent scarp of the Grenoside Rock; it is here 20 ft. thick and 30 ft. of shale intervenes between it and the Better Bed Coal. In the Addlecroft boring, Gawthorpe,[2] this sandstone was found to be 35 ft. thick; it was about the same at Ravenslodge Colliery, between Ravensthorpe and Dewsbury, but was apparently unrepresented at Ingham's and Combs pits, Thornhill.

The Black Bed Coal.—The Black Bed is now the most economically important seam in the Lower Coal Measures of the district. Its thickness varies from 1 to 3 ft., sometimes including a dirt parting. Where it lies at comparatively shallow depths it is practically worked out, but farther eastward it is being actively developed at such pits as White Lee and Mirfield Moor; in the extreme east it is worked at depths of 811 ft. at Howden Clough, 1,200 ft. at Soothill Wood and 957 ft. at Combs. The coal is thickest in the north-west and thins to the east and south. At Beldon Hill, between Great Horton and Shelf, and again between Norwood

[1] Davis, J. W., 'Bone-Bed in Lower Coal Measures,' *Quart. Journ. Geol. Soc.*, vol. xxxii, 1876, pp. 332-340.

[2] This boring is frequently quoted by Green in 'Geology of the Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1878, pp. 130-201, but no details as to exact location are given. It is alongside the junction of Lucy Lane and Botany Lane, Gawthorpe, and 700 yards due west of Lodge Mill Colliery. Indicated on new six-inch geological map Yorkshire 247 S.W.

Green and Wyke it is 3 ft.; around Wibsey and Low Moor 32 to 34 in.; Tong Street, Toftshaw, East Bierley and Hunsworth 24 to 29 in. Around Farnley the lower part of the seam is an inferior stone coal (Johnnies) and the good coal 15 to 24 in. A dirt parting 1½ in. thick in the coal is recorded from Tunnel Pit, beside the tunnel between Low Moor and Bowling; in the railway cutting west of Tyersall Gate the section is coal 1 ft. 10 in., dirty coal 6 in., and at Batley West End coal 1 ft. 6 in., stone 2 in., coal 4 in. Otherwise the coal in the northern part of our area is free from dirt. In the Clifton district the thickness is usually 2 ft. 6 in., but 2 ft. 9 in. is recorded at Green Lane and 3 ft. 1 in. at Coates Pits. It is 2 ft. to 2 ft. 3 in. at Liversedge and Heckmondwike, but 2 ft. 6 in. round Mirfield, 2 ft. 7 in. at Calder Colliery, 2 ft. 3 in. at Ingham's and 2 ft. 6 in. at Combs.

South of the Calder the seam is frequently split by a dirt parting; at Bradley Park there is 2 ft. 6 in. of good coal, but at Heaton Hall, on the outcrop half a mile south-east of Upper Heaton the section is: top coal 1 ft. 6½ in., dirt 1 in., bottom coal 5½ in. At Highburton and Kirkburton the tops and bottoms are each 9 in. and the dirt 3 in. In this area the seam is often known as the Tinker Coal and immediately underlies the Grenoside Rock. At Linfit the tops are 1 ft., dirt about 1 in., and bottoms 6 in. thick.

The value of the Black Bed is somewhat marred by frequent 'washouts.' In the north an important instance was described 50 years ago. "Evidence of what appears to be the site of an old river is seen in the workings of the black bed, where the ironstone, which lies immediately above the coal, appears to have been washed away, and a sandstone deposited in its place. This 'washout," or what is technically known as 'rock roof,' runs in a southerly direction from the outcrop near Beldon Hill, across Wibsey Slack, Buttershaw and Royds Hall, to Lower Wyke, where it joins another 'washout' of the same description, running in an easterly direction from the outcrop at Lightcliffe, through the townships of Wyke, Oakenshaw and Hunsworth, as far as the black bed coal has been worked. The width of the 'washout' varies from 100 to, say, 300 yards, and in some places the coal is partly, and in others totally washed out, and the sandstone formed in its place."[1]

Another small washout has been traced by the Low Moor Company in the Hartshead area; it begins a quarter of a mile south of the cross-roads at Hartshead Moor and runs east-south-east for a distance of half a mile to the great fault through Mirfield Moor and Scholes. The Black Bed was worked to the east of the fault by Strawberry Bank Colliery, but there is no indication of the 'washout' on the plans deposited with the Mines Department. The width near the fault is little more than 100 yards. Another 'washout'

[1] Cudworth, W., 'Round about Bradford,' Bradford, 1876, p. 56.

hardly exceeding 100 yards in width has been traced south of the Calder from near Upper Hopton in a nearly straight line slightly north of east to Calder Colliery, a distance of two and a half miles. As far as the scattered evidence is available, it would appear that a system of streams converging towards Dewsbury existed in this area during or immediately subsequent to the deposition of the Black Bed Coal.

From the Black Bed to the Shertcliffe and Beeston Coals.—The measures succeeding the Black Bed Coal are of widely different character in the north of the present area from those found in the south. North of Colnebridge and Kirkheaton the famous *Low Moor Ironstones* occur on this horizon; while in the south a somewhat massive gritty sandstone, the *Grenoside Rock* immediately overlies the Black Bed Coal. A common horizon may be found, however, in the Crow Coal of the north and the Grenoside Sandstone Coal of the south, which are probably equivalent.

(1) *The Northern Area.*—Between Bradford and Colnebridge the Black Bed is succeeded by shales which contain numerous bands of nodules and above these thin continuous layers of clay ironstone: these were formerly of great importance as a source or iron ore and gave rise to the Bierley, the Bowling and the Low Moor Iron Works (p. 173): the measures are 8 to 10 ft. thick, the bottom 4 to 6 ft. being the richest and known as the 'working measures'; the total thickness of iron ore does not exceed 22 inches and is often considerably less. Sections of the ironstone measures are now rare but have been faithfully recorded in detail in the past.[1] "Each of the layers is generally known by some local name, derived from the shape or appearance of each individual seam; thus we have 'checks' for some of the thin upper layers containing such an abundance of joints that the surface appears chequered like a Roman pavement; 'Rough Measure,' arising from the rough exterior or notched appearance of some of the beds, which are semi-nodular in character; 'Top Balls' and 'Middle Balls,' for those ironstone beds which are composed of nodules of ironstone, each nodule often having as a nucleus a fossil shell [or other fossil]; 'Flat-stone,' the ironstone lying in regular layers or seams of uniform thickness, and with jointing less abundant than in those layers called 'checks.' The shale in which the ironstone is embedded contains plants, *Lepidodendron*, *Ulodendron*, *Calamites*, and ferns in abundance; teeth, scales, spines, and coprolites of fish, and the remains of Labyrinthodonts."[2] At Toftshaw the black shale forming the roof of the Black Bed Coal yielded remains of *Pholiderpeton scutigerum* (Huxley) now preserved in the museum, Cartwright Hall, Bradford.[3]

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[1] 'Geology of the Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1879, pp. 154-165.
[2] *Op. cit.*, p. 155.
[3] Huxley, T. H., 'A Labyrinthodont from Bradford,' *Quart. Journ. Geol. Soc.*, vol. xxv, 1869, pp. 309-311.

The following are detailed sections at Westgate Hill—

Newmarket Colliery, Westgate Hill

	Shale	
	Chockies	
	Shale	
	Top Balls	2 ft. 10 in.
	Shale	
	Flatstones	
	Shale	
	Middle Balls	
	Shale	
	Low Roughs	
	Shale	
	Low Measures	
	Shale	
[Black Bed]	Coal	2 ft. 0 in.
	Seat dirt	0 ft. 6 in.

Red Hill Colliery, Westgate Hill

		Ft.	in.
	Shale		
	Top Balls ...		2
	Shale ...		7½
	Top Flats ...		1½
	Shale ...		4½
	Middle Balls		1½
	Shale ...		10
	Bottom Rufts		1
	Shale ...		7
	Low Measures		¾
	Shale ...		7
'Black Bed'	Coal... ...	2	3¾

Southwards a barren layer of shale comes on between the Black Bed Coal and the ironstone: at Scholes the ironstone is still immediately above the coal, though at Popplewell, quarter of a mile to the west there is 20 in. of 'white earth' between; at High Moor Lane, 1 mile to the south, there is about 5 ft. of shale between the coal and the ironstone and at Clifton about 30 ft. Eastwards there is 34 ft. at Mirfield Moor and rather less than 30 ft. at Ravenslodge. At Batley West End the ironstone is on the coal. South of the Calder the ironstone is nowhere recorded, but the tips in Bradley Park show that it exists there.

The remaining measures to the Crow Coal are not of economic importance, nor is that seam often workable, being thin, variable and much split up by dirt partings. A local thickening of the seam under Shelf Moor, where the section is: Top coal 1 ft., dirt 6 in., bottom coal 4 in., has made it worth mining in that area. Around Low Moor it is known as the '14 Yard Coal' from its distance above the Black Bed; this distance is about the same at Clifton where, in one pit, Green Lane, 33 in. of coal is split into 5 bands by layers of white seat-earth. To the south-east the thickness of these beds increases, being 46 to 54 ft. around Mirfield and Ravensthorpe, 60 ft. at Batley West End and over 100 ft. at Combs

Pit. In some parts, as for instance in Cockers Dale in the north-east almost the whole distance between the two coals is occupied by a sandstone.

(2) *The Southern Area.*—To the south of Kirkheaton the Black Bed Coal is immediately overlain by a bed of sandstone known as the ' Grenoside Rock.' Though comparatively unimportant around Kirkheaton and Fenay Bridge it rapidly increases in thickness and relative importance south of the latter locality and at Highburton forms a prominent elevated plateau. On the opposite side of the Thunder Bridge valley it also forms a well-marked upland plateau extending from Farnley Tyas to Woodsome Hall, and constituting one of the most striking escarpments of all the Coal Measure sandstones. The conspicuous land-mark known as Castle Hill, Huddersfield is capped by a small outlier of this rock.

At Gawthorpe and Cowmes Top the Grenoside Rock consists of two beds of flaggy sandstone separated by shale. This shale parting dies away southwards and in the Kirkburton district where the Grenoside Rock is fully developed it consists of a thickly bedded rough gritty sandstone about 40 ft. thick contrasting strongly with the evenly and finely grained Elland Flagstones below.

Immediately overlying the Grenoside Rock, wherever present, there is found a coal, referred to as the Grenoside Sandstone Coal and identified with the Crow Coal of the country to the north. The outcrop can readily be traced east of Kirkheaton. In the Addlecroft boring, Gawthorpe (see page 55) it was found to be 10 in. thick while in a disused quarry alongside Gawthorpe Green Lane, Whitley Willows it is represented by 4 in. of shaly coal. At Cowmes Bank, Lepton the section is : Coal 4 in., dirt 4 in., coal 7 in. but in Rowley Lane, Lepton, a coal in the corresponding position is only 3in. thick.

The Crow Coal is succeeded by a series of shales with ironstone nodules and thin sandstone beds ; they contain small seams of coal with fireclays, of which two are of fairly constant occurrence in the north ; they are known as the ' 22 Yard ' and ' 32 Yard ' Coals, from their approximate distance above the Black Bed Coal. They seldom reach as much as 1 ft. in thickness and are usually less than 6 in. In the north-east, around Tong, only the seat-earths are present. These measures are well exposed in the banks of Royds Hall Beck, west of Wyke and at the Bradford Brick and Tile Company's pits, Haycliffe Hill, between Great Horton and Wibsey (Plate IVB). They are not found in the south.

60 to 90 ft. above the Crow Coal is an important sandstone known as the ' Oakenshaw ' or ' Clifton ' Rock. In the north two beds can usually be traced, the lower being the Oakenshaw Rock proper, and the upper, where separately named, the Shertcliffe Seatstone. Around Clifton and southwards the two leaves come

together to form the Clifton Rock. The Shertcliffe Seatstone is often flaggy, but the Clifton Rock as a whole is a strong somewhat false-bedded sandstone of fairly coarse grain; it is usually much jointed. Near Wibsey it has been quarried for use, when crushed, as moulding sand; the Oakenshaw Rock is here represented by 67 ft. of alternations of stone and rag, above which a 'swilley' coal occurs locally. Around Bowling and Holme the upper bed is better developed than the lower, but at Tong the upper bed is only 5 ft. thick and the lower 29 ft. with 50 ft. of mudstone between. West of Oakenshaw three beds can be distinguished of which the top is the strongest, but north-east of Bailiff Bridge the whole series appears to have passed into shale. At Battyeford there is a single bed of good stone 50 to 60 ft. thick; eastwards under cover it appears to degenerate somewhat. At Bradley Park and to the north-east of Kirkheaton the Clifton Rock forms a thick bed immediately overlain by the Shertcliffe Coal. Traced southwards it again splits into two beds; a lower bed of sandstone, and an upper bed locally known as the Shertcliffe Seatstone. The lower sandstone forms the prominent feature of Cockley Hill to the east of Kirkheaton. Further south both beds of sandstone thin away and they are practically unrepresented to the south of Lepton.

Resting on the upper part of the Clifton or Oakenshaw Rock, or a very short distance above it, there is found over the greater part of the area a coal known as the *Shertcliffe*; above this are a number of less important coals, several of which when traced eastwards combine with it to form the important seam known as the *Beeston*, or in the extreme south the *Whinmoor* Seam or group of seams.

The Shertcliffe, Churwell and Beeston Coals.—Immediately beyond the eastern margin of the map, a single seam of coal called the Beeston Bed occurs at a number of collieries,[1] but within the present area it has everywhere split into two or more bands. The details of this split were to a large extent worked out by Green,[2] but they are complicated by the nomenclature. The term 'the Lousey Coal' is frequently used for a comparatively good seam at a considerable distance above the Shertcliffe; it is also sometimes called the Upper Lousey and the Shertcliffe the Low Lousey; and thus the names applied in different collieries and districts leads to confusion. The term 'Lousey' is also given in West Yorkshire to any seam of coal of inferior quality regardless of its stratigraphical position. Similarly the terms Little, Thin and Stone coal are used as proper names, but being descriptive, and the series including several thin seams all of which may locally be a 'Stone' coal, the use of the names is of little value for correlation. As a general rule the Beeston Coal consists of a single seam to the east of the present area, splitting westward into the Churwell Thin above and the Churwell Thick

[1] Many detailed shaft sections are given in 'Sections of Strata of the Yorkshire Coalfield,' *Midland Inst. Min. Eng.*, 1927. A first edition, now out of print, appeared in 1914; 2nd edition, 1927.

[2] 'Geology of the Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1878, pp. 175–196.

below. The Churwell Thin is probably the equivalent of the (Upper) Lousey; the Churwell Thick again splits, the lower part continuing as the Shertcliffe Bed, Popplewell Stone Coal or Whinmoor Coal, and the upper passing into as many as five thin seams, amongst which the names Stone Coal and Little Coal are applied, wherever any of them have been worked and a name was required. Greater detail is given in the series of sections in Fig. 5 (p. 85).

In the north the Shertcliffe Coal is 2 ft. 6 in. to 3 ft. Around Clifton it may be as little as 2 ft. and is very variable, 'Johnnies' (inferior stone coal) being found sometimes at the top and sometimes at the bottom. The (Upper) Lousey Coal is 2 ft. to 2 ft. 6 in. thick, including dirt partings, and is 110 to 140 ft. above the Shertcliffe. At Hunsworth and Tong the name 'Trub Coal' is given to one of the stone coals about 1 ft. 6 in. thick 100 ft. above the Shertcliffe. Near Shelf this coal attains its greatest thickness, 22 in., and consists of cannel.

Where there are two good seams separated by a comparatively small thickness of measures either barren or containing only insignificant seams they are known as the Upper and Lower Shertcliffe and, further east, as the Churwell Thin and Churwell Thick or Upper and Lower Beeston. Thus from west to east we find, between Cleckheaton and Liversedge the upper seam is 2 ft. 4 in. of stone coal, the lower 1 ft. 8 in. of soft coal and the intervening measures 36 ft.; at White Lee the coals are 1 ft. 3 in. and 2 ft. 10 in. and the measures 36 ft.; at Batley West End 2 ft. and 6 ft. 5 in. with measures 18 ft.; at Broad Oaks east of Gildersome and quarter of a mile beyond the margin of the map the coals are 2 ft. and 5 ft. 5 in., the measures 29 ft.; the lower seam contains four dirt partings, indicative of the tendency to split westwards to a number of thin seams.

Further south, in the Calder valley the intervening measures are thicker but again thin also in an easterly direction. At Calder Colliery the seams are 1 ft. 10 in. and 1 ft. 3 in. separated by 76 ft. of measures; at Ravenslodge 1 ft. 11 in. and 1 ft. 6 in. separated by 88 ft.; at Ingham's 3 ft. 1 in. and 2 ft. 2 in. separated by 45 ft. 8 in.; and at Combs 2 ft. 10 in. and 6 ft. separated by only 28 ft. 6 in.; the lower seam here is really two, each 1 ft. 3 in. with 3 ft. 6 in. of seat-earth between.

The Beeston as a single seam may be present in the north-east corner of our area; at Farnley Wood on our boundary east of New Farnley it is 8 ft. but includes seven partings totalling 1 ft. 2 in. The line along which the two main seams come together runs east of south. At Shaw Cross one and a quarter miles east of Dewsbury a single seam is recorded, but the section is coal 2 ft. $2\frac{1}{2}$ in., spavin 6 ft. 10 in., coal 1 ft. $2\frac{1}{2}$ in., dirt and coal 2 ft. $5\frac{1}{2}$ in.

In the area south of the Calder valley the conditions are similar to those outlined above. The Shertcliffe Coal lies 27 to 30 ft. above a seam known as the Whinmoor, which is present only in the extreme south; it is exposed in a quarry one mile east of Kirkheaton Church,

where it is 1 ft. thick. Around Lepton and Whitley Beaumont it is 2 ft. 4 in. thick and has been worked along the outcrop. In this area the coal is usually called the Shertcliffe Seam, though sometimes the Low Lousey, but southwards around Linfit and Thorncliffe it is called the Black Band or Cinder Hill Coal ; it is 1 ft. 6 in. to 2 ft. Further east where shafts have been sunk for this coal, as at Grange Moor, Overton and Emley the upper bed is also present. At Shuttle Eye Collieries, Grange Moor the Shertcliffe or Low Beeston is 1 ft. 6 in. ; the Beeston (15 ft. above it) 30 in. to 2 ft. At Prince of Wales Colliery, New Hall Wood, Overton the lower seam is 3 ft. 9 in. including a shale parting of 1 ft., the upper 1 ft. 8 in. with a 6 in. parting of fireclay and the intervening measures 35 ft. Towards its outcrop this upper seam, sometimes referred to as the Top Lousey is seldom of any value ; a section at Linfit, where it has been worked to a small extent is : coal 11 in., dirt 1 ft. 3 in., coal 4 in.

A still higher coal (also known as the Top Lousey) is present at Emley, Overton, Thorncliff, and Linfit. It occurs 50 to 70 ft. below the Blocking Coal and is usually only a few inches thick. In the Thorncliff Green shaft it attained its maximum thickness of 1 ft. but was apparently not worked.

The remaining Lower Coal Measures are of little interest. In the north the thickness varies considerably ; at Coates Pit, west of Hartshead Moor Top the distance from the Blocking Bed to the Shertcliffe Coal is 220 ft. At Gomersal it is 190 ft., Batley 240 to 270 ft. The Lousey Bed Coal occurs in these measures 80 ft. below the Blocking Bed at Coates Pit, 66 ft. at Gomersal and 82 ft. at White Lee.

In the Calder valley the Blocking Bed is 174 ft. above the Shertcliffe at Dark Lane Pit, Ravensthorpe, 223 ft. at Calder Colliery, 264 at Ravenslodge, 244 at Ingham's and 207 at Combs.

In the Flockton district the thickness of these measures is 162 ft. at Grange Moor, and 167 ft. at Prince of Wales Pit, Overton.

DETAILS

The Thin or Pot Clay Coal.—Though rarely exposed, the Thin Coal and its companion marine band appear to be persistent a few feet above the top of the Rough Rock.

A section seen on Thornton Moor, a few hundred yards beyond the northern margin of the sheet, north of Ogden Reservoir gave :—

	Ft.	in.
Black decalcified shale [Marine Band]		
Dark grey shale	3	0
Coal	0	2
Bastard Ganister	1	0
White clay, rusty-coloured towards base	6	0
Rough Rock	—	—

A similar section is seen at the Holmfield entrance to the Queensbury railway tunnel. The coal has been seen in temporary sections along the eastern bank of the Hebble through Halifax, and it and the marine band are visible in the railway cutting one and a quarter miles south of Halifax station at the little faulted inlier.

An excellent section of this coal and associated strata is seen at the eastern end of Elland Tunnel, alongside Elland railway station.

	Ft.	in.
Brown shale and ironstone		
Black shale with marine band including *Gastrioceras subcrenatum*, *Orthoceras sp.*, *Posidoniella spp.*, *Pterinopecten papyraceus* at base	14	—
Coal		5
Fireclay	1	0
Massive gritstone (Rough Rock)	10	0

By the river Calder, however, close to Elland station an excavation showed this seam of coal to have the unusual thickness of 2 ft. 4 in. underlain by 4 ft. of fireclay.

In the Huddersfield district and to the south, the fireclay beneath the coal has been worked somewhat extensively in places. At Salendine Nook on Lindley Moor, the fireclay underlying the Pot Clay Coal has been worked for many years for the manufacture of common pottery ware. Hereabouts the coal has an average thickness of 6 in. At Lockwood it is 8 in. thick and rests on a 4 ft. bed of fireclay which has been worked as a refractory clay (see page 180) ; south of Berry Brow the coal is only 2 to 3 in. thick and the underlying Rough Rock has a ganister-like nature. In this area the prominent band of fireclay closely resembles a bauxite.

The coal and marine band have been noted in many borings east of the outcrop. At Britannia Mills, Bradford, the marine band extends through 4 ft. of black shale and yielded, as well as the usual lamellibranchs, goniatites and *Lingula*, a small gastropod.

At Brookfoot, east of Brighouse the shales with goniatites are 2 ft. thick-below which is 1 ft. of shale with fish remains resting on 6 in. of coal ; the fire-clay is 2½ ft. At Farnley Iron Works the coal is only 1 in. but the fireclay 4 ft, The Thin Coal with its distinctive marine roof and thick bed of fireclay has been proved in numerous borings around Huddersfield. At Mold Green the coal was 4 in. thick and the underlying fireclay 6 ft. in thickness.

The Soft Bed Flags.—In the north the measures between the Thin Coal resting on the Rough Rock and the Soft Bed Coal are round about 70 ft. thick, with a *Carbonicola* band a short distance from the top. The Soft Bed Flags are definitely absent at Holmfield, but can be traced southwards from Ovenden ; on the east of Halifax they are 6 to 12 ft. thick with the *Carbonicola* band just below. In the Farnley boring these measures are 75 ft. thick with 15 ft. of sandstone at the top. The Soft Bed Flags have not been mapped north of the Calder but southwards from the river they rapidly attain importance. Around Huddersfield they are 150 ft. thick, but they thin again to the south. In the small faulted inlier of Lower Coal Measures to the south of Stainland and Holywell Green the Soft Bed Coal is seen to be immediately underlain by hard bands of flagstone. These rapidly thicken in a southerly direction, and on the southern or upthrow side of the prominent Birchencliffe east and west fault they are strongly developed and give rise to a prominent plateau on which the suburbs of Lindley and Marsh are situate. Westward they give rise to a small but distinct escarpment which can be traced continuously from Laund Hill past Reinwood to Gledholt. Two sections seen at Gledholt are of special interest ; both exhibit pronounced false-bedding while in one are evidences of contemporaneous erosion. In the latter lenticular bands of shale occur containing roughly rounded blocks of sandstone, apparently re-eroded portions of the underlying beds of flagstone.[1]

To the north of Huddersfield the Soft Bed Flags form a prominent feature at Rose Hill, Birkby. A fine section of these beds occurs at the western end of Springwood tunnel, Huddersfield ; here are exposed some 30 ft. of hard flags alternating with bands of sandy shale. A similar section is seen along the

[1] This section is figured and described by Green. See ' Geology of the Yorkshire Coal-field ' (*Mem. Geol. Surv.*), 1878, p. 95. The section is still exposed though much overgrown.

southern bank of the River Colne at Lockwood, and small sections are also seen at Rashcliffe.

In the Holme valley to the south, the Soft Bed Flags form a conspicuous feature at Taylor Hill, Berry Brow. A section at the northern end of Robin Hood tunnel, south of Berry Brow shows the Soft Bed Flags to consist of some 25 to 30 ft. of hard nodular flags with shale partings.

Borings made in the town of Huddersfield and at Dalton show these beds in places to range from 100 to 150 ft. in thickness.

The Soft Bed Coal.—This seam has been worked at many points along its outcrops by means of adits, and in the case of the small outlier at Foreside Top by the opencast method. Along the main outcrop an exposure 200 yards north-west of Small Clough Farm, Bradshaw, shows the coal to be 7½ inches thick, with over 2 ft. 6 in. of seat-earth ; and further south at a point 75 yards north-east of the Butts, the coal is 1 ft. thick and has at least 4 ft. of seat-earth.

The seam was recorded as being 1 ft. 4 in. thick in a pit at Green Clough Head, half a mile west-south-west of Thornton, 1 ft. 4 in. with a 2 ft. seat-earth at Catherine Slack, and 1 ft. 1 in. at Hole Bottom Colliery, quarter of a mile north of Queensbury. As this seam is traced eastwards it gradually thins while the measures separating it from the Rough Rock maintain a constant thickness. Thus, at Clayton, the coal is 1 ft. thick and 76 ft. above the top of the Rough Rock ; at Laisterdyke it is 9 in. thick and 74 ft. above ; and to the north of Tong the figures are 3 in. and 72 ft. In the Farnley borehole, however, the coal is 13 in. and the fireclay 19 in., 94 ft. above the Rough Rock.

The outcrop continues along the great escarpment north and east of Halifax and around Dam Head in Shibden Dale. At Holmfield the seam is 2 ft. thick, and in the workings of Quarry House Colliery, Northowram, was 15 in. thick, resting on 30 in. of underclay. At Dam Head Colliery, Shibden Dale. it was only 13 in. thick, while the section exposed in the old Brick and Tile Works in Halifax shows only 5 in. of coal with 3 ft. 6 in. of fireclay, resting on the ganister-like top of the Soft Bed Flags.

The bed was worked from Highfield and Cinder Hill Collieries under the plateau between Southowram and the Hebble valley, where it was 16 to 18 in. thick, though it is sometimes as much as 26 in. at the outcrop. It is still worked for Brookes' Stone Works, Hipperholme at their pit at the valley bottom below Hove Edge, where the thickness is about 12 in.

South of the Calder the seam has an average thickness of 18 in. around Elland, Blackley and Holywell Green though it is recorded to reach the abnormal thickness of 2 ft. 2 in. in one place at Elland. The underlying fireclay 3 ft. thick at Blackley has been worked to a small extent. At Lindley two small outliers of Soft Bed Coal occur and that at Low Hill has been worked. A section of the Soft Bed Coal together with the overlying *Carbonicola* band is seen at the western end of Springwood tunnel, Huddersfield. From thence it can be traced to Gledholt and through the northern end of Greenhead Park and Edgerton Cemetery. In making excavations in the Park and also at the Cemetery numerous shallow workings in this seam have recently been met with.

Several borings in the town of Huddersfield show its thickness to range from 1 to 2 ft. It was formerly worked at the old Fartown Colliery, and also along the southern bank of the River Colne at Lockwood and Kingsmill. It was stated to be of good quality at Fartown, though at Field House Colliery just north-east of Fartown it was found to have deteriorated rapidly and was not worth working. At Lockwood it was not more than 1 ft. 4 in. thick. Along the eastern slopes of the Holme valley, the Soft Bed Coal has been worked at the outcrop in numerous places around Berry Brow. Here it was often described as the Coking Coal, being of good quality and varying from 1 ft. 8 in. to 2 ft. in thickness. A band of hard shale or ironstone crowded with *Carbonicola* impressions invariably occurs 10 to 12 ft. above the coal. These include *Carbonicola acuta* (J. Sow.) and *C. aquilina* (J. de C. Sow.).

The Middle Band Coal and Rock.—The measures between the Soft Bed and Hard Bed coals contain a thin coal known as the Middle Band from its position : it is seldom more than a few inches thick. In the south a sandstone called the ' Middle Band Rock ' occurs beneath that seam ; in the north it is impersistent and is usually referred to as the Middle Band Stone.

In the north the thicknesses of the two parts of these measures is given by the following table :—

Soft Bed Coal to Middle Band Coal to Hard Bed Coal.

	Ft.	Ft.	Total Ft.
Green Clough Head, Thornton	39	27	66
Ford Hill Colliery, Queensbury	—	—	63
Hole Bottom Colliery, Queensbury Station	—	—	57
Clayton	17	35	52
Area N. of Tong ...	28	26½	54½
Farnley bore hole ...	13	27	40
Halifax	—	—	65
Quarry House Colliery, Northowram	—	—	80
Southowram	43	32	75

The Middle Band Stone caps the outlier at Foreside, attaining a thickness of 9 ft., and has been quarried for walling material. At Causeway Top this stone has dwindled to a band 2 ft. thick and it dies out altogether a little further south at Bradshaw.

The Middle Band Coal, usually a seam of from 2 to 6 in. in thickness, locally thickens to 18 in.—and even 30 in. has been recorded—at the Shay, on the north side of Soil Hill. Consequently the coal has been worked at this locality, and is known as the Rattlers Coal. Two sections in the Soil Hill area give further details :—

Road cutting, Keighley-Halifax Road, Causeway Top.

		Ft.	in.
	Sandstone...	4	0
Rattlers Coal	Coal	0	10
	Seat-earth...	1	2
Middle Band Stone	Rubbly siltstone and sandstone... ...	3	2
	Sandstone	0	5
	Sandy and silty mudstone	4	0
	Grey micaceous mudstone	1	6

The Shay, north side of Soil Hill.

		Ft.	in.
	Black shale ... ... 12 ft. to	14	0
	Hard white stone	6	0
Rattlers Coal	Coal	1	6
	Clay	3	0

The white stone and clay in the latter section are used for fire-brick and hearth manufacture.

To the north-east at Green Clough Head the coal is 5 in. thick, under Queensbury it is 6 in., and an outcrop section at Shugden shows 6 in. coal over 5 ft. of seat-earth. To the east at Laisterdyke the coal has been proved to be 6 in. thick, while in the Pudsey area, just north of Tong, it is only 2 in.

At the brick pits east of Halifax Station the coal is up to 1 ft. thick and rests on 4 to 5 ft. of fireclay and bastard ganister. The *Carbonicola* band is about 18 ft. above the Soft Bed, and at Dam Head, Shibden Dale 12 to 20 ft. below the Middle Band. The beds between that seam and the Hard Bed are black and dark grey shales with ironstone nodules.

The Middle Band Coal averages 1 ft. in thickness around Elland and Huddersfield. It lies close to the surface in the lower parts of the latter town and is frequently exposed in temporary sections. In the fine black shales which over-

lie it, fish scales and teeth are abundant in places, while *Lingula* has been found in the roof shales at Honley, just beyond the southern margin of the map.

The Middle Band Rock is of a very variable nature. In the town of Huddersfield it attains a thickness of as much as 30 ft. in places and usually consists of a ganisteroid sandstone of unusual hardness. Several sections have been observed by local geologists during building operations. The Rev. H. Thomas noted that a temporary section at the new electric station in Great Northern Street showed these beds, consisting of about 15 ft. of hard sandstone with shale partings, bent up into a sharp anticline. In other excavations in Queen Street, at the Town Hall, in foundations for the Technical College in Princess Street and in the Market Place it consisted of hard ganisteroid sandstone with abundant impressions of Stigmarian rootlets. At Mold Green the Middle Band Coal was found to be 4 in. thick and the underlying Middle Band Rock 12 ft. At Field House Colliery to the north-east the coal was 8 in. thick while the Middle Band Rock had dwindled down to only 6 ft. in thickness. Along the eastern slopes of the Holme valley at Newsome and Berry Brow the Middle Band Coal ranges from 8 in. to 1 ft. in thickness while the Middle Band Rock becomes reduced to not more than 3 ft. of hard ganister rock.

The Hard Bed Coal.—The roof of this seam is distinctive. It is composed of black shale containing crushed goniatites, and often, also, large calcareous nodules of clay ironstone, called 'baum-pots', which are generally crowded with uncrushed specimens of the same goniatites, together with *Orthoceras sp.* and *Pterinopecten sp.* (see p. 153). A list of 24 species of molluscs and 9 of fish from this band in the neighbourhood of Halifax has been published by Spencer.[1] A second form of concretion found at this horizon is known as a 'coal-ball'; usually spherical, it largely consists of fossilized wood. These, also, are originally preserved by a calcareous matrix, which, however, often becomes replaced by iron pyrites; and in this state are known as 'brass-lumps.' The composition of these concretions is shown by the following chemical analyses[2]:—

	'Coal Balls'		'Baum-Pot'
	Bradshaw	Stocks Pit Shibden Head	Swan Bank Pit Halifax
Ferrous Oxide	3.210	0.167	3.26
Manganous Oxide ...	trace	—	—
Alumina	0.327	trace	1.58
Lime	36.170	46.100	51.79
Magnesia	0.879	0.299	trace
Silica	1.159	1.209	2.05
Sulphuric Acid	0.151	0.010	trace
Chlorine	trace	—	trace
Carbonic Acid	29.000	35.280	40.65
Phosphoric Acid... ...	trace	trace	0.42
Iron Pyrites	21.581	12.168	0.16
Water	0.309	3.006	0.09
Organic matter and loss...	7.214	1.761	—
	100.000	100.000	100.00

In the north the Hard Bed is generally 2 ft. thick and is underlain by a thin bed of ganister and a fireclay. The latter is worked at Ambler Thorn and at the Clayton Fireclay Works and for coarse pots at a small pottery at Causeway Top. A small colliery at Ford Hill, Shibden Head still works this seam for the coal.

[1] *Proc. Yorks. Geol. and Polytech. Soc.*, vol. xiii, 1898, p. 307.

[2] Stocks, H. B., 'On the Composition of 'Coal-Balls' and 'Baum-Pots',' *Proc. Yorks. Geol. and Polytech. Soc.*, vol. viii, 1884.

From Soil Hill to Catherine Slack the Hard Bed seam maintains a thickness of 2 ft., proved at the Shugden Pit, Bradshaw, and Shaw Lane Mine, Catherine Slack. A similar thickness of coal occurs in the Clayton Fireclay Works, High Birks ; but in Clayton a little to the east and in the Hole Bottom Colliery at Queensbury Station 2 ft. 6 in. has been recorded. In the Bradford area thicknesses ranging from 1 ft. 6 in. to 2 ft. have been encountered ; records from the district lying east of this are scarce or do not exist.

The seam crops out along the escarpment north and east of Halifax and along the sides of Shibden Dale, running down to the stream near Shibden Hall. In recent years the fireclay below the Hard Bed has received some attention, although it is not being worked at present. The thickness of the coal ranges from 24 to 27 in. around Shibden Dale and Northowram. Near Shibden Hall it is underlain by 12 in. of ganister and 3 ft. 6 in. of fireclay, and at Holmfield Fireclay Works, where both coal and fireclay are being worked, the coal, 26 in. thick, is underlain by a foot of ganister and 2 ft. of good fireclay. The black shale roof contains the usual marine fossils, both flattened in the shales and solid in nodules. Two erratic boulders, one ' granitoid gneiss or gneissoid granite ' have been recorded from the Hard Bed Coal of Shibden Dale.[1]

In the Farnley borehole the coal is one foot thick, and lies on 7 ft. 4 in. of sandstone, of which a sample seen was ganister-like.

At Messrs. Joseph Norton's works at Siddal the section is : coal 2 ft. 6 in., ganister 0 to 2 ft. 6 in., fireclay 3 ft. 6 in. The thickness of the coal is exceptional for this district, 2 ft. 3 in. being usual. A considerable area of this coal was worked from High Field Colliery and a smaller area from Cinder Hill. At Sunny Bank the section was coal 2 ft. 2 in., ganister 1 ft. Many coal balls were obtained here.[2] None was noticed on the old tips, collectors in the past having worked them very carefully, but the bullions from the roof yielded *Pterinopecten papyraceus* (J. Sow.), *Dimorphoceras sp.*, and *Gastrioceras listeri* (Mart.). The type of *Coelacanthus* Agassiz was from a ' baum-pot at Halifax,' probably from this pit. The coal is now worked at Brookes' Pit, Walter Clough where it is from 2 ft. to 2 ft. 2 in. with 6 to 18 in. ganister and 2 ft. 6 in. of fireclay. To the east of Elland both the coal and the fireclay have been much mined along the outcrop. The coal is here 2 ft. 4 in. thick, and rests on 8 in. of ganister rock and 4 to 5 ft. of yellow fireclay. An excellent section of the seam was exposed during the recent re-survey at a disused gravel pit alongside the L.M.S. railway, 200 yards north of Shaw Laithe, and about one mile east of Elland railway station. Here a loamy gravel with large far-travelled erratics rested in places directly on the upper surface of the coal. The fireclay is at present being worked at the New Hall Fireclay Works, 1,000 yards east of Elland Church. At Storthes fireclay works, Elland, alongside the Huddersfield Road, the fireclay underlying the Hard Bed Coal is 5 ft. 6 in. thick and is employed in the manufacture of firebricks. It is here known as the ' White Clay ' to distinguish it from the ' Blue Clay ' which underlies the Hard Bed Band Coal. Hereabouts are disused Copperas Works where the pyritic concretions associated with the roof of this seam were formerly collected for the manufacture of sulphuric acid.

At the Woodman House and Blackley fireclay works, 700 to 800 yards south of Elland Church, these measures run as follows : fossiliferous shale with bullions, 6 ft. ; coal, 2 ft. 6 in. ; ganister rock, 1 ft. ; yellow fireclay, 4 to 7 ft.

In the small faulted inlier of Lower Coal Measures to the south of Stainland at Jagger Green the Hard Bed Coal has been worked all along the outcrop. It is but of inferior quality here and ranges from 2 ft. to 2 ft. 3 in. in thickness.

At Scar Top, Wappy Springs and at the north-eastern end of Lindley Moor, the fireclay associated with the Hard Bed Coal has been worked. Here one of

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[1] Spencer, J., *Proc. Yorks. Geol. and Polytech. Soc.*, vol. xi, 1889, pp. 96-100.
[2] Cash, W., and T. Hick, ' Flora of the Lower Coal Measures of Halifax,' *Proc. Yorks. Geol. and Polytech. Soc.*, vol. vii, 1879, pp. 73–82.

the main branches of the Rishworth-Birchencliffe faults (see page 123) intersects the workings, the beds in places being highly inclined and slickensided.

To the north of Huddersfield at Fartown it was formerly mined somewhat extensively. An average section is that of New Peace Pit, Field House Colliery; where it runs as follows :—

	Ft.	in.
Coal	2	4
Ganister rock		8
Good fireclay	2	0
Impure fireclay with ironstone	4	0

In a boring at Mold Green, the ganister rock was found to reach the abnormal thickness of 5 ft. 9 in. The Hard Bed Coal resting on about 14 in. of ganister rock was also observed in excavations at the north-eastern corner of Fartown Athletic Grounds in close proximity to the Sheepbridge fault where the beds were bent into a sharp anticlinal fold.[1]

At Ashing Hirst, Primrose Hill and Newsome to the south of Huddersfield it was mined in the past both along the outcrop and by means of shafts, and was stated to be of fair average quality. The coal hereabouts averages 2 ft. 6 in. in thickness, and the underlying fireclay 5 ft. Old crop-workings also occur to the south of Berry Brow where it averages 2 ft. 4 in. in thickness.

Although the majority of the workings in the Hard Bed Coal are comparatively close to the outcrop, occasional attempts have been made within recent years to work it at greater depths, mainly on account of its fireclay. Six years ago two shafts were sunk to this seam at Messrs. Swift and Netherwood's Colliery, Dogley Lane, Woodsome, one mile south-west of Lepton Church. The shafts began 12 ft. above the level of the Better Bed Coal, and reached the Hard Bed Coal at 727 ft. The section of the seam was: Coal, 2 ft. 3 in.; Ganister, 1 ft.; Fireclay, 3 ft. The shafts were later continued to the Soft Bed Coal which was encountered at 822 ft. and found to be 1 ft. 7 in. thick resting on 2 ft. of fireclay. Both these fireclays have been mined for the manufacture of glazed tiles and other ware.

The measures immediately overlying the Hard Bed Coal and its marine roof call for little comment, consisting invariably of dark shaly mudstones with ironstone nodules. In the Brookfoot boring, Brighouse (see page 193) a *Carbonicola* band occurs 78 ft. above the Hard Bed Coal. This would appear to be the same band which is exposed in the upper part of Harrow Clough, Broad Carr, near Stainland, and has been met with in borings in the Huddersfield district, 70 to 75 ft. above the Hard Bed Coal.

The Measures from the Hard Bed Coal to the Elland Flags.—This series of measures includes three coal seams, namely—the 36 Yard Band, 48 Yard Band, and 80 Yard Band Coals,—and a number of sandstone beds. The latter are variable but seem to develop at fairly well-defined horizons.

Between the Hard Bed Coal and the 36 Yard Band Coal no sandstone is present in the district between Holmfield and Queensbury, though there is a tendency towards the development of a sandstone immediately beneath the 36 Yard Band Coal in the Clayton area. Bore records in the Bradford district, again, prove an occasional thin sandy bed only at this horizon. The average thickness of these measures is 85 ft.

The 36 Yard, Hard Bed Band and 48 Yard Coals.—The fireclays associated with these seams are of high economic importance, and are extensively worked for firebrick, hearth, and tile-making (see page 178). The coals themselves are relatively thin and usually unworked. As far south as the River Calder there is a single seam, the 36 Yard Coal. At Elland the Hard Bed Band first appears below it separated by fireclay and in this area the two coals occur. South of the Ainleys, however, the 36 Yard Coal dies away and only the Hard Bed Band Coal is represented. Along the main western outcrop from Soil Hill to Holmfield information as to this seam is first obtained at an exposure 200 yards west of Roper Farm where the coal is 8 in. thick; a little

[1]Bould, C. H., *Trans. Huddersfield Nat. Soc.*, 1891, p. 22.

further south at the Ambler Thorn Fire-Clay Works the same thickness of coal rests on 3 ft. 1 in. of clay. At Holmfield a detailed section obtained at the Howcans Fire-Clay Works illustrates the various qualities of clay :—

	Ft.	in.
Black shale	—	—
Coal	0	8
Best tops fireclay	2	10
Seconds fireclay	0	8
Silica	1	6
Good clay	1	6

To the east of this line the clay is worked at the Clayton Fire-Clay Works, High Birks, where the coal is 1 ft. 2 in. thick and is 85 ft. above the Hard Bed Coal. At Queensbury Station the coal and clay have been worked in the Clayton Fire-Clay Mine, Hole Bottom, where the section was : Coal, 0 to 8 in. ; clay, 4 to 5 ft. ; on galliard.

The coal and fireclay, with the overlying shales with layers of ironstone nodules, are well exposed in the Godley Lane road cutting, between Halifax and Stump Cross. The fireclay has been worked under Bloody Field, from dayholes in the south-east side of this cutting. The fireclay is also worked at Beacon Hill, and between Stump Cross and Hipperholme and at Shibden Hall Colliery, east-south-east of Shibden Hall. Further south an important ganister underlies this coal : at Siddal the coal is 10 in., fireclay 3 ft. 6 in. to 7 ft., and ganister 20 ft. At Allen's Glazed Brick Works, Sunny Bank, the seam is mined ; the coal 7 in. thick being 142 ft. 9 in. from surface ; the clay is described as tops 4 ft. 6 in., bottoms 1 ft. 1 in. At Walter Clough Colliery the section is coal 6 in., fireclay 4 ft. 6 in., ' Johnnies ' 6 in., strong stony clay 5 ft., but 300 yards north-west of the shaft the total thickness of these beds decreases to 7 ft. 6 in. Along the north bank of the Calder there are fireclay works at Ash Grove at the east end of Elland Park Wood and also at Cromwell Bottom : at the latter the coal is 10 in., the fireclay 4 ft. 6 in. to 6 ft., and ganister proved to 15 ft. and said to be 30 ft. thick.

An excellent section of the beds on this horizon occurs in Calder Fireclay Works alongside the River Calder and the L.M.S. railway on the western slopes of Elland Edge. Here the 36 Yard Coal is referred to as the Band or Upper Band Coal and is six inches thick, while below it and separated from it by fireclay we have the first appearance of the Hard Bed Band Coal, which is persistent thence to the southern margin of the map. The section is as follows :—

	Ft.	in.
Shaly mudstone	—	—
36 Yard Coal		6
' Blue Clay '	4	6
Hard Bed Band Coal	1	0
' Seggar Clay '	3	0
Hard Bed Band Rock	6	0

The Blue Clay is a pure refractory clay highly suitable for firebricks. The Seggar Clay is a second quality fireclay. It is so named owing to its employment in making ' seggars,' earthern vessels in which articles of porcelain are packed to undergo the process of fixing within the porcelain furnace. Much of the shaly mudstone overlying the coals has to be removed as overburden and is employed in the manufacture of common bricks.

The next section of these beds is seen in Messrs. Hawkyard's workings at the Victoria Fireclay Works, Elland Upper Edge, 1,000 yards east of Elland Church. The average section here is as follows :—

	Ft.	in.
Shaly mudstone	—	
36 Yard Coal	0	0½
' Blue Clay '	18	0
Hard Bed Band Coal	1	0
' Seggar Clay '	3	0
Hard Bed Band Rock	—	

The valuable bed of blue clay is abnormally thick here and well developed. In places, however, it is found to pass somewhat abruptly into 12 ft. of very hard and tough ganister rock. Messrs. Sharratt's extensive workings at the Storth and the Ainleys are a continuation of the above mentioned workings and exhibit a very similar succession though the average thickness of the blue clay is not more than 8 ft. There is also here a great thickness of overburden consisting of shaly mudstone with bands of ironstone nodules. The latter are collected and occasionally sent to the iron smelting works while from the former common bricks are extensively manufactured. As the beds are traced to the west from the Ainleys along the outcrop the blue clay deteriorates somewhat and the following is the average section at Ainley Top :—

	Ft.	in.
Shaly mudstone	—	
36 Yard Coal	0	2
Good quality fireclay	3	0
Stony clay	3	0
Bastard fireclay and clayey shale	2	6
Hard Bed Band Coal	1	0
Hard Bed Band Rock	6	0+

These fireclays, however, improve in quality at the Woodman and Blackley potteries where they are being worked by Messrs. S. Wilkinson & Sons for firebricks, furnace blocks, sanitary, salt-glazed and enamelled bricks. An excellent and complete section of these beds was measured in the large fireclay pit, 300 yards south-east of Blackley End Baptist Chapel, with the following result :—

	Ft.	in.
Thin flags	—	
Black shaly mudstone with prominent bands of ironstone nodules	20	0
Soft black shale	2	0
36 Yard Coal...	0	2
Soft yellow fireclay (good quality)...	1	6
Hard yellow sandy fireclay...	5	0
Soft yellow fireclay (good quality), with occasional hard nodules with rootlets	9	0
Dark grey fireclay	0	6
Hard Bed Band Coal	1	6
Coal and fireclay in alternate streaks	0	6
Yellow fireclay (second quality)	7	0
Hard Bed Band Rock	8	0+

The 36 Yard Coal is unrepresented to the south of Blackley and the Ainleys. At Grimescar Wood the Hard Bed Band fireclay was formerly worked, and the section here is :—

	Ft.	in.
Shaly mudstone	—	
Seggar Clay	4	6
Hard Bed Band Coal	1	0
Fireclay	3	0
Hard Bed Band Rock	18	0

The fireclay overlying the coal was stated to be of the better quality. It is of interest to note that the fireclay here was originally worked by the Romans for the manufacture of tiles. The Hard Bed Band Rock is of a very variable nature, but in some places where it was formerly quarried it is a very hard, close-grained, and ganister-like stone.

At Messrs. Edward Brooke's fireclay works, Field House Colliery, two miles to the north-east of Huddersfield, the Hard Bed Band fireclay was formerly mined for the manufacture of firebricks and other ware. It was, however, comparatively thin. The average section was as follows :—

	Ft.	in.
Shaly mudstone	—	
Hard Bed Band Coal: coal	0	10
Hard Bed Band Coal: dirt	0	10
Hard Bed Band Coal: coal	0	10
Band fireclay (good quality)	1	6
Fireclay with ironstone	4	0
Shale with ironstone nodules	102	0
Hard Bed Coal	—	

In the New Peace Shaft sinking, 500 yards to the east of here the Hard Bed Band Coal was found to be 2 ft. thick, of which 10 in. consisted of clean coal.

Several borings in the Mold Green district have shown the Hard Bed Band Coal to be 1 ft. thick resting on 4 ft. of fireclay and immediately below it 15 ft. of Hard Bed Band Rock.

The Hard Bed Band Coal with its associated fireclays and underlying rock can be traced along the foot of Dalton Bank, while to the south of Huddersfield the rock forms a well-marked escarpment in Longley Park and at Ashing Hirst and Newsome. The coal hereabouts varies from 10 in. to 1 ft. in thickness and lies a little way above the sandstone from which it is separated by shaly mudstone. The fireclay has been worked on a small scale in a few places but it is much inferior in quality to that of the Elland, Grimescar and Fieldhouse districts.

The '48 Yard Band' Coal is seldom more than a few inches thick. It is exposed in Shibden Dale on the west side of the sewage works south of Shibden Head, where the thickness reaches 14 inches. In the north a sandstone known as the '60 Yard Quarrel' sometimes cuts it out. This rock is best seen just to the north of the Sheet at Thornton and between West Scholes and Hole Bottom Beck. It is a roughly-bedded and rather raggy stone, and consequently has only been used for local walling material. Information to the east of its outcrop is scanty and ill-defined, but bore records in the Bradford area show impersistent sandy beds about this horizon.

North and east of Halifax the coal is usually 10 to 12 in. thick, underlain by 10 to 12 in. of fireclay and 6 in. to 2 ft. of ganister-like sandstone resting directly on the shales with ironstone nodules which extend down to the 36 Yard Band.

The seam was worked long ago at Nab End, Booth Town, where it was 10 to 14 in. thick, and it is probable that the very old shafts on Pepper Hill, east of Booth Town, were sunk to this bed, which was seen to be 1 ft. thick at the outcrop in Howcans Wood, below the eastern edge of Pepper Hill. In the Leeds Fireclay Co.'s works south-west of Hipperholme, a coal 2 to 4 in. thick, resting on 12 in. of shaly ganister-like sandstone, between two faults, is apparently the 48 Yard Band.

Along Siddal Bank it has not been found possible to map this coal; it has been proved at the Cinder Hill Works to be only an inch or two thick. At Cromwell Bottom in the Calder valley it is 8 in. thick and rests on an inferior fireclay. In the shaft at Allen's Works, Sunny Vale it is the same thickness with 5 ft. of fireclay with ironstone balls. At Walter Clough the section is: Coal, 3 in.; Ganister, 3 in.; Clay, 1 ft. The 48 Yard Band is comparatively unimportant to the south of the River Calder, and it has not been found practicable to show it on the map. It appears to be absent in many places. In a shaft sinking alongside Wood Nook Farm, Elland Lower Edge, a seam of coal 2½ in. thick resting on 3 ft. of fireclay occurred 30 ft. above the 36 Yard Coal, and may possibly be a local representative of this seam. Similarly in the sinking of the New Peace Pit at Field House Colliery, Huddersfield an 8 inch seam of coal termed the 'bastard coal' occurred 40 ft. above the Hard Bed Band Coal and may represent the 48 Yard Band of the country to the north. No coal, however, was found at this horizon in the numerous deep borings made at Mold Green and Dalton.

The 80 Yard Band Coal.—This coal is not more than 6 in. thick at most, and in some parts in the south may be absent, but its fireclay is persistent and its position usually to be detected by that of the underlying 80 Yard Rock. In the north, from Old Dolphin round to Catherine Slack the rock is not more than 10 to 15 ft. thick and is often mere rag. The coal is seen 175 yards east of Upper Shibden Hall, Catherine Slack, 6 in. thick resting on 6 ft. of seat-earth with rootlets.

Near Siddal the coal is only 2 in., but the rock which is flaggy forms a noticeable shelf traceable through Elland Park Wood round the Cromwell valley to near Brookfoot. The seat-earth at Cromwell Bottom is described as a 'vitreous' clay. This is 4 ft. 6 in. thick at Allen's Works, Sunny Vale, and the coal 6 in. At the Brookfoot boring the rock is 10 ft. and the shales contain a *Carbonicola* band 18 ft. below its base. The 80 Yard Rock can be traced as a slight but distinct shelf along the western slopes of Elland Edge. It is here a flaggy and shaly sandstone about 20 ft. thick overlain by 2 ft. 6 in. of fireclay, but the 80 Yard Coal is absent. To the north of Grimescar and at Cowcliffe Side the Upper Band Rock is 12 ft. thick, overlain by 6 in. of fireclay, while the Upper Band or 80 Yard Coal is here 2 in. thick ; hereabouts it is 132 feet above the Hard Bed Band Coal. To the east of Huddersfield the rock forms a distinct feature traceable from Dalton Lees along Kilner Bank to Mold Green.

To the south of Huddersfield it forms a well-marked escarpment along the eastern bank of the Holme valley from Kidroyd past Longley towards Hall Bower. A small faulted inlier forms a conspicuous feature at Stirley Hill. In this area the fireclay is from 2 to 4 ft. thick, but the overlying band of coal is reduced to a mere streak or absent altogether in places.

The Elland Flagstones.—The shales above the 80 Yard Band Coal pass gradually up into the flagstones ; the boundary is therefore indefinite but may usually be taken as about 75 ft. above that coal. It is the western edge of the main mass of Elland Flags which, capping the 300 ft. and more of shaly Ganister Coal Series, forms the remarkable escarpment overlooking the gritstone moors to the west ; this scarp runs from near Mountain past Halifax to the Calder valley, descending to the river at Brighouse. To the south, while locally conspicuous, its continuity is broken by the valleys of the Colne and its tributaries.

In the Queensbury area extensive quarrying has been done ; but practically all quarries are now disused. Sections of the flagstone are to be seen in the old quarries ; but the beds of flags and sandstone and the shaly partings are so variable that it will serve no useful purpose to give details of such sections, which in no instance exceed 40 ft. Current-bedding and ripple-marking are prevalent ; some lifts, however, are devoid of both. The two principal joint directions have bearings 140° to 150° and at right angles.

East of Queensbury the beds dip steeply to the south-east in the neighbourhood of a fault, so that near Old Dolphin the whole outcrop is narrow. The large Bailiff Bridge Fault, with a downthrow to the north-east, shifts the outcrop of the flagstone northwards to Clayton. Here a very similar plateau to that at Queensbury is formed, dipping a little south of east, and extending from Fall Top, near Queensbury Station, to Paradise Green. Large quarries at Fall Top, now disused, have yielded some large specimens of fossil tree-stumps and roots. The largest specimen of *Stigmaria ficoides*, which is now preserved in the quadrangle of The University, Manchester came from one of these quarries (see page 54).

The lower division of the Elland Flags caps Swales Moor, north of Booth Town, and forms a wide spread from Dunkirk through Northowram to Hipperholme. It is quarried for both flags and freestone in both these areas. The division also caps Pepper Hill, east of Booth Town, but only the lowest beds are present and they are not worth working.

The plateau between the Hebble and the Bailiff Bridge valleys is cut in two by that of Sunny Vale : on both the main bed of the flags has been extensively quarried. A typical section near Southowram is :—Flags, 6 ft. ;

mudstone, 10 ft. ; good flags, 10 ft. ; mudstone, 10 ft. ; rag, 12 ft. ; flags, 20 ft. ; but details vary rapidly. There are three small outliers of the shale separating the upper from the lower division. South of Hipperholme and at Hove Edge the most important quarries are worked for making artificial stone as well as for natural flags : some of them are 100 ft. deep (Plate VA).

Between the main beds of the Flagstone and the Better Bed Coal an irregular upper leaf of the Elland Flags is usually present. It consists of a poor flaggy sandstone, fine-grained, much subject to the development of thin shaly partings. In addition, it is generally split by a shale parting containing a thin coal and associated seat-earth.

This split sandstone forms a small outlier above the main Queensbury mass at Hunger Hill and is also seen to the south running into Bowl Shaw Clough from the eastern side of Shibden Dale. The seat-earth exists here, but the presence of the coal has not been proved. From Old Dolphin on the north-east side of the Bailiff Bridge Fault this bed forms the dip-slope of Clayton Heights, running down to Brayshaw and Horton Bank Reservoirs, and continues to the east as the steep escarpment above the New Road at Horton Bank until faulted down. It is repeated as a similar escarpment to the north at the foot of which the Bradford-Thornton railway runs from near Clayton to Horton Park. The best sections of this bed were those seen in the two reservoirs on Clayton Heights, in Brayshaw Reservoir during construction and in Horton Bank Reservoir when the water-level was very low. The latter section was as follows :—

		Ft.	in.
Horton Bank Reservoir	Flaggy sandstone ... ... 8 ft. to	10	0+
	Shale : silty at top ; black towards base	10	0
	Coal ... ... ½ in. to		¾
	Seat-earth ... ... 3 ft. to	3	6
	Grey shale, part silty ; with many ironstone nodules mainly congregated 3 ft. below the coal ... 6 ft. to	8	0
	Very fine-grained sandstone, massive ... (becomes 1 ft. 6 in. at S.W. end of Reservoir)	11	0 thins rapidly to S.W.
	Grey shale, with occasional small ironstone nodules and nodular masses of mudstone	12	0+

From Horton Park to the east this bed is concealed except for a small area between Tyersall Gate and Fulneck, where it again outcrops along the valley sides of Pudsey Beck and two of its small tributaries. Here again it appears to be split by a thin shale slack, but neither the coal nor its seat-earth is exposed.

In the Northowram district the upper division is 35 to 50 ft. thick, separated from the lower by 60 to 70 ft. of shale, the total with the lower bed being 215 to 225 ft.

The upper bed forms a strong feature about Dunkirk, not to be compared, however, with the massive scarps formed by the lower division of the flags. Here also it contains a thin coal seam, and east of Stone Chair another thin coal streak lies just below its base.

The beds are best seen in the small wooded valleys running south-east from Stone Chair and Shelf. South of here they form a dip-slope, on which stands Priestley Green. North-east of Tong the bed is only a few feet thick and is very shaly. Around Farnley Iron Works it consists of micaceous sandstone 10 ft. thick.

In the broken country between Gildersome and the Tong-Topcliffe Fault the upper division of the Elland Flags crops out, and from the massive feature it makes on the north side of Hart Hill it must be a bed of some thickness.

In the Farnley borehole the Elland Flags consist of three beds, separated by two rather thick beds of shale. The lowest and main division is about 60 ft. thick and contains the usual shaly beds. The total thickness of the series is 214 ft.

South of Bailiff Bridge the Upper Flags crop in the eastern bank of the Clifton Beck, but the thickness of the shale between them and the lower division is obscured by the alluvium.

South of the Calder valley the Elland Flags give rise to a bold escarpment at Elland Edge, while they also form high ground around Rastrick. In both these places they have been largely worked by mining as well as in extensive quarries. They here consist of two principal beds of flagstone, though towards Fixby a third bed develops between the upper and the lower subdivisions. The lowest or main bed at Elland Edge is from 120 to 130 ft. thick and about 120 ft. of shale separates this from the upper bed which probably averages not more than 25 to 30 ft. in thickness. Practically all the workings are in the lower bed, the lower part of which often constitutes an excellent building stone (see page 186). In the Grimescar district the Elland Flagstones are in three beds, the lowest being by far the most prominent. Around Dalton and Mold Green the Elland Flags cover wide areas, and Round Wood, Waterloo, a tabular hill of very regular form, is capped by an outlier of Elland Flags; it is traditionally regarded as an ancient British settlement; though no evidence of such an origin has been discovered.

In the Huddersfield and Almondbury districts the Elland Flags occur in two or three beds, generally striking from north-east to south-west. Around Almondbury they make a wide spread and produce a very characteristic and striking feature in the topography, giving rise to a succession of flat-topped hills of very regular form (Plate IVA). Along the Burton valley at Kirkheaton and Fenay Bridge they form striking features, though here they are of a very variable nature. They consist of two beds, the lower or main bed 100 ft. thick being separated from the upper group by 25 to 30 ft. of shale. Towards Highburton they show rapid deterioration and here the whole series probably does not include more than 40 ft. of good flagstone.

At Farnley Bank, to the south of Almondbury, the uppermost bed of the Elland Flags is represented in places by a somewhat less fissile and more massive bed which has been quarried as a building stone (see page 186).

A certain thickness of shale separates the top of the Elland Flags from the Better Bed Coal, varying from 30 ft. at its western outcrop to a minimum at Great Horton and Pudsey of 6 to 8 ft. A 22-ft. interval is recorded at Brayshaw Reservoir, Clayton Heights. Around Stone Chair the shale is about 30 ft., south of Norwood Green 10 ft., and about 5 ft. at the outcrop around Cockers Dale and Farnley. At Brighouse it is about 20 ft. Crossing the Calder, the shale has a wide outcrop between Rastrick and Bradley Wood, where it may be as much as 50 ft. thick. East of the Colne the Better Bed is about 20 ft. above the top of the Flags at Upper Heaton, but southwards the distance decreases, till at Fenay Bridge and Kirkburton the fireclay rests directly on the Flags.

The Better Bed Coal.—This seam has been the most valuable of those present in the area, but is nearly exhausted: detailed information is therefore abundant, but to the east is somewhat limited, since owing to the fact that the coal thins in that direction and the depth to it increases it has not been worked. It rests on a fireclay which is worked in the north-east around Farnley, where it is 2 to 4 ft. thick with 20 in. of coal; also north of Shelf where it is 3 ft., but marred by the presence of many small ironstone nodules in the lower part. In the south the fireclay is 4 ft. 6 in. around Cowmes and Kirkburton and persists to the south, though the coal itself dies out.

Commencing at the outcrop in the north-west the coal is 3 ft. thick a quarter of a mile south-east of Queensbury Station. It has been worked out

west of the Bailiff Bridge Fault at Shelf, thicknesses being 3 ft. at Bowl Shaw and 2 ft. 10 in. at White Gin Pit, Shelf.

To the east of the Bailiff Bridge Fault the coal was seen in Brayshaw Reservoir, when under construction, where it was 3 ft. thick and had 6 ft. of underclay; the same thickness obtained in the workings of Reevy Hall Colliery immediately to the east. Three records in Great Horton are:—at Horton Bank, 3 ft. coal over 1 ft. clay; at Upper Green, coal over 1 ft. 1 in. clay; and at Low Green, 2 ft. 11 in. of coal. At Haycliffe Hill just to the south, 2 ft. 4 in. of coal has been recorded.

Under Beck Hill, Buttershaw, Wibsey and the Low Moor district the seam varies from 2 ft. 4 in. in the west to 2 ft. 3 in. at Low Moor, and 2 ft. 2 in. at Wilson Pit, south of Woodhouse Hill. At Bowling records are at variance, neighbouring pits giving 18 to 20 in. and 24 to 26 in. as thicknesses. In the Tong Street area the coal averages 1 ft. 6 in., the neighbouring No. 1 Pit, Tong Colliery, giving 1 ft. 2 in. to 1 ft. 6 in. A quarter of a mile west of Toftshaw the Kaye Pit records 2 ft. 3 in.; but at Toftshaw Bottoms on the other side of the East Bierley Fault the thickness of coal is given as 1 ft. 9 in. At East Bierley itself 1 ft. 7 in. is recorded, while Crosses Colliery and the Hunsworth group to the south give 15 in. and 12 to 14 in. respectively as the seam dimensions. Eastward from here records are few. At The Heights, Pudsey, a section gives:—

	Ft.	in.
Black shale	—	
Better Bed Coal	1	6
Fireclay	2	6
Fireclay with ironstone	—	

and 15 in. is recorded from 'N' Pit, Tong, which worked the seam in the area from Tong village towards the north-east. A boulder of quartzite 'the size of a football' is recorded from the Better Bed near Bradford, and boulders are said to be not very rare in this district.[1]

Farther south the area worked out may be taken roughly as that from the outcrop of the seam to that of the Middle Coal Measures, the boundary being formed by large faults. The thickness of the seam is 3 ft. around Shelf and Norwood Green, decreasing eastwards to 27 in. at Low Moor, 22 to 26 in. at Wyke, 20 in. at Oakenshaw, 18 in. at Scholes, and 18 to 12 in. around Hunsworth. The thickness decreases from north to south around Low Moor and Hunsworth.

In the north-east of the area also the thickness decreases from north to south, being 17½ to 20 in. at White's Dayhole, Farnley, 15 in. east of Tong and at New Farnley, and 13½ in. at Hart Hill, Gildersome, where the fireclay is 4 ft. A borehole at BatleyWest End Colliery proved the Better Bed to be only 10 in. thick, but at Shaw Cross, east of Dewsbury (outside the map) it is again 15½ in. thick. Around Clifton the coal is usually 1 ft. 5 in. to 1 ft. 7 in., and at Mirfield 1 ft. 4 in. with 5 ft. 6 in. of fireclay.

South of the Calder the thickness west of Bradley is usually 1 ft. 9 in., but a section at Bradley Lane Colliery is given as coal 2 ft., boulder clay (*sic*) 6 in. Between the river and Upper Heaton the coal is 1 ft. 5 in. Around Kirkheaton the coal ranges from 1 ft. 6 in. to 2 ft. in thickness, while at the Addlecroft boring near Gawthorpe (see page 55) it was found to be 1 ft. 4 in. thick. At the Victoria Colliery, Fenay Bridge, it maintains the same thickness, while around Kirkburton, at the disused Dogley Bar and Dean Bottom collieries, the coal was 1 ft. 6 in. thick and the underlying fireclay 4 ft. 6 in.

The roof of the Better Bed in places yields many fish and other fossils (p. 158), while around Kirkheaton a band with abundant impressions of *Carbonicola* and *Naiadites* occurs in the overlying shales. Analyses and other particulars of this coal are given on p. 176.

[1] *Proc. Yorks. Geol. and Polytech. Soc.*, vol. xi, 1889, p. 97.

The measures between the Better Bed and Black Bed are, north of the Calder, usually about 120 ft. thick. At Clifton as much as 150 ft. is recorded at one pit and 140 is usual. There is a slight thinning in the extreme east, 100, 104 and 112 ft. being recorded at Wortley, Churwell and Shaw Cross respectively, from north to south, these three sections being all just east of the margin of Sheet 77. A sandstone known as the Thick Stone occurs in the north, is absent in the middle and reappears in the south of the area.

A thin coal is recorded in most pit-shafts traversing these measures a little below the midway point; it has not, however, been observed at the surface. This coal is recorded in Syke Pit, Wibsey, as 2 ft. thick and 56 ft. above the Better Bed Coal. In the Bowling district a seat-earth was encountered at Foot Road Pit, West Bowling, 37 ft. 7 in. above the Better Bed, no coal being noted; to the east, however, in the Bowling Iron Works shaft the coal is 3 in. thick and is 34 ft. above the Better Bed Coal.

A coal seam 1 to 5 in. thick, lying 40 to 45 ft. above the Better Bed, is recorded from the shafts around Low Moor, Wyke and Clifton, and has been called the Better Bed Band or the 14 Yard Coal; the latter is an unfortunate choice of name, the Crow Coal also being given this name in the same area. There appear to be no records of its presence around Tong and Farnley, nor was it recorded in the boring at Batley West End Colliery, though it might have been missed. In Shaw Cross Colliery, just east of the sheet, "Dark Bind and Smit" is recorded 42 ft. 10 in. above the Better Bed, and may be the equivalent of this seam.

Of the sandstones, a thin bed a few feet above the Better Bed Coal, and the Thick Stone form two well-marked parallel features from Long Shaw to Shelf. The same beds surround Reevy Beacon Hill, between Clayton Heights and Wibsey, the Thick Stone being split by a thin bed of shale. In Syke Pit, Wibsey, the Thick Stone is 35 ft. thick, and its top lies 11 ft. below the Black Bed Coal. Part only of this bed is to be seen in the railway cutting on the east side of St. Dunstan's Junction. A quarter of a mile to the east of this, at the Bowling Iron Works, 16 ft. 6 in. of sandstone has been proved at 23 ft. 6 in. below the Black Bed. In Tong Park, the Thick Stone is only 10 to 12 ft. thick and lies almost immediately beneath the Black Bed.

The Thick Stone is in the Low Moor district shown by the shaft sections to be about 27 ft. thick and to lie about 27 ft. below the Black Bed. South of Low Moor the stone, consisting of sandstone and rag, is recorded in shafts as 50 ft. thick, lying 8 or 10 ft. below the Black Bed. It was not seen at the outcrop around Norwood Green. The Thick Stone has been mapped around Cockersdale and New Farnley, where it apparently does not exceed 20 ft. in thickness, its top lying 15 to 20 ft. below the Black Bed. It also makes a feature a short distance below the Black Bed in the side of Hart Hill, Gildersome and its presence is inferred around Moor Head.

The thin sandstone which lies above the Better Bed south of Shelf forms a distinct feature, though it is doubtful if it is as much as 20 ft. thick. It lies 6 to 8 ft. above the Better Bed north of Stone Chair, but when followed to the south-east towards Norwood Green it gets farther away from the Better Bed, and also rapidly disappears. It is not present in the north-east of the area.

No sandstones have been traced between the Better Bed and Black Bed on either side of the Calder valley at Clifton or in the Bradley Park and Upper Heaton districts as far south as Gawthorpe. At Cowmes, 2 miles east of Huddersfield, the mudstones are extensively quarried for the manufacture of bricks. At Gawthorpe Green a variable bed of sandstone corresponding to the Thick Stone appears. From there it forms a distinct feature and can be traced southwards past Fenay Bridge to Far Dean, Highburton. At the latter locality it gives rise to a distinct shelf below the prominent scarp formed of Grenoside Rock. At the Addlecroft boring, Gawthorpe, (see page 55), it was found to be 35 ft. thick, while its thickness at Highburton is 20 ft.; at

the latter locality 30 ft. of shale occurs between it and the underlying Better Bed Coal.

The Black Bed Coal.—Like the Better Bed this coal shows a tendency to thin towards the east and is practically worked out in the area where it is thickest and within a short distance of the surface; but owing to its proximity to the manufacturing centres it is in demand for the woollen industry, and is consequently worked almost throughout the area here described.

In the north the thickness varies from 3 ft. on the west to 2 ft. on the east, with an occasional dirt parting and, around Farnley, an inferior thin coal at the base (p. 56). At Odsal, between Wibsey and Newhall, the workings at Glenfield Colliery show that the coal and part of its fireclay have been cut out by a channel now filled with boulder-clay; this channel has been eroded to a depth of 38 ft. with a width exceeding 120 ft. A number of pebbles or small boulders of quartzite and other rocks are recorded from the Black Bed Coal at Wortley, about one mile east of the north-east corner of the area shown on the map.[1] Owing to its economic importance a number of thicknesses, etc. of the Black Bed Coal are given above (p. 56).

South of the Calder the seam is sometimes known as the Tinker Coal and lies immediately beneath the Grenoside Rock. Numerous disused workings occur near the outcrop. In the Addlecroft boring at Gawthorpe the coal was only 1 ft. thick, somewhat thinner than in neighbouring collieries (p. 55).

The Measures between the Black Bed Coal and the Clifton or Oakenshaw Rock.—These beds in the north contain the Black Bed Ironstone and the Crow and other thin coals; in the south the measures up to the Crow Coal are occupied by the Grenoside Sandstone. The Ironstone Beds are described in some detail on pp. 57, 58 and analyses, etc. are given on p. 174.

A section of the Crow Coal is visible in the railway cutting 350 yards east-north-east of St. Dunstan's Junction, north of Bowling Park:—

		Ft.	in.
	Drift	—	
	Shale	8	0
Crow Coal	Coal	0	8
	Underclay and dirt	3	1½
	Shale	1	11
	Coal	0	3
	Shale	0	6
	Coal	0	3

The following section was recorded from a clay-pit at the junction of New Hey Road and Wakefield Road, Bowling, 700 yards south-east of the above railway cutting:—

		Ft.	in.
	Drift ...6 ft. to	9	0
	Sandstone	6	0
	Shale	2	0
	Sandy shale with bands of sandstone	3	6
	Shale with ironstone nodules	7	0
	Soft shale	1	0
Crow Coal	Coal ...6½ in. to		7
	Parting		½
	Coal ... 6 in. to		5
	Parting ... ¼ in. to		1½
	Coal ... 3 in. to		4
	Underclay	3	6
	Blue shale with ironstone nodules	1	10
	Dark shale	1	3
	Coal		7
	Hard coaly shale		2½
	Underclay	—	

[1] Brownridge, C., *Proc. Yorks. Geol. Soc.*, vol. ix, 1888, pp. 405–7.

This clay-pit has been filled in and is now built over. Sections of the Crow Coal at Syke Pit, Wibsey, in the railway cutting at Cutler Heights north of Dudley Hill, and at the Bowling Iron Works show the great variability of this seam in the north. At the south-west end of Wyke Tunnel the section is: coal, 12 in.; shaly seat-earth, 2½ in.; coal, 2 in.; seat-earth, 21 in.; coal, 3 in.

The '22 Yard' and '32 Yard' Coals are unimportant, never exceeding a few inches in thickness, besides being extremely variable in texture. They are, however, usually present though only represented by smuts and seat-earths in the Tong district and to the east. A good section of these measures up to the Oakenshaw Rock is seen in the Bradford Brick and Tile Company's pits at Haycliffe Hill, between Great Horton and Wibsey (Plate IVB):—

	Ft.	in.
Oakenshaw Rock, much jointed ... ...15 ft. to	20	0
Grey shales	4	6
Coal ... ... 4 in. to		6
Hard bastard ganister ... ... 2 ft. to	2	6
Soft grey seat-earth with ironstone nodules	2	3
Sandstone	1	3
Grey mudstone with ironstone nodules and 'duck eggs'	16	0
Black brittle shale	4	0
Coal (32 Yard)		7
Black carbonaceous shale ... ... 8 in. to		10
Soft seat-earth	2	6
Alternations of thin sandstone, shale and mudstone with many ironstone nodules near the base ...	23	6
Shale with nodules and thin bands of ironstone ...	4	0
Coal (22 Yard)	(touched)	

Another section of these beds is in the approach-cutting to the Low Moor-Bowling railway tunnel. Road improvements at Manchester Road, Odsal, two-thirds of a mile north-west of the last locality, resulted in the temporary exposure of a split in what is probably the 32 Yard Coal.[1]

Farther south no new sections of the ironstone series were obtained, but what appears to be a 'wash-out' occurs in it south of Low Moor, the sandstone which ordinarily overlies the series in this area coming down and forming the roof of the coal.

At the outcrop at Norwood Green and Lightcliffe the sandstone appears to be almost directly above the coal, but whether the ironstone beds were present or absent could not be ascertained. This sandstone is exposed below the Crow Coal in the cutting at the south-west end of Wyke Station and the 19 ft. 6 in. of 'Warrells' recorded above the ironstone in the near-by Flathers Pit appears to represent it, as may 6 ft. of stone at Hartshead and Battyeford. The same bed can be readily traced round the sides of Cockers Dale, where it occupies almost all the space between the Black Bed and the Crow Coal.

There are 16½ ft. of sandstone measures in this position at Howden Clough Colliery, and 30 ft., with a 2-in. coal, in Batley West End shaft.

Figures giving the south-easterly thickening of the measures between the Crow Coal and the Black Bed are given above (p. 58).

The Oakenshaw or Clifton Rock.—From Great Horton to Wibsey the lower bed of this rock forms a steep escarpment; the same bed forms a less marked ridge from Beck Hill to Buttershaw, along which it has been much quarried. A small quarry on Wibsey Slack has supplied stone which, when crushed, yielded a sand suitable for moulding.

A swilley coal on top of the lower bed of the Oakenshaw Rock was formerly visible in quarries between Wibsey Bank and the Independent Chapel.

[1] *Naturalist*, 1922, pp. 61–4.

	Ft.	in.
Coal		3½
Dirt		½
Coal	1	4½
Black shale		5½
Hard coal		4¾
Clay		½
Black shale	1	0
Sandy underclay ... ... 1 ft. to	1	6
Sandstone	—	

Round Bowling and Holme the upper division of the Oakenshaw Rock appears to be better developed than the lower. It, however, becomes thin at Toftshaw Bottoms and west of Bierley Hill is unimportant. A small faulted outlier of the lower bed occurs at Hill Green, Tong. In the north-east corner of the sheet the Clifton Rock forms a sharp feature at Cud Hill, west-south-west of Upper Moor Side, but becomes thin and shaly farther east.

The Clifton Rock forms a plateau around Wyke and Royds Hall, and also covers some area around Oakenshaw. It is exposed in Royds Hall Beck and outcrops between Norwood Green and Bailiff Bridge. It varies considerably in this area. West of Oakenshaw it consists of three beds, the uppermost of which is the strongest; north-east of Oakenshaw this uppermost bed consists of two parts, divided by a thin shale band. A quarry in the lower and thicker parts shows 30 ft. of thin-bedded flags.

Towards Scholes some shale is present, but it cannot be mapped separately from the sandstone. North-east of Bailiff Bridge the whole series appears to have passed into shale and no sandstone at all could be mapped.

A massive sandstone is developed between Wyke and Royds Hall, and has been quarried in the past.

The sandstone in the quarry at Carr House has in its lower part a somewhat sugary texture. No trace of the coal mentioned in the original memoir was seen above the sandstone here.[1] In the valley of the beck west of Royds Hall, 22 to 30 ft. of sandstone with shaly beds are exposed. They rest on 30 ft. or more of shaly beds.

Around Clifton only one bed is recognizable, though the good stone is mainly to be found at the top and bottom; the section at Hartshead Pit is Top Delph (i.e., a good stone for quarrying) 13 ft., stone and rag 45 ft., Bottom Delph 13 ft. At Battyeford at least 25 ft. of massive sandstone is seen in the old quarries in the Mirfield Fathers' grounds.

South of the Calder the quarries north-west of Bradley show hard white evenly-bedded sandstone to a depth of 30 ft. East of the Colne and opposite Battyeford the rock has a decidedly coarser grain. Farther south two beds can again be distinguished east of Kirkheaton, but they thin away to the south and are not recognizable beyond Lepton.

The Shertcliffe, Churwell and Beeston Coals.—In the north the thickness of the Shertcliffe seam is usually between 2 ft. 6 in. and 3 ft. A smaller seam called the Little Coal exists a short distance above the main bed in the sequence, and it is the thinning out of the measures separating these two seams which, to the east, brings in the type of seam known as the Beeston Bed.

[1] 'Geology of the Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1878, p. 173.

The Shertcliffe Bed was exposed in the valley of Royds Hall Beck where it overlies about 8 ft. of Clifton Rock in the valley bottom. The section recorded is :—

		Ft.	in.
	Sandstone and sandy shale	—	
Shertcliffe Bed	Coal		8½
	Dirt	1	0
	Coal	1	4
	Underclay	3	6
	Sandstone	—	

This seam has been worked from the Victoria and Rakelands Pits between Odsal House and the Low Moor Fault, the coal being partly a stone coal and 2 ft. thick. A small wedge of the bed has been faulted up and is exposed at the side of the Huddersfield Road, Hill Top, Low Moor, where the stony nature of the coal can be seen.

		Ft.	in.
	Grey to grey-black, brittle shale	4	0
Shertcliffe Bed	Coal, stone coal at base	2	7
	Grey shale	1	9
	Coal smut		¼
	Grey shale with white streak	1	2
	Massive jointed sandstone	4	0

The wedge-shaped faulted area comprising Odsal Wood and part of the West Bowling Golf Links must cover a similar area of unworked Shertcliffe Bed, since the shaft of the Tunnel Pit reached the Black Bed at 387 ft. No details of the shaft are available.

In the Dudley Hill–Tong Street area the seam has been exhaustively worked, while at Tong Street Colliery the Little Coal, which has there a thickness of 12 to 14 in., has been mined.

In the Victoria Brick Works, Dudley Hill, the shales and underclays from the measures between the Clifton Rock and a horizon about 30 ft. above the Little Coal are quarried and ground for brick and tile-making. The resulting section shows the Little Coal to be 1 ft. 1 in. thick, the lower 4¼ in. being rather shaly; while the Shertcliffe Bed is 1 ft. 10 in. thick with two dirt partings arranged as follows :—

		In.
Shertcliffe Bed	Coal	2
	Dirt	3
	Coal	10
	Dirt	3½
	Coal	10

The same strata are exposed in the two nearby cuttings on the disused Low Moor Branch of the L. & N.E. Railway. The Shertcliffe Bed has been grubbed out and a clean section of the seam is not available, otherwise the following represents the succession :—

		Ft.	in.
	Grey-buff shales	—	
Little Coal	Coal		2½
	Clay		6
	Shaly coal		9
	Grey seat-earth passing down into grey shale	9	0
Shertcliffe Bed	Coal (obscured)	—	
	Shale	6	0
Clifton Rock	Sandstone	—	

Arranging the records of these seams from collieries between Dudley Hill and Tong in a geographical order from west to east, these data are obtained :—

	Broadbent's Colliery Dawson Lane, Tong Street.	Broadbent's Colliery Parratt Fold, Tong Street.	Gittin's Colliery, Tong Street.
Little Coal	Coal 0′-9″	Coal 0′-10″	Coal 0′-11″
	Measures 21′-0″	Measures 15′-0″	Soft shale 9′-0″
Shertcliffe Coal	1′-9½″ { coal 0′-2½″ / dirt 0′-2″ / coal 0′-9″ / dirt 0′-3½″ / coal 0′-10″ }	1′-9½″ { coal 0′-2½″ / dirt 0′-2″ / coal 0′-9″ / dirt 0′-3½″ / coal 0′-10″ }	1′-11½″ { coal 0′-3″ / shale 0′-1½″ / coal 0′-10″ / shale 0′-4″ / coal 0′-10½″ }
	Old Collieries Holme Lane End, Tong Street.	No. 1 Pit, Tong Colliery, (Bowling Iron Co., Ltd.).	Charles Pit, Tong.
Little Coal	Coal 1′-1″	Coal 0′-10″	Coal 1′-3″
	Blue shale 15′-0″	Underclay 5′-6″	{ Underclay 2′-11″ / Shale 2′-2″ }
Shertcliffe Coal	2′-3½″ { coal 0′-4″ / clay 0′-2″ / coal 0′-10″ / coal & / clay 0′-4″ / coal 0′-9½″ }	coal 2′-4″	coal 2′-10″
	Rush Pit, Westgate Hill.	Field Pit, Booth Holme Colliery, Tong Lane.	Tong Old Colliery.
Little Coal	Coal 0′-11″	Coal 0′-11″	1′-8″ { coal 1′-6″ / dirt 0′-5″ / coal 0′-2″ }
	Shale 3′-6″	Shale 2′-2″	Underclay 1′-2″
Shertcliffe Coal	2′-0″ { coal 0′-4″ / dirt 0′-2½″ / coal 0′-10″ / dirt 0′-1½″ / coal 0′-10″ }	2′-3″ { coal, mixed 0′-5″ / coal 0′-2″ / dirt 0′-1″ / coal 0′-9½″ / dirt 0′-2″ / coal 0′-10½″ }	2′-10″ { coal, mixed 0′-5″ / coal 0′-7″ / dirt 0′-6″ / coal 1′-3″ / dirt 0′-1″ / cannel 0′-7″ }

The thicknesses given for the seams are those of coal only.

North of this colliery tract a series of natural sections in and around Holme and Holme Wood gives the following sequence :—

		Ft.	in.
Coal		0	2
Shale		0	11
Coal		0	0½
Shale		0	6
Coal		0	0½
Shale		0	1
Dirt		0	3
Little Coal		1	2
Dark underclay		2	–
Shale		3	6
Shertcliffe Bed 2 ft. 10 in.	Coal	0	6
	Underclay	0	5
	Coal	0	10
	Dirt and coal	0	7
	Coal	0	11
Dirt		0	1
Underclay		—	

South of the Dudley Hill and Westgate Hill district the Shertcliffe Bed outcrops along the eastern side of the High Royds Beck valley and has been worked under the country to the east. Two outcrop sections, one at the north end of the outcrop at Toftshaw Bottoms along the eastern side of the tramway, the other in a quarry near the disused Clifford Pit, 600 yards farther south, have yielded accurate records of the two seams for this locality. These are recorded below and amplified by information concerning the same seams obtained by the collieries in working the area immediately to the east.

Toftshaw Bottoms.	Qy. near Clifford Pit, Hunsworth.	Hunsworth No. 6.	Hunsworth No. 2.	Crosses Colliery.
Little Coal 0′-11″ { Coal 0′-9″ / under-clay 0′-6″ / coal 0′-2″	1′-1″ { coal 0′-10″ / underclay 0′-7″ / coal 0′-3″	{ Coal 0′-9″ / Coalash 1′-7″	stone coal (local only) 1′-3″ / underclay 6′-0″ / coal 0′-10″	coal 1′-0″
underclay 4′-0″	5′-11″ { dk. shale 1′-0″ / hd. un'clay 3′-8″ / dirt 0′-2″ / underclay 0′-10″ / dirt 0′-3″	measures 4′-3″	underclay 4′-0″	scale 4′-0″
Shertcliffe Coal 2′-5½″ { coal 0′-3½″ / clay 0′-2″ / coal 1′-2″ / dirt 0′-2″ / coal 1′-0″	2′-3″ { coal 0′-5″ / dirt 0′-1″ / coal 1′-0″ / dirt 0′-3″ / coal 0′-10″	{ coalash 1′-2″ / coal 2′-3″	coal 2′-7″	1′-10½″ { coal 0′-4″ / dirt 0′-1½″ / coal 0′-8½″ / dirt 0′-3″ / coal 0′-10″
underclay 1′-3″				
Clifton Rock sandstone —				

The Beeston Bed was measured by the late R. Russell at the outcrop in Farnley Wood, at a spot east of New Farnley and just beyond the edge of the map. The detailed section is as follows:—

	Ft.	in.	Ft.	in.
Coal...	1	3	—	
Dirt...	—		0	0¼
Coal...	0	3	—	
Dirt...	—		0	1½
Coal...	0	1½	—	
Shale	—		0	5
Coal...	1	8	—	
Shale	—		0	2¾
Coal...	0	5	—	
Shale	—		0	3
Coal...	0	1¼	—	
Dirt...	—		0	0¼
Coal...	1	10	—	
Shale	—		0	1½
Coal...	1	2	—	
	6	9¾	1	2¼

A seam 8 ft. thick recorded (not in detail) in Sowden Air Pit No. 4, at Upper Moor Side, is apparently the Beeston Bed in its undivided form.

South of New Farnley the bed splits up rather abruptly into two seams, the Churwell Thin and Thick Coals, which are, in the shaft of Farnley Wood Colliery, already 30 ft. apart. (See Diagram).

The actual split is not seen, but the two beds were said to come very close together in the north part of the workings of Farnley Wood Colliery.

The Shertcliffe Bed is present between Wyke and the Bailiff Bridge fault, and crops out in Royds Hall Beck, where it was measured in the original survey; one section gave a total of 2 ft. 3½ in. including 5 dirt partings amounting to 4½ in.[1] but it has since been grubbed out and cannot now be seen. It is not a stone-coal here. The seam is recorded as 21 in. thick in a borehole at the south end of Royds Hall Great Wood.

In the country around Scholes the Shertcliffe Bed is a stone coal, and is called the Popplewell[2] Stone Coal. It is worked out here. A section at Whitehall Colliery, east of Scholes, shows 3½ in. of "Basset," resting on 4 in. of "Johnnies," on 6 in. of "Muck," on 13½ in. of Stone Coal. The roof is of black shale, in which are badly-preserved fish remains.

Other sections are recorded from Chairbarrows Pit and Coates Pit, Clifton, and the thicknesses at the following places are:—First Drift Pit, Wyke, 30 in.; Old Popplewell Pit, 22 in.; First shaft below the Moravian Chapel, Wyke, 30 in.

With regard to the seams lying above the Shertcliffe Bed in the country west of Hunsworth, which are equivalent to the upper part of the undivided Beeston seam, the correlation is not quite certain.

The matter is discussed in considerable detail in the Memoir on the Geology of the Yorkshire Coalfield, on pages 179 to 189. In this account a stone-coal which lies about 30 ft. above the Shertcliffe Bed in the Scholes district is called "Coal a," and is correlated with the topmost of the three coals of Hunsworth and with the Churwell Thin Coal. The intermediate coal (coal b of Hunsworth, etc.) is taken to be absent in the Scholes area, and there is certainly no coal in the measures between the two seams in that area. This is likely to be the correct interpretation, but there is also another coal to be considered, which around Scholes is approximately a further 30 ft. higher and at Gomersal only 22 ft. higher, and is about 10 in. thick. It is not certain that this should not be the equivalent of the Churwell Thin Coal, i.e. "Coal a,"

[1] 'Geology of the Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1878, p. 182.
[2] Popplewell is a quarter of a mile west of Scholes.

in which case the coal about 30 ft. above the Shertcliffe Bed would be " Coal b." This would make the distance between tne upper and lower equivalents of the Beeston Bed about 60 ft.

The matter cannot be definitely proved one way or the other, owing to the gaps left in the chain of sections by the loss or destruction of records of old sinkings. The Shertcliffe Bed is nearly worked out in the country around Hunsworth, where its thickness is 22 to 26 in. at Hunsworth Lodge Colliery, 2 ft. in Hunsworth Engine Pit, and 26 to 29 in. at dayholes in Hunsworth Wood, just east of Oakenshaw. The coal was seen during the original survey in the railway cutting south of Oakenshaw, but no complete section could be measured.

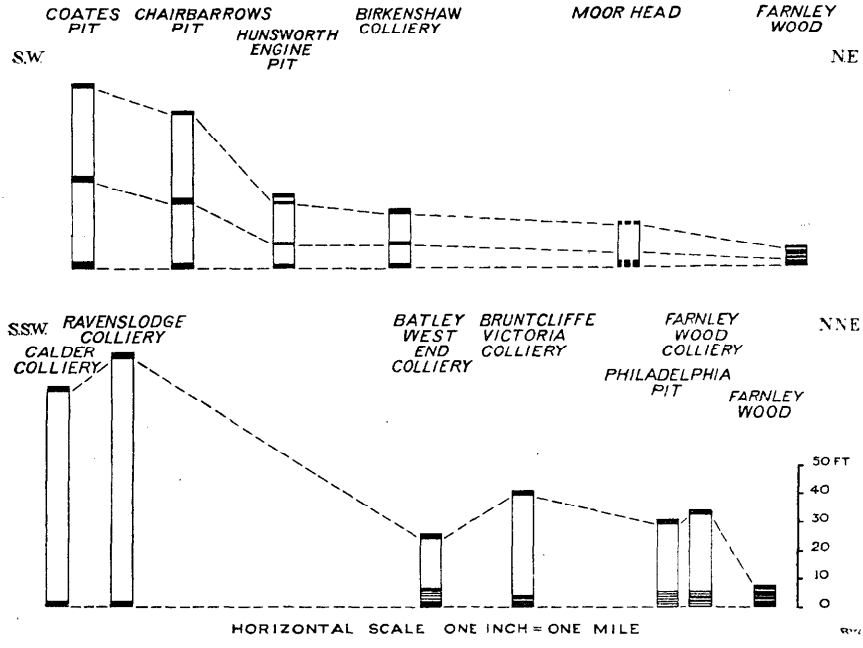

Fig. 5.—*Sections showing the passage of the Shertcliffe Coal and various stone coals through the Churwell Thick and Thin to the Beeston Coal.*

In the neighbourhood of Birkenshaw three beds are the equivalent of the Beeston Seam, the section at Birkenshaw Colliery showing an upper 14 inch coal separated by 10 ft. of strata from a middle 12 in. coal, separated by 6 ft. of strata from a lower 2 foot coal, the whole occupying 20 ft. 2 in. In the bore-hole at Gomersal Mills, two coals 20 ft. apart are recorded in this position, but with another seam a further 22 ft. above. It is uncertain whether or not this upper seam belongs to the Beeston group. At Howden Clough the two seams are not so widely separated, the space occupied by them and the intervening measures being about 20 ft. In the country between Farnley and Batley these seams, the Churwell Thick and Churwell Thin, are somewhat close together. They are being actively worked in the Batley district, where the coal finds a ready sale for use in factories.

In the Clifton area, worked for very many years by the Low Moor Company, the sections have all been published either in the Memoir on the Geology of the

Yorkshire Coalfield or in the Sections of Strata[1]: Green's conclusions, outlined above, hold good in every way. At Nunbrook Colliery, south of Hartshead and east of Kirklees Park the section of the Shertcliffe Coal was shale roof, coal 4 in., dirt 6 in., coal 1 ft. 6 in., seat-earth. Further north, between Hartshead and Cleckheaton, this seam is again a stone coal and is called the Blakcup Stone Coal; a section at Mount Pleasant near Marsh is trub 8 in., shale 5 in., stone coal 11 in. At Southfield Colliery, half a mile west of Robert Town it is blue bind, shale 5 in., dirt 3 in., coal 1 ft. 4 in., seat-earth. Here a washout has been proved in the Shertcliffe coal; the margin runs about 30° north of east past Owlet Hurst and has been traced for a distance of 750 yards, but the width is unknown. At Park Farm, in the Spen Valley due east of the last, the Shertcliffe (' Beeston ') Seam consists of Top Coal 5 in., dirt 5 in., Bottom Coal 1 ft. 8 in.: the seam lies 210 ft. below the Blocking Bed and 225 ft. above the Black Bed.

The Whinmoor Coals.—In the extreme south the coal next succeeding the Clifton Rock or its equivalent is known as the ' Whinmoor ', but it is not found as far north as the Calder Valley; the Shertcliffe, Black Band or Beeston Coal, which appears to be continuous throughout the area lies about 30 ft. above the Whinmoor where present.

The Whinmoor Coals are of greater importance to the south of the present area. Where workable in the present area they are only an inferior seam and are mainly worked along or close to the outcrop.

The most northerly point at which the Whinmoor Coal can be definitely recognised as such is in Rods Beck, 400 yards due south of Lodge Mill Colliery, and half a mile north of Lepton Church. It is here 1 ft. thick being overlain and underlain by shaly sandstone. From thence its outcrop can be traced past Greave House, Lepton, to Beldon Brook.

In Beldon Brook the Whinmoor Coal which has been worked along the outcrop is 20 in. thick and is overlain by strong flaggy sandstone. Old crop-workings also occur at Linfit. To the south of here the Whinmoor Coal splits into two separate seams, the Top Whinmoor and Low Whinmoor; while at Hallas half a mile north-east of Kirkburton a dirt parting further separates the Top Whinmoor Coal into an upper and lower bed, the section hereabouts being as follows:—

		Ft.	in.
Top Whinmoor	Coal	0	6
	Dirt	1	0
	Coal	1	2
	Measures	24	0
Low Whinmoor	Drubby Coal	1	2

The Black Band, Shertcliffe or Beeston Coal can be traced continuously throughout the present area. It is separated from the underlying Whinmoor Coal, where present, by about 27 to 30 ft. of shale with impersistent bands of sandstone.

An excellent section of this coal is exposed in a quarry alongside Carr Mount Farm, one mile east of Kirkheaton Church. It is here 1 ft. thick and rests on a 3 in. bed of fireclay which overlies alternating shaly sandstone and sandy shale referred to as the Shertcliffe Seatstone. It has also been worked from day-eyes alongside Rods Cottage, Rods Beck, half a mile south-west of Whitley Beaumont. Here the coal is 2 ft. 4 in. thick overlain by rather massive flaggy sandstone. Numerous old crop workings also occur alongside Thurgory Lane, Lepton. In this area the seam is of good quality being a hard bright coal, but the fact that both roof and floor frequently consist of hard sandstone has prevented it being extensively worked. In this area it is usually known as the Shertcliffe Coal though locally it has also been referred to as the Lower Lousey.

[1] *Midland Inst. Min. Eng.*, 2nd Ed., 1927.

In Beldon Brook between Lepton and Linfit crop-workings in this seam occur. In this area and to the south of here it is usually spoken of as the Black Band Coal. In Beldon Brook it averages 2 ft. in thickness being overlain by hard flags and flaggy shale.

Around Linfit and Thorncliff the Black Band, sometimes referred to as the Cinder Hill Coal, has been fairly extensively mined both along the outcrop, and also from shafts at Linfit Bridge and Thorncliff Green. In this area it varies from 1 ft. 6 in. to 2 ft. in thickness.

The Beeston, Shertcliffe, or Black Band Coal is of sufficient importance to have been mined at considerable depths to the east of the outcrop. Thus it has been reached in colliery shafts at Grange Moor, Overton and Emley. Throughout this area it consists of an upper and lower bed separated by a varying thickness of measures. At the Shuttle Eye Collieries, Grange Moor, the Beeston or Shertcliffe coal occurs 162 ft. below the Blocking Coal. The top or inferior seam is 30 in. to 2 ft. thick, and is separated from the low or main Beeston Coal by 15 ft. of measures. The lower Beeston seam averages 1 ft. 6 in. in thickness. At the Prince of Wales Colliery in New Hall Wood, Overton the following is the detailed section of the two seams :—

		Ft.	in.
Top Shertcliffe or Upper Beeston	Foul Coal	0	4
	Fireclay	0	6
	Coal	0	10
	Measures	35	2
Bottom Shertcliffe or Low Beeston	Coal	1	4
	Dark grey shale	1	1
	Coal	1	4

At the Speedwell Pit, Emley, the Top Beeston Coal, 1 ft. 10 in. thick, lies 140 ft. below the Blocking Coal.

The Measures between the Shertcliffe and the Blocking Bed Coals.—In the north these measures contain two coals that have been named, the Trub Coal and the Lousey Bed ; trub is a local term for a shaly stone coal. There are no important sandstones. The total thickness is 220 ft. at Coates Pit, Clifton ; 190 ft. at Gomersal, and 240 to 270 ft. at Batley.

In Royds Hall Beck several exposures of parts of these measures have been recorded. The Trub Coal is sufficiently developed to have been worth working ; it is represented as a fairly good quality stone coal. Between the Halifax Road and Mannerley Lane the seam section is :—

		Ft.	in.
	Black shale...	1	5
Trub Coal	Shaly cannel	1	0
	Cannel		10

A little further downstream opposite the mill ruins this section was measured :—

		Ft.	in.
	Black platy shale	1	6
Trub Coal	Cannel coal...	0	6
	Soft grey-buff shale	0	3
	Shaly coal	0	4
	Grey-buff shale	4	3
	Coal	0	9
	Clay		—

In the same area the Lousey Coal is represented by three thin seams with clay partings. The following section is from Parish Wood, Riding Hill :—

		In.
Lousey Coal	Coal	$4\frac{3}{4}$
	Clay	$2\frac{3}{4}$
	Coal	2
	Clay	1
	Coal (earthy)	$2\frac{3}{4}$
	Underclay	—

This group of measures occupies a large area from Dudley Hill to Tong mainly to the north of the Tong Street—Westgate Hill road. Stream sections within this area reveal the existence of a number of very thin coal seams which can be correlated in a few instances only. The shaft sections of No. 1 Pit, Tong Colliery, Charles Pit, and Booth Holme Field Pit show a sequence of measures with these thin coals, commencing in the cases of the latter two pits just above the Trub Coal:—

No. 1 Pit, Tong Colliery	Ft.	in.	Charles Pit	Ft.	in.	Booth Holme Field Pit	Ft.	in.
			Measures ...	15	6	Measures ...	7	4
			Trub Coal ...	1	6	Trub Coal ...	0	9
			Measures ...	13	6			
			Coal	0	3	Measures ...	36	5
			Measures ...	12	3			
			Coal	0	2	Blk. bassett	0	9
Measures ...	40	0	Measures ...	40	0½	Measures ...	36	9
Coal	0	5	Coal	0	10½	Coal ...	0	11
Measures ...	6	0	Measures ...	19	11	Measures ...	11	1
Coal	0	0½						
Light seat ...	1	3	Coal	0	3¾	Coal (stone)	0	5
Coal	0	1						
Measures ...	34	0	Measures ...	2	3¼	Measures ...	21	10
Little Coal ...	0	10	Little Coal ...	1	3	Little Coal ...	0	11
Measures ...	5	6	Measures ...	5	1	Measures ...	2	2
Shertcliffe Coal	2	4	Shertcliffe Coal	2	10	Shertcliffe Coal	2	8

The Lousey Coal has not been proved in the Tong area: the last record of the seam is from Hunsworth No. 2 Pit, where it is 1 ft. thick. In a boring at Westgate Hill the coal is apparently represented by 1 ft. 2 in. of black shale.

Around Shelf the Trub Coal attains a thickness of 22 in. Just west of Hunsworth it appears to be represented by a few thin streaks of coal and coaly shale.

The Lousey bed is, at Coates Pit, Clifton, about 80 ft. below the Blocking Bed, the section from top to bottom reading coal 17 in., seat-earth 3 ft., coal 5 in., seat-earth 4 in., coal 6 in. Sections which vary somewhat from this were recorded from the Low Moor Popplewell Pit and from Primrose Hill, Scholes. Here the coal seems to have been worked a little in the past.

It outcrops also around Hunsworth and in the valley of Lodge Beck, south-west of Birkenshaw. A section measured here, in Lodge Range, shows two thin coal beds, the top 8 in. and the bottom 2 in. thick, separated by 5 in. of underclay. In the water-bore at Gomersal Mills 2 ft. of coal was recorded 66 ft. below the Blocking Bed. This is the Lousey Bed, but the recorded thickness is probably too great. In the country around Philadelphia at least three thin coals are present between the Churwell Thin and the Blocking Bed, and the Lousey Bed is probably represented by one of them.

Further south the Trub Coal is not recognizable. The Lousey Bed crops between Cleckheaton and Liversedge: here and at Strawberry Bank Colliery a short distance to the south the thickness is 2 ft. 7 in. about 75 ft. below the Blocking Bed and 114 ft. above the Shertcliffe. This thickening is very local; to the south the thickness is 1 ft. 5 in. at Hartshead and 1 ft. in the crop from Kirklees Park to Battyeford. South-eastwards it is 1 ft. at Park Colliery, near the railways east of Owlet Hurst, but the distance from the Blocking Bed has increased to 102 ft. Half a mile farther south a boring gives the section as coal 2 in., dirt 2 in., coal 4 in., at a distance of 94 ft. from the Blocking Bed; while at Conyers Colliery on the opposite side of the Spen alluvium the top coal is 13 in., dirt 5 in., bottom coal 2 in.

South of the Calder the Lousey coals (Top Lousey and Low Lousey) are comparatively unimportant seams which occur at varying distances between the Beeston or Shertcliffe and the Blocking or Silkstone coals. At Gawthorpe, near Kirkheaton, a coal described as the Top Lousey and 28 in. thick lies 25 ft.

above the Beeston Coal and is described as a worthless coal. A coal 9 in. thick which occurs in a corresponding position in Beldon Brook between Lepton and Linfit is similarly described as very poor.

At Thorncliffe and Linfit it has been worked somewhat; at Linfit Colliery the following is an average section :—

	Ft.	in.
Coal	0	11
Dirt	1	3
Coal	0	4

This seam is sometimes referred to as the 'Mucky Coal,' a name more usually applied to the Lime or Three Quarter seam in the Middle Coal Measures, and not infrequently to any inferior or shaly coal irrespective of its stratigraphical position.

CHAPTER IV

MIDDLE COAL MEASURES

Introductory

The Middle Coal Measures occupy a comparatively small part of the area here described: they nowhere reach as far north as the boundary of the map. The edge of the measures extends east to west from Gildersome to Drighlington, thence south-west to just beyond Cleckheaton, south-east to the Calder near Mirfield, and then approximately south through Lepton to the southern margin of the map (see Fig. 1, p. 2). Within this area occurs a faulted inlier of Lower Coal Measures of triangular shape between Cleckheaton, Liversedge and Heckmondwike together with other smaller inliers; while faulted outliers or extensions of the Middle Coal Measures, of which the largest forms a wedge stretching from Drighlington and Birkenshaw north-westwards to West Bowling, occur beyond the western margin of the main belt of Middle Coal Measures. The total area occupied by the Middle Coal Measures is approximately thirty-six square miles. The base of this subdivision is taken by general consent at the Blocking Bed (or Silkstone) Coal. This horizon can be readily recognized; but it does not correspond with the line of subdivision adopted in Lancashire or desirable on palaeontological grounds (see pages 48, 163, 164).

The highest coal present in the area is the Gawthorpe Seam, of which a small outlier occurs at Lower Soothill; this coal is the approximate equivalent of the famous Barnsley Bed of the country to the south-east or the Warren House Coal to the east.[1] The thickness of the measures between the Blocking Bed and the Gawthorpe Coal is about 945 ft., and only a few feet of higher beds are present in the Soothill outlier.

As a general rule the beds of sandstone in the Middle Coal Measures are neither so thick nor so persistent as those in the Lower, and consequently do not give rise to such prominent features. The most important sandstone, the Thornhill Rock, however, forms a plateau bordered on the west by a strong escarpment along the eastern margin of the present area from Bruntcliffe on the north to Overton on the south; this is especially well marked at Thornhill and to the east of Dewsbury. Other important sandstones which are well developed in this area are the Lepton Edge, Birstall, Emley and Horbury Rocks, and they give rise to a more varied landscape than is usual in Middle Coal Measure tracts. The remaining measures consist mainly of shale.

[1] Wray, D. A., 'The Barnsley Coal and its variations,' Appendix VI in 'Summary of Progress' for 1926 (*Mem. Geol. Surv.*), 1927, pp. 127–137.

The more important coals which have been largely wrought are the Blocking Bed, the New Hards or Middleton Main, the Old Hards or Brown Metal Coals, the two Flockton or Adwalton Coals and the Haigh Moor. Secondary seams are the Wheatley Lime or Three Quarters, the Green Lane and the Joan. A band of ironstone known as the Tankersley Ironstone or Cockleshell Bed is prominent in the south a short distance above the Flockton Thick Coal and was worked many years ago. Compared with those of the Lower Coal Measures the fireclays are of little economic importance.

No marine fossils whatever are met with in these beds; but bands rich in *Carbonicola*, *Naiadites* and ostracods occur at numerous horizons. They have been found to overlie the Blocking, New Hards, Green Lane, Old Hards and Flockton Thick and Thin coals at several places within the present area. The Tankersley Ironstone is largely made up of casts of *Carbonicola* shells. The roofs of the Blocking Bed, the Middleton Bed and the Adwalton Stone (or Flockton Thick) Coal yield numerous fish remains.

Plant impressions are abundant at several horizons. The most prolific horizons in the present area appear to be the roofs of the Wheatley Lime and Old Hards Coals, where these coals are immediately overlain by sandstone or sandy shale. Fuller details of the palaeontology are given on p. 153, etc., and of the palaeobotany on p. 163.

General Stratigraphy

From the Blocking Bed to the Middleton Main Coal.—The Blocking Coal, which corresponds in relative position with the Silkstone Coal of South Yorkshire (not that of the country around Wakefield which is the Middleton Main)[1] is a seam of fair quality coal which has been largely worked out in the present area. In the north it is being worked on a small scale round Gomersal; it is usually divided into three parts by dirt bands; at Upper Lane Colliery, a recent sinking between Gomersal and Cleckheaton, the section is clod 8 in., top coal 13 in., muck 1 in., middle coal 7 in., muck 1 in., bottom coal 10 in. In the Calder valley the seam is usually about 20 in. thick without partings; at Mirfield Moor, however, the section is coal 2 ft. 3 in., seat-earth 5 ft. 8 in., coal 1½ in., black scale 4½ in., coal 5 in. As far south as Emley it varies from 16 to 24 in. usually with one parting about the middle. Within recent years it has been worked at and close to the outcrop south of Lepton. Beyond Emley it falls off much in quality and thickness and in some places disappears altogether. The roof-shales of the Blocking Coal were examined in pits at Grange Moor, Flockton, Emley and Overton, where they consist of fine dull black shale yielding *Carbonicola*, *Naiadites*, *Spirorbis*, ostracods and fragments of *Megalichthys*; some poorly preserved plant remains including species of *Neuropteris* and *Sphenophyllum* were found in addition

[1] Green, A. H., 'Geology of the Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1878, p. 247; and Kendall, Prof. P. F., 'Correlation of seams in Yorks. Coalfield,' *Trans. Inst. Min. Eng.*, vol. liv, 1917, pp. 67–76.

(See page 161). The measures from the Blocking Bed to the Wheatley Lime Coal are about 85 ft. thick in the north, and contain two insignificant bands of sandstone which have occasionally been quarried on a small scale for flags. Around Mirfield the sandstone becomes a single stronger bed known as the Falhouse Rock and forms the high ground from Crossley and Knowl to the Calder; the total thickness of the measures increases to 100 ft. or more; to the east it is 80 ft. at Ingham's Pit, Thornhill. South of the river the Falhouse Rock is 60 ft. thick at Falhouse where it consists of hard white fine-grained sandstone, regularly though somewhat thinly bedded. In the past it has been employed locally for building purposes. At Dransfield Hill and Gregory Springs between Falhouse and Hopton it forms prominent features but appears to be absent in the adjoining area of Liley Clough.

The Wheatley Lime or Three-Quarters Coal is present throughout the area and has been mined to a considerable extent, though only a second class coal. In the north it is only 13 in. thick at Birkenshaw but the section in the cutting north of Cleckheaton Station is: Coal 3 in., parting 1 in., coal 7 in., parting ½ in., coal 8½ in.; a 7 in. coal lies 5 ft. below. At Gomersal and Batley West End the coal is only 12 and 11 in. respectively. A short distance to the south it is 26 in. at Howley Park where it is worked and the same at Batley Carr, though here it is earthy and inferior. Between Liversedge and Robert Town the Lime Coal has been worked to a small extent at several collieries, the thickness being 2 ft. 3 in. to 2 ft. 6 in. It is exposed in a brick pit on Mirfield Moor where it is 22 in. thick with one parting. In the Calder valley it is 2 ft. at the outcrop at Cotewall, 2 ft. 5 in. at Ravenslodge Colliery and 2 ft. 11 in. at Cowmes. To the south the thickness ranges from 1 ft. 6 in. to 3 ft. In some places the roof consists of shale, in others of hard sandstone. In the latter case fossil plant impressions are very abundant in the stone immediately overlying the coal. At Linfit Hill the overlying sandstone is well developed and forms a marked feature. The Wheatley Lime Coal has been extensively worked by means of day-eyes and shallow workings around Liley Clough and Whitley Wood near Hopton Mills, and also between Whitley Lower and Grange Moor. Over much of this area a thin or 'Crow' Coal overlies it. To the east, between Thornhill and Overton it has been largely mined. An extensive 'washout' was encountered here, trending approximately north and south and extending from under the village of Thornhill to Overton; it was about 500 yds. wide under Thornhill Edge. Around Emley and Emley Moor the coal is often referred to as the Thick Bed, the Blocking Coal being locally known as the Thin Bed. At Speedwell Pit, Emley Moor, one mile west of Emley Church, the average section from the stone roof to the seatstone is: inferior Crow coal 6 in., clod 8 in., coal 3 ft.

In the north a coal known as the Middleton Eleven Yard occurs from 21 to 33 ft. below the Middleton Main. This coal was formerly regarded as the equivalent of the Three Quarters or Wheatley Lime

Coal,[1] but shaft sections at Batley West End and Gomersal Collieries and a boring at Gomersal (p.173) show clearly the presence of two seams, of which the upper dies out to the south, where, however, one or two insignificant and nameless seams occur below the Wheatley Lime. The character of the Middleton Eleven Yard at Gomersal suggests that the seam is dying out: the section is coal smut 3 in., spavin and ironstones 33 in., coal 3½ in., soft white earth 9 in., dirt 10 in., coal 3 in. A thin sandstone is usually present in the north a short distance above the Wheatley Lime Coal, corresponding to that already mentioned as sometimes forming the roof of the coal in the south. The distance from that seam to the Middleton Main or New Hards is 70 to 80 ft. around Gomersal, 45 to 60 ft. in other parts of the area north of the Calder and 60 to 70 ft. in the south.

From the Middleton Main to the Old Hards Coals.—The important seam known as the Middleton Main in the north is usually called the New Hards in the south; near the Calder valley it is often called the Cromwell or sometimes the Yard; this last name, corresponding to the Three Quarters (Wheatley Lime) below it, is better avoided as it is also used for a higher seam. The name Silkstone used further east hardly reaches our area. In the north the Middleton Main is 2 ft. 4 in. thick in an outlier at Westgate Hill. East of the Birkenshaw fault the coal is practically worked out. Around Gildersome Street a 4 in. parting separates 2 ft. 3 in. of tops coal from about 1 ft. 6 in. of bottoms. A little further south there are often two partings, and the bottom bed is an inferior coal known locally as 'Whetstones.' The thickness is from 3 ft. 4 in. to 4 ft. 6 in. but from Gomersal to Batley it thins considerably, being only 14 in. at Batley Carr. At the outcrop north-west of Robert Town it is 2 ft. 11 in. and near Heckmondwike 1 ft. 6 in. to 2 ft. 6 in. On the west side of Dewsbury there is 19 in. of coal but on the east the seam is washed out; the boundaries of the washout are, however, unknown. At Combs Colliery the thickness is 2 ft. 11 in. but a one-inch parting separates the bottom from the rest; this part is called 'lime coal' and corresponds to the 'Whetstones' further north.

South of the Calder the seam is of very uniform character and has been extensively mined: on Emley Moor it is somewhat inferior but it improves in an easterly direction. It usually consists of an upper coal known as the 'hard best' 18 to 28 in. thick, a dirt parting varying from a mere film to 3 ft. and a lower coal 5 in. to 1 ft. in thickness. At Whitley Wood and Whitley Lower where this coal was worked at and close to the outcrop it was locally known as the Yard Coal, since it averaged 3 ft. in thickness. In some old workings on Emley Moor between Bunkers Hill and The Hut the New Hards Coal revealed the following section:—

	Ft.	in.
Black coal	4	6
Cannel coal	1	6

[1] 'Geology of the Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1878, pp. 256–259.

This abnormal thickness and development, however, did not extend over any considerable area. The coal evidently lay in a kind of 'swilley' for around the edges of the small area it came down to 18 in. in thickness, when further working was abandoned; a swilley also occurs in this seam at Thornhill. In the Silkstone and Barnsley districts where the New Hards more frequently exhibits such characteristics it is often referred to as the Swilley Coal on this account.

The roof of the Middleton Main is well known as yielding numerous fossil fish remains [1] including the type form of the genus *Megalichthys* Agassiz now in the Leeds Museum. This fossiliferous roof was seen during the re-survey at Cricket Hill, north-east of Gildersome, at Gregory Lane, Kirkheaton, at Briestfield and at Cockermouth near Lepton Edge: it was crowded with *Carbonicola*, *Naiadites* and ostracods together with fish scales and indeterminate plants.

The Green Lane or Middleton Little Coal lies 60 to 80 ft. above the Middleton Main or New Hards. Here and there the intervening measures contain unimportant sandstones and, in the north one or two thin and worthless coal seams, one of which was seen and mapped at Cricket Hill north-east of Gildersome. The Middleton Little seam, in the western part of its northern outcrop is of no value, but it thickens eastward. At Drighlington it is 1 ft. thick and on either side of the Gomersal ridge only about 8 in. with dirt streaks in the lower part. It increases to 2 ft. 3 in. at Street Pit, Gildersome, 2 ft. 6 in. at Bruntcliffe and rather more round Morley.

A little further south it is only about 6 in. at White Lee, but at Howley Park it reaches 3 ft. $3\frac{1}{2}$ in. with 7 in. of dirt in two partings; in Dewsbury it is again only 1 ft., though Ravenslodge Colliery between that town and Ravensthorpe gives the section as: Coal 6 in., dirt 4 in., coal 16 in. South of the river it again improves, being 2 ft. 4 in. at Ingham's Pit, Thornhill. It has been largely mined near the outcrop from near Hopton Mills southwards to the western edge of Emley Moor, averaging 1 ft. 6 in. in thickness. At Briestfield it varies from 14 to 22 in. Around Thornhill Edge and Emroyd Colliery it was 2 ft. 4 in. to 2 ft. 9 in. though not of good quality; but at Grange Moor, Denby Grange and Overton where it is still being mined, the thickness ranges from 1 ft. 6 in. to 1 ft. 10 in. Throughout the southern area the roof is a *Carbonicola* band from which *Naiadites*, *Spirorbis*, ostracods and the scales and teeth of fish have also been obtained (see p. 162).

In the north the distance from the Middleton Little to the Brown Metal Coals is 50 to 60 ft. A local bed of sandstone, the Gomersal Rock, caps the ridge on which that village stands; it lies some 40 ft. above the Middleton Little Coal and forms a well-marked escarpment overlooking the Spen Valley; its maximum thickness, around Swincliffe, may be as much as 20 ft. South of

[1] Davis, J. W., 'Distribution of Fossil Fishes in the Yorkshire Coalfields,' *Proc. Yorks. Geol. and Polytech. Soc.*, vol. vii, pt. iii, 1881, pp. 228–241.

the Calder nearly the whole of these measures is sometimes sandstone. In Liley Clough only two thin bands are present, but from Whitley Beaumont past Lepton Edge to Flockton and Emley Moors a thick bed forms a prominent scarp and is known as the Lepton Edge Rock ; the two so-called moors are elevated plateaux formed by it. It is a strongly current-bedded flaggy sandstone with lenticles of sandy shale ; at Flockton it is 35 ft. thick.

The Old Hards and Brown Metal Coals.—The coals which occur above the Lepton Edge Rock are known in the country to the north as the Brown Metal group. Of these the most persistent appears to be the middle coal, which occurs throughout the present area constituting a valuable seam of coal known as the Old Hards. In the Emley district it is generally called the Parkgate. There appears to be little doubt that it corresponds to the important and valuable seam known by that name throughout the South Yorkshire Coalfield.

The Brown Metal group consists typically of three coals of which the first is the uppermost ; the third is not persistent and appears to die out westwards as well as southwards. The First and Second Brown Metal Coals come together westwards towards the outcrop ; at Birkenshaw and south of Gomersal they form a single thick bed known from its average thickness as the Two Yard Seam. The relations of these coals would no doubt be easily elucidated but for the fact that a large washout has destroyed much of the evidence over the critical area. Along a belt extending roughly from Birkenshaw and Drighlington in a south-south-east direction this group of coals is generally absent, its place being occupied usually but not always by the sandstone of the Birstall Rock. The position is shown diagrammatically in Fig. 6. Near the edge of the Birstall Rock the Two Yard Bed frequently swells out considerably ; but it may be split up by dirt partings or may be represented by disturbed lenticles of coal. Under Popeley Fields the coal is worked out ; it was 5 ft. 8 in. thick with 10 in. of dirt in the middle, but near White Lee on the edge of the washout one section gave a total thickness of 14 ft. 5 in. of which 5 ft. 4 in. was dirt, sandstone, etc.[1] An outlier of the Brown Metal series occurs at Robert Town, where the section is :—

		Ft.	in.	
Two Yards Coal	Coal	2	8	
	Underclay	3	6	to 4 ft.
	Hard coal	1	10	
	Coal	0	5	
	Measures	15	0	
3rd Brown Metal	Coal	1	7	

Between Dewsbury and the Spen valley the Old Hards or Second Brown Metal Coal has sometimes been called the Daw Green Coal ; in this area all three seams are sometimes present but the Birstall

[1] 'Geology of the Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1878, p. 293, figs. 30, 31.

Rock frequently cuts out the First and sometimes the Second. A recent section in the Huddersfield Road south of Crow Nest showed the Second or Daw Green Coal 2 ft. 6 in. thick immediately overlain by Birstall Rock. In the isolated hill between Thornhill Lees and Savile Town all three coals are present, each succeeded by a sandstone and liable to be cut out by it; one instance is figured by Green (*op. cit.*, p. 625, fig. 84), another in the First Brown Metal may be seen in the cutting on the new Midland Railway. A typical section of the whole series is that at Ingham's Colliery, namely First Brown Metal Coal 2 ft. 2 in., measures 13 ft. 5 in., Old Hards Coal 2 ft. 1 in., measures 21 ft. 9 in., Third Brown Metal 1 ft. 4 in. East of the split of the Two Yard Coal and of the boundary of the Birstall Rock similar sections occur in the north around Gildersome and Morley: at Dean Hall Colliery the shaft record gives First Brown Metal 2 ft., measures about 23 ft., Second Brown Metal 22 to 24 in., measures 15 ft., Third Brown Metal Coal 13 in.

In the south only the Old Hards Coal is of importance, though the First and Third Brown Metal Coals are sometimes represented; the latter lies 22 to 26 ft. below the Old Hards and is not more than 8 in. thick; the First Brown Metal is 8 to 12 in. thick and 28 to 30 ft. above the Old Hards. The Old Hards has been one of the most important coals of the district but is now largely worked out. Around Overton it is 2 ft. to 2 ft. 5 in. thick and at Emroyd 2 ft. 8 in.; but the top 6 and 8 in. respectively is inferior. A dirt parting sometimes occurs; at Flockton Moor the section is: Coal 18 in., dirt 2 in., coal 4 in. The Birstall Rock lies mainly above the coal, but small washouts in the form of sinuous channels occur here and there. Where the roof of the Old Hards Coals consists of rock, plant remains are abundant in some localities. In the crop workings in this coal at Grange Moor, where the roof consists of shale, a *Carbonicola* band was seen.

The Birstall Rock.—Some indications of the occurrence of this rock have been given above; it is usually a coarse massive sandstone, sometimes, especially in the south, divisible into two or three bands. Coal, shale and ironstone nodules occur as pebbles, clearly indicating the erosion of Coal Measures previously laid down. At Birstall it reaches a thickness of 100 ft. though at its most northerly occurrence half a mile south-east of Tong Church it is only 30 ft. and half a mile south-west of the escarpment at Birstall it has decreased to 10 ft. and dies out altogether a short way further west. South of the Staincliffe Fault at Mount Pleasant the Birstall Rock forms a plateau between the Spen and the Batley valleys extending almost to the Calder; here the irregular base of the rock is round about the level of the Old Hards Coal which is sometimes present beneath it and sometimes washed out. South of the Calder the rock is usually above the Old Hards; it is well developed around Whitley Wood and Overton and caps the plateau of Grange Moor. It dies out somewhat abruptly to the south of Flockton village, though

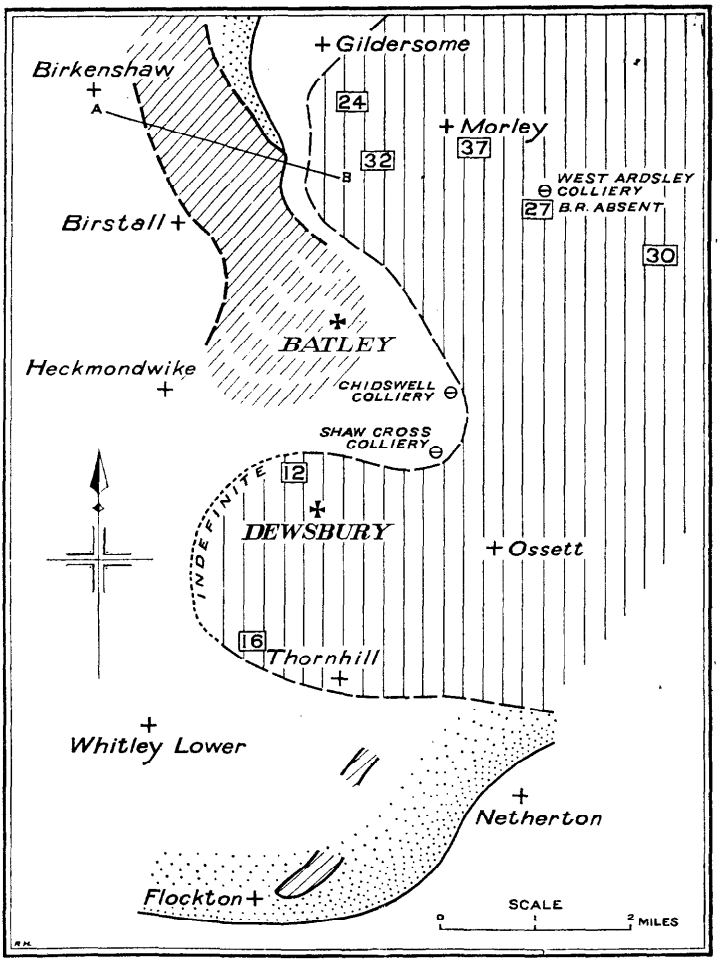

Fig. 6.—*Sketch map of the split of the Old Hards Coal into First and Second Brown Metal Coals, and of the Birstall Rock Washout.*

apparently fully represented in a boring on Emley Moor. Throughout this district it is frequently in two beds each about 30 ft. thick separated by 10 to 16 ft. of sandy shale and bind.

The Birstall Rock has been extensively quarried as building stone around Birstall, while at Grange Moor and Flockton it has been worked on a small scale for purely local requirements (pp. 110, 187).

The Birstall Rock appears to be of the nature of an extensive 'washout', and indicates that differential earth-movements preceded and accompanied its deposition. Certain conclusions which have been drawn from a study of the available sections are given on page 112 and are shown diagrammatically in Figure 6.

The Flockton or Adwalton and the Joan Coals.—Above the Old Hards and Brown Metal Coals comes a pair of seams generally known in the north as the Adwalton Black Bed and Stone Coal and in the south as the Flockton Thin and Thick; between them lies a sandstone called the Emley Rock and a varying amount of shale or mudstone with ironstone nodules.

The Adwalton Black Bed or Flockton Thin lies about 80 to 100 ft. above the Old Hards according to the thickness of Birstall Rock present. Near the northern outcrop east of Birkenshaw it has been largely mined and is nearly exhausted; it usually consists of 2 ft. to 2 ft. 6 in. of bottom coal with a further 5 to 8 in. of top coal above a dirt parting. At Adwalton Moor just west of Adwalton the total reaches 3 ft. 3 in. In the east the dirt parting thickens, being 14 in. at Dean Hall Colliery north of New Brighton and 25 in. at Morley West End and Batley West End, but the coal itself remains practically constant. Between Birstall and Heckmondwike it is often called the Yard Coal, corresponding to the name Two Yard Coal for the seam below. East of Dewsbury it has been called the Dewsbury Bank Coal; at Chickenley Heath Colliery on the edge of the map just south of the Wakefield road the section was: Coal 4 in., dirt 13 in., coal 2 ft. 6 in. South of the Calder the Flockton Thin Coal is only 18 to 20 in. thick at Thornhill, Denby Grange and Overton, but at Whitley Lower it ranges from 2 ft. to 2 ft. 2 in. Around Emley it is thinner. The roof of this coal both north and south of the river is a *Carbonicola* band with *Naiadites*, ostracods, etc.

From the Adwalton Black Bed or Flockton Thin to the Adwalton Stone Coal or Flockton Thick is 35 to 50 ft., of which distance a considerable portion is occupied by the Emley Rock. In the north this rock is a fine-grained sandstone inclined to be flaggy, with many partings of shale; Drighlington village lies on its dip-slope. Along the outcrop in the escarpment between Thornhill and Thornhill Lees no sandstone could be mapped, but at Thornhill Colliery it was found to be 12 ft. thick. Around Emley and Emley Moor it is 20 to 30 ft. thick and forms the plateau on which the village of Emley is situated.

The Adwalton Stone or Flockton Thick Coal is a compound seam formed of several layers separated by varying thicknesses of dirt and shale; the top layer is a cannel formerly of such great value for gas-enriching that the seam is worked out wherever it occurs. To this layer the seam owes the name in common use in the north. Over the country from Adwalton and Gildersome Street southwards to the Batley district the general character of the seam is constant, though its thickness varies somewhat. It consists of three divisions, a bed of stone coal or cannel at the top 6 to 16 in. thick resting on a further 5 to 14 in. of coal, the 'Middle Bed' which is separated by a parting usually 1 to 9 in. thick from the 'Low Bed Coal' 10 to 18 in. thick. It has been suggested that the cannel as a rule thickens at the expense of the Middle Bed Coal.[1] To the south of the Calder valley, the bed of cannel was found to be 11 in. thick at Briestfield, but south of here it dies out somewhat rapidly. The lenticular character typical of cannels is therefore here well exemplified.[2]

The lower coal bed varies from 12 to 14 in. and the upper from the same to 2 ft. 6 in. The parting may be only a thin layer of dirt, but sometimes swells out to 6 ft. of spavin and shale. The cannel where present forms the top part of the upper coal; it is very pure, unlaminated, and has a clean fracture. At Briestfield the Flockton Thick is referred to as the Briestfield Stone Coal. At Thornhill the cannel, 1 ft. thick, forms the whole of the upper band, as at Staincliffe, and is separated from the lower, also 1 ft. thick, by 6 ft. of measures. The cannel often contains numerous fish remains, spines, teeth, plates etc.: from Overton coprolites only have been recorded.[3] The roof shales everywhere contain *Carbonicola*.

The measures between the Adwalton Stone or Flockton Thick Coal and the Joan Coal are hardly more than 35 ft. at the northern outcrop but increase southwards, being up to 50 ft. near the Calder and 60 ft. in the south; they consist mainly of shale with silty bands, and have been dug for brickmaking in some places (see p. 188), as at Healey between Heckmondwike and Batley, where a thin impersistent sandstone and a coal occur. In the south these measures contain a well-marked band of ironstone known as the Tankersley Ironstone or Mussel Shell Bed. The ironstone itself is largely a mass of *Carbonicola* shells mineralized by carbonates of iron and lime; these render it one of the most characteristic and easily recognized ironstones of the Coal Measures. Fossils collected from this band at Flockton Mill include *Carbonicola*, *Naiadites*, *Spirorbis*, ostracods and fish remains. In this area it occurs mainly to the east of Flockton and Emley, where it has been worked to a small extent by bell pits, which have long been overgrown. On the east part of Emley Moor a flaggy sandstone occurs just below the Joan Coal.

[1] Ashley, T., 'Occurrence of Adwalton Stone Coal and Halifax Hard Coal,' *Proc. Yorks. Geol. and Polytech. Soc.*, vol. xiv, 1901, pp. 253—260.

[2] *Ibid.* This is well shown on the map and sections accompanying the above mentioned paper.

[3] Simpson, M., 'Coprolites in the Stanley Shale and Flockton Stone Coal,' *Proc. Geol. and Polytech. Soc. W. Riding Yorks.*, vol. ii, 1844, p. 171.

The Joan Coal, though persistent, is seldom of sufficient thickness or quality to have been worked. At Ringshaw Beck, north of Drighlington, it is only 6 in. thick; it increases southwards and near Dewsbury is 1 ft. 10 in. to 2 ft. 3 in. Here it has been worked to some extent around Earlsheaton and is also known as the Mitchell or Parson's Coal. On the south it averages 2 ft. 2 in. around Flockton and has been worked under Flockton Green; the section was: soft impure coal 1 ft., parting 1 in., good coal 1 ft.; only the lower bed was worked as an inferior house coal. On the east of Emley Moor the seam is 3 ft. thick and has been largely worked along the outcrop.

Above the Joan Coal lie blue shaly mudstones with layers of ironstone nodules which pass upwards by alternation with sandy bands to the base of the Thornhill Rock; the distance to this somewhat irregular and vague line varies from 30 to 85 ft.

The Thornhill Rock.—This sandstone which is the thickest and most conspicuous rock in the Middle Coal Measures of the district forms a number of bold escarpments and gives rise to an abrupt and varied surface contour. The main mass forms prominent features along the east side of Howden Clough and by Lower Soothill and Hanging Heaton to Dewsbury Bank; the plateau, of which these features are the edge, passes eastwards out of the area. In the south the ridge on which Thornhill village stands falls abruptly to the Calder on the north and the Howroyd valley on the south; the southern scarp known as Thornhill Edge rises 200 to 300 ft. above the valley floor, and constitutes one of the most striking features of the district. The Thornhill Rock also forms a good escarpment at Overton bordering a plateau extending eastwards from Overton and Flockton Green. There are numerous outliers of Thornhill Rock due in part to faulting and to denudation at Drighlington, Adwalton, at Popeley Fields, between Batley and Howden Clough and to the south-west of Overton.

The rock varies considerably; normally it is finely and closely grained, though occasionally coarse; massive and regularly bedded as a rule it locally shows strong current-bedding and is sometimes marred by numerous ironstone nodules enclosed as pebbles. The most important development of the rock is in the country between Bruntcliffe and Howley Park, where it is about 120 ft. thick.

Building stone of excellent quality is raised from the large quarries south-east of Bruntcliffe; the upper half is false-bedded with layers of rag and shale, the rest being a massive sandstone (p. 116). At Crackenedge, Dewsbury about 80 ft. of rock is exposed in a quarry but it is split up by beds of sandy shale and also contains a 5 in. bed of coal and dirt. At Thornhill the rock is about 65 ft. thick and has been largely quarried for local use.

The Haigh Moor and Gawthorpe Coals.—The next coal seam, the Low Haigh Moor lies 70 to 90 ft. above the Thornhill

Rock east of Howley Park but only about 20 ft. above it in the south. In the former region the lower 50 ft. or so is sandy shale with thin sandstone beds and the remainder rather sandy mudstone with bands and nodules of ironstone and a thin bed of black shale with small *Carbonicola, Naiadites* and fish fragments. The Low Haigh Moor Coal is of little importance, being 16 in. thick east of Howley Park. In the south, measures higher than the Thornhill Rock occur only in two little faulted areas, one south-east of Thornhill Church, and the second between Emley Church and New Hall Wood. In the first named the Low Haigh Moor has been proved to be 2 ft. thick.

The Top Haigh Moor is about 35 ft. above the Low seam. It outcrops around Lower Soothill and has been worked in Soothill Wood Colliery where it was about 3 ft. thick with 2 in. dirt in two partings. Where the railway passes across our boundary north-east of Hanging Heaton an exposure showed 3 ft. 10 in. of hard coal above which was 20 in. of dirt with coal streaks and 2 to 4 in. of coal at the top.

In the Lower Soothill area, in which alone the measures now described occur, a sandstone comes close above the Top Haigh Moor Coal; it is probably over 30 ft. in thickness, 20 ft. of rather massive stone being seen in a quarry.

Two thin coals are recorded from sections east of the edge of the sheet, lying about 60 and 100 ft. above the Top Haigh Moor Coal. The upper has been called the 27 Yards Band Coal, and was seen in the railway cutting N.E. of Hanging Heaton, where it is 14 in. thick. The lower band has nowhere been seen within the area shown on Sheet 77.

A seam which has been called the Beck Bottom Stone Coal[1] occurs about 120 ft. above the Top Haigh Moor Coal and 65 ft. below the Gawthorpe Bed, and has been mapped east of Lower Soothill. A section of what must be this seam is seen in the cutting just mentioned, in the faulted area close to the Staincliffe Fault.

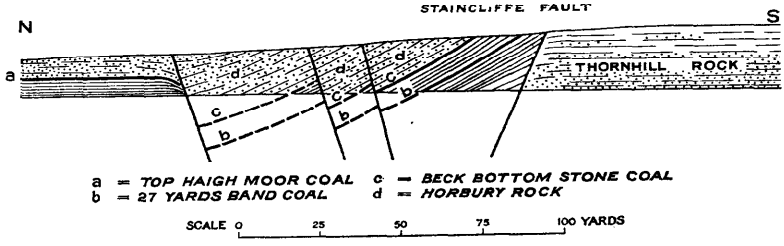

Fig. 7.—*Section across the Staincliffe Fault at Hanging Heaton.*

There the coal is 2 ft. thick, with 3 in. of coal 3 ft. above it. A little over 20 ft. lower down is the 27 Yards Band Coal, with a thickness of 14 in. (Fig. 7). Close above the Beck Bottom Stone Coal lies a bed of sandstone, apparently the Horbury Rock in an attenuated

[1] 'Geology of Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1878, p. 693.

state; its full thickness is 35 to 40 ft. as seen in the railway cutting. Its base forms a strong feature east of Lower Soothill.

The outcrop of the Gawthorpe Coal is shown round the hilltop east-north-east of Lower Soothill, close to the edge of the map. At the southern edge of this small outlier the coal is exposed and is at least 2 ft. 6 in. thick, although the full section could not be measured. In an old borehole, at Chidswell, nearly a mile south-east of here 3 ft. of hard coal is recorded resting on 13 in. of soft coal.

The outlier of coal near Lower Soothill owes its preservation to a thin sandstone bed which lies close above it. This sandstone is the highest horizon in the coal measures represented in Sheet 77. Only a few feet of it are present in the outlier.

Details

The Blocking Bed.—In the north the Blocking Bed outcrops round the hamlet of Toftshaw, where it has been worked and was locally known as the Toftshaw Bed. The section at Toftshaw Colliery was top coal 13 in., parting 1½ in., coal 5 in., black shaly dirt 3½ in., coal 4 in. In all this district the top coal is the main part of the seam and in one instance reaches 1 ft. 6 in. At Gomersal, where the thickness is above the average, it is still worked to a small extent (p. 91).

West of Royds Hall a small area of Blocking Bed is let in by the high dip against the Bailiff Bridge fault. Some attempt to work the seam has evidently been made in the past, but there is no section available.

The coal is next seen east of Bailiff Bridge, where it is recorded as 30 in. thick at Coates Pit, Clifton, and in an old clay pit just south of Scholes the following section, measured from the top, was once visible:—dirty coal 1½ in. coal 15 in., underclay 8 in., coal 13 in., dirt ½ in., coal ½ in.

There are old sinkings to the coal around Cleckheaton, the seam at Tofts Colliery (Old) consisting of a top bed 14 in. thick separated by 4 in. of clay from a 4 in. middle bed, separated by 1½ in. of shale from a 6 in. bottom bed.

At Snelsins Bridge, north-west of Cleckheaton the section at the outcrop, measured from the top downwards, is coal 18 in., seat-earth 6 in., coal 2½ in., seat with coal streaks 12 in., coal 4 in.

In the faulted trough at Hightown and Robert Town the Blocking Coal is usually 2 ft. 4 in. and the same towards Heckmondwike and in the outcrop by Owlet Hurst. Southwards it is usually less: a considerable area has been worked round Northorpe where it was 1 ft. 8 in. The outcrop between Knowl and the Calder is not accurately known, being mainly across park land; on the original six-inch map it was omitted, though inserted to form a colour boundary on the one-inch.

In Whitley Wood, Liley Clough and St. Gregory Springs to the north of Hopton this coal has been extensively worked along and close to the outcrop. It here averages from 1 ft. 6 in. to 1 ft. 10 in. in thickness, the upper 1 ft. yielding a household coal and the lower portion being used as an engine coal.

The outcrop of the Blocking Coal in the upper part of Liley Clough is much cut up by the prominent east and west fault running from Whitley Lower past Dransfield Hill towards Kirkheaton. Around Falhouse and to the south of Whitley Lower it has been somewhat extensively worked. Here it is from 1 ft. 10 in. to 2 ft. thick, the upper part of the seam being of the better quality.

Under Grange Moor its average section is as follows:—

	Ft.	in.
Best coal	1	6
Baring coal	0	3
Coal and dirt	0	5
Underclay	—	

The Blocking Coal has been extensively worked all along the outcrop from Lidgate near Lepton to Linfit and Thorncliff. At Lidgate the coal is from 2 ft. to 2 ft. 2 in. thick and is overlain by flaggy shale and sandstone. At Flockton Moor Colliery the average section is as follows: 'Tops,' 6½ in.; dirt parting, ½ in.; and 'Bottoms,' 4 in. At Thorncliff Colliery it is 2 ft. thick.

The coal has also been mined under Emley Moor, where the average section was as follows:—

	Ft.	in.
Top coal	1	1
Hard coal	0	1
Baring coal	0	1½
Spavin	0	2
Hard coal	0	1½

Towards the south-east it falls off much in quality and thickness; in some places disappearing altogether. At the Standbacks shaft, 1,200 yards south-west of Emley Church, it was found to be only 6 in. thick.

At Denby Grange Collieries, Overton, it averages 1 ft. 1 in. in thickness, while in Howroyd Beck three-quarters of a mile to the south it was found in a boring to be not more than 9 in. in thickness.

The measures next above the Blocking Coal call for little comment except in the south. At the south end of Liley Wood there are numerous old overgrown bell pits along both sides of Liley Clough where the shale overlying the Blocking Coal contains abundant ironstone nodules and has been worked in the past for iron ore. These beds would appear to be a local representative of the Claywood Ironstone of the Sheffield district.

Falhouse Rock.—Although absent in Liley Clough and around Liley Hall the Falhouse Rock reappears in the grounds of Whitley Beaumont Park and thence can be traced southwards to Lepton and Linfit. In Linfit Wood it dies out by passing laterally into sandy shale and mudstone. Eastward in borings at Emley Moor it was found to be 15 ft. thick while under Emley it attained a thickness of 22 ft. At Thornhill it is apparently represented by bands of stone bind and bind, while at Denby Grange Collieries, Overton it consists of 8 ft. of sandstone.

The Wheatley Lime Coal.—The Lime or Three-Quarters Coal crops in the north on the west and south of Westgate Hill; a section by the chapel at the north-west end of Birkenshaw showed it to be 13 in. thick resting on 3 ft. 9 in. of underclay. East of the Birkenshaw Fault the pits have only been worked down to the Middleton Main and the Three-Quarters Coal is therefore unknown. The outcrop of the Wheatley Lime Coal is indicated with some certainty in the country between Cleckheaton and Birkenshaw by the feature made by a thin sandstone bed close above it. Around Gildersome it could not be mapped, but there is some indication of its presence at Cockersdale. The coal is thin around Gomersal, being 12 in. at West Pit, and the section at Gomersal Colliery being: Clod 16 in., dirt 11 in., coal 7 in.

A coal 11 in. thick is recorded at this horizon in the Batley West End Shaft, and a detailed section from here shows: Streaky coal 2 in., coal 1 in., dirt 1 in., coal 10½ in., dirt and coal 4 in., the measurements being from top to bottom. At Howley Park Colliery the seam is 2 ft. 2½ in. thick, with two dirt streaks.

From Hightown Heights to Robert Town the Lime Coal is about 2 ft. 6 in. thick in all but much split up by dirt, whence its name of 'the Mucky Bed.' At Hare Park Colliery near Aquila the section was: Coal 1 in., dirt 3 in., coal 8 in., dirt 3 in., coal 8 in., dirt 4 in. At Lumb Lane, Robert Town the dirt was a single band 6 in. thick with 10 in. coal above and 12 in. below. The coal seems to improve both east and south; it was worked from Ravenslodge Colliery where it was 2 ft. 5 in., and at the outcrop on the opposite side of the river there was 2 ft. of coal. In the southern area the Wheatley Lime is often overlain by a Crow (i.e., thin) coal. The following is the section exposed in Falhouse Beck, south of Pendle Hill, Whitley Lower:—

		Ft.	in.
Crow coals	Coal	0	3
	Dirt	0	2
	Coal	0	4
	Shale parting		—
Wheatley Lime	Dirty coal	1	3
	Coal...	0	9
	Underclay	1	6

At Emroyd Colliery the Wheatley Lime Coal ran as follows :—

		Ft.	in.
Crow coals	Soft coal	0	6
	Parting		—
	Coal with pyrites	0	8½
	Parting		—
Wheatley Lime	Coal	0	8
	Hard bed coal	0	3¾
	Soft coal	0	4
	'Bottoms,' shale and coal	0	7

The Soft and Hard Bed coals constituted the most valuable part of the seam. Around Overton the Wheatley Lime is 2 ft. 9 in. in thickness.

At the Shuttle Eye Collieries, Grange Moor a crow coal again overlies the seam. In places it has a shale roof, in others one of strong stone. Average section :—

	Ft.	in.		Ft.	in.
Crow coal	0	4	to	0	6
Strong stone		0	to	4	6
Clod and strong shale	0	9	to	1	6
Wheatley Lime Coal...	2	4	to	2	6

The Wheatley Lime Coal has also been worked along the outcrop at Linfit and Thorncliff. Its roof hereabouts consists of strong sandy shale or flagstone. At Flockton Moor Colliery where it was mined the average section was as follows :—

	Ft.	in.
Lime coal	0	4
Shale	0	9
Clod	1	3
Coal	3	0
Clay	0	8
Seatstone	1	6

Around Emley an average section is :—

	Ft.	in.
'Tops' coal	1	0
'Sheard' or parting...	0	0⅛
Good coal	1	7
Hard coal	0	4
'Sheard' or parting...	0	0⅛
Baring coal	0	2

It has not been found possible to map the outcrop of the Middleton Eleven Yard Coal, and most of the available information has been given above; the section at Batley West End is coal 6 in., seat-earth 22 in., coal 9 in.

The coal has been proved in a shaft at Westgate Hill and must outcrop round the hill about 30 ft. below the Middleton Main; no exposure was found. A thin sandstone a short way above the Three Quarters Coal forms a platform round the foot of Westgate Hill; it has been quarried near the north end of East Bierley and is exposed along the railway cutting north-west from Birkenshaw station. It is a fine-grained sandstone with many shaly partings. In

the cutting the dip on either side of the main road bridge indicates a slight anticline.

Westgate Hill rises from the flat formed by this sandstone but consists entirely of shales with occasional ironstone nodules, with the Middleton Main Coal outcropping round the crest almost at the top of the Hill. Near the top the shales were found to be impregnated with iron oxide which formed a hard cement, this at least helping to form a protecting cap for the shale.

Middleton Main, Cromwell or New Hards Coal.—The section of this coal at Westgate Hill has already been given (p. 93). At Sykes Pit, 550 yards west-north-west of Drighlington church, a ' stone coal ' 2 ft. 10 in. thick is recorded, separated by 2 ft. 8 in. of black shale from the underlying Middleton Main Coal 4 ft. thick. This ' stone coal ' probably refers to a bed of highly carbonaceous shale which often occurs in the roof of the Middleton Main. All along the northern outcrop the coal has been worked by day eyes and open workings and has been mined east of Gomersal, where it is practically worked out.

In the country around Gildersome, Adwalton and Bruntcliffe the thickness of the seam varies from 3 ft. 4 in. to 4 ft. 6 in., with 1 to 8 in. of dirt, usually in the form of two thin partings, in the lower part of the seam. The ' whetstones ' at the base are 6 or 7 in. thick between Adwalton and Cockersdale ; in the workings of College Colliery, Birstall, the lowest 15 in. of the seam was a cannel coal, apparently a variation of the ' whetstones.' This was only a local development.

At the west end of Gomersal Tunnel a section shows the Middleton seam to be 4 ft. 5 in. thick, with 8 in. of dirt. This is above the average for this neighbourhood.

In the old outcrop workings near St. Peters Church at Birstall the seam is seen to decrease in thickness from north to south, being 3 ft. 10 in. with 9 in. of dirt 8 in. from the bottom in Monk Ings, and 2 ft. 6 in. thick just south of the Church.

This thinning is seen also south of Gomersal. In the shallow workings east of Spen the seam consists of 2 ft. of coal separated by 15 in. of seat-earth from a lower 4 in. layer of inferior coal, and in an old pit south of Gomersal (Little Gomersal Colliery), it is 26 in. thick.

It is 2 ft. 10 in. to 3 ft. 4 in. with 2 to 8 in. of clay 6 in. from the base at Batley West End Colliery, and 3 ft. 2½ in. with a 7-inch parting 5 in. from the base at Howley Park Colliery. At Batley West End the lowest 6 in. is ' whetstones.'

The seam is said to be thin along a belt about a mile wide extending from Gomersal to Batley.[1]

It is 2 ft. 4 in. in the shaft at Roche Colliery, 2 ft. 8 in. at Soothill Wood Colliery, with a 4-inch parting 4 in. from the bottom, and at Cross Bank Colliery, Healey, only 20 in., but resting on 9 ft. of seat-earth with thin coal layers. Still further south, at Batley Carr Colliery it is only 14 in. thick.

At the outcrops round about Robert Town the thickness of this seam is 2 ft. 11 in. to 3 ft. 3 in. and it is often called the Yard Coal. This thickness is maintained at Ravenslodge, but nearer in to Dewsbury the thin belt is reached and it falls to 1 ft. 7 in. On the opposite side of the river the coal has been largely worked round Ingham's Pit, Thornhill ; it is still about a yard thick, the upper part being the best : there are here several swillies in this seam. The name Yard Coal was also used in the south around Whitley Wood and Whitley Lower. Old crop workings occur all around Liley Clough and Whitley Beaumont, at Lepton Edge and on the western slopes of Emley Moor.

The New Hards Coal has also been extensively mined around Briestfield. In Briestfield Beck the section showing the New Hards Coal is as follows :—

[1] ' Geology of Yorkshire Coalfield ' (*Mem. Geol. Surv.*), 1878, p. 265.

		Ft.	in.
	Black shale...	0	3
	Shale with ironstone nodules	0	2
	Dirt	0	4
New Hards	Coal	2	2
New Hards	Dirt	0	3
New Hards	Coal	1	2
	Underclay	3	9
	Sandstone in thin bands	—	
	Shale with ironstone nodules	—	

At Sowood and Fells Collieries, Briestfield, the coal similarly consists of a lower and upper bed separated by a dirt parting 3 to 5 in. in thickness.

At Denby Grange Collieries, Overton, where the New Hards Coal has been extensively mined, it consists of an upper and lower seam with a shale parting ranging from 5 to 18 in. in thickness. Under Grange Moor where the same coal has been mined at numerous pits the dirt parting is only one to two inches thick, and absent altogether in some places. At the Leys Quarry Pit, Grange Moor, the average section is as follows :—

	Ft.	in.
Top coal	1	3
Coal	0	9
White earth	2	3
Bottom coal	0	9

The dirt parting between the two seams increases in thickness to 18 in. around Flockton. At Lane End Pit the upper seam is 1 ft. 10 in. thick, the dirt parting 1 ft. 5 in. and the lower, ' bearing ' or ' lime ' coal, 2 in.

Around Emley and Emley Moor the average section is as follows :—

	Ft.	in.		Ft.	in.
Shale with ironstone nodules ...	—			—	
Coal	2	0	to	2	3
Spavin...	1	2	to	2	5
Coal	0	6	to	1	0
Hard Spavin	—			—	

The Carbonicola band in the roof of this coal is mentioned above (page 94).

The Measures from the Middleton to the Middleton Little Coals.—Close above the Middleton Bed in the district around Gomersal occurs a bed of sandstone a few feet thick, of no importance except that it facilitates the tracing of the Middleton Bed outcrop. At Birstall it is seen passing laterally into shaly measures, and around Gildersome no sign of a sandstone was seen above the Middleton Bed. In the shaft sections of Street Pit, Gildersome, Bruntcliffe, Morley West End and Batley West End, one and sometimes two thin and worthless coal seams are recorded between the Middleton and Middleton Little Beds. One of these seams, probably the upper was seen and mapped at Cricket Hill N.E. of Gildersome, and is called ' Thin Coal.' A thin sandstone lies close under the Middleton Little Bed at Drub. It dies out just south of that place, and is not seen elsewhere.

The Middleton Little or Green Lane Coal.—The Middleton Little or Green Lane Coal lies about 80 ft. above the Middleton Bed in the Adwalton and Gildersome districts, the distance decreasing southwards to 65 ft. at Upper Batley and Howley Park. The seam thickens from west to east. Where first seen in the north-west and west of its field it is thin and worthless.

In Spring Gardens Pit, Drighlington, it is a foot thick, and at its outcrop on the east and west sides of the Gomersal ridge it is still thinner, the exposure at the east end of Gomersal Tunnel showing it to be about 8 in. thick, with dirt

streaks in the lower part. The old sinkings about here also show it to be a thin band. The thickness around Birkenshaw is not known, no sections of Birkenshaw or Hunsworth Lodge Collieries or of the old sinkings to the Middleton Bed here having been kept. It has never been worked and is evidently thin, as in the neighbouring localities of Gomersal and Drighlington.

East of Drighlington and Gomersal the seam attains workable thickness, being 2 ft. 3 in. at Nethertown Colliery, Drighlington and Street Pit, Gildersome, although of inferior quality at the former place, 2 ft. 6 in. at Bruntcliffe Colliery, and still thicker around Morley east of the edge of the sheet. At Howley Park Colliery it is 3 ft. 3½ in. thick with 7 in. of dirt in two partings. It is generally thin around Batley and north of Dewsbury, being 11 in. near Carlinghow, while the section at Cross Bank Colliery, Batley, gives an upper 4-inch bed. separated by 2 ft. 4 in. of black shale from a lower 15-inch bed.

At Prospect Pit, Robert Town the Little Coal is 1 ft. 6 in., but only 1 ft. near Boothroyd, Dewsbury, whereas on the opposite side of the river at Ingham's Pit it is said to be 2 ft. 4 in.

To the south of Thornhill the Green Lane Coal varies from 1 ft. to 2 ft. 9 in. A measured section in Briestfield Beck, close to Freckleton is as follows :—

	Ft.	in.
Coaly dirt	0	2
Coal	1	1
Soft coaly shale	0	6
Hard spavin or underclay	—	

The same seam has also been mined around Flockton and Emley though it appears to be of inferior quality. Around Flockton it ranges from 1 ft. to 1 ft. 9 in. in thickness, while in the Emley district its average thickness is 1 ft. 2 in.

In the succeeding measures the Gomersal Rock thins out both east and south, passing into shale ; it may be as much as 20 ft. thick around Swincliffe where it has been quarried to a small extent. Between Gildersome and Adwalton a bed of sandstone has been observed close under the Brown Metal Coal, and appears to occupy a slightly higher horizon than the sandstone of Gomersal. It cannot be traced any distance and seems to be a very local bed : a similar thin sandstone appears beneath the Old Hards at the outcrop south of the Calder opposite Ravensthorpe.

The Lepton Edge Rock in the south gives rise to some prominent features, as mentioned above (page 95).

The Brown Metal Series and Old Hards Coals.—These seams, owing to their importance and interest have been treated comparatively fully above. Further details of the undisturbed coal are given below and of the Birstall Rock ' washout ' on page 111.

The Old Hards at Bushey and Newmarket Collieries was 5 ft. 7 in. thick with 2 ft. 5 in. of dirt, of which 1 ft. 8 in. occurred between the two main parts of the seam. This parting probably indicates the beginning of the split into 1st and 2nd Brown Metal Coals, which takes place rapidly east of here.

In the country to the north around Adwalton and Cockersdale, the coal is of similar thickness, varying from 5 ft. 4 in. to 5 ft. 8 in. with 14 to 20 in. of dirt, and has been worked by the various Nethertown Collieries, Spring Gardens Pit and from dayholes. The Birstall Rock is close above the coal at Spring Gardens Pit and at Thick Thorn Bank.

East of a line through Moor Head and Howden Clough the split into 1st and 2nd Brown Metal Coals takes place, as the following details show :— At Horse Riggs Colliery, about 600 yards south-west of Gildersome Street, the coals are only separated by 25 in. of dirt, just west of Gildersome Street itself there are 7 ft. of intervening strata, and at Street Pit, in the village, the parting is 21½ ft. thick.

At Gildersome Colliery, on the north-east side of the village, the parting increases rapidly in thickness from 10 ft. in the west to 30 ft. in the east of the workings.

The 1st Brown Metal Coal here is 17 to 25 in. thick, while the 2nd Brown Metal Coal, which is 3 ft. 11 in. at Horse Riggs, with only an inch of dirt, becomes less valuable to the north-east, being 2 ft. 6 in. to 3 ft. 2 in. with 9 in. to 10 in. of dirt in Gildersome Colliery. The dirt parting thickens still more to the north-east, the seam being unworkable at Branch End Colliery, east of Gildersome. The 3rd Brown Metal Coal is also recorded from Street Pit, where it is separated from the 2nd Brown Metal Coal by 14½ ft. of measures. It is 12 in. thick, as compared with 19 in. east of Gildersome. The details at Dean Hall Colliery are given above. On the east side of Gildersome, between Maggot Row and Philadelphia, the 1st and 2nd seams are about 30 ft. apart, the 1st being 2 ft. thick with two thin dirt partings in the middle, and being worked from Branch End Colliery,[1] the 2nd not being worked because of the thickening of the parting seen at Gildersome Colliery; it is about 22 in. thick. The 3rd Brown Metal seam is here 17 to 19 in. thick, and good coal. The distance between the three seams increases somewhat to the east, 36 ft. parting the 1st and 2nd, and 24 ft. parting the 2nd and 3rd at Morley Main Colliery, a little beyond the eastern edge of the sheet.

A similar split is seen when the seam is followed eastwards from Howden Clough, as 500 yards south-east of Gildersome Street, at Lodge Colliery, a boring was made to 24 ft. below the 1st Brown Metal Coal without finding the 2nd.

In the country north of Dewsbury the coal is said to be 4 ft. thick with dirt partings at Roche Colliery, White Lee, but it is washed out 30 yards east of the shaft. Further south we find a coal with a thickness of 3 ft. worked at Birkdale Colliery under the name of Old Hards, while a borehole, close to the Technical School, Dewsbury, proved the presence of all three of the Brown Metal Coals, the 1st, 1 ft. 10 in. thick being separated by 9 ft. of measures from the 2nd, 3 ft. thick (called the Old Hards Coal), which was separated by 9½ ft. of measures from the Third Brown Metal Coal, 13 in. thick.

In the valley of the Batley Beck two instructive sections were seen, which suggest that the coal is washed out in much of this area where little is known of it (p. 112).

The Brown Metal Coal is in the shaft of Batley Colliery, 165 ft. below the Adwalton Stone Coal. East of here the seam is beginning to split, as is indicated by the shaft-sections of Shaw Cross and Chidswell Collieries, outside the area of the map. The approximate line of splitting is shown on the diagram on p. 97, but the position of the line is doubtful around Dewsbury.

In the outlier at Robert Town the sections of the Old Hards vary slightly, but the upper coal averages 2 ft. 6 in., the parting of underclay 4 ft. and the bottom or hard coal 2 ft.; the Third Brown Metal lies about 15 ft. lower. In the outcrop between Popeley Fields and Heckmondwike the total thickness is 6 ft. 3 in. including 3 partings. Further south, along the east bank of the Spen Brook the crop is at the base of the Birstall Rock which sometimes cuts out the coal; a recent sewer section showed below the sandstone, coal 1 ft. 6 in., to 2 ft. 4 in., dirt 0 to 12 in., coal 1 ft. 6 in. Wisps of coal can be seen in the sandstone in the railway cutting just north of the Calder towards Dewsbury. South of the river the Third Old Hards crops in the river bank just north of the road bridge, the Second round the west and north of the hill from near Thornhill Station through the churchyard to Savile Town and the First a little below the top of the hill between Savile Town and the railway. Owing to faulting the First and Second are seen in the cutting east of Thornhill Station where the Midland Railway crosses the Lancashire and Yorkshire; the First is 2 ft. thick and the Second 2 ft. 3 in. to 2 ft. 9 in. with two partings about 11 ft. 6 in. below the First. The section at Ingham's Pit, Thornhill is given in the general account.

At the Denby Grange Collieries, Overton, the Third Brown Metal is possibly represented by an 8-inch seam of coal which lies 22 ft. below the Old Hards; at the Hope Pit this seam consisted wholly of cannel. At Flockton Collieries

[1] Abandoned while this Memoir was in the press.

a seam on about the same horizon is only two inches thick. In a boring on Emley Moor, however, a coal 8 in. thick was met with 26 ft. below the Old Hards. This again may be a local representative of the Third Brown Metal.

In the Flockton district, a so-called ' stone ' or impure cannel coal occurs 15 to 20 ft. below the Old Hards seam. It was formerly mined on a small scale by means of day-eyes in Palace Wood, about half a mile west of Flockton Church. Here it was 1 ft. 5 in. in thickness and was separated from the overlying Old Hards Coal by 21 ft. of blue bind and shale. At Flockton Moor the same bed, encountered in a boring, was 1 ft. 2 in. thick consisting of stone and black coal and separated from the overlying Old Hards by 16 ft. of bind.

The Old Hards Coal has been extensively worked around Whitley Lower, Briestfield, Grange Moor and Liley Wood. It has also been largely mined under Thornhill, Emroyd and Overton. A thin impersistent dirt parting occurs in places around Grange Moor ; the following section at Shuttle Eye Collieries is an average for the district :—

	Ft.	in.
Top coal	0	5
Scale	0	1
Best coal	1	5

Around Flockton the Old Hards is a first class house coal and has been largely mined. The following is an average and detailed section at Lane End Pit, Flockton Green :—

	Ft.	in.
Lime coal	0	4
Scale	0	$0\frac{3}{4}$
Good coal	1	$9\frac{1}{2}$
Scale	0	$0\frac{3}{4}$
Inferior coal	0	5
Hard coaly scale	0	$1\frac{1}{4}$

Around Emley, where the Old Hards Coal has also been largely worked, it has an average thickness of 2 ft.

The First Brown Metal Coal is apparently represented in borings at Grange Moor by an 8 in. seam of coal which lies 30 ft. above the Old Hards. A 1 ft. seam of coal known as the Bobby Coal also occurs 28 ft. above the Old Hards at Denby Grange Collieries. It has a thick bed of strong spavin beneath it, and is overlain by Birstall Rock which is here of a somewhat massive nature.

The Birstall Rock

(1) *Details.*—The most northerly occurrence of Birstall Rock is at Thick Thorn Bank, about half a mile south-east of Tong Church, where it is a fairly massive sandstone about 30 ft. thick. At its base is about a foot of incoherent ochreous loam with scattered ironstone nodules resting on $4\frac{1}{2}$ ft. of shale with coal streaks, below which is the Brown Metal Coal.

As the outcrop is followed towards the south and south-east the sandstone gets thinner and dies out close to the Whitehall Road between Drighlington and Cockersdale.

Between Thick Thorn Bank and the outcrop east of Birkenshaw there is no positive evidence of the presence of the Birstall Rock, because detailed shaft-sections have not been kept, but it is probably developed in some thickness here and may wash out the Brown Metal Coal, there being no records of that seam having been worked under this area, although shafts have been dug to the underlying Middleton Bed. The rock was close above the coal in workings now disused just south-west of Thick Thorn Bank.

The rock outcrops on the east side of Kittle Point Beck, half a mile east of Birkenshaw Church, but is thin and is absent 200 yards to the south-west. The Brown Metal Coal is also absent here, but appears to have been replaced by shaly measures. When the outcrop is followed to the south-east the rock is seen to get thicker, while its base transgresses to lower horizons, getting to within 50 ft. of the Middleton Little Bed near Oakwell. It is finely exposed in

the cutting west of Upper Birstall Station (Copley Hill), and here and in Birstall it must be at least 80 ft. thick.

In the cutting just mentioned (between Copley Hill and Oakwell) is displayed about 50 ft. of false-bedded sandstone. Towards the north-western end of the cutting the lowest beds seen are shales and mudstones, apparently a parting. The base of the Birstall Rock is a most irregular line at the north-west end of the cutting. The sandstone appears to die out rapidly towards the bridge over the line north of Oakwell, the cutting by the bridge being in grey mudstones. At this end the basal beds of the sandstone contain much redeposited matter; in fact some thin beds are conglomerates, containing pebbles of coal, ironstone, iron-stained sandstone and mudstone. Streaks of shaly water-deposited coal also occur, the thickest seen being 4 inches. These basal beds appear to be strongly false-bedded, though this is possibly due to faulting. In one place the north side of the cutting is for a few yards dug in mudstone and black shale, which may be faulted up, or may be a lenticle. These irregularities may be due to earth-movements set up on consolidation of the sediments. Near the east end of the cutting the sandstone is rather lumpy, and contains pebbles of ironstone and brashy layers which are full of derived nodules of ironstone.

Much of Birstall stands on the outcrop of the rock, which is here about 100 ft. thick. The numerous quarries are all disused; they show sections in false-bedded sandstone of rather variable nature, which was used for building.

Only half a mile south-west of the escarpment at Birstall the rock has decreased in thickness to about 10 ft. and dies out altogether a short way to the west. Beneath it the Brown Metal Coal is developed (p. 96). Further west, however, at Gomersal Hill Top there is a small outcrop above the Brown Metal Coal, and between there and Spen a slight feature indicates the presence of a thin stone bed at this horizon. It is unfortunate that erosion has proceeded so far as to render these two isolated occurrences of little value in affording clues as to the former distribution of the Birstall Rock in the area west of Birstall.

South of Birstall the rock is exposed in the valley-bottom along the Bradford-Dewsbury road. It is quite thin north of White Lee but thickens very quickly to the south-east, being 113 ft. thick at Cross Bank. It was once quarried in the valley here, and produced a fine-grained, massive white sandstone of good quality, but the area is now largely built over. In the shaft at Batley West End there is at least 22 ft. of stone, but at Howley Park Colliery, one mile east of Cross Bank, only 17 ft.

In the thin strip of country between the Healey and Staincliffe faults nothing is known of the rock but it is probably of considerable thickness, as immediately to the south, around Mount Pleasant, it makes a rather wide spread, forming well-marked escarpments at Pismire Hill (west of Dewsbury) on the west, and along the west side of the valley between Batley and Dewsbury on the east. The rock has been quarried extensively for building stone around here but is no longer worked.

In the outlier at Robert Town about 25 ft. of strata are present above the Old Hards Coal, but there is no sandstone: presumably the western margin of the Birstall Rock south of Heckmondwike was approximately along the Spen valley; in fact there seems reason to believe that the southward deflection of that valley at Heckmondwike was caused by the stream in its south-easterly course impinging on the abrupt edge of the Birstall Rock. On the plateau at Boothroyd and Crow Nest there is 60 ft. of rock present; the numerous old quarries are mostly filled in. The rock forms a strong escarpment on the east side of the Batley-Dewsbury valley, and is exposed in the railway cuttings and in numerous old quarries. It contains beds of sandy shale here, and is probably more than 50 ft. thick. It disappears beneath the surface in Dewsbury.

South of Dewsbury, Birstall Rock caps the hill between the river and the railway; it has been largely quarried, though the lowest beds are spoilt by being conglomeratic. At Thornhill it is poorly developed, and further south

is usually in two distinct beds. The village of Whitley Lower is built on a faulted outlier of Birstall Rock. The Pinnacle is a prominent scarp of this rock overlooking the Calder valley; it is 600 yards due south of Whitley Reservoir and in it is a disused quarry showing strongly false-bedded sandstone with many lenticular shaly layers in which coal wisps and fragments are very frequent.

Small faulted areas of Birstall Rock also occur at the Back o' th' Moon and in Howroyd Beck, Foxroyd, one mile to the west of Thornhill. At Healey Farm, Briestfield, it also gives rise to a conspicuous knoll.

From Grange Moor to Gozley or Denby Grange Wood and Emroyd it covers considerable areas, and here typically exhibits a two-fold development. The lower bed of sandstone ranges from 30 to 50 ft. in thickness and the upper from 20 to 30 ft., the two being separated by sandy shales ranging from 10 to 16 ft. in thickness.

One mile due west of Flockton Church the Birstall Rock has been quarried at Cropper Gate. This appears to be the lower bed and has been referred to as the Cropper Gate Rock.[1] The quarry shows 15 ft. of thickly bedded yellow sandstone with lenticular shale partings. Numerous large ferruginous concentric and concretionary masses up to 4 ft. across known as 'mares' apparently rendered further exploitation unprofitable, and the quarry now stands disused. Other quarries in the Birstall Rock are at Cardwell Delf, about half a mile west of Flockton Church. Around Flockton the Birstall Rock runs as follows:—

	Ft.	in.
Sandstone	27	6
Sandy shale	15	0
Sandstone	27	6

But although at Flockton it is so largely developed as to fill up nearly the whole space between the Old Hards and Flockton Thin Coals, it thins away with remarkable abruptness in a southerly direction and is practically unrepresented on the south side of the valley of Flockton Beck.

Eastwards it also thins away, for there is practically no sandstone above the Old Hards Coal in the Prince of Wales Colliery shaft in New Hall Wood.

(2) *The Washout of the Brown Metal and Old Hards Coals.*—All along the south-western outcrop of the Birstall Rock the Brown Metal Coal has never been found, although thorough search must have been made in the past, and it seems certain that the Birstall Rock, which here attains so great a thickness, occupies the position of the seam.

At and to the north of Howden Clough evidence of the eastern edge of the washout has been found. The coal crops out around Howden Clough, and has been worked in the past, being locally very thick, and in several beds, as much as 9 ft. of coal occurring in places.

Just south-east of Howden Clough Colliery surface excavations have exposed several beds of coal separated by partings of clay and mudstone, while in one place coal, mudstone and sandstone of Birstall Rock type are interbedded. This recalls the section at Smithies (p. 95). These thin sandstone beds are here the only representatives of the Birstall Rock, but about 200 yards to the north-west a shaft sunk at Howden Clough Colliery found the Brown Metal Coal absent, its place being occupied by Birstall Rock.

Just north of here, beyond the south-western boundaries of the workings from New Market, Bushey and Horse Riggs Collieries the coal was proved to be absent in places, e.g., under Bank Wood and under the Great Northern Railway just north of Gelderd Road. At these places roads were driven 30 yards in from the roll where the coal ended, and went through stone without finding any coal. The boundaries of the washout as far as they can be traced are shown on figure 6.

Nothing is known of the Brown Metal Coal between Birstall and Howden Clough and it is almost certainly washed out. From Drighlington to Howden

[1] Green, A. H., 'The Geology of the Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1878, p. 302.

Clough the eastern limit of the washout corresponds closely with that of the Birstall Rock, though the shaft at Spring Gardens Colliery just west of Drighlington Church goes through a fairly thick bed of sandstone above the coal.

The seam is washed out in the shaft of Batley West End Colliery, but the feather-edge of the coal was found 32 yards west of the shaft, dipping steeply towards the washout. A section of the seam taken near here shows the abnormal thickness of 13 ft. 7 in., of which 7 ft. 6 in. is coal, the rest being dirt in four partings.

At Roche Colliery, White Lee, the coal is said to be 4 ft. thick, with partings, and to be washed out by sandstone 30 yards east of the shaft, while just over half a mile to the east-south-east, at Cross Bank Colliery, the coal appears to be washed out also, no record of it appearing in the shaft-section. Two sections in the valley of the Batley Beck suggest that the coal is washed out in much of this area: the first, at the Atlas Brick Works, just west of Batley Sewage Works, showed an irregular streak of dirty coal 3 to 7 in. thick and possibly redeposited, resting on an underclay containing patches of coal. On top of the coal streak were the sandstones of the Birstall Rock. The lowest 3 ft. of sandstone contained streaks of coal, and it appeared to be a section of the washout actually occupied by the Birstall Rock. The second section, in the cutting 80 yards north of Batley Carr Station, showed a local unconformity at the base of the Birstall Rock cutting into the Brown Metal Coal.

Between Dewsbury and the Spen valley the base of the Birstall Rock is approximately at the horizon of the Old Hards Coal, which is sometimes cut out; more often the sandstone forms the roof of the coal. On the south side of the Calder up to 20 ft. of shale may intervene between the coal and the sandstone, though even here the latter sometimes cuts down locally below the coal. Farther south a few cases are known where channels have been cut in the coal, though as a rule the base of the Birstall Rock is well above it. One of these is at Thornhill Colliery, while at Emroyd it was recorded that the place of the coal was taken by water-worn and rounded pebbles and boulders, evidently representing the sites of former channels of running water by which the coal was removed and the gravel of water-worn pebbles deposited. A washout extending in a north-east and south-west direction for about 600 yards was proved in the workings of this coal under Flockton Green. It appeared to be a sinuous channel about 100 yards across in its widest part.

(3) *Conditions of deposition.*—The evidence got from mapping indicates that the Birstall Rock from Drighlington to Birstall occupies a definite channel about a mile wide running a little east of south, and washes out the Old Hards or Brown Metal Coal (see sketch, p. 97). South of here the rock spreads out and covers a wider area from east to west and does not wash out the Old Hards Coal everywhere in the Batley and Dewsbury area, and is usually above the Old Hards Coal south of Thornhill. The maximum thickness decreases south of Batley, while shale partings appear in the rock, and it dies out suddenly along a line between Flockton and Netherton. It is not known how far the rock extended westward from Dewsbury, as the outcrop runs irregularly from Heckmondwike to Flockton, but it is improbable that it went beyond the present Spen valley.

The Birstall Rock was deposited shortly after the formation of the Top Brown Metal Coal, on a surface sloping gently from north to south. The subsidence and slight tilting which occurred after the Brown Metal Coals were formed appears to have been accompanied by a certain amount of flexuring, if the unconformity at Batley Carr (see above) be taken to indicate a fold and not derangement of strata due to a fault.

In the area north of Birstall the rock was laid down in a definite channel by currents of some force which were able to wash away the Old Hards Coal and in places as much as 30 ft. of the underlying muddy sediment. On either side of this channel mud was being deposited in quieter water, although at times the area became land, as is shown by the presence of thin coals in the

old shafts at Dean Hall Colliery, between Gildersome and Morley,[1] and in the shaft at West Ardsley Colliery.[2]

South of Birstall the sand was spread out over a wider area by currents which were slackening in force, as the incoming of shale partings show, and only in places were channels cut through the horizon of the Old Hards Coal. The water must still have been very shallow all over this area, as the presence of three thin coals in Ingham's Pit, Thornhill, between the Top Brown Metal Coal and the top of the Birstall Rock show that banks on which vegetation grew appeared at times above the water.

The line between Flockton and Netherton, along which the Birstall Rock dies out rather suddenly, indicates the general slackening of currents to a point where sand could no longer be transported.

The Adwalton Black Bed or Flockton Thin Coal.—In the north-east this coal is of good quality, with a dull lustre, and is often more than 2 ft. 6 in. thick; consequently it is practically worked out. It is still worked on a small scale south-east of Gildersome[3].

The seam was measured in Kittle Point Wood, half a mile east of Birkenshaw, where it is 2 ft. 10 in. thick, with a thin dirt parting about 4 in. from the top. It varies little from this thickness in the area between Birkenshaw, Drighlington, Gildersome Street, and southward through Howden Clough to Batley, although in places it becomes more than 3 ft. thick, as at Adwalton Moor (just west of Adwalton), where it is 3 ft. 3 in. with 1½ in. of dirt 6 in. from the top, and around Birstall, where it just exceeds 3 ft. The thin parting near the top of the seam is very constant, but thickens somewhat to the east being 14 in. at Dean Hall and 25 in. at Morley West End.

Between White Lee and the Staincliffe Fault the thickness is about 3 ft. and the coal is referred to as the Yard Bed. On the west of Dewsbury an exposure in a brick-pit now built over gave the section: dirty coal 1 in., dirt 1 in., coal 2 ft. 2 in., clay 1 in., coal and dirt 2 in. To the east the coal was called the Dewsbury Bank Bed and was 2 ft. 3 in. thick; it is worked out.

At Thornhill Collieries, Emroyd Colliery (now disused), and also around Denby Grange and Overton the Flockton Thin Coal runs from 1 ft. 6 in. to 1 ft. 8 in. in thickness. To the south-west of Thornhill the Flockton Thin Coal crops out on either side of Howroyd Beck. The following is a measured section of this coal and associated beds in Howroyd Beck at Mug Mill, three quarters of a mile due south of Thornhill Church[4]:—

		Ft.	in.
Flockton Thin Coal	Dirt and coal	0	3½
	Coal	1	4
	Clay	0	1
	Coal	0	3
	Underclay	0	4
	Dirt	0	0½
	Underclay	0	3
	Coal	0	1
	Dirt	0	1
	Coal	0	1
	Clay	0	1½
	Coal	0	3½

At Whitley Lower, the Flockton Thin Coal averages from 2 ft. to 2 ft. 2 in. in thickness and around Grange Moor and Flockton 1 ft. 8 in.; it is usually somewhat thinner around Emley, averaging 1 ft. 2 in. to 1 ft. 6 in. The Emley Rock calls for no special comment beyond what is given above (page 98).

[1] A 4-in. coal 8 ft. above Top Brown Metal in one shaft and a 2-in. coal 26 ft. above Top Brown Metal in the other shaft.

[2] A 5-in. coal 30 ft. above Top Brown Metal.

[3] Workings abandoned while this memoir was in the press.

[4] Green, A. H., 'The Geology of the Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1878, p. 309.

The Adwalton Stone or Flockton Thick Coal.—This seam is present in the narrow strip of country between the Birkenshaw Fault and the parallel fault immediately to the south-east. An exposure in Ringshaw Beck against the first fault shows the crop workings of the coal and the Carbonicola band just above it. From Adwalton and Gildersome Street to the Batley district the coal consists of three divisions, a bed of stone coal at the top, 6 to 16 in. thick, resting on a further 5 to 14 in. of coal, the 'Middle Bed', which is separated by a parting usually 1 to 9 in. thick from the 'Low Bed Coal,' 10 to 18 in. thick. The parting between the Middle and Low Beds is sometimes thicker, as at Morley West End Colliery (17 in.), while at Staincliffe and Clerk Green the Middle Bed Coal has disappeared, the section being 3 ft. 5 in. to 4 ft. 5 in. with 12 to 20 in. of dirt in the middle, the top 15 to 17 in. being a stone coal. The following are detailed sections:—

Bruntcliffe Colliery:—3 ft. 4 in. with 9 in. of dirt 16 in. from the base; the top 8 in. is a stone coal with 1 in. of shale below it.

At the railway junction north of Moor Fields:—3 ft. 6 in. with 1½ in. of dirt 16 in. from the base, the top 10½ in. a stone coal.

Morley West End Colliery:—5 ft. with 17 in. of dirt 16 in. from the base, the top 16 in. a stone coal.

At White Lee Colliery the section is stone coal 11 in., 'Johnnies' 2 in., Middle Bed 1 ft. 2 in., muck 2 in., Low Bed 1 ft. 7 in. On White Lee Common the coal has been largely worked by bell-pits. In Dewsbury Bank an exposure long since built over showed stone coal 10 to 11 in., bind 2 ft. 3 in., coal 1 ft., but the record of a shaft at Earlsheaton mentions only the stone coal. At Thornhill the cannel (1 ft. thick) forms the whole of the upper part of the seam, and is separated from the lower bed, also 1 ft. thick, by 6 ft. of measures. Around Lower Whitley and at Bunkers Hill the average section of the Flockton Thick Coal is as follows:—

	Ft.	in.
Stone coal, or cannel	1	0
Middle Coal	1	0
Clay or dirt parting ... 4 in. to	1	10
Bottom Coal	1	0

A day-working in Briestfield village gives the following section:—

	Ft.	in.
Stone coal, or cannel	0	11
Middle Coal	0	11
Clay	1	8
Bottom Coal	1	1

The upper cannel bed dies out to the south of Briestfield, and is only occasionally present around Flockton in a much attenuated form. South of Flockton it dies out altogether. At Grange Moor the top coal, 20 in. thick, is separated from the bottom bed, 12 in. thick, by a dirt parting ranging from 1 to 2 ft. in thickness. The average section in the collieries at Denby Grange and Overton is as follows:—

	Ft.	in.
Top Coal	1 ft. to 2	0
Dirt parting	1 ft. to 2	2
Bottom Coal	11 in. to 1	3

Around the village of Flockton the Flockton Thick Coal is 4 ft. 2 in. thick and consists of an upper and lower bed separated by a parting of underclay or muck, usually 2 ft. or more in thickness. At the Lane End Pit, Flockton Green it constituted a first class household coal, being very hot and clean and of moderate hardness. The average section here is as follows:—

	Ft.	in.
Inferior coal	0	3
Top Coal	1	4
Bind	1	3
Bottom Coal (high grade)	1	2
White bind	—	

Old crop workings in the Flockton Coal occur around Flockton Mill and along the sides of Flockton Beck. A thin upper layer of cannel is present here, but dies away in a northerly direction. Hereabouts the seam runs as follows :—

	Ft.	in.		Ft.	in.
Cannel or stone coal...	0	4	to	0	5
Top Coal	1	3	to	1	4
Parting	1	3			
Bottom Coal	1	4	to	1	6

To the south of Flockton the coal consists of two seams separated by a variable thickness of spavin and shale. The top bed is usually as much as 2 ft. thick and occasionally runs up to 2 ft. 6 in. It also yields a good house coal in this area, while the low bed is an inferior seam. At Emley Moor the Flockton Thick Coal is 3 ft. 6 in. thick, but 6 in. in the middle of the seam consists of clay or spavin.

About a mile to the east of Emley the coal has been worked from several pits, now disused, and the following section at Emley Woodhouse Pit is an average for the district :—

	Ft.	in.
Top Coal	2	2
Muck	3	2
Bottom Coal	1	4

The Tankersley Ironstone.—The Tankersley Ironstone crops out in Mouse Hole Dike, Kirkby Wood 500 yards due south of Flockton Church and also in Flockton Beck to the east of Flockton Mill. At the latter locality numerous overgrown bell-pits occur along or close to its outcrop. Furnace Grange, the name of the adjoining farmstead, clearly suggests the site of former iron-ore smelting activities. Numerous old overgrown bell-pits also occur in the Rough and Hillhouse Wood, between Denby Grange and the Manor House, Flockton.

The Joan Coal.—This coal is only 6 in. thick at the northern outcrop, but thickens slowly southwards. In the neighbourhood of Dewsbury it reaches 1 ft. 10 in. to 2 ft. 3 in. and has been worked, often under the name of the Mitchell or Parson Coal.

The Joan coal crops out along the southern slopes of Thornhill Edge, and also on Emroyd Common and to the south of Overton. The following is a measured section of the seam in Birk Wood, just south of Overton :—

	Ft.	in.
Dirt	0	3½
Coal	0	2
Dirt	0	4
Coal	1	3

The Flockton Thick Coal under the eastern part of Emley Moor is overlain by a flaggy sandstone, and on this in turn rests a 3 ft. seam of coal which judging by the fact that it lies 60 ft. above the Flockton Thick Coal is obviously the local representative of the Joan Coal, though under a different form. It here covers a large area between Windmill Hill Lane and Stringer House and lies quite close to the surface with little cover. During successive disputes in the mining industry it has been extensively worked and though of inferior quality has been found to be a useful fuel substitute for industrial purposes. It consists of 3 ft. of soft dull coal underlain by 1 ft. 8 in. to 2 ft. of alternate layers of black shale and cannel; the latter being locally referred to as 'Johnnies.' The whole bed was mined, though a strong draught is necessary to ignite and burn the lower portion of the seam.

The Thornhill Rock.—The northern outliers are formed by the lowest beds, which are too shaly to be valuable, though in Popeley Fields there are old quarries showing up to 20 ft. of sandstone. In the main mass south of Bruntcliffe and Morley quarries are very numerous. An old quarry at New Brighton shows about 60 ft. of false-bedded massive sandstone with beds of

sandy shale. South-east of Bruntcliffe old quarries show about 100 ft. of sandstone, the top half being false-bedded with beds of shale and shaly sandstone, the rest being a massive sandstone.

There are several large quarries, mostly disused, about half a mile north-north-east of Howley Park. Two quarries worked by the Finsdale Quarry Co., Ltd., show about 80 ft. of stone. The top 54 ft., however, is not used, being false-bedded and containing large ferruginous concretions. These concretions are rather common in the upper part of the Thornhill Rock of this area. Several quarries have lately been opened in the country east of Howley Park by Messrs. George Armitage and Sons, Ltd., The New Howley Park Quarry Co., Messrs. Pawson Brothers, and Messrs. Thomas Clough and Sons, Ltd. A boring here has proved the stone to be 120 ft. thick, with 12 ft. of sandy shale near the base. Some of these quarries were started in the shale above the Thornhill Rock, and in one of them measures with the Low Haigh Moor Coal are exposed in the overburden. The sections here show about 60 ft. of good stone with the base of the rock still about 20 ft. lower. Above the good stone is about 20 ft. of poor shaly sandstone with a considerable thickness of shale above this. The stone raised here is a fine-textured freestone which comes out in big blocks. It is pale blue when unweathered. It is used locally and in many different parts of England for building and monumental work and is sawn into flags.

The false-bedded and shaly sandstone which occurs above the valuable stone is not used, and has to be removed before the lower bed can be got. The junction between the massive stone and the poor stone is rather irregular, shaly beds putting in at somewhat different horizons in different localities. Similarly the junction between these stone beds and the overlying shales is often irregular and badly defined.

A section of Thornhill Rock at the west end of Soothill Wood Tunnel (S.E. of Howley Park) shows the lower beds containing irregular layers and pockets of sandy mudstone and shale with rolled ironstone nodules, with in addition large numbers of redeposited ironstone nodules in the sandstone. Just south of these quarries the rock is thrown down underground by a large fault. A thin strip of Thornhill Rock is exposed between the Healey and Staincliffe faults, on the south side of Batley, and the upper part of the rock is visible in the valley-bottom west of Lower Soothill. The ground is mostly built over, but about 35 ft. of sandstone is exposed below the railway 300 yards west of Soothill Wood Colliery.

Thornhill Rock caps the high ground north-east of Batley, and makes a prominent escarpment which swings round from Hanging Heaton along the east side of the valley to Crackenedge. In the quarry here about 80 ft. of rock is exposed, but it is split up by beds of sandy shale and also contains a 5-inch bed of coal and dirt. The best stone is in the lowest 20 ft. The top 30 ft. contains large sandy concretions which weather out leaving cavernous spaces. At Earlsheaton the main road to Wakefield passes through a cutting which shows about 50 ft. of sandstone, strongly current-bedded: further south there are old overgrown or built-over quarries along the scarp. In the railway cutting east of Earlsheaton Station there are two thin coals in the base of the Thornhill Rock.

South of the river the rock averages 65 ft. in thickness around Thornhill and Overton. In the Midland Railway cutting it is strongly current-bedded at the top; the lower part though more massive, contains many ironstone nodules as pebbles. In the many quarries around Thornhill, all disused, the grain is usually fine and close, but the bedding is sometimes regular and at other times extremely irregular. At Hostingley Colliery one mile east of Thornhill Church the rock was found to be 68 ft. 6 in. thick. South-east of Overton it shows rapid attenuation and dies out altogether to the south of Midgley (just beyond the eastern border of the map).

The Low Haigh Moor Coal.—This seam is thin and of no consequence: its outcrop could only be mapped over a small area east of Howley Park, where it is 16 in. thick.

There are only two small areas to the south of the River Calder where measures higher than the Thornhill Rock occur. These are respectively (1) a small faulted triangular area to the south-east of Thornhill Church, along the eastern margin of the map, and (2) a small area, also bounded by faults extending from Emley Church to New Hall Wood. The latter is a long narrow faulted strip let down between two prominent N.E.-S.W. faults, the position of both of which has been fully proved in underground workings. In the first-mentioned area near Thornhill, a disused mine shaft occurs 750 yards south-east of Thornhill Parish Church; this was sunk to the Low Haigh Moor Coal which was encountered at a depth of 18 ft. Except the fact that the seam was found to be 2 ft. thick, no further particulars as to its relative value are available. This small area is bounded on the west by a prominent N.W.-S.E. fault running past Thornhill Church towards Middlestown.

In the second area extending from Emley Church to New Hall Wood, shales with thin bands of sandstone and unimportant coals are seen and call for no special comment.

Top Haigh Moor Coal.—This seam lies about 35 ft. above the Low Haigh Moor Coal, the intervening measures being shaly, with a thin sandstone bed just above the low seam developed locally east of Howley Park. It outcrops around Lower Soothill, where exposures of the seam were seen in certain places. It is of variable thickness, as the sections to be given will show.

It has been worked in Soothill Wood Colliery, where it was normally about 3 ft. thick, with 2 in. of dirt in two partings. The thickness varied in the workings, however, and in a swilley was as much as 4 ft.

An exposure 400 yards north-north-east of Soothill Wood Colliery shows the coal to consist of two beds parted by 3 ft. of seat-earth. The lower bed is 12 to 14 in. thick, and 2 ft. of the upper bed was seen, the section not being complete. A somewhat obscure section 100 yards east of here shows about 3 ft. 4 in. of coal. The coal was seen in the cutting close to the more easterly bridge over the railway south of Lower Soothill; the section was rather obscure, but appeared to be 2 ft. 8 in. of coal separated by 8 ft. of seat-earth and mudstone from a lower bed 1 ft. thick.

In the Lower Soothill area there is a rather thick sandstone close above the Top Haigh Moor Coal. An old quarry in Lower Soothill shows 20 ft. of rather massive stone, and the complete thickness probably exceeds 30 ft. This stone has also been quarried north-east of Hanging Heaton.

The remaining measures cover so small an area that all the information available has been given in the general account.

CHAPTER V

GEOLOGICAL STRUCTURE

The principal element in the tectonic structure of this district is the Pennine Anticline, the axis of which runs in a N.N.W. and S.S.E. direction from the neighbourhood of Todmorden past Blackstone Edge to Bleaked Gate Moors at the southern margin of the area. The Pennine Anticline is markedly asymmetrical with steep dips on its western flank and low dips to the east. This difference is clearly shown by the horizontal section (Figure 2) and is further clearly brought out by comparing the relative widths of outcrop of corresponding measures on either side of the anticlinal axis. Thus the base of the Coal Measures is about one mile to the west of Blackstone Edge, while on the eastern side of the axis the total width of outcrop of the corresponding measures up to the base of the Coal Measures is at least eight miles.

In the original survey of this area, Hull [1] attached great structural significance to a supposed fault which he maintained could be followed very close to or alongside the axis of the Pennine Anticline. This fracture he referred to as the ' anticlinal fault.' As has been already indicated elsewhere [2] it has been found practicable to trace an apparently unbroken succession across the axis of the anticline in many places. The main fractures have been found to run obliquely to the axis of the anticline and are more conspicuous in the country to the west, while any faults close to the anticlinal axis have a relatively small effect on the tectonic structure of the area.

From the Pennine anticline the rocks have a very gentle and on the whole fairly uniform inclination to the east throughout the present area. These uniform and gentle dips give rise to a very characteristic type of landscape consisting of extensive and nearly flat-topped plateaux floored by grit or sandstone and ending in ' edges ' or abrupt escarpments as a rule facing westwards. This ' ridge and furrow ' type of scenery is very characteristic of the Millstone Grit moorlands and is also seen, though to a lesser degree, in the Coal Measure tracts.

The uniform nature and gentle easterly inclination of the strata is well illustrated by the following details. Along the eastern slopes of the Pennine anticline on Rishworth, Soyland and Wadsworth Moors the top of the Kinderscout Grits, at which occurs the marine band characterized by *Reticuloceras reticulatum*, mut. α

[1] Hull, E., ' The Geology of the Burnley Coalfield ' (*Mem. Geol. Surv.*), 1875, pp. 9, 88, 100.
[2] Wray, D. A. and W. Lloyd in ' The Geology of the Rossendale Anticline ' (*Mem. Geol. Surv.*), 1927, pp. 35 and 38.

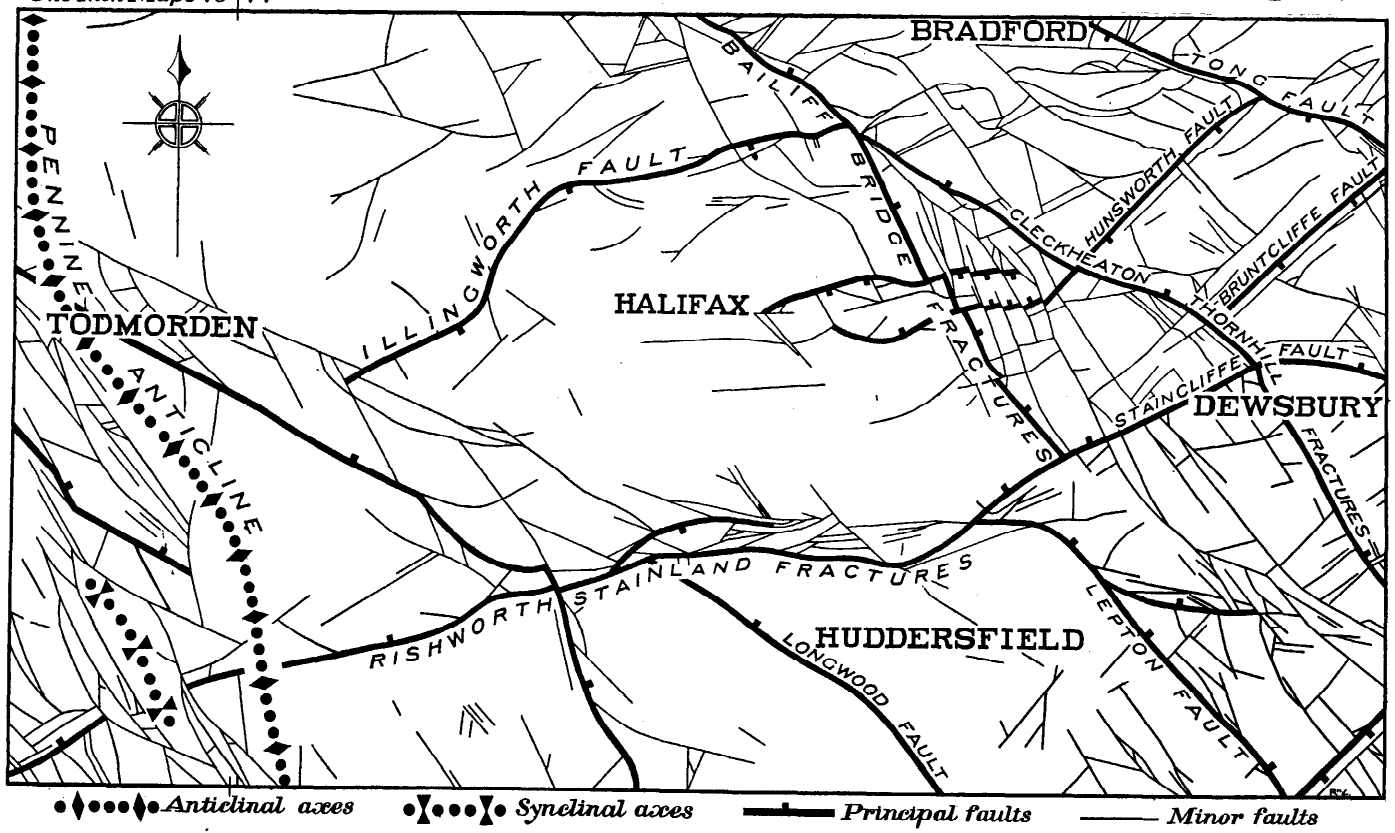

Fig. 8.—*Map of the principal Faults and Folds.*

Bisat is at levels varying from 1,100 to 1,250 ft. O.D. In a boring at Longwood, seven and a half miles to the east (see page 191), this horizon was met with at a depth of 345 ft. below O.D., at Mold Green (see page 189) at a depth of 1,100 ft. below O.D. and at Halifax at a depth of 562 ft. below O.D. Each pair of these figures gives an almost uniform gradient of this well recognizable horizon over distances up to ten miles of approximately 1 in 25, or an angle ranging from 2½ to 3 degrees. In several parts of the area minor exceptions to this uniform structure occur and these will be discussed below.

On Worsthorne Moors, to the west of the present district, Mr. Lloyd [1] finds that the Pennine anticline very closely approximates to a simple monocline. Further south in the Todmorden and Walsden districts, this monoclinal structure, much cut up by later faulting, is less pronounced. The same features also characterize the Blackstone Edge district. In the southern part of our area, however, on Bleaked Gate Moors the asymmetry is still less noticeable, the axis is broader, while secondary anticlinal folds parallel to the main anticlinal axis also occur. Such a one is well seen in Axe Edge (Figure 2).

In its course from north to south, therefore, the Pennine Anticline would appear to pass from a simple monocline into several broader folds, perhaps eventually dying out in a southerly direction in a complex fan-like virgation in the Midland Counties. There appears to be general agreement that the Pennine folding did not continue far into the Midlands, and the earth stresses which produced it doubtless found relief in the accentuation and intensification of the already existing Charnian and other folds.

Faulting

The principal faults of the district may be broadly classified into two main systems. The main faults of the Todmorden district, the Slaithwaite, Longwood and Lepton faults, the Bailiff Bridge, Cleckheaton and Thornhill fractures and the Tong fault all approximate to a general north-west and south-east direction. The second system of faulting which varies in direction between east to west and north-east to south-west includes the prominent Rishworth and Stainland fractures and the Staincliffe, Illingworth, Hunsworth and Bruntcliffe faults (see sketch map, Fig. 8). In addition to these there are a large number of minor faults with very varying directions. Another feature which it is essential to point out is that the much greater frequency of minor faults in the eastern part of the area, as shown on the map, is probably more apparent than real. The Coal Measures have been extensively mined in this area and consequently practically every fault, even of very slight or no tectonic significance, is known and has been mapped in that area. It is not improbable that if the Millstone Grit was known in similar detail, the faults would be found to be equally numerous over the central and western

[1] See especially one-inch geological map, New Series, Sheet 76 (Solid) Rochdale, 1927.

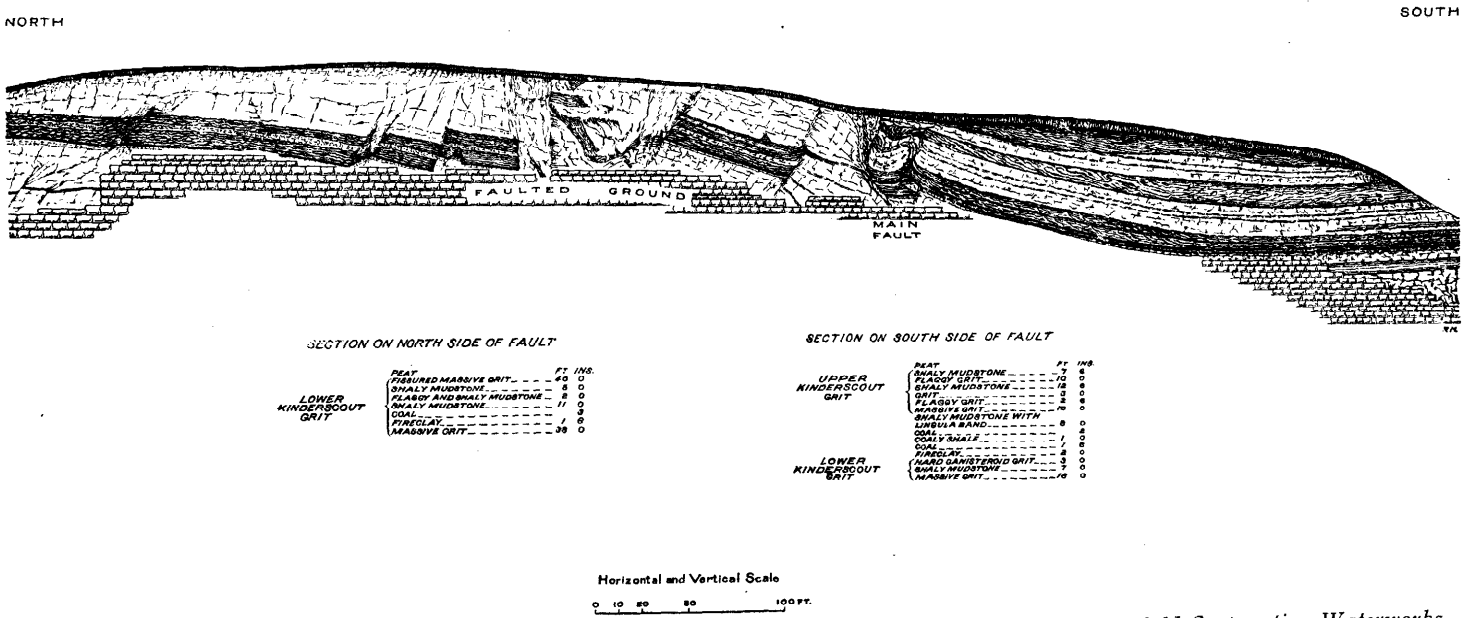

Fig. 9.—*Section across faulted ground in dam trench, Green Withens Reservoir, Rishworth Moor, Wakefield Corporation Waterworks.*

part of the district. We are fortunate in having the exact effect of a fault on Millstone Grits accurately represented in a scale-drawing by Mr. Clemesha Smith of the section seen in the dam-trench for Green Withens Reservoir, Rishworth: this drawing is reproduced on a small scale in Fig. 9. The effects of the numerous faults on the geological structure of the coal measure districts are shown in Fig. 10: which gives a succession of calculated contours on the surface of the underlying Rough Rock.

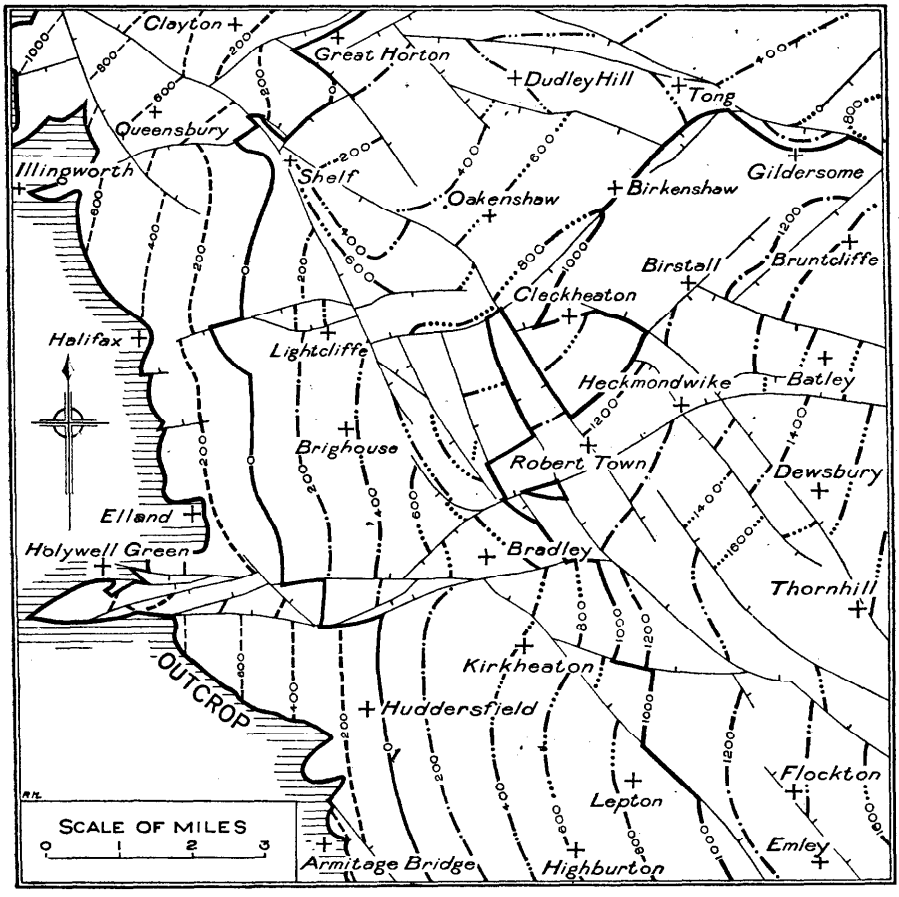

Fig. 10.—*Contour Map of the underground surface of the Rough Rock.*

There is no clear evidence that the two main fault systems are of different geological age. It is true that the Rishworth and Stainland fractures, together with the Staincliffe fault which represents their easterly continuation, appear to displace and in some cases cut off somewhat abruptly the north-westerly faults but this in itself does not necessarily indicate later age. It is quite conceivable that an earlier powerful fracture may deflect and even interrupt the course of later minor faulting.

Around Wyke, Bailiff Bridge, and Scholes the rectangular system of fractures would appear to be all part of one main system of faulting ; it is definitely known that the north-west to south-east faults sometimes shift those intersecting them and are themselves shifted by them within a very short distance ; in some cases the shift appears to be mutual. This area compares admirably with the system of fractures produced in Daubrée's experiments,[1] in which a brittle material such as a piece of glass, was subjected to a twisting strain till it shattered.

A broad and shallow asymmetrical anticlinal fold has been traced from the neighbourhood of Buttershaw southwards through Wyke to about a mile east of Bailiff Bridge where it dies out. The anticline pitches in a southerly direction. This fold which runs parallel to the main Pennine Anticline and also resembles it in having steeper westerly dips, lies within a triangular area bounded by the Bailiff Bridge and Cleckheaton fractures, and the westerly continuation of the Hunsworth fault. A lateral movement along the course of these faults would give rise to a torsional movement in this anticlinal area, and if the strain were sufficient, relief would be found in the production of a rectangular series of fractures exactly comparable to those produced in Daubrée's experiments referred to above. We seem therefore justified in considering that the rectangular fractures of the Bailiff Bridge and Scholes districts are the direct result and expression of some such torsional movements.

Although this type of structure is clearly brought out in the Bailiff Bridge and Scholes district, it is by no means confined to isolated areas, and if a general map of the faults of the Southern Pennines is examined,[2] it will be apparent that the principle is applicable to the whole of the area. Thus an unequal or irregular uplift along the line of the main Pennine axis would give rise to similar torsional movements in the rocks affected, and produce the characteristic rectangular form of faulting. There is no evidence available within the limits of the present area to fix the age of the faulting except that it is clearly Post-Carboniferous in age. The above conclusions, however, would seem to suggest that the greater part of the faulting was intimately associated with the uplift of the Pennines, and hence probably part of one system and of the same geological age.

The Rishworth, Stainland and Staincliffe faults.—One of the most prominent lines of fracture in the area is the fault which can be traced from the southern end of Blackstone Edge across Rishworth Moors and past Krumlin to Birchencliffe. East of here it bifurcates, but the main fracture continues east-north-easterly to the north of Deighton and runs through Kirklees Park, Norristhorpe, Heckmondwike and Staincliffe ; it then trends east just to the north of Hanging Heaton.

[1] Daubrée, A.,' Etude synthétique de Géologie Expérimentale,' Paris, 1879, p. 300 ; also Becker, G. F., *Trans. Amer. Inst. Min. Engin.*, vol. xxiv, 1894, p. 130.

[2] An excellent map of the several fault systems is given in Kendall, P. F. and H. E. Wroot, ' Geology of Yorkshire,' Leeds, 1924, p. 243.

This prominent fault crosses the Pennines, and in East Lancashire forms the southern boundary of the Middle Coal Measures basin at Rochdale. Throughout the greater part of its course it has a large downthrow to the north.

The course of the fault was well seen during the construction of the containing dam for the Green Withens Reservoir at Rishworth (see Figure 9) and is also still exposed in Green Withens Clough at the Castle Dean Rocks. At Butts Clough, Rishworth, it brings the massive Kinderscout Grit, well exposed in the Booth Dean valley, against the Middle Grit Series, and its throw hereabouts cannot be less than four hundred feet. At Ringstone Edge it is slightly shifted by a north and south fault, and to the east of Krumlin it splits up into numerous branches.

The main fault which runs close to Sowood Green and through Wappy Springs to Birchencliffe is well seen in several places. Its course across the Huddersfield-Halifax main road can be fixed to within very narrow limits close to Birchencliffe Church. Hereabouts its throw is five hundred feet, and it brings in a faulted trough of Coal Measures at Holywell Green. A branch fault which runs through Stainland with a large downthrow to the south forms the northern limit of this Coal Measure basin.

The effect of the Rishworth-Stainland fault and its numerous branches on the country to the south of Elland is illustrated in Figure 4, where the levels of the principal coals have been proved by mining operations.

Around Deighton the main fault breaks up somewhat into a complex series of fractures; east of here it is known as the Staincliffe fault, and in the vicinity of Staincliffe its downthrow to the north has been proved by mining operations to be 285 ft.

Healey fault.—From Healey to Lower Soothill there is a fault of some importance which lies about a quarter of a mile north of the Staincliffe fault and runs parallel to it. It has, however, a downthrow to the south with a maximum throw of 150 ft. On the south side of Batley these two faults give rise to a trough occupied mainly by Thornhill Rock.

Illingworth fault.—This fault can be traced for a distance of about nine miles from the Cragg valley across Blackwood Common and the Luddenden valley, past Illingworth and Catherine Slack to the north of Shelf. It has a downthrow to the south of about one hundred feet: at Illingworth the shift produced by it in the scarp of the Rough Rock is a conspicuous feature in the landscape.

A prominent fault which runs in a south-easterly direction through Todmorden across Soyland Moors to Rishworth appears to be an easterly continuation of the *main Cliviger valley fault* which can be traced to Burnley in a north-westerly direction, where it forms the southern boundary of the Burnley coal basin.[1] This

[1] 'The Geology of the Rossendale Anticline' (*Mem. Geol. Surv.*), 1927, p. 107. See also one-inch geological map, New Series, Sheet 76 (Solid) Rochdale, 1927.

fault has a large downthrow to the north-east. At Rishworth and Ringstone Edge it is intercepted by a north and south fault which can be traced from thence to Slaithwaite.

The Longwood fault.—The Longwood fault is a north-west and south-east fracture which can be traced continuously from Outlane to Stirley Hill. It has a downthrow to the north-east of less than one hundred feet, and is the only fault of any importance affecting the succession in this district.

The Bailiff Bridge fractures.—The principal Bailiff Bridge fault runs south-south-easterly between Clayton and Queensbury and through Shelf, Norwood Green, Bailiff Bridge and Clifton to Kirklees Park, where it is abruptly cut off by the Stainland and Staincliffe faults. It has a large downthrow to the east, which has been proved to be 420 ft. in the Better Bed Coal to the north of Bailiff Bridge. To the west of the fault the measures dip gently eastward, but east of the fault, there is a highly faulted area stretching towards Cleckheaton. For about one third of a mile east of the Bailiff Bridge fault the measures have a pronounced south-westerly dip which exceeds 30° in close proximity to the fault, while further east they maintain their general east and south-easterly dip.

The Cleckheaton and Thornhill fractures.—A series of prominent faults bifurcate from the Bailiff Bridge fault at Shelf, and trend south-easterly through Wyke and Cleckheaton to Dewsbury where they cross the Staincliffe fault. One of the principal is that which runs through New Road Side and between Scholes and Cleckheaton to Robert Town. Its downthrow is 108 ft. to the north-east at New Road Side but decreases in amount when traced to the south-east.

Another fault which can be traced from the southern suburbs of Bradford through Low Moor, Cleckheaton, and Westfield (near Heckmondwike) to Boothroyd near Dewsbury is known as the Cowmes fault.[1] In the Low Moor district it has a downthrow to the south-west of 60 to 70 ft.

To the south of Dewsbury, the above fault system is represented by a series of south-south-easterly fractures running through Thornhill. The principal one which runs close by Thornhill Parish Church has been met with in the New Hards and Black Bed coal workings at Combs Colliery where it has a downthrow of 120 ft. to the east.

The Tong fault.—This prominent fracture which runs east-south-easterly from Tyersall Gate past Tong and to the north of Gildersome and Morley has a downthrow of over 350 ft. to the south in the neighbourhood of Tong. South-east of here its throw increases to over 400 ft. in the vicinity of the railway through Morley, where it brings the Thornhill Rock against the Blocking Coal. In the neighbourhood of Cockersdale, however, its throw

[1] Green, A. H., 'The Geology of the Yorkshire Coalfield,' (*Mem. Geol. Surv.*), 1878, p. 621. Cowmes is the old spelling of Combs.

is reversed over a considerable distance owing to a singular disturbance which affects the strata on the south side of the fault. Around Gildersome and Moor Head the beds are folded into a dome, the northern half of which is cut off by the fault. Steeper dips characterize this half-dome-like structure and in the centre of the fold the beds below the Better Bed Coal are brought to the surface. These measures are brought against beds on the north side of the fault which contain the Churwell Thick Coal and have a normal east and south-easterly dip.

The Hunsworth fault.—This fault which can be traced from the Tong fault in a south-westerly direction runs through Birkenshaw and Hunsworth to the country between Scholes and Cleckheaton. In the Birkenshaw district it has a throw of 210 ft. to the south-east, but diminishes to 150 ft. around Hunsworth, and to less than 100 ft. in the Cleckheaton district. It is shifted by the several branches of the Bailiff Bridge fractures, and at Lightcliffe the Hunsworth fault system would appear to be represented by a trough-faulted area containing the Better Bed and Black Bed Coals let down between the Elland Flags. The throw to the south of the northern branch is 120 ft. to the west of Hipperholme, and 150 ft. or more near Bottom Viaduct, north-east of Lightcliffe.

The Bruntcliffe fault.—The Bruntcliffe fault runs from the north of New Brighton in a south-westerly direction through Bruntcliffe, Howden Clough and Birstall towards Heckmondwike. It resembles the Hunsworth fault in having a downthrow to the south-east diminishing in a south-westerly direction. Around Bruntcliffe it forms the north-western faulted edge to a wide development of the Morley Rock, and at Bruntcliffe Colliery where its downthrow to the south-east amounts to about 240 ft., the Middleton Bed is worked on the downthrow side of the fault and the Beeston Coal on the upthrow side. At Howden Clough its throw has diminished to about 120 ft. while to the south of Birstall its throw is comparatively small.

A fault parallel to the Bruntcliffe fault has been traced from Gildersome in a south-westerly direction through Birstall to Popeley Fields where it intersects the Cleckheaton and Thornhill group of fractures. It has a downthrow of 120 ft. to the south-east at Popeley Fields but in the Howden Clough district its throw has diminished to 36 ft. It dies out altogether further to the north-east at Gildersome station.

Between White Lee and Popeley Fields on the north-east and the Spen valley on the south-west the structure of the ground is exceedingly complicated. In some respects the map must be regarded as hardly more than one possible interpretation of the known facts. This area puzzled A. H. Green, who attempted a solution by the insertion of a conjectural fault concealed for the greater part of its course by alluvium. He states that the " fault at Mill Bridge has not been seen or proved in any part of its line, but

some such fault seems to be necessary to account for the depth of the Blocking Coal (84 yards) at the shaft near Flush Mill, for the same coal is only a few yards deep in the valley at Mill Bridge. We have accordingly laid down a fault provisionally between Flush Mill and Mill Bridge." [1] He also mentions that some of the coal-outcrops are calculated. Subsequent working of the Black Bed Coal from Strawberry Bank Colliery has shown that no fault exists at or near Green's conjectural line. Future development may not improbably prove one or more mistakes in the new survey, though the additional information available since Green's day has enabled us to produce a more accurate map than his.

Another fault which runs in a W.N.W.—E.S.E. direction has been proved in colliery workings at Upper Batley and to the north of Lower Soothill. At Upper Batley it has a downthrow to the south of 105 ft. To the west, in Birstall, it intersects the Bruntcliffe fault, and appears to be cut off by the N.E.—S.W. fault which runs through Popeley Fields. To the north of Lower Soothill, the Upper Batley fault brings the measures containing the Haigh Moor and Gawthorpe coals against the Thornhill Rock.

The Lepton fault.—The Lepton fault branches from the Rishworth and Stainland fractures at Colnebridge and runs in a south-easterly direction through Kirkheaton, Houses Hill, Lepton Edge and across Flockton and Emley Moors. At Cockley Hill to the east of Kirkheaton it was met with in the Black Bed Coal workings, and its throw to the north-east is hereabouts 200 ft. At Lepton Edge its throw is only about 100 ft. but it again gradually increases in throw when followed to the south-east; and at Flockton Moor where it was proved in the workings in the New Hards, Wheatley Lime and Blocking coals its throw is about 120 ft. Further south it passes close by the Speedwell Colliery shafts at Emley, with a throw here of 140 ft.

A prominent east and west fault joins the Lepton fault at Cockley Hill, Kirkheaton and passes through the southern part of Gregory Spring Wood to near Whitley Church. At Gregory Springs it shifts the outcrop of the Blocking Coal for a lateral distance of a mile and its total downthrow to the north is about 210 ft. To the south of Whitley Church there are outcrop workings in the Green Lane and Blocking coals alongside one another so that its throw here is about 230 ft.

The Emley faults.—A pair of north-east to south-west faults which produce a trough-shaped structure occur at the south-eastern margin of the map, and have been traced from the Lepton fault through Emley to the southern part of New Hall Wood. These have been fully proved in mining operations. The northern one has a downthrow to the south-east of about 36 ft. at Emley which increases to over 70 ft. in New Hall Wood. The southern one has a throw to the north of about 85 ft. at Emley.

[1] 'Geology of the Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1878, p. 658.

In the country between Thornhill, Whitley, Flockton and Overton a number of faults have been proved in mining and the more important of these run in a north-west and south-easterly direction. The *Denby Grange fault* which runs from Whitley past Denby Grange and Flockton Church has a downthrow to the north-east of about 20 ft. in the north which increases to about 60 ft. in the neighbourhood of Kirkby. The *Bunkers Hill fault* which has been traced from near Hopton Hall past Bunkers Hill, Round Hill Wood, and Hope Colliery Shaft to New Hall Wood is more important. Around Briestfield its throw in the Flockton Coal is about 60 ft. to the north-east, but southwards at Hope Pit, Overton and in New Hall Wood it increases to over 120 ft.

A third parallel fracture is the *Overton fault*, which runs from the south of Ravensthorpe past Foxroyd and Edge Top, Thornhill, and through the village of Overton into the Coxley Valley. The throw of this fault varies from 40 to 70 ft., the larger throw being found in the more northern part of its course.

CHAPTER VI

GLACIAL AND RECENT DEPOSITS

The greater part of the present one-inch sheet lies within the drainage area of the River Calder and its several tributaries, a small area only along the north-eastern margin of the map draining into the Aire valley. The Aire-Calder watershed runs from Ovenden Moor through Queensbury, Wibsey, Dudley Hill, Drighlington and Bruntcliffe to the north of Birstall (Fig. 11).

With the exception of a small spread of boulder clay which occurs at the head of the Spen valley and to the south of Bradford, no glacial drift which can be indubitably ascribed to the effect of an ice-sheet occurs in Calderdale or its tributary valleys.

Several isolated patches of glacial gravel and loamy drift occur but these may well have all been the product of melt-waters of an ice-sheet which covered the higher ground of East Lancashire and which on melting overflowed through the Walsden and Cliviger gorges into the valley of the Yorkshire Calder. Several patches of gravel and stony clay which occur in the vicinity of Huddersfield have been claimed as the direct result of an ice-sheet though this explanation of their presence has not been universally accepted.[1] There is a complete absence of foreign stones in these clays, but it is difficult to realize what other agency than an ice-sheet could have produced the stiff yellow clays with large subangular blocks of local stone.

The glacial drift both around Bradford and to the south of that town has been clearly shown by its contents to be the product of an ice sheet advancing down Airedale in a south-easterly direction. Filling up the greater part of the Aire valley it succeeded in overriding the Aire-Calder watershed from Wibsey eastwards to Dudley Hill. In general the deposits left by the ice-sheet vary from a normal type of boulder-clay to one which might be regarded as a gravel. Commencing with a tough bluish-grey clay, weathering yellow, with numerous boulders and a variable content of pebbles and gravel, mostly far travelled, the incorporation of an increasing amount of locally derived material leads through intermediate types to one which is largely composed of angular and subangular fragments of the local rocks in a clayey or sandy matrix; occasional small erratic pebbles are, however, included. This change takes place towards the edge of the drift-covered area, the boulder-clay losing its distinctive character as the limits of the once ice-covered

[1] Woodhead, T. W., 'Occurrence of Boulder clay at Huddersfield,' *Naturalist*, 1917, pp. 219–232. Kendall, Prof. P. F. and H. E. Wroot, 'The Geology of Yorkshire,' 1924, p. 571.

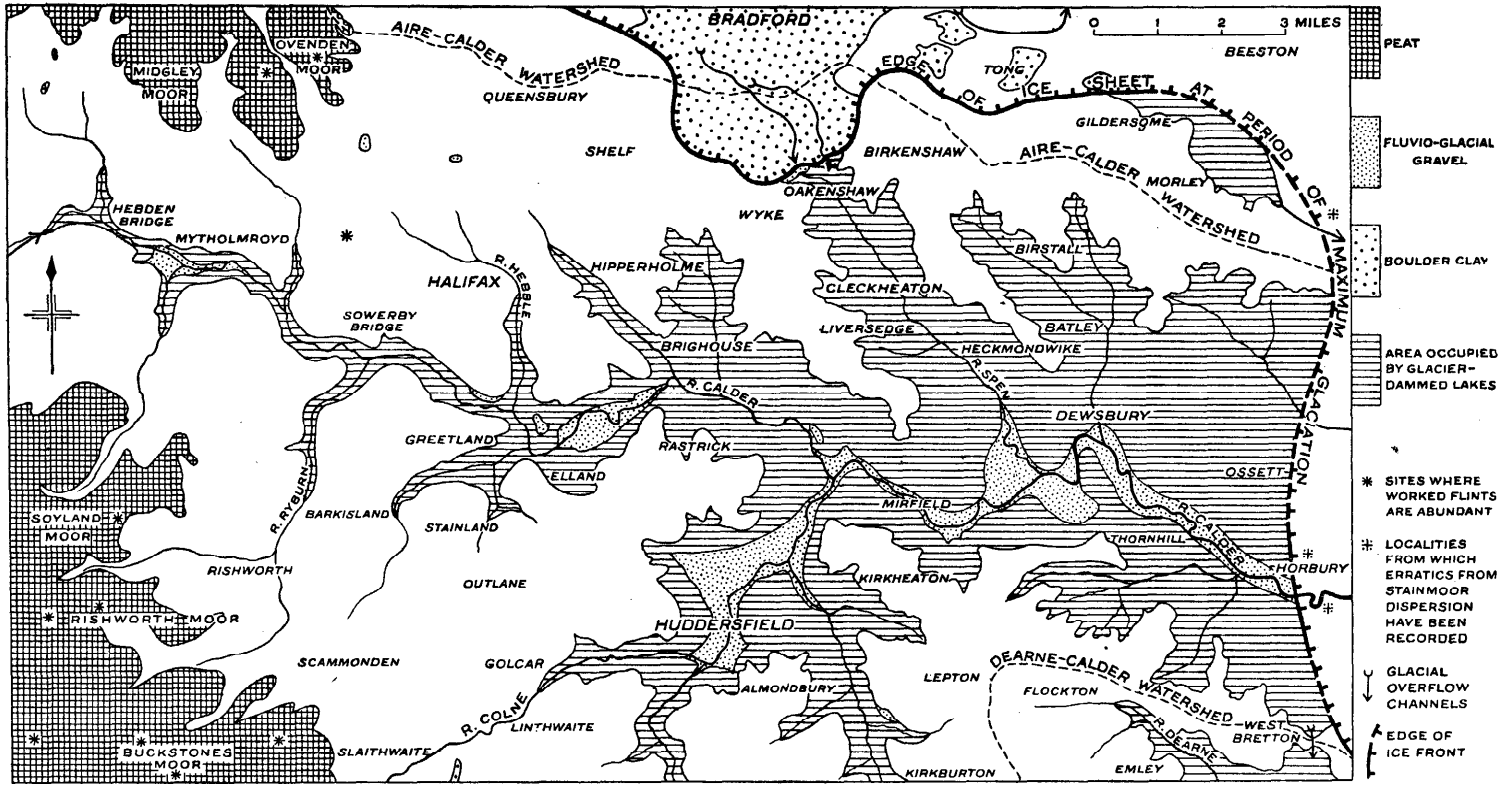

Fig. 11.—*Sketch map of the Superficial Deposits.*

area are approached. A rather similar variation is to be observed in connexion with the relief of the country passed over by the ice. On the low-lying ground, in hollows and on the 'lee' side of hills with respect to the direction of advance of the ice, the drift tends to be thick and of the typical boulder-clay character; but it is thin and contains a higher percentage of locally derived material on the hillsides opposite to the advance of the ice, that is, those slopes facing north or north-west.

Positive evidence of the flow of the ice is not forthcoming in the area under review but just beyond the northern border of the one-inch map, at Laisterdyke, there are glacial striae with a bearing S.72°E.[1]

The Superficial Deposits of the Calder Valley

In the valley of the Calder the bed of the river is composed of sandy clay and loam. In the upper part the valley is for the most part comparatively narrow; lower down it broadens out somewhat, the principal alluvial flats occurring north of Elland and to the south and west of Dewsbury. There is, however, a marked tendency for the valley to consist of a chain of open flats linked by more gorge-like sections where the river has cut through the more prominent sandstones, and the river deposits are mostly found immediately below these gorges: thus the boulder deposit above Mytholmroyd, misleadingly named by Spencer the 'Mytholmroyd Moraine'[2] lies in the lee of the Lower Kinderscout Grit; those of Elland in that of the Rough Rock at the head of a wide spread of alluvium which gradually narrows to the gorge through the Elland Flags at Brookfoot and Brighouse. The superficial deposits in the floor of the valley attain a greater thickness in its lower reaches, being forty to fifty feet in thickness near Dewsbury.

Near Mytholmroyd two patches of glacial gravel occur along the southern slopes of the valley. The more westerly, the "Mytholmroyd Moraine," extends upstream from the confluence of the Cragg Brook with the Calder for about half a mile; it lies at 300 to 425 ft. above sea level, is at least 8 ft. thick and consists of sandy rubble with both local and far-travelled erratics. The boulders include 'granophyres, andesites, rhyolites, Eskdale and Buttermere granites, ash, felsite, chert, Silurian grit and vein-quartz.' These are more rounded than the local grits and ganisters and are evidently water-worn; many show flat soles, but no unmistakable striations were seen during the re-survey, nor by previous observers.[3]

At Brearley, to the east of Mytholmroyd the glacial deposit consists of sand with many large local boulders and attains 12 ft. in thickness; it is exposed in the river-cliff beside the railway three-quarters of a mile east of Mytholmroyd Station; no foreign stones

[1] 'Summary of Progress' for 1925 (*Mem. Geol. Surv.*), 1926, p. 67. See Survey Photograph No. 3550.

[2] Spencer, J., *Halifax Naturalist*, vol. i, 1896, pp. 45-50.

[3] Law, R. and W. Simpson, 'Drift Deposits at Mytholmroyd,' *Proc. Yorks. Geol. and Polytech. Soc.*, vol. xiv, 1901, pp. 231–236.

were seen during the survey but Buttermere granophyre has been recorded; Lake District volcanics have also been recorded from Hebden Bridge, Luddenden Foot and Sowerby Bridge.[1]

Around Elland several patches of glacial drift occur. One of these is a deposit of buttery clay, yellow above and blue below, which occurs along the northern slope of the Calder valley at Copley Station at about 275 O.D. It is about 8 ft. thick and contains boulders of local origin up to 3 ft. long.[2] Another isolated patch of glacial gravel caps the elevated ridge to the north of Elland on which Exley Hall is built, at a level of about 375 ft. According to Davis, who originally described the deposit, the material was all of local origin,[3] though during the recent re-survey of this area foreign stones were found among the material dug up in Exley Cemetery. The bed is at least 10 ft. thick in places.

Similar gravel is also seen in section in the cutting at the eastern end of Elland Railway Station. It here consists of 15 feet of fairly well bedded gravel with numerous pebbles of red and grey granite, quartzite, volcanic rocks, etc., resting on a steep slope of dark grey shaly mudstones. A wide spread of this gravel also occurs alongside the railway to the north-east of Elland.[4] The whole of the alluvial flat of the River Calder hereabouts appears to be underlain by the same material. Thus in making excavations at Elland Sewage Works in Low Fields, the alluvium, consisting of sandy silt 4 to 5 ft. thick, was found to rest on a coarse gravel which was full of pebbles and boulders of granites, volcanic rocks, and other far-travelled erratics. Some of the latter attain a considerable size, up to 4 ft. A long list of boulders, mostly from the Lake District, found here and in excavations for the piers of the railway bridge north of Greetland has been given by Spencer; he mentions that one boulder showed ice-scratches (*op. cit.*).

In Kirklees Park on the left bank of the River Calder another isolated patch of glacial gravel occurs at Castle Hill, the highest point in the park, at about 300 feet O.D., or about 130 feet above the level of the Calder alluvium. A small gravel pit in it shows 10 feet of current-bedded gravel and sand with boulders up to 2 feet across. With the exception of fragments of chert all the material appears to be of local origin.

At Battyeford near Mirfield the Calder valley is contracted somewhat and in putting down foundations for a bridge in 1907 a great thickness of gravel was encountered, with many far-travelled erratics.[5] This bed has also been proved near Mirfield station.

Between Mirfield, Dewsbury and Thornhill the River Calder follows a wide meander, and alongside the river alluvium at Lower

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[1] 'Erratic Blocks of the British Isles' (8th report of Committee), *Rep. Brit. Assoc.* for 1903 (Southport), 1904, pp. 231–258.

[2] *Halifax Naturalist*, vol. viii, 1904, p. 191.

[3] Davis, J. W., 'Erratic Boulders in the Valley of the Calder,' *Proc. Geol. and Polytech. Soc. W. Riding of Yorks.*, vol. vi, 1871-1877, pp. 93-100.

[4] This has unfortunately been coloured in error as river gravel on the newly published one-inch map.

[5] Kendall, Prof. P. F. and H. E. Wroot, 'Geology of Yorkshire,' 1924, p. 721.

Hopton, Northorpe, Thornhill Lees and Savile Town there occur low terraces consisting of either sandy loam with pebbles and boulders or clay with pockets of gravel. They probably represent remnants of an older alluvium or possibly flood gravels of slightly older date than the main mass of alluvium which floors the present river valley; near the river at Hopton 4 to 8 ft. of clay has been worked for brick-making; at Northorpe 4 ft. of clay overlies gravel, and at Thornhill Lees the deposits are similar; in Savile Town the cutting near the junction of the railway shows 10 ft. of sandy loam with angular and subangular pieces of local sandstones.

A deposit of a very similar nature occurs in a deserted meander of the Burton or Lees Beck at Waterloo, one mile to the west of Huddersfield. Thirty years ago in draining operations for the new hospital, the humerus and scapula of the Wild Ox (*Bos primigenius*) were obtained from this deposit.

At Dewsbury the total thickness of river deposits exceeds 40 ft. The most complete section was in a sunk well, recorded by Davis as follows:—[1]

	Ft.
Earth and sandy subsoil	7½
Boulders, principally sandstone (merging into next)	24
Boulders, nearly all crystalline rocks	6
Clay with sand and boulders	5
Total to underlying Coal Measure Sandstone ...	42½

In the second layer of boulders local rocks were as rare as far-travelled in the upper layer; they were up to 1 ft. in diameter and rolled, not striated.

Sections revealed here in digging the foundations of gas-holders were noted by the same writer, and, in slightly different form, by Green.[2] Davis mentions that about 9 ft. down many tree trunks were found in a horizontal position; he remarks that they had no small branches attached, but were washed and rolled. Green, however, states that some of these showed the marks of an axe and apparently of a saw; in a neighbouring section at Raven's Wharf he saw many large trees together with squared beams, some of which had undoubtedly been sawn. The date of this deposit remains problematical.

The Superficial Deposits of the Tributary Valleys and Upland Areas

Scattered patches of gravel occur at varying levels in the tributary valleys, and also occasionally in the upland areas; in every case they are of comparatively small extent, and considerable uncertainty exists as to their exact age and origin. The more important ones occur in the Colne valley.

To the south of Slaithwaite a tributary valley of the Colne known as Bradley Clough contains a thick deposit of very coarse

[1] *Proc. Geol. and Polytech. Soc. W. Riding Yorks.*, vol. vi, 1871–1877, pp. 93–100.
[2] 'Geology of the Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1878, p. 784.

gravel, over which the present stream meanders. The gravel contains numerous large subangular boulders of grit, some of very considerable size. The deposit has every appearance of glacial drift, but contains only local material; it may well be the product of a small lobe of ice descending from the prominent plateau of Rough Rock, known as Shooters Nab which occurs to the south.

Judging from numerous isolated sections, similar gravels and stony clays probably cover a considerable area around the town of Huddersfield. These have been described in detail by Dr. T. W. Woodhead.[1] Excellent exposures of these gravels were seen in excavations at the British Dyes Company's works, at the junction of Lees Beck and the River Colne, and a good section is still to be seen in an old brick pit at Hillhouse to the north of Huddersfield. This section shows 10 ft. of coarsely bedded gravel with boulders of coal measure sandstone and grit up to 5 ft. across; one of the largest weighing several tons is now preserved in the gardens of the Tolson Memorial Museum at Huddersfield. The deposit here rests in a shallow hollow in the Coal Measure shales. All these deposits are considered to be of glacial origin.

Two small patches of gravel also occur on the high ground to the north of Halifax. One of these at Holmfield occurs at 675 ft. above sea level, while the second at Mixenden at 850 ft. consists of clay with blocks of grit and sandstone, all of local origin.[2]

In the Hebble valley a bed of stiff clay with angular blocks of grit 20 ft. thick has been seen near Shroggs Park, Halifax, on the north bank of the stream; a more sandy clay with boulders occurs in the valley bottom near Halifax Gas Works, and laminated clay on the west bank between Skircoat Road and Well Head Lane, Halifax.[3]

A thick mass of gravel also occurs alongside the Booth Dean valley at Rishworth close to Wheelwright's Mill and at about 600 ft. above sea level. This occurs in the form of a delta at the foot of a deserted meander of the Booth Dean Beck.

Driftless Areas

The upland areas which have never been glaciated reveal but few exposures of the underlying solid rock except where deeply trenched by the major stream courses. Invariably there is a considerable development of rotted and kaolinised grit debris, while along many of the slopes of the western moorlands extensive screes and landslips occur and still further obscure the solid geology. During the construction of a small reservoir embankment in the Upper Booth Dean valley at Rishworth, a fine section of the type of superficial deposits which normally occurs in these unglaciated moorland valleys was exposed, and a detailed diagrammatic representation of the succession shown at the time was made by Mr. A. G. Beaumont,

[1] Woodhead, T. W., 'Occurrence of Boulder-clay at Huddersfield,' *Naturalist*, 1917, pp. 219-232.
[2] 'Geology of the Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1878, p. 775.
[3] *Halifax Naturalist*, vol. i, 1896, pp. 20-25; vol. vii, 1902, pp. 81-88.

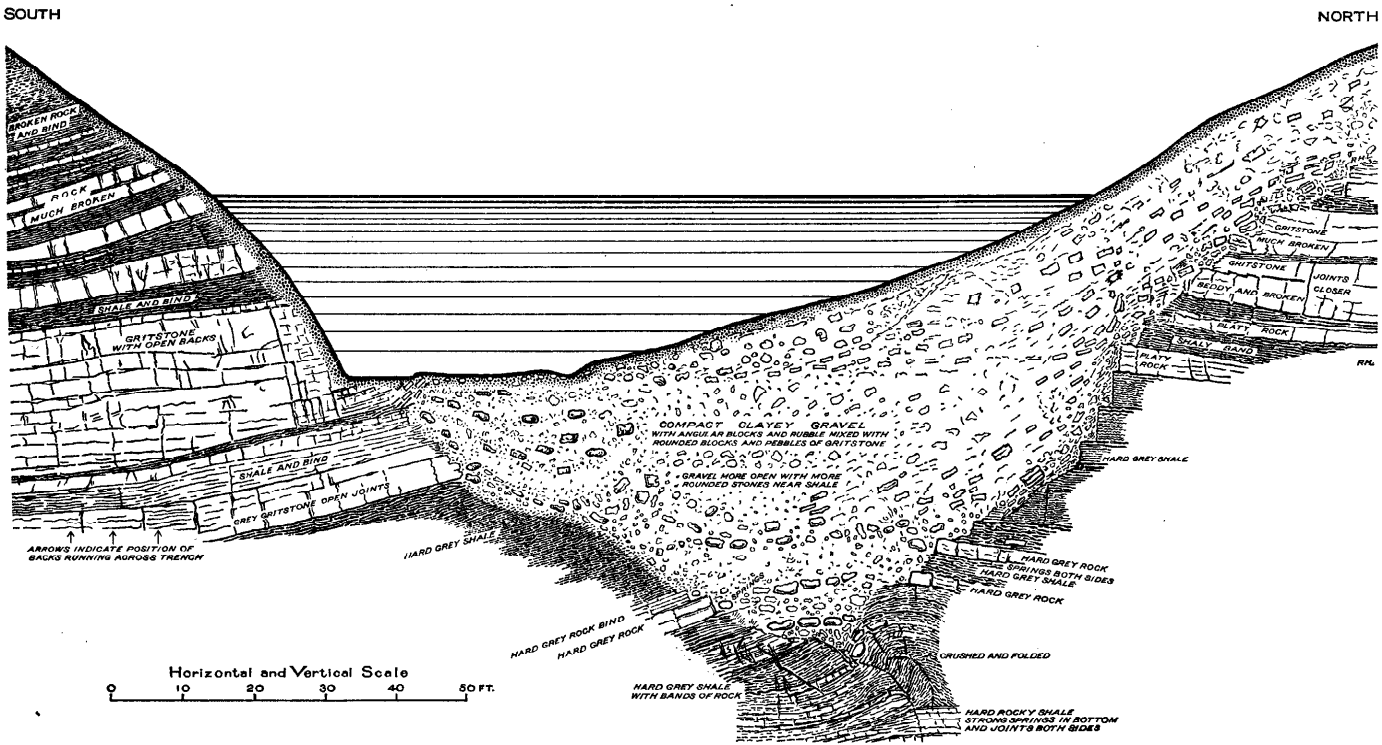


Fig. 12.—*Section across the Booth Dean Reservoir, Rishworth.*

the Resident Engineer to the Wakefield Corporation Waterworks. This is reproduced in Figure 12.

Among the more extensive landslips may be noted the north-eastern slopes of Rishworth Moors at Blackwood and Pike End, the upper parts of the Deanhead valley around Scammonden, the southern slopes of Buckstones Moss, notably at the foot of March Hill, where this type of topography is remarkably well developed; the eastern slopes of Wholestone Moor, and in the lower Holme valley east of Beaumont Park, Huddersfield.

Another distinctive feature of the western moorlands is the occurrence of isolated pillars and stacks of weathered grit in many places. Such features are fairly frequent on Blake and Soyland Moors, where they form prominent landmarks and are known under such distinctive names as the Holder Stones, the Dove Stones and the Temple, &c. The frequency of their occurrence is in itself confirmatory evidence of the unglaciated nature of these uplands.

Such isolated stacks and pillars are equally characteristic of the Blackstone Edge, Bleakedgate, and Buckstone Moors. One of the most conspicuous groups is that known as the " Rocking Stones " on Rishworth Moors where the undercutting action of the wind together with the finer particles of weathered grit has removed the softer incoherent beds and produced isolated tabular blocks of fantastic form, which were originally regarded by Hull, as " ancient sea cliffs in the Old Glacial Sea." [1] Another of these large blocks which occurs on the upper slopes of Waystone Edge was also claimed by the same author as an erratic,[2] but it is clearly one of the larger isolated blocks of massive Pule Hill Grit which has been removed a short distance from its original position by extensive landslips.

The Probable Sequence of Events in Glacial and Post-Glacial Times in Calderdale.

The sporadic and irregular occurrences of the superficial deposits in the Calder basin are insufficient evidence in themselves to supply a connected account of the sequence of events in Glacial and Post-Glacial times in Calderdale. An attempt is made below, however, to piece together the scattered evidence in accordance with the facts observed in adjoining areas in the hope that the tentative views put forth may provide a basis towards the ultimate solution of the difficult and puzzling glacial problems this area presents.

Physiographically, the Calder valley offers a marked contrast to all the more northerly Pennine valleys. Glacial drift only occurs in small isolated patches, and it appears to have had no native glacier of its own, though its upper portion was probably invaded by an ice-sheet from the west. On the other hand Airedale was occupied by an extensive ice-sheet which covered much of the lower ground with boulder-clay, and in the vicinity of Bradford overrode the Aire-Calder watershed leaving an extensive patch of boulder-clay around

[1] Hull, E., ' The Geology of the country around Oldham ' (*Mem. Geol. Surv.*), 1869, p. 12 and fig. 3.

[2] *Ibid*, p. 60.

Low Moor at the head of the Spen valley. With the retreat of the ice-sheet in Airedale an aligned series of glacier-dammed lakes were produced at the head of the several tributary valleys. Thus, as the ice-front withdrew down each tributary valley the melt-waters produced a small lake held up by the ice-front, and from each of these the water overflowed over the dividing spur of the adjoining watershed into the next valley at a lower level.

The spur between each tributary valley was thus trenched by a series of parallel channels, and at the present day they remain exceedingly sharp and well-defined. The conditions prevailing on the south side of the Aire valley in the Bradford district have been described by Messrs. Jowett and Muff [1] who state that " at the period of maximum glaciation, there stretched along the southern border of the Airedale glacier, a series of six lakes, the surface levels of which fell from about 1,325 feet in the north-west to about 700 feet in the Bradford basin. The overflowing waters from these lakes discharged into the head of the Spen valley, and so into Calderdale." [2] There are two well-defined overflow-channels at the head of the Spen valley, which can be traced from Great Horton and West Bowling respectively to the vicinity of Oakenshaw. Both of these channels cut through the wide patch of boulder-clay at the head of the Spen valley and enter it at a level of about 400 ft. above O.D.

In a similar manner the extensive ice-sheet which invaded the uplands of East Lancashire on its retreat produced a series of glacier-dammed lakes in the upper reaches of the Roch valley around Littleborough ; [3] the conspicuous gorge which truncates the Pennine watershed at Walsden marks the main overflow-channel of this system of glacier lakes into the valley of the Yorkshire Calder.[4]

The volume of water entering Calderdale on the gradual shrinkage and retreat of the ice-sheets in East Lancashire and Airedale must have therefore been very considerable, including as it did the larger part of the melt-waters from the southern edge of the Airedale glacier, and also from the very extensive series of glacier lakes described by Dr. Jowett in East Lancashire.[5] This, together with the drainage of the Calder basin itself, must have exceeded by many times the present discharge of the Calder ; and to the torrential action of this great quantity of water must be ascribed the removal of any traces of direct glaciation from the upper part of the valley, and the semi-gorge-like condition which characterizes Calderdale at the present day. The glacial gravels at Mytholmroyd, Elland, Mirfield and Dewsbury containing granite and Lake District volcanic

[1] Jowett, A. and H. B. Muff, ' The Glaciation of the Bradford and Keighley District,' *Proc. Yorks. Geol. Soc.*, vol. xv, 1905, pp. 193-247.
[2] *Op. cit.*, p. 228. See also Stephens, J. V., in ' Summary of Progress ' for 1924 (*Mem. Geol. Surv.*), 1925, pp. 53-57.
[3] ' Geology of the Rossendale Anticline ' (*Mem. Geol. Surv.*), 1927, pp. 131-140.
[4] *Op. cit.*, p. 135.
[5] Jowett, A., ' The Glacial Geology of East Lancashire,' *Quart. Journ. Geol. Soc.*, vol. lxx, 1914, p. 199.

rocks were presumably transported thither by the melt-waters entering Calderdale by the Walsden gap.

The glacial drift containing only material of local origin in the Colne valley on the other hand possibly indicates the presence of small ice-sheets or corrie glaciers in the upper part of that valley at the period of maximum glaciation.

The conditions that prevailed in Glacial times in Lower Calderdale have been described by Lower Carter and others.[1] In describing the sporadic occurrences of glacial drift in the Barnsley and Doncaster districts, Lower Carter states that the ice-sheet occupying these lowland areas at the period of maximum glaciation reached as far as the Dearne valley in a westerly direction and closed the present outlet of the Calder valley.[2] He further adds that "we cannot stop the movement short of Woolley Edge ridge, on the eastern slope of which, up to 250 feet, are several drift gravel patches." At Horbury several erratics have also been recorded belonging to the North Sea dispersion; most conspicuous amongst these is the Scandinavian rhomb-porphyry, and accompanying it were boulders of Shap granite and brockram, rocks clearly belonging to the Stainmore-Vale of York ice stream.[3] The result of the latter intrusion would be to produce an extensive lake in Calderdale fed by the overflows coming through the gaps at Walsden and at the head of the Spen valley. The bottom of the overflow channel between Woolley Edge and West Bretton is 405 feet above O.D. so that the impounded glacial Lake Calderdale must have extended far up the main valley and also the principal tributary valleys, the Colne, Holme, etc. The waters from this lake would be discharged at this period into "Lake Don by way of which they would pass by the Kiveton gorge into the Triassic plain, which was then probably also a glacial lake."[4]

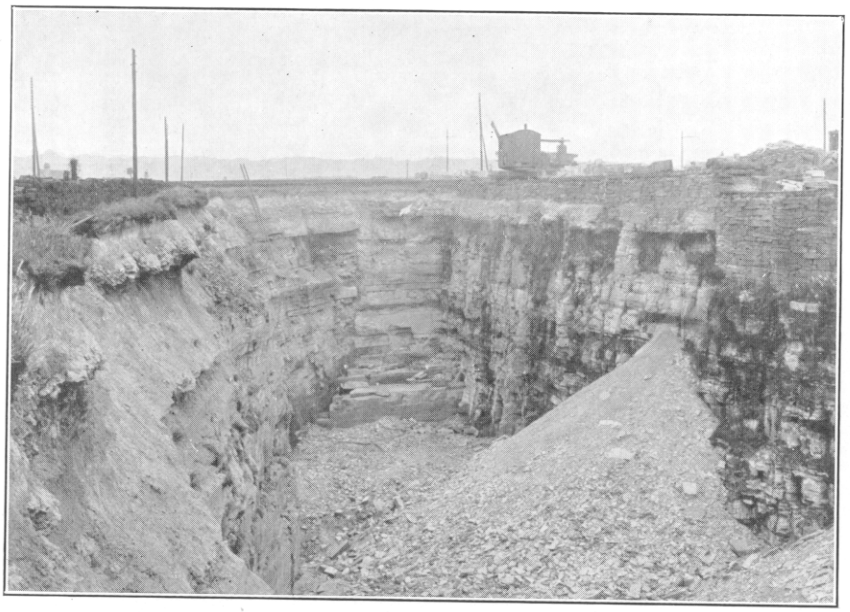
Although the conditions outlined above are in general accord with the scattered patches of glacial drift met with in the present area, and also with the level of the numerous overflow-channels that have been recognized, there is no clear and confirmatory evidence that the various ice-sheets closely corresponded with one another on their retreat. There is, moreover, a marked absence of any deposits of lacustrine origin within the Calder valley. In addition there are no deltaic deposits of any great extent at the head of the Spen valley. The possible explanation of their absence may be that the ice-barrier across the lower part of Calderdale at Horbury was the first to contract and ultimately retreat, and that the torrents of water liberated by the Airedale and East Lancashire ice-sheets which entered Calderdale by the head of the Spen valley

[1] Carter, W. L., 'The Glaciation of the Don and Dearne Valleys,' *Proc. Yorks. Geol. Soc.*, vol. xv, 1905, pp. 411-436; Wray, D. A., 'A New Record of Glacial Drift near Wakefield, and its bearing on the Late Glacial Changes in Lower Calderdale,' *Naturalist*, 1915, pp. 125-128.

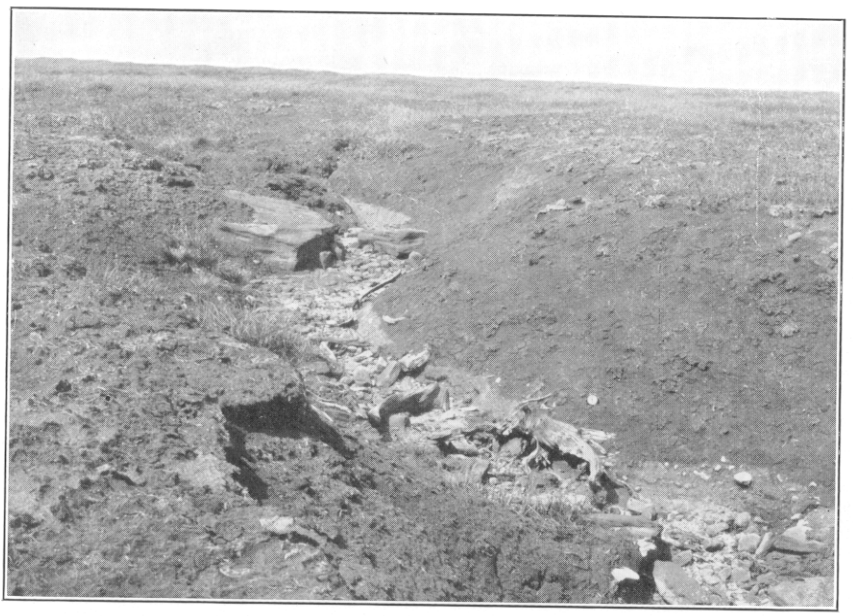
[2] *Op. cit.*, p. 434.

[3] Wray, D. A., *ibid.*, p. 125; Fearnsides, W. G., *Brit. Assoc. Adv. Sci. Rep.*, 1901, p. 286.

[4] Carter, W. L., *ibid.*, p. 435.



A.—ELLAND FLAGS IN BROOKES & CO.'S QUARRIES, HOVE EDGE, HIPPERHOLME, HALIFAX.



B.—PEAT, WITH BIRCH STUMPS AT BASE, TURLEY HOLES MOOR, NEAR MYTHOLMROYD.

To face p. 139.

and the Walsden gap respectively, were the principal agency in the dispersal and subsequent removal of such deposits.

PEAT

The elevated moorlands in the western part of the area are largely covered with peat. The largest patches occur on Wadsworth and Ovenden moors to the north of Hebden Bridge while to the south of the Calder valley are the peat covered moorlands of Manshead, Soyland, Blackstone Edge, Rishworth and Buckstones. Generally speaking the peat occurs at altitudes of above 1,000 feet above sea level; it appears to be uniform in composition throughout, consisting largely of cotton-grass. Usually it is dark brown in colour and spongy in nature, although in the thicker deposits the lowest stratum assumes a deep black colour. The moors are mainly overgrown by cotton-grass, heather and bilberry only occurring in a few isolated localities where there is a good drainage.

The peat normally ranges from 2 to 15 feet in thickness; the greatest thickness was observed in excavations at Blackstone Edge for the Oldham Corporation Waterworks where its total thickness in one place was 25 feet.

At the base of the peat is usually a layer of matted twigs and branches, occasional stems and roots of birch and other trees. This layer is frequently exposed in the numerous small water-courses that cut through the peat; good examples may be seen on Turley Holes, Blackstone Edge, or any of the larger moorlands, where sufficiently deep stream-sections occur (Plate VB). During the removal of the peat within recent years on Blackstone Edge Moors the base of the deposit has been found to contain innumerable tree stumps in erect position with the roots penetrating the weathered grit debris below. It seems clear, therefore, that these moorlands originally constituted a woodland area. The plant association gives a good general indication of the climatic conditions that originally prevailed in these areas. Of the forest trees the more important include the Scotch fir, oak, birch, hazel, ash, alder and willow. The conditions would therefore appear to have been more favourable to trees than at the present day when the area supports only cotton-grass and heath with stunted trees in the more sheltered cloughs.

The succession of the several layers at the base and beneath the peat has been studied in some detail by Dr. T. W. Woodhead and numerous botanists and archaeologists who have recognized in the bleached sand immediately underlying the peat two distinct bands characterized by the style of workmanship of the numerous later palaeolithic (Tardenois) flint implements which it has yielded. In the layer with tree stumps are found neolithic remains, while those of the Bronze Age are in the lowest part of the pure peat. The well known Roman paved roadway which crosses Blackstone Edge, on the eastern slopes of which it is known as Dhouls Pavement, appears to be situated about the middle of the peat. It is thus

practicable to date the original forest growth and the formation of the peat with considerable certainty.[1]

Ancient Flint Workings

One of the more interesting features observed within recent years is the occurrence of numerous sites on the high moorlands where worked flints have been found in considerable numbers.

One of the most prolific collecting grounds is that of March Hill on Buckstones Moor. From this locality alone over six thousand flint chips have been obtained within recent years, of which nearly five hundred appear to show clear evidences of human workmanship. Four distinct workshop sites have been located. Another prolific area is that of Cupwith Hill on Slaithwaite Moors, where several thousand flint chips have been recovered since 1920. Other workshop sites include Manshead Moor; Dog Hill, Rishworth Moors; and Windy Hill on Bleakedgate Moor. Occasional finds have also been recorded from Blackstone Edge, White Hill and Waystone Edge Moors, and also from Ringstone Edge, Rishworth. In the north flints are known to occur on Warley Moor and on Saltonstall Moor north-west of Wainstalls.[2]

The great majority of the worked flints are referable to the Mas d'Azil and Tardenois types, and presumably date from a period linking Palaeolithic with Neolithic times. At March Hill and Cupwith Hill, Neolithic and Bronze Age arrowheads have been found in addition, while two well-shapen hammerstones of quartzite have been recovered from Windy Hill.[3]

[1] See especially Richmond, I. A., 'Huddersfield in Roman Times,' *Tolson Memorial Museum Handbook, No.* 4, Huddersfield, 1925; and Woodhead, T. W., and O. G. E. Erdtman, 'Remains in the Peat of the Southern Pennines,' *Naturalist*, 1926, pp. 245–253.

[2] Davis, J. W., 'Chipped Flints on the Yorkshire Moors, near Halifax,' *Yorks. Arch. Journ.*, vol. vi.

[3] For full details of the finds see Petch, J. A., 'Early Man in the district of Huddersfield,' *Tolson Memorial Museum Handbook, No.* 3, Huddersfield, 1924.

CHAPTER VII

PALAEONTOLOGY

Throughout the Millstone Grits and the lower part of the Lower Coal Measures the fossils of greatest interest and importance, both in themselves and as aids to stratigraphy, are the remains of marine animals. These occur at numerous horizons, termed marine bands, in which the fossils are exceedingly abundant; such bands are, however, individually of small thickness, sometimes only a few inches, while the intervening measures yield no marine fossils. The marine bands are found at intervals throughout the Millstone Grits, but only two, or possibly three, are found in the Lower Coal Measures, and then only in the lowest part of the series: in all about seventeen have been found within the limits of the area here described. Though thin they are on the whole remarkably persistent.

The Goniatite Zones

In the somewhat limited fauna goniatites are the most abundant and characteristic members. Within recent years the goniatite fauna has been the subject of extensive research by Mr. W. S. Bisat, whose detailed palaeontological studies combined with extensive collecting have enabled him to institute a zonal succession based on these forms.[1] During the re-survey of this area Mr. Bisat has been in active collaboration with the officers engaged, and has critically examined and identified the large numbers of goniatites that have been collected. The zonal succession outlined by Mr. Bisat (in his paper quoted above) has been fully tested and found to be of high stratigraphical value; by its means it has been found practicable to make an effective correlation of the several beds of grit and sandstone over widely separated areas.[2] With rare exceptions, the goniatites, though abundant in the marine bands, are represented only by crushed impressions; but in each fossiliferous horizon, one form usually predominates to such an extent that its identification is greatly facilitated, although the specimens are often fragmentary and in a comparatively poor state of preservation. The test ornament is, however, usually well preserved, and Mr. Bisat's work has shown that this furnishes a very delicate and reliable evolutionary index. Each marine band contains specimens of varying ages and stages of growth which can readily be referred to the one species and thus the differences due to age can be studied in some detail. Occasionally nodules containing goniatites occur in the marine bands and furnish uncrushed specimens exhibiting suture lines, the shape of the shell, and sometimes finer markings on

[1] Bisat, W. S., 'The Carboniferous Goniatites of the North of England and their Zones,' *Proc. Yorks. Geol. Soc.*, vol. xx, 1924, pp. 40–124.

[2] A comprehensive correlation of the Millstone Grits in the Central Pennine Area has been given by Wray, D. A., *Proc. Yorks. Geol. Soc.*, vol. xxi, 1929, p. 249.

the shell, not well preserved in specimens obtained from the shaly matrix.

The goniatites characteristic of the Carboniferous rocks of this area are all referable to the family Glyphioceratidae, and by far the most characteristic genus is *Reticuloceras* Bisat, of which the genotype is *Reticuloceras reticulatum*.[1] For a full description of the diagnostic characters of this genus and its several species reference should be made to Mr. Bisat's paper, where all these forms are described in great detail.

The Range of *Reticuloceras reticulatum*

This species is a characteristic Millstone Grit form, and in the lower part of the Middle Grit series the several mutations of it are by far the most abundant fossils found. *Reticuloceras reticulatum* occurs in each of the three marine bands underlying the Kinderscout Grit at Crimsworth Dean, Hebden Bridge. This is referred to by Mr. Bisat as the type form. The several mutations characteristic of the Middle Grit series are respectively mutation α, mut. β and mut. γ. *Reticuloceras reticulatum* type form is a comparatively coarsely ornamented shell with roughly crenulate transverse linear ornaments and fairly strong spirals. Occasional specimens do occur in which the ornamentation is finer and more delicate, but as a general rule in the type form it is distinctly coarse (see Fig. 13 for diagnostic characters).

The name *Reticuloceras davisi* has been given to what appears to be merely the old-age form of *R. reticulatum*; it occurs together with *R. reticulatum* type form at Crimsworth Dean and elsewhere, but the old-age specimens of *R. reticulatum*, mut. α from higher horizons are indistinguishable from it and are given the same name.

The stream level in Crimsworth Dean is little more than 275 ft. below the base of the Kinderscout Grit. Consequently a comparatively short sequence of beds below the Kinderscout Grit can outcrop in this valley (pp. 25-27). The succession may be conveniently summarized as follows:—

	Ft.
Marine band with *Reticuloceras reticulatum* (type form)	—
Shale	6
Kinderscout Grit (main mass)	175 to 200
Shale	70
Marine band with *R. reticulatum, Homoceras striolatum, Eumorphoceras ornatum*	—
Shale	30
Todmorden Grit	15 to 30
Shale	45 to 50
Marine band with *R. reticulatum, Homoceras striolatum, Eumorphoceras ornatum*	—
Shale	18
Marine band with *R. reticulatum, Homoceras striolatum*	—
Shale	80 to 100

[1] Phillips, J., 'Geology of Yorkshire: Part ii, The Mountain Limestone District,' London, 1836, p. 235 and Plate xix, fig. 26–32.

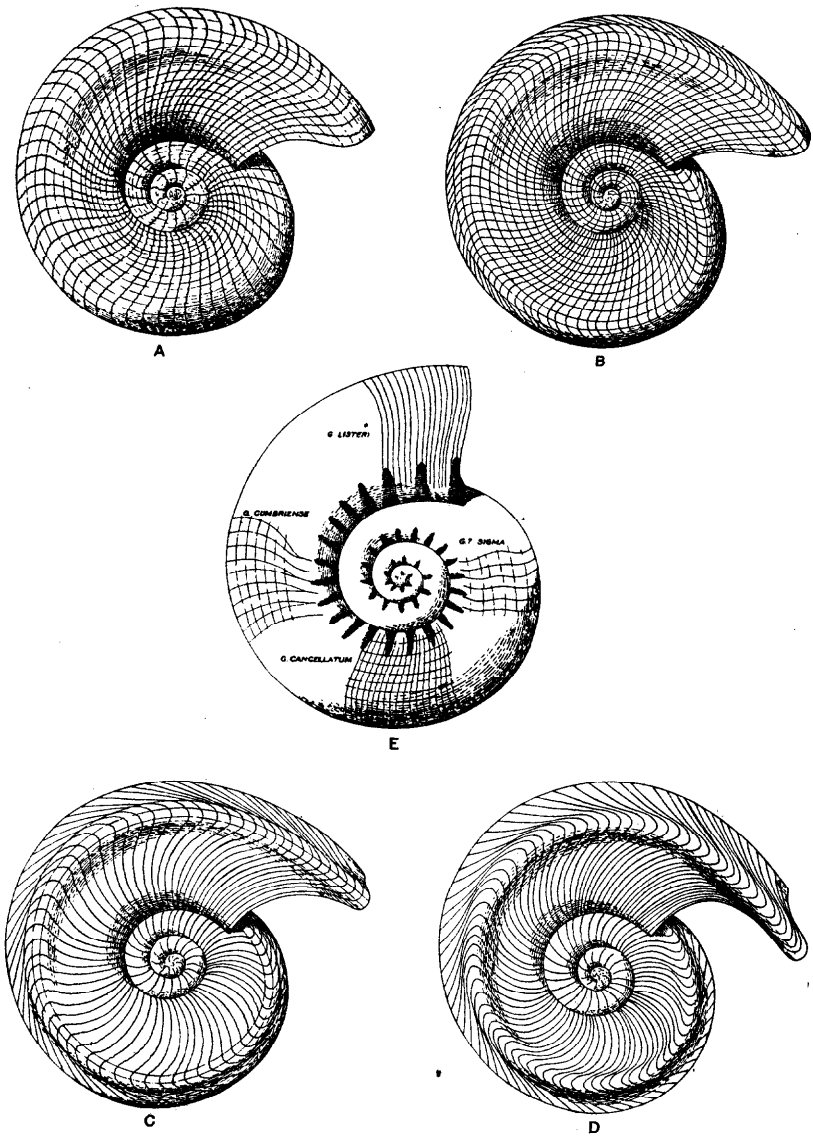


Fig. 13.—*Diagrammatic representations of some of the chief diagnostic features in* Reticuloceras recticulatum *(Phill.) and some species of* Gastrioceras; *reproduced from diagrams prepared by Mr. S. W. Hester.* A–D, Reticuloceras reticulatum: A, *type form*; B, *mutation* α; C, *mut.* β; D, *mut.* γ. E, *composite diagram showing some of the chief types of ornament in* Gastrioceras. *These are combined in one figure for convenience, and do not illustrate evolutionary stages.*

The two lowest marine bands are exposed on the west bank of the stream at Black Scouts, Crimsworth Dean. The marine band between the Todmorden and Kinderscout Grits is exposed in the bank of the stream, 200 yds. north-east of Outwood Farm, Crimsworth Dean. This exposure consists of a band of limestone nodules or 'bullions' often packed with uncrushed specimens of goniatites succeeded by six feet of black shale containing many crushed specimens of the same species. The specimens found here are *Reticuloceras reticulatum* and *Homoceras striolatum*, and also the old-age form *Reticuloceras davisi*. It is from the bullions of this locality that the majority of the specimens collected in the past, and usually labelled "Crimsworth Dean" or "Horsebridge Clough," have come. The marine band overlying the main mass of the Kinderscout Grit, characterized by *Reticuloceras reticulatum* type form, is exposed on the left bank of the stream, 100 yards north of Jack Bridge, Crimsworth Dean. It is the highest horizon in this district from which the type form of *R. reticulatum* has been obtained. These three marine bands underlying the Kinderscout Grit have also been described from the Todmorden district [1] and from the equivalent Edale Shales of North Derbyshire.[2]

The Subzone of *Reticuloceras reticulatum*, mut. α

The upper part of the Kinderscout Grit throughout the area represented by Sheet 77 is overlain by a thin seam of coal, and over the greater part of the area this is succeeded by a thick series of dark shaly mudstones. Towards the base of these mudstones, usually a few feet above the coal, a thick marine band invariably occurs which can be readily recognized. This horizon marks the base of the Subzone of *Reticuloceras reticulatum*, mut. α. Although this is by far the most predominant goniatite, the following cephalopods occur in addition: *Homoceras striolatum* (Phill.), *Homoceratoides divaricatum* (Hind), *Dimorphoceras sp.*, and *Nautilus sp.*

In comparison with the type form of *R. reticulatum*, mutation α has an extremely delicate ornament, the transverse lines being also much closer than in the type form. The transverse ornaments where crossed on the lingua by the spirals have a characteristic and very marked angulation. The surface of the lingua is slightly raised into a low ridge, and the angulation referred to above frequently produces a characteristic polygonal appearance, according to Mr. Bisat 'reminiscent of the framework of a rigid airship of Zeppelin type' (see fig. 13B).[3] A closely related form which is common at this horizon in some localities, but which differs from the typical mutation α in the later development of the delicate test ornament, is referred to by Mr. Bisat as 'early mutation α.' Another variant, which is the predominant form in this marine band

[1] Lloyd, W. and J. V. Stephens, 'The Stratigraphical Succession below the Kinderscout Grit in the Todmorden District,' *Proc. Yorks. Geol. Soc.*, vol. xxi, 1927, p. 12.

[2] Jackson, J. W., 'The Succession below the Kinderscout Grit in North Derbyshire,' *Journ. Manch. Geol. Assoc.*, vol. i, 1925–6, pp. 17–23.

[3] Bisat, W. S., *op. cit.*, p. 116.

to the south and west of Rishworth, is intermediate in characters between mutation α and mutation β and is described as 'late mutation α.'

The examination of the material collected from some twenty localities scattered throughout the present area has revealed the interesting fact that lateral variations in fauna occur at this horizon; *Reticuloceras reticulatum* type form and mutation α both occur together at Huddersfield; mutation α alone occurs at this horizon around Rishworth and Slaithwaite, while everywhere to the west and south of these localities the form described by Mr. Bisat [1] as late mutation α is predominant and occurs to the exclusion of other forms of *Reticuloceras*.

The Mold Green boring at Huddersfield (see page 189) showed the following features: the 3 ft. of shale overlying the coal which rested directly on the Kinderscout Grit yielded plant impressions only; the succeeding 3 ft. contained *Naticopsis brevispira*, and species of *Pterinopecten*, *Lingula*, *Posidoniella* and *Bellerophon*, but no goniatites. Resting on this was 2 ft. of dull black shale with many of the above forms, but in addition the goniatite *Reticuloceras reticulatum* type form was abundant. The succeeding 15 ft. of shale contains a similar fauna with the exception that *Reticuloceras reticulatum*, mut. α is predominant. In addition were many forms intermediate in character between the type form of *Reticuloceras reticulatum* and the mutation α, which are described by Mr. Bisat as early mutation α. The marine band is overlain by shales barren of any marine organic remains. At Mold Green, therefore, this marine band is no less than 20 ft. thick and shows forms ranging from type form to early and typical specimens of the mutation α.

Three miles to the west of Mold Green, the same horizon was met with in a boring at Quarmby Clough, Longwood, at a depth of from 807 to 812 ft. (see page 191). Here the total thickness of shale with marine fossils was apparently not more than 9ft., but it yielded a similar assemblage to that of Mold Green, with the exception that forms resembling *Reticuloceras reticulatum* type were rare, the mutation α being predominant.

In numerous natural sections to the west of Huddersfield the same marine horizon is exposed. Material has been collected from Butts Clough, Rishworth; Merry Dale Clough, Slaithwaite; Greenwood and Horse Hey Cloughs, Manshead Moor; Eastwood Bridge in Deanhead Clough, Scammonden; and in Park Clough, Hey Green, Marsden. In all these localities the most abundant fossils are casts of *Reticuloceras reticulatum*, mutation α, apparently typical of this mutation as defined by Mr. Bisat.[2]

In the upper part of Deanhead Clough, Scammonden, a marine band clearly on the same stratigraphical horizon as that outlined above contains *Reticuloceras reticulatum*, late mutation α as the predominant form. This is the case in all the following localities

[1] *Op. cit.*, p. 116.
[2] *Op. cit.*, pp. 115, 116.

to the west of Rishworth and Marsden:—Hard Head, Broad Rake, Dry, Linsgreave, Tom, Dan and Culvert Cloughs on Rishworth Moors. It is in fact, quite clear from stratigraphical considerations that, as Mr. Bisat had already surmised, both early and late mutations α are local variants of the typical *Reticuloceras reticulatum*, mutation α.[1]

Fossils have been collected from this horizon at the following localities within the area of one-inch map 77 (Huddersfield):—

1. Left bank of Caty Well Brook, below Caty Well Bridge and 120 yards south-east of 'Cat i' th' Well,' Wainstalls.
2. Left bank of Foster Clough, 110 yards N.N.E. of Foster Clough Bridge and one mile N.N.E. of Mytholmroyd Railway Station.
3. Excavation for water conduit in stream bed, 140 yards E.N.E. of Ebenezer Chapel, Elboro Lane, Luddenden.
4. Bank of Load Clough, 250 yards N.E. of footbridge over Luddenden Brook, and 700 yards S.E. of Luddenden Parish Church.
5. Horse Hey Clough, 300 yards N.W. of Baitings Farm, Manshead Moor, Ripponden.
6. Upper part of Greenwood Clough, 1,000 yards W.N.W. of Baitings Farm, Manshead Moor, Ripponden.
7. Butts Clough, Rishworth, 100 yards N.E. of Wheelwrights' Mill.
8. Deanhead Clough, 50 yards north of Eastwood Bridge, Scammonden.
9. Green Holes, Great Clough, 50 yards above its junction with Deanhead Clough, Scammonden.
10. Shot Scar, Hard Head Clough, 800 yards E.N.E. of Haigh Reservoir, Marsden.
11. Dry Clough, Waystone Edge, 550 yards W.N.W. of White Hill, Rishworth Moors.
12. Linsgreave Clough, Waystone Edge, 750 yds. north of White Hill, Rishworth Moors.
13. Castle Shore Clough, upper part of Longden End Clough, Black Moor, Blackstone Edge Moors.
14. Great Whinning Gulf, upper part of Culvert Clough, Bleaked Gate Moor.
15. Tom Clough, below March Hill Holes, 650 yards south-west of Buckstones House, Marsden.
16. Dan Clough, south side of March Hill, 650 yards W.S.W. of Haigh Reservoir, Marsden.
17. Green Owlers Clough, 280 yards north of Park Farm, Hey Green, Marsden.
18. Park Clough, 70 yards east of Park Farm, Hey Green, Marsden.
19. Merry Dale Clough, 500 yards west of Clough House Mills, Slaithwaite.
20. Depth of 807-812 ft., boring at Quarmby Clough Mills, Longwood (see p. 191).
21. Depth of 1340-1355 ft., boring for water at Bankfield Mills, Mold Green (see p. 189).

The Subzone of *Reticuloceras reticulatum*, mut. β

There are three distinct stratigraphical horizons at which marine bands occur in which the goniatite *Reticuloceras reticulatum*, mut. β is the predominant form, and these, it is of interest to note, yield specimens exhibiting what appear to be successive evolutionary stages in the development of that form. These details have been discussed by Mr. Bisat in his monograph already referred to (p. 117).

[1] Bisat, W. S., *ibid.*, p. 117.

Detailed mapping in the present area has fully substantiated Mr. Bisat's work and shown the great reliability of these mutations as zonal indices. The lowest of these marine bands, characterized by early mutation β, is apparently confined to the area south and west of Rishworth, having as yet been nowhere met with in the country to the east and north. It has been observed in all the localities given above where the zone of *Reticuloceras reticulatum*, mut. α is characterized by the predominance of the form late mutation α. In the list given on page 146, these localities are nos. 9–18 inclusive.

The band with *Reticuloceras reticulatum*, early mutation β, is usually separated from the underlying marine band by about 30 ft. of shale. The intervening shales are practically barren, having only yielded occasional impressions of *Lingula* and *Posidoniella*.

The marine band characterized by the typical mutation β is one of the most widely persistent of all the marine bands, and is equally characteristic of the adjoining country to the west.[1] It occurs 60 to 70 ft. below the Midgley or Pule Hill Grit, and also immediately above the Scotland Flags. The predominant form, typical of mutation β as defined by Mr. Bisat, appears to correspond most closely with the goniatite described by Salter as *Goniatites bilinguis*.[2] *Reticuloceras reticulatum*, mutation β differs from mutation α in the general absence of crenulation produced by the crossing of the transverse and spiral linear ornaments except in early stages in well-preserved adolescent forms, or on the linguae. Another characteristic feature is that the lingua projects markedly forward on the lateral area even in early stages, the width also being much less than in mutation α (see fig. 13c).

Other cephalopods which occur in the marine band characterized by *R. reticulatum*, mut. β include *Homoceratoides divaricatum* (Hind) and species of *Dimorphoceras* and *Orthoceras*.

This marine horizon, despite its wide persistence, is always comparatively thin, and, as far as is known, does not exhibit any marked faunal variations. Throughout the greater part of the present area it consists of soft grey mudstones containing small earthy nodules in which goniatite casts are common. Fossils have been collected from this horizon at the following localities within the area of one-inch map 77 (Huddersfield) :—

1. Left bank of Caty Well Brook, 100 yards above Caty Well Bridge, Wainstalls, Halifax.
2. Excavations above western reservoir, Nell Nook, Midgley, Halifax.
3. Right bank of Netherends Beck, 80 yards S.W. of Triangle Vicarage, Triangle.
4. Railway cutting, 50 yards west of bridge and south of Millhouse, between Sowerby Bridge and Triangle.
5. High Lee Clough, 240 yards E.N.E. of Little Haven Farm, half a mile south of Triangle station.

[1] Wright, W. B., in 'The Geology of the Rossendale Anticline' (*Mem. Geol. Surv.*), 1927, p. 115.

[2] Salter, J. W., in 'The Geology of the Country around Oldham' (*Mem. Geol. Surv.*), 1864, p. 60.

6. Pike Clough, 300 yards E.N.E. of Pike Farm, Pike End, Rishworth.
7. Lench Holes, 350 yards S.W. of Leach House, Blackwood, Rishworth.
8. In Red Lane Dike Clough, 150 yards west of Lower Moulson Place, Stainland.
9. Upper part of Hard Head Clough, Burne Moss, Marsden.
10. Green Hill Clough, 200 yards north of Ashton Binns, Marsden.
11. Crimble Clough, Slaithwaite, 180 yards east of Rockwood and 1,000 yards north of Slaithwaite Railway Station.
12. Old quarry, east side of Varley Road and 150 yards E.N.E. of Mansergh House, Slaithwaite.
13. Depth of 572 ft., boring for water at Quarmby Clough Mills, Longwood (see page 192).
14. Depth of 1,114 ft., boring for water at Bankfield Mills, Mold Green, Huddersfield (see page 190).

The shales which overlie the Midgley or Pule Hill Grit constitute a readily recognizable horizon throughout the present area; for they include a thick marine band containing forms which range from the typical *Reticuloceras reticulatum*, mutation β of Mr. Bisat to late mutation β; and in some areas forms which are referred to as early mutation γ by Dr. W. B. Wright.[1] All forms may be present, though the typical mutation β is confined to the lower part of the band, and early mutation γ is typical of the upper portion. For the most part, however, late mutation β is the dominant form. In the Mold Green boring, Huddersfield (see page 189) early mutation γ occurred to the exclusion of other forms. In the Longwood boring (see page 191) and in the Rishworth and Colne Valley districts forms referable to late mutation β are dominant, while early mutation γ is unrepresented. The remaining cephalopod fauna of this bed is somewhat limited, being confined to species of *Orthoceras* and *Dimorphoceras*.

Fossils have been collected from this horizon at the following localities within the area of one-inch map 77 (Huddersfield):—

1. Butts Clough, 220 yards south-west of Clough Head Farm, Rishworth.
2. Stream section alongside Huddersfield-Rochdale main road, Cupwith Hill, 200 yards east of eighth milestone.
3. Blake Clough, Slaithwaite Moors, 300 yards E.S.E. of Blake Clough Farm, and 100 yards east of Moorfield.
4. Disused quarry and brickworks, Lane Top, Linthwaite, immediately east of Spring Grove Mills.
5. Left bank of Bradley Brook, Holt Head, Slaithwaite, 150 yards north-east of Holt Laith.
6. Depth of 450 ft., boring for water at Quarmby Clough Mills, Longwood (see page 191).
7. Depth of 970 ft., boring for water at Bankfield Mills, Mold Green, Huddersfield (see page 189).

The Subzone of *Reticuloceras reticulatum*, mut. γ

The Nab End Sandstone or Beacon Hill Flags are succeeded by dark shales and shaly mudstones in which one, and frequently two marine bands occur a short distance above the top of the sandstone or flags. These two bands are separated by 2 to 10 ft. of shale. In the lower one the final mutation (mut. γ) of the species

[1] Wright, W. B., 'New Goniatites from the Millstone Grit of Lancashire,' in 'Summary of Progress' for 1925 (*Mem. Geol. Surv.*), 1926, Appendix VIII, p. 194.

Reticuloceras reticulatum occurs, while in the upper one *Gastrioceras ? sigma* Wright is the dominant form.[1]

Very occasional specimens of a form, apparently an early *Gastrioceras*, occur in association with the early mutation γ at some of the localities quoted above, but these become relatively more plentiful at the present horizon. These two marine horizons do not appear to have so wide a distribution as the lower horizons characterized by mutations of *Reticuloceras reticulatum*. Thus in the two deep borings made near Huddersfield mentioned above they are apparently absent; nor have they been recorded further north than Luddenden in the Calder valley. It is also of interest to note that to the north of Todmorden Mr. Lloyd finds that only the *Gastrioceras ? sigma* band persists, the mutation γ band being represented by a band of shale full of *Lingula* impressions. To the north of this area also both these bands apparently die out. Among the distinctive features by which *Reticuloceras reticulatum*, mut. γ can be recognized is the almost invariable occurrence of an internal rib adjoining the lingua, which gives rise to a spiral groove on the internal cast. There is also an absence of transverse constrictions, with the result that the continuity of this groove is uninterrupted and produces a striking feature. This groove usually has well marked margins, acute or sub-acute on the ventral side, and rounded on the lateral side. The transverse linear ornaments on the lateral area form a well-marked curve in passing from the umbilicus to the lingua (on which they show no crenulation), with the concavity facing forwards. Close to the umbilicus itself, the ornamenting lines are frequently bent backwards. The spiral ornaments are also practically absent, being only occasionally faintly developed on the lingua (see fig. 13D).

Other cephalopods which have been recorded from the mutation γ band include *Homoceras proteum* (Brown), *Homoceratoides divaricatum* (Hind), and species of *Orthoceras*, *Dimorphoceras*, and *Gastrioceras*; *Bellerophon* also occurs.

Fossils have been collected from this horizon at the following localities within the area of one-inch map 77 (Huddersfield) :—

1. Bank of Load Clough, about 1,200 yards south-east of Luddenden Parish Church.
2. Right bank of Black Brook opposite Bowers Mill, Barkisland.
3. In Butts Clough, Rishworth, 90 yards south-east of Clough House Farm, Rishworth.
4. Small stream section, Steel Lane Head, 180 yards W.S.W. of Wormald Farm, Upper Bottomley, Barkisland.
5. Bottomley Clough, 140 yards east of Bottoms Farm, Barkisland.
6. In Red Lane Dike, below Owlet Edge, 250 yards N.W. of Royal George Inn, Pole Moor, Scammonden.
7. In Gosport Clough, 300 yards N.W. of Church, Outlane, Huddersfield.
8. In Gosport Clough, 500 yards N.W. of Church, Outlane, Huddersfield.
9. In clough, 250 yards west of Lee Green Farm, Lee Hill, Outlane.
10. Heath House Wood, 150 yards north of Heath House Mill, Golcar.

[1] Wright, W. B., 'New Goniatites from the Millstone Grit of Lancashire,' in 'Summary of Progress' for 1925 (*Mem. Geol. Surv.*), 1926, p. 197.

The Range of *Gastrioceras*

In the marine bands occurring in the upper Millstone Grits and Lower Coal Measures above the Warley or Huddersfield White Rock, *Reticuloceras reticulatum* ceases to be a dominant form and in its place various species of the genus *Gastrioceras* become the chief members of the fauna.

The genus *Gastrioceras* is first represented by isolated forms which occur in the marine band characterized by *Reticuloceras reticulatum*, mut γ. These include *Gastrioceras lineatum* Wright and the form doubtfully referred to the same genus by Dr. Wright, and described by him as *Gastrioceras ? sigma*.[1]

These forms are not very abundant, but have been recorded from the majority of the localities given on page 149 for the Subzone of *Reticuloceras reticulatum*, mut. γ. A very distinctive feature is the wide occurrence of a thin marine band usually about six feet above the marine band characterized by *Reticuloceras reticulatum*, mut. γ, in which the obscure form *Gastrioceras ? sigma* occurs to the total exclusion of all other goniatites. Several lamellibranchs, however, occur in addition (see p. 157). The great stratigraphical value of this horizon is that it has been noted in places where the marine band characterized by *Reticuloceras reticulatum* mut. γ is believed to be absent.[2]

Reticuloceras reticulatum, mut. γ, the final mutation of *Reticuloceras*, though predominant in the marine band immediately overlying the Beacon Hill Flags and persisting into the marine band overlying the Warley or Huddersfield White Rock, appears to be limited to the lowest layer of that marine horizon. This is the last appearance of the genus *Reticuloceras*. The following species of *Gastrioceras* occur in the marine bands in the Lower Coal Measures and the upper Millstone Grits above the Warley or Huddersfield White Rock, and appear to attain their maximum development in the following order:—*Gastrioceras cancellatum* Bisat; *G. crencellatum* Bisat, *G. crenulatum* Bisat, *G. cumbriense* Bisat; *G. subcrenatum* (Schloth.); and finally the associated species *G. listeri* (Martin), *G. circumnodosum* Foord, and *G. coronatum* Foord and Crick.

There is a very close relationship between the two genera *Gastrioceras* and *Reticuloceras*. Typical forms of *Gastrioceras*, however, invariably show a marked development of ribs or tubercles on the sides of the broad umbilicus, and there is also a second lateral lobe or division of the lateral saddle. The latter appears to be a distinguishing feature of *Gastrioceras*. The several species of *Gastrioceras* appear to be closely allied and many intermediate forms have been observed. The several species successively appearing in the upper Millstone Grits and Lower Coal Measures would appear to constitute an evolutionary series, though not necessarily in a line

[1] Wright, W. B., 'New Goniatites from the Millstone Grit of Lancashire,' in 'Summary of Progress' for 1925 (*Mem. Geol. Surv.*), 1926, Appendix VIII,, p. 194.

[2] Wright, W. B., in 'The Geology of the Rossendale Anticline' (*Mem. Geol. Surv.*), 1927, p. 116.

of simple descent. Some of the characteristics of the chief species are shown in the diagram, p. 143, fig. 13E. The following descriptive notes are based upon the descriptions originally given by Mr. Bisat, with some emendation :—

Gastrioceras cancellatum [1] has a delicate test-ornament consisting of a reticulate pattern or mesh produced by the intersection of numerous transverse and spiral raised linear ornaments. The relative strength of these two sets of lines is variable, but most frequently the spiral lines are less numerous and are more widely spaced than the transverse ones. They are also often rather more strongly developed. The transverse linear ornaments arise from the outer ends of the short plications at the umbilical margin, but also in the interspaces between these. A pronounced lingua is also a feature of *G. cancellatum*.

A closely related form is *G. crencellatum*, first described as a variety of *G. cancellatum*.[2] In this, the lateral ornaments, transverse and spiral, are approximately equal in strength and equally spaced. The spiral lines are therefore usually more closely spaced than in *G. cancellatum*. The transverse ornaments have a crenulate character and may appear to be relatively coarsely developed where they cross the plications of the shell at the umbilical margin. The strength and width of spacing of the two sets of linear ornaments is somewhat variable. It is probable that the lingua will be found to be usually less strongly pronounced than in *G. cancellatum*.

In *G. crenulatum* [3] there is a marked increase in the width between the transverse linear ornaments, with or without a strengthening, and a reduction in the strength of the spiral ornaments, which are more numerous and crowded than the transverse ones. The lingua is reduced to a shallow curve, decreasing with the advancing age of the individual. A still further stage in the development of the ornaments is shown in *G. cumbriense* (originally described as a variety of *G. crenulatum*),[4] in which the transverse lines are well spaced and are barely crenulate ; they are prominent in comparison with the closely spaced spiral ornaments, which are more weakly developed, as a rule, than in *G. crenulatum*. There is a tendency for secondary, weaker transverse lines to make their appearance between the primary ones.

By means of a large suite of bullions collected by Mr. James Lomax at Shore, near Littleborough, Dr. W. B. Wright has been able to show that there is a continuous passage between *Gastrioceras coronatum*, through *G. listeri* to *G. circumnodosum* (recorded as *G. subcrenatum* by Dr. Wright), seeming to indicate, as had been previously suggested by Haug,[5] that there are no real lines of demar-

[1] Bisat, W. S., '*Gastrioceras cancellatum* (sp. nov.) at Meanwood, Leeds,' *Trans. Leeds Geol. Assoc.*, Jubilee Volume, xix, 1923, p. 47.
[2] *Proc. Yorks. Geol. Soc.*, vol. xx, 1924, p. 122.
[3] *Ibid.*, p. 120.
[4] *Ibid.*, p. 121.
[5] Haug, E., 'Études sur les Goniatites,' *Mem. Soc. Géol. France, Paléont.*, vol. vii, No. 18, 1898.

cation between these species.[1] *G. coronatum* differs from *G. listeri* in having a wider umbilicus, finer ornament, more depressed whorls, and a broader and more flattened periphery. In the matter of nomenclature, Mr. Bisat informs us that while von Buch's name *G. carbonarium* should be abandoned in favour of the earlier name *G. subcrenatum*, given by Schlotheim, the goniatite to which these names refer occurs at a lower level than the species determined as *G. carbonarium* by most English authors, a distinct form which he believes to be the one described by Foord in 1903 under the name *Gastrioceras circumnodosum*.[2]

The Subzone of *Gastrioceras cancellatum*

Gastrioceras cancellatum is confined to the marine band in the shales overlying the Upper Meltham Coal where present, and elsewhere the top of the Warley or Huddersfield White Rock. This forms one of the best known and most readily recognizable marine horizons in the whole of the Millstone Grits. In the Huddersfield district it is frequently referred to as the Meltham marine band, and it is clearly the local representative of the Holcombe Brook marine band of East Lancashire.[3]

The fauna of this marine band includes in addition to the predominant form *Gastrioceras cancellatum* and *Reticuloceras reticulatum*, mut. γ which occurs sparingly, the cephalopods *Gastrioceras crenulatum* Bisat and *Homoceratoides divaricatum* (Hind), the brachiopods *Lingula* and *Productus*, the gastropods *Loxonema* and *Bellerophon*, as well as lamellibranchs, crinoid columnals and fish scales (see page 154). The fossiliferous horizon usually occurs about 30 ft. above the Meltham Coal, or the top of the Warley or Huddersfield White Rock. In the intervening shales *Lingula* occurs sparingly. From this horizon, in a boring for water at Brockholes, four miles south of Huddersfield, and just beyond the southern margin of the present area, a remarkably well-preserved specimen of the Elasmobranch fish *Edestus newtoni* showing the jaw and teeth has been found.[4] Fossils have been collected from this horizon at the following localities within the area of one-inch map 77 (Huddersfield) :—

1. South side of Slaughter Gap, Hunter Hill, Wainstalls; four miles north-west of Halifax Parish Church.
2. Eastern end of Bonny Wood Clough, 280 yards N.N.E. of Hollin Hall Farm, Leymoor, near Golcar.
3. From depth of 150 ft., boring at Quarmby Clough Mills, Longwood (see p. 191).
4. From depth of 675 ft., boring at Bankfield Mills, Mold Green, Huddersfield (see p. 189).

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[1] Wright, W. B., in 'Summary of Progress' for 1922 (*Mem. Geol. Surv.*), 1923, p. 42.
[2] Foord, A. H., 'Monograph of the Carboniferous Cephalopoda of Ireland,' part V, p. 196, pl. xlix, figs. 10, 11. (*Palaeontographical Society*).
[3] Wright, W. B., in 'The Geology of the Rossendale Anticline' (*Mem. Geol. Surv.*), 1927, p. 117.
[4] Woodward, A. S., 'On a new species of *Edestus* from the Upper Carboniferous of Yorkshire,' *Quart. Journ. Geol. Soc.*, vol. lxxii, 1916, p. 1.

The Subzone of *Gastrioceras crenulatum* (and *G. cumbriense*)

The next succeeding marine band characterized by *Gastrioceras cumbriense* is always extremely thin, but appears to have a very wide distribution. It occurs about the centre of the thick mass of shales underlying the Rough Rock. Both *Gastrioceras crenulatum* and *G. cumbriense* are very common, and the fauna includes in addition the following cephalopods: *Orthoceras sp.*, *Homoceratoides divaricatum* (Hind), and a variant of *Gastrioceras crenulatum* not yet named. Fossils from this horizon have been collected by the Geological Survey from the following localities within the area of one-inch map, Sheet 77 (Huddersfield) :—

1. North side of Wamesley Scar, Cold Edge, 440 yards north of Hunter Hill, Halifax.
2. South side of Slaughter Gap, Hunter Hill, Wainstalls; 100 yards west of locality given on p. 152.
3. Right bank of Dodgson Clough, 150 yards above Clough Farm and one mile north-west of Wheatsheaf Inn, Mount Pellon, Halifax.
4. Bank above Upper Wat Ing, Norland.
5. Dean Clough, 150 yards south of Delves Farm, Netherton.
6. From depth of 52 ft., boring at Quarmby Clough Mills, Longwood (see page 191).

MARINE BEDS IN THE COAL MEASURES

Throughout the present area, the Rough Rock is overlain by a thin coal, which marks the commencement of the Lower Coal Measures, and above this occurs a marine band. Goniatite impressions are remarkably abundant but generally too badly preserved for specific identification. Some forms, however, collected from the Elland district are identified by Mr. Bisat as *Gastrioceras subcrenatum* (Schloth.) or a closely allied species : by an unfortunate error this fossil is called *G. subcrenulatum* in the list on the margin of this sheet of the one-inch map. Fossils have been collected by the Geological Survey from this horizon at the following localities :—

1. Southern end of Holmfield-Queensbury railway tunnel, north of Halifax.
2. Eastern end of Elland tunnel, L.M.S. Railway, Elland station.
3. Calder Colliery, No. 1 Pit boring, Ravensthorpe, Thornhill; depth 913 to 928 ft.
4. Disused quarry opposite Steps Mill, Honley, south of Huddersfield.
5. Boring at Brookfoot Dye Works, near Brighouse; depth 479 ft. (see page 193).

The marine band overlying the Halifax Hard Bed Coal is the highest marine horizon in the Coal Measures of this district. This coal has been extensively mined in the past and consequently large collections have been made of the fossils from the roof shales. Usually the marine band is a dead black shale, but in many places calcareous concretions or bullions occur in great abundance, and in these uncrushed specimens of goniatites are very common. They have practically all been referred to the closely related species *Gastrioceras listeri*, *G. ' carbonarium '* (=*G. circumnodosum* Foord), and *G. corona-*

tum. During the re-survey of this area fossils have been collected from the following localities by the Geological Survey :—

1. Clay pit, 100 yards south-east of Soil Hill Pottery, N.N.W. of Halifax.
2. Old coal crop workings, Jagger Green Lane, Old Lindley, Stainland.
3. Old coal crop workings, Woodman House Pottery, Elland.
4. Old coal crop workings, 200 yards south of Horse and Jockey Inn, Huddersfield Road, Elland.

The Genera *Homoceras, Homoceratoides, Dimorphoceras*

The genus *Homoceras* Hyatt, which is represented by the two species *H. striolatum* [1] and *H. proteum*,[2] closely resembles *Reticuloceras* but differs from that genus in the absence of ribs in the young forms, and also the general absence of spiral striae. *Homoceras proteum* has been recorded from the majority of the marine bands, its range extending as high as the mutation γ band, while *H. striolatum* occurs in the Upper Sabden Shales and also in the mutation α band immediately overlying the Kinderscout Grit. The genus *Homoceratoides* Bisat is very closely related to both *Homoceras* and *Reticuloceras*. Thus it shows close agreement with *Homoceras* in the character of its adult ornament and with *Reticuloceras* in its earliest ribbing. It is invariably represented in the majority of the marine bands by the one species *Homoceratoides divaricatum*,[3] and consequently it is not of any value for the purposes of zoning. A form, however, with some slight differences of ornamentation described as *Homoceratoides prereticulatum* Bisat [4] is apparently confined to the Upper Sabden Shales or the beds below the Kinderscout Grit. In *H. prereticulatum* the surfaces of the ribs are slightly inclined so as to rise towards the aperture of the shell, while in *H. divaricatum* the upper surfaces of the ribs are more or less parallel to the general surface of the shell.

The genus *Dimorphoceras* Hyatt is represented in practically all the marine horizons by fragmentary forms or impressions, but this group requires further study to ascertain whether any of the species have any zonal value. All the forms found agree in having an almost smooth test, the delicate transverse markings of which have a noticeable forward wave at the latero-ventral shoulder. They also all agree in having a closed, or nearly closed umbilicus with a rounded funnel-shaped approach.

Other Marine Fossils

Marine lamellibranchs, gastropods, brachiopods and crinoid remains occur in practically all the marine bands in the Upper Carboniferous rocks of this district. In some of the fossil bands, such as that immediately overlying the Middle Band Coal, or that occurring in a shale parting in the upper part of the Pule Hill Grit

[1] Phillips, J., 'Geology of Yorkshire: Part ii, The Mountain Limestone District,' 1836, p. 234 and plate xix, fig. 14–19.
[2] Brown, T., *Trans. Manch. Geol. Soc.*, 1841, p. 217.
[3] Hind, W., *Geol. Mag.*, 1918, p. 448.
[4] Bisat, W. S., *op. cit.*, p. 112.

at Slaithwaite, no goniatites have yet been found associated with them. In the shales immediately overlying the Middle Band Coal only impressions of *Lingula* have been met with. For the purposes of zoning, the gastropods and brachiopods have not yet been sufficiently studied, the several 'species' being recorded from widely varying horizons. The marine lamellibranchs *Pterinopecten, Aviculopecten, Posidonomya,* and *Posidoniella* have, however, been the subject of a detailed study by Dr. J. W. Jackson, who finds that many of the species have a limited vertical range and can thus be used to supplement the goniatite succession for the purposes of zoning.[1] The material collected during the re-survey of the present area has been submitted to Dr. Jackson, and his identifications give the following results :—

Posidoniella laevis (Brown) is common in the marine band characterized by *Reticuloceras reticulatum,* mut. β, but also occurs in the marine bands below the Kinderscout Grit at Crimsworth Dean.

Posidoniella minor (Brown) is characteristic of the marine bands below and immediately above the Kinderscout Grit.

Posidoniella multirugata J. W. Jackson is characteristic of the marine bands yielding species of *Gastrioceras,* viz., *G. cancellatum, G. cumbriense, G. subcrenatum, G. listeri.*

Posidoniella rugata J. W. Jackson. Characteristic of the marine bands close above the Kinderscout Grit, namely those of *Reticuloceras reticulatum,* mut. α and early mut. β.

Posidonomya gibsoni Salter. Apparently confined to the roof of the Halifax Hard Bed Coal.

Posidonomya insignis J. W. Jackson. This form is characteristic of the Subzones of *Gastrioceras cancellatum* and *G. cumbriense,* but occurs at lower horizons as well. A form that is practically indistinguishable from it is also common in the marine band of *Reticuloceras reticulatum,* mut. α.

Pterinopecten elegans J. W. Jackson is recorded from the Subzone of *Reticuloceras reticulatum,* mut. γ, but is more abundant in those of *Gastrioceras cancellatum* and *G. cumbriense.* A closely related form described by Dr. Jackson as *Pterinopecten* aff. *elegans* is common in the *Reticuloceras reticulatum,* mut. γ band and has been recorded from the *Gastrioceras ? sigma* band.

Pterinopecten papyraceus (J. Sow.) is very common in the roof of the Halifax Hard Bed Coal, and has also been recorded from the shales immediately overlying the Thin Coal above the Rough Rock.

Pterinopecten rhythmicus J. W. Jackson is common in the marine bands below the Kinderscout Grit and apparently confined to them.

Pterinopecten speciosus J. W. Jackson is characteristic of the Subzones of *Reticuloceras reticulatum,* mut. α and mut. β, being most abundant in the mut. α band immediately overlying the Kinderscout Grit. There is also an isolated record of this species from the *Reticuloceras reticulatum,* mut. γ band at Butts Clough, Rishworth.

For a detailed account of the diagnostic characters of the species referred to above, reference should be made to Dr. Jackson's paper, where also all the principal forms are figured.

In the following list the species of marine fossils (exclusive of fish-remains and cephalopods) found in the Carboniferous rocks at

[1] Jackson, J. W., 'New Carboniferous Lamellibranchs and Notes on other Forms,' *Mem. and Proc. Manch. Lit. and Phil. Soc.,* vol. lxxi, 1926-7, pp. 93–122.

numerous localities within the area of the one-inch map (Sheet 77) are given.[1] The geological horizons are indicated by numbers as follows:—

1. Subzone of *Eumorphoceras ornatum*, *Homoceras striolatum*, and *Reticuloceras reticulatum*, type form, Upper Sabden Shales, Black Scouts, Crimsworth Dean, Hebden Bridge.

2. Subzone of *Homoceras striolatum*, *Reticuloceras reticulatum*, type form, Upper Sabden Shales, Outwood, Crimsworth Dean, Hebden Bridge.

3. Subzone of *Reticuloceras reticulatum*, type form. In shales immediately overlying Main or Lower Kinderscout Grit, Jack Bridge, Crimsworth Dean, Hebden Bridge.

4. Subzone of *Reticuloceras reticulatum*, mut. α. In shales overlying Upper Kinderscout Grit.[2]

5. Subzone of *Reticuloceras reticulatum*, early mut. β. In shales usually about 30 ft. above the Subzone of *Reticuloceras reticulatum*, mut. α.[2]

6. Subzone of *Reticuloceras reticulatum*, mut. β. In shales underlying Midgley or Pule Hill Grit.

7. Lamellibranch band. In thin shale parting in upper part of Pule Hill Grit, Old Quarry, west side of Varley Road and close to Windy Bank Farm, Slaithwaite.

8. Subzone of *Reticuloceras reticulatum*, late mut. β. In shales immediately overlying Midgley or Pule Hill Grit.[2]

9. Subzone of *Reticuloceras reticulatum*, mut. γ. In shales overlying Beacon Hill Flags or Nab End Sandstone.

10. Band with *Gastrioceras ? sigma*. In shales 6 to 8 ft. above the band characterized by *Reticuloceras reticulatum*, mut. γ.[2]

11. Subzone of *Gastrioceras cancellatum*. In shales overlying the Warley or Huddersfield White Rock.[2]

12. Subzone of *Gastrioceras cumbriense*. In shales 50 to 100 ft. above the Subzone of *Gastrioceras cancellatum*.[2]

13. Subzone of *Gastrioceras subcrenatum*. In shales overlying Thin Coal above the Rough Rock.[2]

14. In shales overlying the Middle Band Coal, Halifax; and near Honley, south of Huddersfield.

15. In shales overlying the Halifax Hard Bed Coal.[2]

MARINE FOSSILS

(exclusive of fish and cephalopods)

The numbers in heavier type indicate that the species is very common at that horizon.

Crinoidea

Crinoid columnals, 1, 2, 4, 5, 11, 12.

Brachiopoda

Ambocoelia carbonaria (*Dav.*), 12.
Chonetes sp., 2, 4.
Lingula mytiloides *J. Sow.*, 4, 6, 7, 9, 13, 14, 15.
,, squamiformis *Phill.*, 9.
,, sp., 4, 6, 9, 10, 11, 12, 13, 14, 15.
Orbiculoidea nitida (*Phill.*), 2, 5, 6, 7, 12, 13.
Productus, sp., 2, 4, 8, 11, 12.

Lamellibranchiata

Aviculopecten carboniferus (*Stevens*), **4**, 5.
,, *cf.* neglectus (*Geinitz*), 8.

[1] With the exception of the lamellibranchs dealt with by Dr. J. W. Jackson, the fossils have been determined by Mr. J. Pringle.

[2] Full list of localities given on pages 146–154.

Cypricardella sp., 7.
Edmondia sp., 7.
Leiopteria longirostris *Hind*, 2.
,, sp., 4.
Myalina *cf.* peralata *de Koninck*, 4, 5.
,, vernuelli (*M'Coy*), 4, 6.
,, sp., 4, 6, 7, 9, 10.
Nucula aequalis *J. de C. Sow.*, 2.
,, sp., 4, 5, 6, 7.
Nuculana stilla (*M'Coy*), 4, 8.
,, sp., 6, 8.
Parallelodon tenuistriatus (*M. & W.*), 12.
Posidoniella laevis (*Brown*), 1, 2, 3, **8.**
,, *aff.* laevis (*Brown*), 9.
,, minor (*Brown*), 1, 2, 3, **4.**
,, *aff.* minor (*Brown*), 5, 6, 11, 13, 15.
,, multirugata *J. W. Jackson*, 11, 12, 13, 15.
,, rugata *J. W. Jackson*, 4, 5.
Posidonomya gibsoni *Salter*, 15.
,, insignis *J. W. Jackson*, **4**, 5, 6, 8, 9, **11, 12**, ? 13.
,, *cf.* insignis *J. W. Jackson*, 5.
Pterinopecten elegans *J. W. Jackson*, 9, **11, 12.**
,, *aff.* elegans *J. W. Jackson*, **9**, 10, ? 11, 13.
,, papyraceus (*J. Sow.*), 13, **15.**
,, rhythmicus *J. W. Jackson*, **1, 2.**
,, speciosus *J. W. Jackson*, 3, **4**, 5, 6, ? 9.
,, *cf.* speciosus *J. W. Jackson*, 6.
Sanguinolites ovalis *Hind*, 4, 7.
,, tricostatus (*Portlock*), 2, 4.
,, sp., 4, 5, 7, 12.
Scaldia sp., 7.
Schizodus antiquus *Hind*, 2, 4, 5, 6.
Syncyclonema sp., 12.

Gastropoda

Bellerophon *cf.* decussatus *Flem.*, 4, 12.
,, sp., 2, 4, 5, 6, 11, 12.
Loxonema sp., 4, 11, 12.
Macrochilina elegans *Hind*, 2.
,, gibsoni *Hind*, 2.
,, reticulata *Hind*, 2.
Naticopsis brevispira (*Brown*), 4, 7.
,, globosa (*von Hoeninghaus*), 7.
Raphistoma sp., 12.

Scaphopoda

Entalis *cf.* meekianum (*Geinitz*), 8.

FISH-REMAINS

Fish-remains occur at several horizons in the Upper Carboniferous rocks of this district. Usually they are in a very fragmentary condition, consisting generally of isolated teeth, scales, or spines.

The most prolific horizons are the thin-bedded black shales immediately overlying some of the coal seams in the Coal Measures. In some seams such as the Middleton Main and Adwalton Stone Coals, with which a seam of cannel is associated, fish-remains also occur in the cannel. A large number of species has been described by J. W. Davis from the cannel associated with the Adwalton Stone or Flockton Thick Coal. The same writer has also investigated the

fish fauna of the roof-shales of the Better Bed Coal. A large number of forms has also been described by Dr. E. D. Wellburn from several horizons in the Millstone Grits and Lower Coal Measures of the Halifax district. These have been recorded in several papers, published chiefly in the *Proceedings of the Yorkshire Geological Society*, and are incorporated in the lists given below.

The genera *Acanthodes, Coelacanthus, Elonichthys,* and *Megalichthys* appear to have a very wide distribution, being found in nearly all the fish-bearing localities and constituting the most characteristic genera in these measures.

Some horizons at which fish-remains are known to occur are not included in the list given below. Thus fish-remains are generally of frequent occurrence in the black shale immediately overlying the Middle Band Coal, but no records of specific determinations are available. This seam being never profitable to work, its roof shales are seldom exposed and opportunities of collecting from them are rare.

A collection of about 700 specimens from the roof-shales of the Better Bed Coal at Low Moor and Clifton is in the Museum at Brighouse. These have recently been examined by Professor D. M. S. Watson, F.R.S.; he remarks that " of these only one, the tail of a *Megalichthys*, represents any considerable part of the animal: the remainder, apart from two or three jaws, are isolated teeth, spines and scales. The fauna is remarkable from the individual and specific abundance of Elasmobranchs; such fish as *Pleuroplax* and *Ctenoptychius* are much more abundant than they are in any corresponding fauna which I have examined. The absence of Platysomids and the extreme rarity of Palaeoniscids is no doubt spurious; when broken up the individual bones and scales of these fish are small and delicate and may easily have escaped collection. The fact that *Rhizodopsis sauroides* is only represented by a single scale is, however, remarkable, because these scales are large and massive and usually very abundant in any part of the Coal Measures."

A number of species are recorded below for the first time from the roof of the Blocking Bed Coal. These were collected by Mr. C. F. Cameron of Lepton from this horizon in the Grange Moor district. In the following list the species of fish-remains found in the Carboniferous rocks at numerous localities within the area of the one-inch map (Sheet 77) are given. The localities and geological horizons are indicated by numbers as follows:—

1. Upper Sabden Shales, Crimsworth Dean, Hebden Bridge.
2. Shales above Kinderscout Grit, Wadsworth Moor, Halifax.
3. Shales above Kinderscout Grit, Ivy Clough, Halifax.
4. Shales above Kinderscout Grit, Boulder Clough, Halifax.
5. Shales above Kinderscout Grit, Kiln House Wood, Halifax.
6. Shales above Midgley Grit, Halifax district.
7. Shales above Nab End Sandstone, Halifax district.
8. Shales above Warley Rock, Halifax district.
9. Shales overlying thin coal above Rough Rock, water boring at Brookfoot Dyeworks, Brighouse.

10. Shales above Soft Bed Coal, Halifax district.
11. Shales above Hard Bed Coal, Halifax district.
12. Shales above Hard Bed Coal, Victoria Colliery, Lepton, near Huddersfield.
13. Shales above 36-Yard Band Coal, Halifax district.
14. Shales above Better Bed Coal; Low Moor, Wyke, and Clifton districts.
15. Shales above Better Bed Coal, Rowley Hill, Lepton, near Huddersfield.
16. Shales above Black Bed Coal, Low Moor.
17. Thin seam of cannel above Black Bed Coal, Low Moor.
18. Beeston Coal, Rowley Hill, Lepton, near Huddersfield.
19. Shales above Blocking Coal, Grange Moor collieries, near Flockton.
20. From roof of Middleton Main Coal, Adwalton district, and also thin seam of cannel above Middleton Main Coal, Tong, near Bradford.
21. Roof of Adwalton Stone (or Flockton Thick) Coal, Tingley, near Leeds.

Nos. 1 to 11, 13, 16, 17 and 20 are identifications by Dr. Wellburn, and the majority have already been recorded by him in his numerous papers, published chiefly in the *Proceedings of the Yorkshire Geological Society*. Nos. 14 and 21 are records of identifications made by J. W. Davis, to which have been added, for No. 14, several identified by Professor Watson from the Brighouse Museum; No. 21 occurs to the east of the area represented by Sheet 77, but it is included because the Adwalton Stone (or Flockton Thick) Coal is a well-known horizon for fish-remains in the present area. Nos. 12, 15, 18 and 19 are from specimens collected by Mr. C. F. Cameron of Lepton and now preserved in the Tolson Memorial Museum, Huddersfield. These were identified by Professor D. M. S. Watson, F.R.S., on behalf of the Geological Survey.

I. *Elasmobranchii*

Acanthodes major *Davis*, 14.
,, wardi *Eg.*, 2, 3, 4, 5, 14, 16, 20, 21.
,, sp., 12.
Acanthopsis wardi *Eg.*, 14, 15.
Callopristodus pectinatus *Ag.*, 14, 16, 21.
Cladodus mirabilis *Ag.*, 1, 2, 14.
Ctenacanthus hybodoides *Ag.*, 21.
Ctenoptychius apicalis *Ag.*, 14, 15, 21.
,, sp., 21.
Deltodus sp. nov., 14.
Diplodus gibbosus *Ag.*, 14, 16, 17, 20, 21.
,, tenuis *A. S. Woodw.*, 14, 16, 17, 18, 21.
,, sp., 19.
Helodus simplex *Ag.*, 14, 16, 20, 21.
,, sp., 11, 14, 20.
Janassa clavata *M'Coy*, 14.
,, linguaeformis *Atth.*, 14.
,, sulcatus *Wellb.*, 11, 14.
Orodus elongatus *Davis*, 1.
Petalodus hastingsiae *M'Coy*, 14, 16, 20.
,, ornatus *Wellb.*, 14.
Phoebodus sp., 14.
Pleuracanthus alatus *Davis*, 21.
,, alternidentatus *Davis*, 21.
,, cylindricus *Ag.*, 14, 20, 21.
,, denticulatus *Davis*, 14.
,, laevissimus *Ag.*, 14, 16, 17, 20, 21.
,, robustus *Davis*, 21.
,, tenuis *Davis*, 14.
,, wardi *Davis*, 14?

Pleuroplax affinis *Ag.*, 14.
,, attheyi *W. J. Barkas*, 10, 11, 14.
,, rankinei *H. and Atth.*, 10, 11, 14, 16.
Sphenacanthus aequistriatus *Davis*, 14.
,, horridus *Wellb.*, 21.
,, hyboides *Eg.*, 14, 16, 19, 20, 21.
,, minor *Davis*, 16.

II. *Ichthyodorulites*
Euctenius unilateralis *W. J. Barkas*, 21.
Gyracanthus formosus *Ag.*, 14, 16, 17, 21.
Homacanthus microdus *M'Coy*, 14.
Hoplonchus elegans *Davis*, 10, 11, 14, 15.
Lepracanthus colei *Owen*, 14.
,, rectus *Wellb.*, 14.
Ostracanthus dilatus *Davis*, 21.
Stemmatodus sp., 14.

III. *Dipnoi*
Ctenodus cristatus *Ag.*, 14, 20, 21.
,, elegans *Davis*, 21.
Sagenodus inaequalis *Owen*, 14.
,, sp., 14.

IV. *Teleostomi*
Acrolepis hopkinsi *M'Coy*, 1, 2, 3, 11, 21.
Cheirodus granulosus *Young*, 11, 14, 17, 21.
,, striatus *H. and Atth.*, 14, 17.
Coelacanthus corrugatus *Wellb.*, 14.
,, distans *Wellb.*, 14.
,, elegans *Newberry*, 10, 11, 14, 16, 20, 21.
,, elongatus *Huxley*, 21.
,, granulostriatus *Wellb.*, 14.
,, lepturus *Ag.*, 14, 21.
,, phillipsi *Ag.*, 11.
,, robustus *Newberry*, 14.
,, spinatus *Wellb.*, 14.
,, tingleyensis *Davis*, 14, 21.
,, tuberculatus *Wellb.*, 14.
,, woodwardi *Wellb.*, 14.
Cycloptychius carbonarius *Young*, 14, 16, 21.
Elonichthys aitkeni *Traq.*, 1, 2, 3, 6, 7, 8, 10, 11, 14.
,, caudalis *Traq.*, 14.
,, egertoni *Ag.*, 11, 14, 21.
,, obliquus *Wellb.*, 2, 3, 13, 19.
,, oblongus *Traq.*, 14.
,, semistriatus *Traq.*, 11, 14.
,, woodwardi *Wellb.*, 14.
Gonatodus (? molyneuxi *Traq.*), 14.
Megalichthys coccolepis *Young*, 10, 21.
,, hibberti *Ag.*, 10, 11, 14, 16, 17, 20, 21.
,, intermedius *A. S. Woodw.*, 12, 14, 16, 19, 21.
,, pygmaeus *Traq.*, 14, 16, 19, 21.
,, sp., 15, 18, 19.
Mesolepis scalaris *Young*, 14, 21.
,, wardi *Young*, 14, 21.
Rhadinichthys hancocki *Woodward and Sherborn*, 14.
,, macrodon *Traq.*, 14.
,, monensis *Eg.*, 3, 10, 11, 12, 14, 16, 17.
,, planti *Traq.*, 17 ?
Rhizodopsis sauroides *Will.*, 8, 11, 12, 14, 16, 17, 20.
,, sp., 12, 19, 21.

Strepsodus sauroides *Binney*, 11, 14, 16, 19, 20.
,, sulcidens *H. and Atth.*, 2, 14.
,, sp., 12, 19.

NON-MARINE LAMELLIBRANCHS

In the Coal Measures there are numerous fossiliferous bands characterized almost exclusively by forms referable mainly to the genera *Carbonicola*, *Anthracomya* and *Naiadites*. These fossils are now generally regarded as being of estuarine or freshwater habit, and it may be considered as definitely established that they are not ordinarily associated with any of the marine forms which have been mentioned in the preceding pages. Within recent years a detailed study of these forms, which become very abundant in the Middle Coal Measures, has shown that they may be referred to several distinct species or varieties, which have a considerable value for the purposes of zoning.[1] As yet, however, no similar study of the forms which occur in the Lower Coal Measures and the lower part of the Middle Coal Measures has been undertaken, mainly because of the poor state of preservation of the shells. During the re-survey of the present area a collection of these forms, with a few other fossils, was made from several horizons, and these have been identified by Mr. Pringle. Below is given a brief account of these horizons and localities.

1. *In shales overlying the Soft Bed Coal.* A few feet above the Soft Bed Coal occurs a *Carbonicola* band which appears to be almost invariably present when the beds on this horizon are exposed. In a railway cutting 150 yards north of Honley Station it yielded the following forms (Register-numbers A.T. 3462–3467) :[2] *Carbonicola* cf. *robusta* (J. de C. Sow.), *Carbonicola sp.*, and *Beyrichia arcuata* Bean.
2. *In shales about 70ft. above Halifax Hard Bed Coal.* Specimens collected from Harrow Clough, 200 yards N.E. of Copriding, Old Lindley, Stainland (Reg. Nos. A.T. 3177-3182) : *Carbonicola* cf. *aquilina* (J. de C. Sow.).
3. *In roof-shales of Beeston Coal.* In the shales immediately overlying this seam at Caphouse Pit, Denby Grange Collieries, Overton, the following forms were obtained (Reg. Nos. Tm. 494–497) : *Carbonicola sp.*, *Naiadites sp.*, *Spirorbis sp.*, and Ostracods.
4. *In roof shales of Blocking Coal.* The following forms were obtained by Mr. C. F. Cameron of Lepton from the roof of this seam at Shuttle Eye Colleries, Grange Moor, and identified by Mr. J. Pringle : *Carbonicola ovalis* (Mart.), *Carbonicola aquilina* (J. de C. Sow.), and *Carbonicola sp.* In the roof shales of this seam at an old pit on Brown Hill, Grange Moor, and 600 yards E.S.E. of St. Bartholomew's Church, the following forms (Reg. Nos. Tm. 466-469) were obtained : *Carbonicola sp.*, *Naiadites sp.*, and Ostracods. A similar assemblage was obtained from Speedwell Pit, Emley Moor Collieries, Emley (Reg. Nos. Tm. 488, 489).
5. *In roof shales of Wheatley Lime Coal.* From the shales overlying this coal at Chapel House Pit, Emley Moor Collieries, and 1,100 yards W.S.W., of Emley Church, forms referable to the genera *Carbonicola* and *Naiadites* were obtained (Reg. Nos. Tm. 486, 487).

[1] Davies, J. H. and A. E. Trueman, ' A Revision of the Non-Marine Lamellibranchs of the Coal Measures, and a Discussion of their Zonal Sequence,' *Quart. Journ. Geol. Soc.*, vol. lxxxiii, 1927, pp. 210–259.

[2] The numbered specimens are preserved in the Palaeontological Department of the Geological Survey, Jermyn St., London, S.W.1.

6. *In roof shales of New Hards Coal.* A crop working in the New Hards Coal, 200 yards south of the Dartmouth Arms, Linfit Lane Top, Lepton, yielded abundant impressions of *Carbonicola*, but they were too poorly preserved to be specifically identifiable.
7. *In roof shales of Green Lane Coal.* Throughout the Briestfield, Grange Moor and Flockton districts a *Carbonicola* band immediately overlies this seam. At Shuttle Eye Collieries, Grange Moor, the following were obtained: *Carbonicola sp., Naiadites sp., Spirorbis sp.*, and Ostracods (Reg. Nos. Tm. 470–475). A similar assemblage was obtained from crop-workings alongside the Temple, Liley Lane, Whitley Beaumont Park, Lepton; and from workings south of the Dartmouth Arms, Linfit Lane Top, Lepton.
8. *In roof shales of Old Hards Coal.* Crop workings in this seam at a point 220 yards S.S.E. of Flockton Church, Flockton, yielded *Carbonicola sp., Naiadites sp., Spirorbis sp.*, and Ostracods (Reg. Nos. Tm. 479-481).
9. *In roof shales of Flockton Thin Coal.* Crop workings in this seam at Brown Hill, Grange Moor and 300 yards south of Huntroyd, yielded the following assemblage (Reg. Nos. Tm. 498, 499) : *Carbonicola sp., Naiadites sp., Spirorbis sp.*, and Ostracods.
10. *In roof shales of Adwalton Black Bed.* Doles Wood Colliery, Drighlington : *Carbonicola acuta* (J. Sow:). (Reg. No. J.S. 63).
11. *In roof shales of Flockton Thick Coal.* Workings in this seam at Windmill Hill Lane, S.W. of Six Lane Ends, Flockton, yielded forms referable to the genera *Carbonicola* and *Naiadites* (Reg. Nos. Tm. 491–493).
12. *In roof shales of Adwalton Stone Coal.* Ringshaw Beck, 750 yards N.W. of Drighlington Church : *Carbonicola* cf. *turgida* (Brown). (Reg. Nos. J.S. 61, 62).
13. *Tankersley Ironstone.* This band of ironstone is very largely made up of *Carbonicola* shells. A section in it alongside a stream, 300 yards E.S.E. of Flockton Mill, Flockton yielded the following forms (Reg. Nos. Tm. 476–478) : *Carbonicola sp., Naiadites sp.* (young forms), *Spirorbis sp.*, and Ostracods. A similar assemblage was also obtained in a stream section in Kirkby Wood, Flockton, 500 yards south of Flockton Church (Reg. Nos. Tm. 482–485).

While this memoir was passing through the press Dr. Trueman described a number of new species of *Carbonicola* and *Anthracomya* [1] from the Millstone Grits and Lower and Middle Coal Measures ; the types of several of these were collected by the Survey from the area here described ; the following additions can be made to the above list :—

Carbonicola pseudoacuta and *C. ornata* from the Millstone Grits, between the White Rock and the Rough Rock, immediately under the Cancellatum marine band, in a boring at Victoria Mills, Huddersfield ; *Carbonicola decorata* from the Lower Coal Measures, about the horizon of the Whinmoor or Beeston Coals at Caphouse Pit Dump, Overton ; *Carbonicola regularis* from the Middle Coal Measures, Tankersley Ironstone in a stream-section at Kirkby Wood near Flockton ; and *Anthracomya lenisulcata* from the base of the Lower Coal Measures, immediately over the Pot Clay Coal in a boring at Phoenix Mills, Huddersfield. The presence of such forms in the Millstone Grits between the White Rock and the Rough Rock strengthens the case for regarding the beds above the White Rock as part of the Lower Coal Measures rather than of the Millstone

[1] *Ann. and Mag. of Nat. Hist.*, Ser. 10, vol. iv, 1929, pp. 82–95.

Grits, as indicated by the distribution of the goniatites *Reticuloceras* and *Gastrioceras*.

AMPHIBIA

Remains of Labyrinthodonts have been found in the roof of the Better Bed Coal, in the shales between the seams of the Black Bed Ironstones,[1] and in the roof of the Black Bed Coal. From the first horizon there are seven bones in the Brighouse Museum, of which Prof. D. M. S. Watson, F.R.S., writes, "they are all definitely determinable as Embolomeri, although not sufficient for generic identification." From the last Prof. Huxley first described[2] a new species, *Pholiderpeton scutigerum*, found at Toftshaw, near Bradford; the type is now in the museum at Cartwright Hall, Bradford.

PALAEOBOTANY

Such information as to fossil plants from the Millstone Grits as calls for comment has been incorporated in the stratigraphical account of that formation (Chapter II). In the Coal Measures the flora is of greater importance than the fauna, which is confined to certain thin bands and is chiefly represented by freshwater forms: moreover, it is the partial destruction of plant-remains that has produced the coal seams.

It is therefore to the palaeobotany that we must look for fixing suitable subdivisions of the formation. Within the present area, the subdivisions represented belong to the Lower and Middle Coal Measures; and Kidston's work on the flora has shown that these measures respectively belong to the Lanarkian and Westphalian (or Yorkian) Series. The conventional base adopted for the Middle Coal Measures in Yorkshire is the horizon of the Blocking (or Silkstone) Coal. This horizon, as has been already pointed out (page 48) does not correspond with that adopted in Lancashire since the Better Bed Coal, not the Blocking Bed is the equivalent of the Arley Mine (p. 164). Before any definite statement as to the position of any botanical break in the Yorkshire Coal Measures can be made the records for the whole coalfield must be studied, and more collecting is advisable, especially from the rocks between the Better Bed and the Blocking Coal. As long ago, however, as 1890 Kidston adopted the Better Bed as the base of the Middle, and the Elland Flags as the top of the Lower Coal Measures. In the first part of his series of papers on the Yorkshire Carboniferous Flora he says—"we have drawn the dividing line between the Middle and Lower Coal Measures at the Elland Flagstone. The members of the Geological Survey, on the other hand, draw the dividing line below the Silkstone Coal [=Blocking Bed]. There is no marked break in the series, but palaeontological evidence is strongly in favour of drawing the dividing line at the Elland Flagstone, and this is the view taken by many of the Yorkshire Palaeontologists."[3]

[1] 'Geology of the Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1878, p. 135.
[2] *Quart. Journ. Geol. Soc.*, vol. xxv, 1869, pp. 309–311.
[3] *Trans. Yorks. Nat. Union*, pt. xiv, 1890, p. 5.

In view of these conclusions, it is somewhat remarkable, therefore, to find that in all his later publications on the Yorkshire Carboniferous flora, Kidston adopted without comment the conventional horizon of the Blocking (or Silkstone) Coal as the line of subdivision between the Lanarkian and Westphalian (or Yorkian) Series.

Extensive lists of fossil plants from the district here described have been published at various times.[1] These records, and, in many cases, the specimens on which they were founded, were studied by Kidston when he prepared his reports on the Yorkshire Carboniferous Flora, which may therefore be taken as superseding them.[2] The majority of our records of fossil plants from the Yorkshire coalfield are due to careful collecting over very many years by Mr. W. Hemingway, now of Derby. These furnished the basis of Kidston's Reports.

In 1896 Kidston dealt in detail with the many excellent specimens of *Dactylotheca plumosa* which he had seen from Yorkshire, its numerous variations, and known distribution ; and in the following year he described new species of *Sigillaria* and Sigillarian fructifications.[3] These papers, together with his later work on certain groups of fossil plants already published [4] have led to some modifications in his general lists, particularly in nomenclature. The species recorded by him from within the area of the Huddersfield Sheet, brought up to date by Dr. Crookall in the light of the works referred to, are listed at the end of this section. While these local lists are necessarily an insufficient foundation for any general conclusions, it may be pointed out that at the horizon of the Better Bed ten new species come in and one dies out, at the Blocking Bed only two come in and five die out. Of the county area in general, the plants belonging to groups of which Kidston's criticial examinations are available 55 species are recorded from the measures between the Better Bed and the Blocking Coal ; of these 26 are practically confined to and characteristic of the Westphalian.[5] A small number of additional records, given by Kidston in the memoir last referred to, have been incorporated in the list. Recognizable plants collected during the re-survey include *Lepidodendron aculeatum* Sternb. from the Hard Bed at Brigg Royd, Netherton ; *L. obovatum* Sternb. from the Black Bed at Glenfield Colliery, Odsal ; *Alethopteris sp.*, *Mariopteris sp.*, and *Calamites sp.* from the same horizon at Bradley Park. A number of fossil plants from the district are preserved in the Halifax

[1] Cash, W. and T. Hick, 'Contributions to the Fossil Flora of Halifax,' in four parts, *Proc. Yorks. Geol. and Polytech. Soc.*, vols. vii and viii, 1879–1885. Spencer, J., *ibid.*, vol. xiii, 1898, pp. 302–310 and others.

[2] *Trans. Yorks. Nat. Union*, 1st Report, pt. xiv, 1890, pp. 1–64 ; 2nd Report, pt. xviii, 1893, pp. 65–82 ; 3rd Report, *ibid.*, pp. 83–96 ; 4th Report (with index to 1, 2, 3, 4), *ibid.*, pp. 97–127 ; 5th Report, pt. xix, 1896, pp. 129–144 ; 5th Report (concluded), pt. xx, 1898, pp 145, 146 ; 6th Report, pt. xxi, 1898, pp. 147–176.

[3] 'Fossil Flora of the Yorkshire Coalfield,' *Trans. Roy. Soc. Edinburgh*, vol. xxxviii, 1896, pt. 2, No. 5, and vol. xxxix, 1897, pt. 2, No. 5.

[4] 'Fossil Plants of the Carboniferous Rocks of Great Britain' (*Mem. Geol. Surv., Palaeontology*), vol. ii, parts 1–6, 1923–1926.

[5] Wray, D. A., 'The Carboniferous Succession in the Central Pennine Area,' *Proc. Yorks. Geol. Soc.*, vol. xxi, 1929, pp. 282–285.

Museum, but the identifications have not been revised : they include exceptionally fine specimens of *Lepidodendron gracile* L. and H. (=*L. ophiurus* Brongt.) from Northowram and *Ulodendron minus* L. and H. from the ironstone of Low Moor. In the Tolson Memorial Museum at Huddersfield are specimens collected by Mr. C. F. Cameron of Lepton from the roof of the Better Bed Coal at Elliott's Quarry, Cowmes, Lepton ; and from the roof of the Old Hards Coal at Grange Moor Colliery, near Flockton. These have been identified by Dr. Crookall and are incorporated in the list at the end of this account. The last named horizon is one of the most prolific in the district, but up to date records are mainly from the area to the east.

One feature of the district deserves special mention—the ' coal-balls ' occurring in the Hard Bed Coal. These are calcareous concretions found in the seam of coal, in which the remains of plants are perfectly preserved, the detailed structures being petrified before they were destroyed or seriously distorted ; they have therefore added immensely to our knowledge of the structure of primitive plants and provided valuable evolutionary data.

The ' coal-balls ' of Yorkshire have been studied by a committee of the British Association which reported in 1882 and 1883. In the first report it was pointed out that the Halifax district was the only one from which satisfactory specimens were obtainable ; those from further north towards Bradford and south around Huddersfield were so pyritous that the plant-structures were no longer recognizable.[1] The only pit then working the Hard Bed seam was Sunny Bank (p. 67) ; a list of plant-remains from this pit is given in the Report for 1882.

The second report gave only a few botanical details of some of the species enumerated above.[2]

More recently the formation of coal-balls has been studied in detail by Dr. Stopes and Professor Watson,[3] who used material from Lancashire, though their conclusions are equally applicable to Yorkshire : the conditions of formation are mentioned above (p. 51) ; of the plants they remark that those found in the coal-balls (i.e., occurring in the coal itself) differ from those in the roof nodules and the shales and sandstones that form the bulk of the Coal Measures. The former grew *in situ* and indicate a marsh flora ; the latter, represented

[1] Dr. A. Heard has lately perfected a method by which pyritised remains can be treated to show their internal structure : see *Quart. Journ. Geol. Soc.*, vol. lxxxiii, 1927, pp. 197, 198.

[2] *Ibid.*, for 1883 (Southport), 1884, p. 160.

[3] Stopes, M. C. and D. M. S. Watson,' Distribution and Origin of the Calcareous Concretions in Coal Seams, known as " Coal Balls ",' *Phil. Trans. Roy. Soc.*, Series B, vol. cc, 1909, pp. 167–218.

by drifted fragments, grew for the most part on dry land. Owing to this difference of facies the flora of the shales and sandstones shows a clear connexion with that of the succeeding Permian formation, whereas that of the coal seams is very different. It may be said that this evidence of a double flora, the one represented by land plants and the other by swamp plants, does not apply to the Yorkshire area, where swamp-plants only are found. There are also interesting differences, not only in the chemical composition of the 'coal-balls' but also in the lateral distribution of the genera and species they include, though this cannot be fully dealt with here.

The following list includes a revised list of all records of fossil plants from the area. The majority are taken from the six Reports on the flora of the Yorkshire Coal Measures given by Kidston to the Yorkshire Naturalists' Union: these have been checked and in some cases renamed, the old name being given in brackets. The records are indicated in the left-hand column by the number of the page in the reports; additions from Kidston's 'Fossil Plants of the Carboniferous Rocks of Great Britain' by the word 'Memoir'; those collected by Mr. C. F. Cameron of Lepton, and now preserved in the Tolson Memorial Museum, Huddersfield, by the word 'Huddersfield'; those collected during the course of the re-mapping by 'Survey': the specimens represented by the two last groups were identified by Dr. Crookall.

1. Low Moor
2. Northowram
3. Cold Edge, Halifax
4. Cowmes
5. Dewsbury Moor
6. Kirkheaton
7. Holywell, nr. Halifax
8. Clifton
9. Alverthorpe
10. Sowerby
11. Sunny Bank, Halifax
12. Barkisland
13. Hebden Bridge
14. Luddenden valley
15. Hipperholme
16. Elland
17. Wyke
18. King Cross, Halifax
19. Nab End, Fly, nr. Halifax
20. Wheatley valley
21. Flockton
22. Ringby
23. Bradshaw, nr. Halifax
24. Bank Top, Halifax
25. Shibden Head
26. Dark Lane, Mirfield
27. Sowerby Bridge
28. Mount Tabor, Halifax
29. Ovenden
30. Stanley Colliery, Liversedge
31. Brigg Royd, Netherton
32. Glenfield Colliery, Odsal
33. Morley
34. Pildacre, nr. Earlsheaton

Page	Species	Horizon
	PTERIDOSPERMAE AND FILICALES	
38, 73 107 136	Alethopteris lonchitica (*Schloth.*)	Millstone Grits (3, 7, 10) Black Bed (1, 26) White Rake (1) Old Hards Coal (21) ? (8)
39	Alethopteris decurrens (*Artis*)	? (9)
Huddersfield	Mariopteris dernoncourti *Zeiller*	Flockton (34)
Memoir	Mariopteris beneckei *Huth*	White Rake (1)
35, 72 136 160 Huddersfield	Mariopteris nervosa (*Brongt.*) (as M. muricata (*Schl.*) and M. muricata forma nervosa (*Brongt.*)	Millstone Grits (3, 10, 14) Better Bed (1) Black Bed (1) White Rake (1) Dewsbury Rock (5) Middleton Main (33)
29	Mariopteris latifolia (*Brongt.*) (as Sphenopteris latifolia)	? (1)
29	Mariopteris acuta (*Brongt.*) (as Sphenopteris acuta)	White Rake (1)
18 Huddersfield	Dactylotheca plumosa (*Artis*)	? (6) Blocking Bed (21)
40 136	Neuropteris heterophylla *Brongt.*	Millstone Grits (10) White Rake (1) Old Hards Coal (21)
42 137 Huddersfield	Neuropteris gigantea *Brongt.*	Millstone Grits (10) White Rake (1) Old Hards Coal (21)
Huddersfield	Neuropteris tenuifolia (*Schloth.*)	Better Bed (4)
105	Crossotheca schatzlarensis (*Stur*)	White Rake (1)
30 Memoir	Crossotheca hoeninghausi (*Brongt.*) (as Sphenopteris hoeninghausi)	White Rake (1) Hard Bed (11) Better Bed (1, 8) Black Bed (1, 8) White Rake (1, 8)
Memoir	Myriotheca anglica *Kidston*	Better Bed or Black Bed (30)

Page	Species	Horizon
Memoir	Zeilleria frenzli *Stur*	Popplewell Stone Coal (30)
Huddersfield	Sphenopteris striata *Gothan*	Old Hards Coal (21)
	EQUISETALES	
131 154	Calamites undulatus *Sternb.*	Elland Flags (22) Old Hards Coal (21)
16	Ditto (as Calamites varians *Sternb.*)	White Rake (1)
66	Calamites varians *Sternb.* forma schutzei *Stur*	Elland Flags (2)
17	Calamites goepperti *Ett.*	Elland Flags (2)
20 67 154 Huddersfield	Calamites suckowi *Brongt.*	Millstone Grits (4, 10, 27) Elland Flags (2, 22) Black Bed (1) White Rake (1) ? (4) Better Bed (4)
67	Calamites carinatus *Sternb.* (as Calamites ramosus)	Elland Flags (22)
22	Asterophyllites equisetiformis *Schloth.*	White Rake (1)
133	Asterophyllites charaeformis *Sternb.*	Old Hards Coal (2)
	SPHENOPHYLLALES	
26 143 163	Sphenophyllum cuneifolium (*Sternb.*)	Black Bed (1) White Rake (1) Old Hards (21)
	CORDAITALES	
59 144 172 59, 81	Cordaites principalis (*Germar*) Artisia transversa (*Artis*)	Millstone Grits (10) White Rake (1) ? (2) Millstone Grits (14, 19) White Rake (1)
144 175	Artisia approximata *Brongt.*	Millstone Grits (10, 29)
	LYCOPODIALES	
44	Lepidodendron lycopodioides *Kidston*[1] (? *Sternb.*) (as L. dichotomum *Sternb.* (*pars*)	Elland Flags (2) Better Bed (8)

[1] Kidston recorded this plant (*loc. cit.*) as *L. dichotomum* Sternb. (in part). In a later report, however (*op. cit.*, p. 110), he observed that these specimens are referable to *L. lycopodioides* Sternb., and expressed doubt as to their relationship to *L. dichotomum* Zeiller. There is some doubt, however, as to whether *L. lycopodioides*, as understood by Kidston, is identical with either of these species. This is a matter for future investigation.

Page	Species	Horizon
Huddersfield	Lepidodendron ? rimosum *Sternb.*	Better Bed (4)
166	Lepidodendron peachi *Kidston*	Soft Bed (11)
46, 76 138 165 Survey	Lepidodendron aculeatum *Sternb.*	Millstone Grits (10, 12, 13, 14, 28) Hard Bed (1)[1] Elland Flags (2, 15) Better Bed (1) Black Bed (1) Ironstone Bed (1) Hard Bed (31)
46, 76 165	Lepidodendron obovatum *Sternb.*	Millstone Grits (10) Soft Bed (11) Hard Bed (11) Black Bed (1, 32)
57, 142 168	Sigillaria tessellata *Brongt.*	Millstone Grits (10, 12, 19, 20, 29) Ironstone Bed (1) ? (1, 21)
169 54, 78 168	Sigillaria semipulvinata *Kidston* Sigillaria discophora (Koenig)	Black Bed (1) Millstone Grits (18) Soft Bed (11) Hard Bed (24) Better Bed (17) Black Bed (1) Ironstone Bed (1)
141	Sigillaria elongata *Brongt.*	Old Hards Coal (21)
55, 141	Sigillaria scutellata *Brongt.*	Millstone Grits (10) White Rake (1)
78, 141	Sigillaria mammillaris *Brongt.*	Hard Bed (23) Old Hards Coal (21)
57	Sigillaria sp.	Black Bed (1)
77	Lepidophloios acerosus (*L.* & *H.*)	Hard Bed (23)
49	Lepidophloios laricinus *Sternb.*	Black Bed (1) White Rake (1)
Huddersfield	? Lepidophloios sp.	Better Bed (4)
167	Halonia tortuosa *L.* & *H.*	Millstone Grits (10)
50	Halonia sp.	Elland Flags (16) Ironstone Bed (1)

[1] Either the locality or the horizon of this entry is incorrect.

Page	Species	Horizon
50	Lepidostrobus variabilis *L. & H.*	Soft Bed (11) Better Bed (1, 17)
51	Lepidostrobus lanceolatus (*L. & H.*)	White Rake (1)
52, 112	Lepidostrobus geinitzi *Schimper*	Soft Bed (11, 25) Black Bed (1)
142	Stigmaria ficoides (*Sternb.*)	Millstone Grits (10)
96	INCERTAE SEDIS Pinnularia prostrata (*Artis*)	Ironstone Bed (1)

CHAPTER VIII

ECONOMIC GEOLOGY

Water Supply

The public supplies for the large towns of this area are largely drawn from impounding reservoirs on the high moorlands along the western edge of the district. Having a comparatively high rainfall, and being sparsely populated, practically the whole of the moorlands constitute catchment areas for several large town supplies.

The borough of Halifax is supplied from Wadsworth Moors, while the Morley Corporation has a catchment reservoir on the moors to the south of the Calder valley. The large reservoirs on Soyland and Blackstone Edge Moors are jointly held by the Oldham and Rochdale Corporations, while Rishworth Moors and the northern slopes of Moss Moor supply the reservoirs of the Wakefield City Council at Green Withens and Ringstone Edge respectively. An additional reservoir is also in course of construction in the upper part of the Ryburn valley. To the south of this the Huddersfield Corporation obtains a small proportion of its public supply at the head of the Deanhead valley, and also on the eastern slopes of Wholestone Moor at Longwood reservoirs. The thickly populated areas around Dewsbury, Batley and in the Spen valley obtain their water mainly from moorland reservoirs to the south of the present area.

The water obtained from these gritstone moorlands is remarkably pure and soft, though it requires treatment with lime to neutralize the possibility of injurious effects due to the presence of peaty acids; these react on the lead pipes and in the past have endangered this valuable source of supply.

In addition to gravitational supplies, the Millstone Grits and Lower Coal Measure sandstones are of considerable importance as sources of underground water supply, and many of the mills, factories, breweries, etc. have their own supplies from wells sunk or bored to the various water-bearing strata. The water from the several beds of gritstone in the Millstone Grits is invariably very soft and free from impurities, and is consequently extensively employed in the washing and scouring processes in the spinning and weaving mills, and also in the numerous dye-works connected with the woollen and cloth industries.

A large number of borings have been made into the Millstone Grits, and in the majority of cases they have yielded a copious supply of excellent water. The relatively low porosity of the Millstone Grits is, however, a factor of considerable significance which should always be borne in mind in sinking operations, for in some cases a boring has been found to be almost dry after penetrating

a considerable thickness of massive gritstone. Where the grit is fissured or jointed abundant water is obtainable, but where the rock is close in grain and unjointed it does not yield any large quantity. The chances of success are also greater in faulted or sharply folded areas though it is not possible to say, from a knowledge of the surface geology, whether the rock at a particular site will yield water.

The lowest bed tapped is the Lower Kinderscout Grit which has been reached in some places in the Halifax and Huddersfield districts, and also in the Colne valley (see sections in Appendix I, pp. 189–196).

A number of wells in Halifax obtain water from the Middle Grits. Many years ago abundant water was obtained from the Rough Rock on which the town stands, but the deep cutting through that bed for the high-level railway, made about 1890, cut off much of the supply to wells farther down the dip-slope. Several of these were then deepened and good supplies were obtained from the Midgley Grit, for example, 34,000 gallons per day at Ramsden's Brewery and 6,000 per hour at Clark's Bridge.

Several factories at Elland, and also in the Colne valley at Slaithwaite, Linthwaite and Milnsbridge obtain a copious supply of water from the Middle Grits. The Huddersfield White Rock has proved a valuable horizon, but it is found to thin away rapidly under the east of Huddersfield, and consequently fails as a suitable source of water at Mold Green and Dalton. At Armitage Bridge and Honley to the south of Huddersfield, however, it yields a copious supply. A remarkable feature is the large proportion of sodium carbonate it sometimes contains; the following is an analysis of the water from a boring to this horizon near the southern margin of the sheet at Honley :—

Silica	0.56 grains per gallon
Magnesium Carbonate	0.36 ,, ,, ,,
Sodium Carbonate	38.92 ,, ,, ,,
Sodium Chloride	4.74 ,, ,, ,,
Sodium Sulphate	0.18 ,, ,, ,,

Hardness: Calculated equal to 0.47 grains of calcium carbonate per gallon.

The Rough Rock still gives good yields of soft water to the east of Halifax; the Brookfoot Dye Works near Brighouse get water from this bed (see Appendix for section). Several deep wells in the vicinity of Huddersfield also yield a considerable supply of soft water from the Rough Rock; others have had to be deepened as the Rough Rock has been found to be occasionally close-grained and free from joints, and consequently yields little water. A boring at Birkby obtains 10,000 gallons of water per hour from the Rough Rock, while three in Leeds Road, Huddersfield yield an average of 6,000 to 7,000 gallons per hour or 120,000 gallons per day.

As a general rule, the water from deep borings into the Coal Measure sandstones is appreciably harder than that obtained from

the Millstone Grits, and at Huddersfield it is of a character quite unsuitable for any purposes except cooling. A boring to the Soft Bed Flags at the New Peace Pit, Highfield Fireclay Works in Leeds Road yielded a large supply of water. As the following analysis shows, however, it was extremely hard and highly ferruginous.

Silica	...	...	...	...	...	2.10	grains	per gallon
Ferric sulphate	...	...	...	...	...	17.50	,,	,, ,,
Calcium sulphate	...	...	...	...	...	51.00	,,	,, ,,
Magnesium sulphate		...	...	...	...	20.37	,,	,, ,,
Sodium sulphate	...	...	...	...	...	27.26	,,	,, ,,
Sodium chloride	...	...	...	...	...	9.68	,,	,, ,,

Hardness: Calculated equal to 54.47 grains of calcium carbonate per gallon.

The Elland Flags supply several wells in Brighouse; at the Wire Mills 28,000 gallons per hour is obtained. At Low Moor a good yield of soft water is got from these beds. The Elland Flags also yield a plentiful supply of soft water at Kirkheaton, Almondbury and Fenay Bridge. A recent boring to these flags at Greenside, Dalton, two miles east of Huddersfield has an average yield of from 12,000 to 15,000 gallons per hour.

The Clifton, Birstall and Thornhill rocks have all been utilized to some extent at, or a little to the east of, their outcrops. The first yields 7,000 to 8,000 gallons per hour at Gomersal.

Water from old coal workings usually contains much iron, but can be utilized after treatment. A dyeworks near Hunsworth uses water from old coal mines belonging to the Low Moor Company; it is aerated by compressed air, treated with lime and then filtered, the iron being precipitated; the supply is very large.

For some industrial purposes the water from the streams and rivers is suitable and is largely utilized.

In many places within the present area springs occur, especially where the more important beds of grit are faulted against an impervious mass of shale. In some cases, as at Soyland, they are of sufficient importance to supply a village. The waters are sometimes strongly alkaline or ferruginous and have in the past been in repute for medicinal purposes. In the early part of the nineteenth century important medicinal springs or 'spas' existed at Slaithwaite in the Colne valley and at Lockwood near Huddersfield, but both are now disused.

Ironstone

Layers of clay-ironstone nodules occur frequently in the Coal Measures but it is only in the shales just above the Black Bed Coal that they are sufficiently abundant to have been worked specially. A detailed section of these beds has already been given (p. 58). The nodular beds are the more valuable; thin continuous layers occur a little higher, but are inferior, and if mixed to any extent with the other ores are said to make an inferior quality of iron. The working measures are usually divided into two parts, the Black Bed Iron-

stone below and White Bed above; as mentioned above, each band in the series has its own name or names. The yield per acre is from 1,000 to 1,200 tons of best ore. Around Low Moor and Bowling the ores are exhausted and they are no longer raised at Churwell and Hunslet. They are got chiefly at Wyke, Scholes and Beeston and incidentally, but in smaller quantities, by some of the collieries working the Black Bed Coal. It is a usual practice to obtain the Black Bed Coal by a first and the ironstone by a second working. Great care is taken that the ore is thoroughly cleaned of adhering shale before it is calcined. The ironstone is spread on the surface of the ground to weather and is repeatedly turned and cleaned. The ore is calcined in a Gjers continuous kiln.

The Low Moor White Bed mines are clay-ironstones varying in colour from a light brown-grey to a black-grey. The Black Bed mines are all dark blackish-grey clay-ironstones, compact and hard. There is no marked difference in the composition of the two mines except in the proportion of silica, which is higher in the White Bed than in the Black Bed. Analyses give the percentage of metallic iron as from 29.15 minimum to 30.79 maximum. The finished Low Moor iron has obtained a world-wide celebrity; the first quality contains as much as 99.75 per cent. iron with .104 silica .041 phosphorus and only a trace of sulphur.[1]

The Low Moor and Bowling Iron Works owe their existence to the Better Bed Coal (p. 176), which was first used for smelting imported ores. Low Moor began in the first half of the eighteenth century and Bowling in 1784. Iron was made in this neighbourhood in Roman times; heaps of cinders have been found in which were imbedded coins of Carausius, Diocletian, Constantine and Constantius, but the fuel used was probably charcoal. In the 12th century the monks of the many Yorkshire religious houses were getting and smelting iron ore in many parts. Soon after the middle of the 12th Century 'Ralf Fitz Nicholas gave to the monks of Fountains in his wood of Bradley, all the dead wood required for their smelting and for charcoal, and whatever iron ore they could find.' The site of these works was close to the River Calder.[2] The ores here would be those above the Black Bed Coal corresponding to the Low Moor Beds.

The Tankersley Ironstone.—This band of ironstone has been more extensively worked in the country to the south than within the area of the present one-inch map. In the country between Thornhill, Flockton and Emley it occurs at about 20 ft. above the Flockton Thick Coal (see page 99); about 12 to 15 in. of ironstone occurs in three courses in about 6 ft. of shale. The yield is stated to have been 2,000 to 3,400 tons per acre. No published analyses appear to be in existence, but the lime percentage is probably high

[1] 'Special Reports on Mineral Resources' (*Mem. Geol. Surv.*), vol. xiii, 'Pre-Carboniferous and Carboniferous Bedded Ores,' 1920, pp. 40–43.
[2] 'Victoria County History of Yorkshire,' vol. ii, 1912, p. 343.

on account of the Carbonicola shells.[1] In the middle of the twelfth century the Tankersley Ironstone was being somewhat extensively worked by the monks from Rievaulx and Byland Abbeys at Flockton and Emley. Charcoal was employed for smelting the ore, and 'bloomeries' or primitive forms of furnaces existed at Flockton and at Bentley Grange, one mile to the east of Emley. The industry reached its fullest development in the thirteenth century, and gradually fell away later. At the end of the sixteenth century there is a record of the Tankersley Ironstone being worked in the vicinity of Bentley Grange, but shortly afterwards the workings were abandoned and have not since been reopened. Around Bentley Grange, Furnace Grange and Flockton Mill there are several acres occupied by the overgrown bell pits close to the outcrop of the ironstone, which bear witness to the extent of these primitive iron-ore workings in mediæval times.[2]

Coal

The thicknesses and characters of the various coal seams, together with the associated measures have been given in some detail in the stratigraphical accounts in Chapters III and IV. Some mention has also been made of the extent to which they have been worked.

The earliest references to the coal-mining industry in this district are to be found in legal documents belonging to the thirteenth century. In 1274 Richard le Neyler gave sixpence for license to dig 'sea-coals' at Hipperholme during the year for his smithy[3]; the seam worked was probably the Hard Bed. The same license was held by the same 'nailer' in 1308, and in 1335 Richard Gibson was fined for digging coals at Hipperholme without license. The pits were presumably shallow, but water seems early to have been a trouble: in 1378 "Johannes de Handsworth Woodhouse venit juxta unum colepitte et subita per infortuniam cecidet in puteum unde submersus fuit."[4]

References become more frequent in the fifteenth and sixteenth centuries, and in the records of the Court Leets in connexion with the Manor of Wakefield, there are allusions to the digging of coal at Flockton in 1515.[5] It was not until the advent of the steam engine however, together with its general employment for pumping and winding that the coal industry grew to any large dimensions in this district. The present area probably reached its fullest development some sixty to seventy years ago when there were no less than one hundred and twenty separate collieries in the vicinity of Halifax, Huddersfield and Dewsbury, while the total production of coal from

[1] 'Special Reports on Mineral Resources' (*Mem. Geol. Surv.*), vol. xiii. 'Pre-Carboniferous and Carboniferous Bedded Ores,' 1920, p. 44.

[2] A full account of the Tankersley Ironstone Workings with a sketch map illustrating their occurrence is given in Wray D. A., 'The Mining Industry in the Huddersfield District,' *Huddersfield Museum Handbook, No. VI*, 1929, pp. 1–24.

[3] *Yorks. Archaeol. Soc.* (*Records Series*), vol. xxix, p. 26, quoted in 'Victoria County History of Yorks.,' vol. ii, 1912, p. 338.

[4] Lister, J., 'Coal Mining in Halifax' in Wheater, W., 'Old Yorkshire,' 1885.

[5] Wray, D. A., *op. cit.*, pp. 13–16.

the corresponding area was upwards of one third of the entire production of the county of Yorkshire. This area however, except along the south-eastern margin, is reaching exhaustion, the majority of the more valuable seams having been worked out.

The main features of, and the principal uses for which the seams are, or have been worked is summarized below:—

The Soft Bed is of fair quality and has been largely worked at comparatively shallow depths; its name of the 'coking coal' is due to its use for making soft coke for smithy purposes: it is a fair engine coal or second class household. Recently it has been found to rival the Better Bed Coal as a sulphur-free fuel, and it is now being sought as a substitute for that seam.

The Hard Bed on the contrary is decidedly sulphurous owing to the amount of pyrites present; it is chiefly employed as an engine coal, being only used locally for household purposes. Much of its use has been for works where the ganister or fireclay underlying it has been the primary factor. Formerly the lumps of pyrites found in the coal and the roof were of value for the manufacture of sulphuric acid, and this by-product assisted the working of the coal to some extent.

The Thirty Six Yard or Hard Bed Band Coal is utilized in works where its fireclay is being mined.

The Forty Eight Yard Coal was worked long ago at Nab End, Boothtown and under the hill above Scout Hall, Shibden Dale; it was 10 to 14 in. thick and was used as a house coal.[1]

The Better Bed Coal has long been famous as yielding a pure sulphur-free coke for metallurgical purposes, but is nearly exhausted; it has been worked where only 1 ft. thick. Analyses of the hard and soft parts of the seam, supplied by Messrs. Robert Heath and Low Moor, are as follows:—

	Hard	Soft
Fixed Carbon	83.45	84.03
Sulphur	0.41	0.41
Ash	1.08	1.75
Moisture	2.08	1.72
Hydrogen	5.35	4.98
Oxygen and Nitrogen	7.63	7.11
	100.00	100.00

The yields of coke are 66.8 and 69.2 per cent. respectively: the ash is white in colour. The following percentages of sulphur show the uniformity of the seam:—[2]

Sample taken from forge, Bowling	0.54
'Hunting' Coal, Bowling	0.38
'F' Pit Coal, Bowling	0.42
Holme Pit Coal, Bowling	0.46
Wibsey Pit (J. Tordoff)	0.57
" " "	0.52

The Black Bed is now the most important seam in the area to the north of the River Calder and is being worked at the majority

[1] Spencer, J., 'Halifax Coal Strata,' *Proc. Yorks. Geol. and Polytech. Soc.*, vol. xiii, 1898 pp. 302–310.

[2] 'Geology of Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1878, p. 130.

of the larger collieries. It is usually a soft friable coal, dull in appearance, and burning to a red ash. It furnishes a household coal of moderate quality, but is more used as an engine coal in the numerous mills. Not infrequently it is a good gas coal, but for household purposes it usually requires careful screening. Around High Burton and Kirkburton the lower part is a stone coal and was used for gas, while the upper part is an engine coal. Some good cannel has been obtained at Dewsbury Moor and Mirfield, but towards Farnley the Stone Coal or Johnnies is of no value and decreases the value of the seam. It yields a hard coke but is rather sulphury.

The Shertcliffe Coal and its equivalents have been, and to a small extent are being, worked as an engine coal. The Churwell Thin gives a good coke for ironworks in some parts, but near Tong is too sulphury. The Beeston is said to give a good malting coke.[1] The stone coals at Blakcup, Popplewell and elsewhere were formerly used for gas making at Bradford.

The Blocking Bed, though inferior to its southern equivalent, the Silkstone, has been worked to a considerable extent. It is used both for household and engine purposes.

The Wheatley Lime or Middleton Eleven Yard is a soft tender coal; it has been worked to some extent, though it usually deserves its alternative name of the Mucky Bed; the ash content is high. It is worked as a steam coal at Howley Park.

The New Hards, Cromwell or Middleton Main is on the whole a good coal with little ash; the best part is a good house coal and was used also for gas; engine and smithy coals were largely produced; malting coke was also made. Over a large part of the area it is worked out. The inferior 'whetstones' at the base are pyritous.

The Green Lane or Middleton Little is being worked as a second-class coal in the Grange Moor and Flockton districts. It has also been worked in the north east of the present area, and was a good coal at Howley Park. It was sometimes used for making coke for iron smelting.

The Old Hards or Brown Metal Coals have been practically exhausted, being of considerable value where not washed out by the Birstall Rock (p. 109); the greater part was usually a bright coal leaving only a small amount of white ash, but the value, of course, varied with the character of the seam or seams. The Old Hards was a first-class house coal, hot and clean.

The Flockton Thin has been worked to a considerable extent giving an excellent house coal with little ash which is reddish brown in colour. In the north as the Adwalton Black Bed it was somewhat inferior, with a higher ash percentage.

The Flockton Thick or Adwalton Stone Coal has been worked to a large extent, mainly for the sake of the cannel, which in this district may be regarded as exhausted. It was of the greatest value for gas-enrichment when gas was used directly as an illuminant, but the introduction of the incandescent mantle killed the

[1] Holgate, B., 'Minerals of Yorks. Coalfield as applied to manufacture of Iron,' *Proc. Geol. and Polytech. Soc. W. Riding Yorks.*, vol. vi, 1879, pp. 137–148.

demand. It was also tried as an oil-producer; the yield was only 20 to 24 gallons of light oil, but that was many years ago [1] and modern methods would no doubt give a much higher figure. The cannel left an excellent coke containing only about 9 per cent. ash. The bituminous parts of the seam were only second-class, and were used locally for house and engine-purposes: the ash content was high.

The Joan Coal, though very constant in occurrence is not fit to work except to the east of Dewsbury: there it is soft and tender but has been worked, wherever thick enough, as a house coal of somewhat poor quality.

The remaining coals are present over such a small area that they call for no comment here.

Ganister and Fireclay

While fireclays have been worked at several horizons in the Lower Coal Measures, ganister is practically confined to the beds next below the Hard Bed and the 36 Yard Coals respectively. The topmost beds of several of the Millstone Grit rocks, beneath coal seams, are often of a ganister-like character but though worked in the country to the south [2] none of these has so far been worth working within the present area.

At Ambler Thorn Fireclay Works the clays below both the Hard Bed and the 36 Yard Coals are used; 'Black pottery' is manufactured at the Soil Hill Pottery from the Hard Bed fireclay; the products are chiefly flower-pots, bread-jars, pitchers and bowls.

At the Cinder Hill Works, Siddal, near Halifax, Joseph Morton and Co. now make little use of the ganister below the Hard Bed, the fireclay being now more valuable; the ganister is not persistent, varying from 2 ft. 6 in. down to nothing.

The ganister or ganister-like rock below the 36 Yard Coal is here as much as 20 ft. thick and is worked open-cast and by day-eyes.

A pit to work the 36 Yard ganister was being opened at the time of the re-survey at Ashday, near Cromwell Bottom: the rock was already proved to a depth of 15 ft. and was stated to be 30 ft. thick.

At Siddal the fireclay of the Hard Bed is 3 ft. 6 in. thick, the upper 2 ft. being the best; that of the 36 Yard Coal is 3 ft. 6 in. to 7 ft.; both are largely worked for firebricks, etc., the latter is also worked for firebricks, pipes, etc., at the Ashgrove Fireclay Works at the east end of Elland Park Wood and at the Ashday Works, quarter of a mile further east. Here the clays of the 48 Yard and the 80 Yard Coals have both been tested; the first is described as an inferior fireclay and the latter as a vitreous clay.

Allen's Glazed Brickworks at Sunny Bank south of Hipperholme mine the 36 Yard clay at a depth of 142 ft.; there is 4 ft. 6 in. of top clay and 13 in. of bottom (inferior) clay. The same bed is worked at Brooke's Colliery (Walter Clough) quarter of a mile to the south-

[1] 'Geology of the Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1878, p. 315.

[2] 'Special Reports on Mineral Resources' (*Mem. Geol. Surv.*), vol. vi, 'Refractory Materials: Ganister etc.' (Resources and Geology) 2nd Ed. 1920, pp. 28, 29.

east. The clay is again 4 ft. 6 in. : the galliard or ganister 12 ft. below varies from 2 ft. 6 in. to 8 in. and contains 92% silica.

The Leeds Fireclay Co. have works at Beacon and Ellen Royd, Northowram, and at Shibden Hall, Southowram. The first two are worked by day-eyes and the third also by a shaft. The fireclay worked is that of the 36 Yard Coal, 3 ft. 9 in. to 4 ft. 9 in. thick. Refractory, sanitary and glazed goods are made. To the east and south of Elland the thick bed of fireclay associated with the 36 Yard and Hard Bed Band Coals is extensively worked for the manufacture of firebricks and other refractory goods (for detailed sections see pp. 68–71). At the Calder Fireclay Works which adjoin the L.M.S. railway and the River Calder, the 'Elland Blue Clay' underlying the 36 Yards Coal is 8 ft. thick, and is employed for the manufacture of firebricks and sanitary ware.

At New Hall Fireclay Works, one mile east of Elland Church, Messrs. Luty & Co. work the fireclay underlying the Halifax Hard Bed Coal, which is referred to as the 'White Clay' to distinguish it from the fireclay associated with the 36 Yard and Hard Bed Band Coals.

The Victoria Fireclay Works at Elland Upper Edge are worked by Messrs. Hawkyard & Co., and here the Blue Clay in places attains the abnormal thickness of 18 ft. Laterally, however, it sometimes disappears altogether being replaced by 12 ft. of hard ganister rock. The Blue Clay occurs between the 36 Yards Coal above and the Hard Bed Band Coal below, and the fireclay underlying the latter which is 4 ft. thick is referred to as 'Seggar Clay.' It is however inferior in quality to the 'Blue Clay.'

The Storth Brick Works at Elland Edge which adjoin the Huddersfield main road are worked by Messrs. D. Sharratt & Sons., Ltd. Here the Hard Bed fireclay or 'White Clay' averages 5 ft. 6 in. in thickness, while the 'Blue Clay' has an average thickness of 7 ft. Both clays are employed in the manufacture of firebricks, pipes, and a variety of refractory ware.

The Blackley and Woodman fireclay works belonging to Messrs. S. Wilkinson & Son, are about one mile to the south of Elland. Here the several beds worked are the Hard Bed Band Coal and Clay, the Hard Bed Coal and Clay, and the Soft Bed Coal and Fireclay. Detailed sections are given in Chapter III, (pp. 64–71). Firebricks, coke-oven bricks, refractory goods and sanitary ware are manufactured here.

In Grimescar Wood, one mile to the north of Huddersfield, the Hard Bed Band fireclay was formerly mined. The Leeds Fireclay Company also formerly worked the Hard Bed Band and Hard Bed fireclays at Fieldhouse, to the north-east of Huddersfield. At the New Peace Pit, the beds ran as follows :—

	Ft.	in.
Blue shale	—	
Hard Bed Coal	2	4
Ganister	0	8
Fireclay	6	0

The lower 3 ft. of clay is inferior and not worked.

The fireclay which overlies the Rough Rock and forms the seat-earth of the Thin or Pot Clay Coal is of some economic importance in the Huddersfield district. At Salendine Nook is has been worked continuously since the sixteenth century for the manufacture of common pottery ware.[1] The same bed has also been employed for the manufacture of firebricks and refractory ware. At Lockwood, one mile east of Huddersfield it averages 4 ft. in thickness, and is stated to be of a very refractory nature, showing on analysis 72 per cent. of alumina and 25 per cent. of silica.

In the neighbourhood of Farnley the seat-earth of the Better Bed is a valuable fireclay and is worked extensively, though mainly to the east and north-east of the area of the present one-inch map. It is used for a variety of purposes, such as gas retorts, firebricks, coke-oven blocks, furnace-linings, terra-cotta and sanitary goods. At White's Dayhole No. 2, Farnley Iron Works the section is:— Better Bed Coal 1 ft. 8 in., shale (fireclay) 0 to 1 ft. 2 in., fireclay 7 in. to 4 ft. The 'shale' was once rejected as useless, but analysis has shown it to be a valuable fireclay.

The following are analyses of fireclays used in the district and mentioned above:—

	1.	2.	3.
SiO_2	46.77	70.26	64.34
TiO_2	1.33	1.21	1.33
Al_2O_3	34.30	18.00	29.47
Fe_2O_3	1.80	.96	2.67
MnO	trace	trace	
CaO	.31	.15	.27
MgO	.49	.30	.51
K_2O	.58	.41	1.18
Na_2O	.05	trace	.20
Li_2O	trace	nt. fd.	
H_2O at 105°C.	2.17	1.37	
HO_2 above 105°C.	11.89	6.31	
P_2O_5	trace	trace	
FeS_2	.46	.75	
Organic Matter	.17	.41	
CO_2	.02	.07	
Total	100.34	100.20	99.97
Loss on ignition...	14.55	8.59	10.34

No. 1. 36 Yard Bed, Halifax, Analysed by R. Sutcliffe. Geol. Surv. Lab. No. 689.
No. 2. Hard Bed, Halifax. Lab. No. 688.
No. 3. Better Bed Fireclay, Wortley; analysis from *Journ. Soc. Glass Technology*, vol. iv, No. 14, August 1920, p. 169.

[1] Wray, D. A., 'The Mining Industry in the Huddersfield District,' *Huddersfield Museum Handbook, No. VI*, 1929, p. 16.

Natural Gas and Oil

Reference has already been made to the former production of oil from the Flockton Thick Coal (see page 178); small traces of oil and natural gas are in fact not infrequent in the Carboniferous Rocks of this district. In boring for water in the Millstone Grits these products are sometimes encountered, and one of the most interesting cases within recent years occurred in a deep boring for water at the Prospect Mills, Longwood.[1] The boring was carried into the Pule Hill Grit, and yielded a copious supply of water. During the progress of the boring a compact grit (Huddersfield White Rock) was met with at 186 ft. and yielded large quantities of natural gas under high pressure. Unfortunately it took fire and did considerable damage before being successfully plugged. The gas was eventually conducted to the boiler house and for several weeks supplied two large fires before any considerable diminution occurred. The gas was analysed by the Hempel Method by Mr. G. Lawton of Huddersfield Technical College with the following result:—

Methane	60.77
Hydrogen	26.67
Nitrogen	12.99
Carbon Dioxide	0.12
	100.55

Oxygen, Carbon monoxide and unsaturated hydrocarbons were tested for, but were absent.

A deep boring for water at Messrs. L. B. Holliday's Dye Works, Deighton, also yielded a considerable quantity of inflammable gas from the same geological horizon, viz., the Huddersfield White Rock. At Birstall a boring encountered gas in the Birstall Rock (Middle Coal Measures).

Peat

Although a thick deposit of peat covers wide expanses on the moorlands, particularly in the south-western part of the area, it has been little employed for economic purposes. On Buckstones and Slaithwaite Moors it is dug and dried and employed on a small scale for fuel, but its use is purely local. Within recent years a scheme has been considered to dig the peat somewhat extensively on Slaithwaite Moors with a view to its employment for medicinal purposes, but up to the present this has not materialised.

Building Stones, Flagstones, etc.

The beds of grit, sandstone and flags which cover a considerable part of the area have been quarried in many places. Many of the sandstones of the Millstone Grits, Lower and Middle Coal Measures, more particularly the Scotland Flags, Rough Rock, Elland Flags and Thornhill Rock, have a high reputation as building stones and

[1] Woodhead, T. W., *Annual Report Huddersfield Nat. Soc.* 1917–1918, p. 13.

flagstones. The older parts of the principal towns such as Halifax and Huddersfield are largely built of Rough Rock, while the Elland Flags or their equivalents have been extensively employed in both Bradford and Leeds. Many of the moorland villages are also built from the local grits and sandstones of the Millstone Grits, while to a lesser degree many of the sandstones of the Coal Measures have been employed in the lowland villages.

The Kinderscout Grit.—Owing to its massive nature and coarse grain, the Kinderscout Grit is little quarried for building purposes, though it was employed locally in the past, and there are numerous large disused quarries throughout the area. Prior to the extended employment of cement the Kinderscout Grit was quarried in large blocks for engine beds and other purposes where stone of a massive nature was required. At the present time it is intermittently worked by the Corporation Waterworks Departments for the construction of reservoir embankments and other constructional works where large blocks of stone are required.

There are several large disused quarries in the Kinderscout Grit on Erringden, Soyland and Blackstone Edge Moors.

Within recent years the Kinderscout Grit has been quarried for the construction and repair of reservoir embankments at a quarry close to the Rocking Stones and at Derby Delph quarries on Rishworth Moors. Each of these quarries shows about 30 ft. of massive thick-bedded gritstone.

The Scotland Flags and Readycon Dean Series.—In the northern part of the sheet where this subdivision consists largely of massive flagstones it has been somewhat extensively quarried in places; the most important locality is Midgley, where the Scotland Quarries, from which the series is named, are worked by J. Schofield and Son.

There are several quarries close together, varying in depth up to 100 ft., but the upper 60 ft. is inferior and mostly waste; parts of it are raggy and the flags are often strongly ripplemarked and have numerous worm-castings on the bedding-surfaces. The lower 40 ft. is a massive fine-grained sandstone, blue-grey where unweathered. It is sawn into ashlar, setts, sills and paving flags.

Large quarries in this bed farther west are all disused.

In the Colne valley it includes a bed of hard ganister rock which was formerly quarried on a small scale close to the southern end of Varley Road, Slaithwaite.

The Midgley or Pule Hill Grit.—This bed which is frequently a massive gritstone has been quarried in the past in numerous localities. There are large disused quarries at Lumb, Spa Green, and Hanging Stones Wood, Ripponden. It is being quarried at the present time in large blocks for building purposes at the Park Edge or Clock Face quarries, Pike Law, Rishworth. One of the largest flawless blocks extracted has been utilized as a War Memorial in the centre of Rishworth village. At the Wholestone Quarries,

Krumlin, the Pule Hill Grit is very coarse-grained and massive, and is intermittently employed for reservoir embankment work.

In the Colne valley the Pule Hill Grit has been quarried at Golcar, Linthwaite and Slaithwaite. At the last-named locality two quarries are still being worked for building stone.

The Nab End Sandstone and Beacon Hill Flags.—The Nab End Quarries in the Nab End Sandstone at the northern extremity of Blackwood Common have been largely worked, but at the time of the re-survey only two men were employed: about 25 ft. of thickly-bedded medium-grained grit is seen. The main output is setts and walling-stone, but building blocks can be produced when required locally.

The Nab End Sandstone is quarried on a small scale at West Green, half a mile east of Luddenden Foot. There is 35 ft. of pale massive sandstone, rather flaggy at the top, used mainly for setts. The same rock is being worked on a small scale between Sowerby Bridge and Warley Town.

Bowood Quarry in the Nab End Sandstone between Triangle and Lumb shows 35 ft. of fine flaggy sandstone, somewhat shattered. J. Shaw and Co. produce setts and walling-stone.

At Sowood to the north of Outlane the Beacon Hill Flags have been worked in several quarries, but in each case the flagstones are strongly current-bedded. On the south side of the Colne valley a thick bed of ganister rock appears in the upper part of the Beacon Hill Flags. This is at present being worked in the Meltham district to the south of the present area.

The Warley Rock, Barkisland Flags or Huddersfield White Rock.—Around Barkisland, where this subdivision consists wholly of flagstone, the bed was formerly worked for flags, both for roofing and paving purposes. Their use has, however, been entirely superseded by slates, artificial materials and flagstone brought from other districts. On the opposite side of the Blackbrook valley the stone is of a more massive nature and has been worked and employed locally for building purposes. (For details see p. 44).

The Huddersfield White Rock has been quarried in the past at Outlane, Golcar and Linthwaite and much employed for local building purposes. There are large disused quarries at Scar Wood, Golcar, and also off Cowslersley Lane, Linthwaite. A large proportion of the older buildings in the Colne valley are built of the whitish freestone from this horizon.

The Rough Rock and Rough Rock Flags.—With the exception of Crosland Hill and Wholestone Moor districts, to the south-west of Huddersfield, the Rough Rock, owing to its massive nature and the consequent high cost of quarrying, is now seldom worked; but large disused quarries occur throughout the district. The flagstone series which underlies the Rough Rock and is known as the Rough Rock Flags is, however, worked somewhat extensively. The flags vary greatly in thickness and in some places are absent altogether.

At West End, Halifax, on the Rough Rock scarp near Cote Hill D. Dawson and Co. are working the Rough Rock Flags. About 80 ft. are exposed but only the bottom 10 ft. are of much value for making setts, etc., the rest being poor and often current-bedded.

The quarries in North Dean Wood, facing the Calder opposite Copley, where the Rough Rock Flags are exceptionally well developed are disused.

Quarries in the Rough Rock Flags around Mount Tabor are all disused, but those on either side of the road from there to Moor End are active; a typical section is shale and rag 20 ft., even-bedded flags with thin partings up to 40 ft. Setts are the chief product, but paving stones are also produced.

In the district known as Upper Greetland, to the west of the village of Greetland, the local representative of the Rough Rock Flags is being quarried, the material being described in the trade as 'Greetland Stone.' The working is now confined to two principal quarries, Greetland Nook and Moor quarry, and these each reveal about 30 ft. of flaggy gritty sandstone. The flaggy nature is very strongly pronounced in the lower beds. The stone is worked for flags and building stone. Although used locally, chiefly in the Halifax district, smaller quantities are sent to distant parts. Greetland Church was in part built with stone from the Moor quarries, and also in part from the more massive beds of the Rough Rock proper on Norland Moor.

The Rough Rock Flags are being worked on a small scale at Longwood Edge, while there are also quarries working the lower beds of the Rough Rock on Wholestone Moor.

The extensive plateau of Crosland Moor to the west of Huddersfield consists of Rough Rock, and here there is a large number of important quarries which still form one of the main centres of stone quarrying in West Yorkshire. The town of Huddersfield together with the adjoining villages are very largely built of 'Crosland Hill Stone' and there is also a considerable export of the stone to more distant centres. The majority of the public buildings in Huddersfield are built of this material, which appears to weather well and to be admirably adapted to the district. The exception is in the case of Huddersfield Parish Church where it appears to have weathered badly, but this is duc to the frequent error of laying the stone oblique to the bedding planes. The beds worked at Crosland Moor belong to the Rough Rock proper but are even-grained freestone, not a true gritstone. An average section of a working face in the main quarries is as follows:—

	Ft.
7. *Baring*; weathered grit, sand, etc.	up to 12
6. *Greet*; or grit	,, 18
5. *Top Ashlar* or *freestone*	,, 50
4. *Tiger* and *mares* . . . average 2 ft.: in places ...	,, 40
3. *Flat-bedded ashlar* or *bottom freestone*	,, 15
2. *Tiger* and *mares* (sometimes absent)...	,, 12
1. *Flatstone* or *flag-rock*	,, 12

Resting on bluish-grey shaly mudstone.

Bed (1) is the local representative of the Rough Rock Flags and is seldom worked except for flag stones. Beds (2), (4) and (6) consist of coarser grained gritstone and are, among other disadvantages, too tough to work. The best building stone comes from Bed (5); both this and Bed (3) are worked. Although the 'mares' or 'mare-balls,' which consist of spherical (and often ferruginous) concretionary masses, are of most frequent occurrence in the *Tiger* beds they are by no means confined to them, but are occasionally found in the freestone; when they become too frequent such a working-face has to be abandoned. The stone is usually worked in large open quarries, but in one case where the overburden has proved too thick and expensive to remove mining on a small scale has been resorted to.

The Soft Bed Flags.—These beds are strongly developed around Huddersfield (see p. 63) and were formerly quarried in the Marsh and Gledholt districts. All the quarries are now disused and the majority are filled in and built over.

The Elland Flags.—The Elland Flags are still being fairly extensively quarried in the district. Around Northowram, Southowram, Hipperholme and Brighouse are numerous quarries working these beds.

On the plateau around Southowram the Elland Flags have everywhere been quarried. The chief active quarries belong to S. Marshall and Sons, and produce flagstones and some setts. A typical section at New Farm Quarry south of the village is: Poor Flags 10 ft.; Flags 4 to 8 ft.; Mudstone passing down into flags 8 to 16 ft.; Good Flags 30 ft. (not bottomed). The lowest part is largely worked by galleries. Quarries near Hill Top belong to the same firm.

Around Northowram there are many large quarries, mostly disused; the average section is flags and shale, mostly useless, 20 ft. on 25 ft. of flagstone. The outlier between Pule Hill and Holmfield contains good flags and building-stone, and much of the hilltop has been worked over. Quarries belonging to S. Smith and Sons and other firms show up to 70 ft. of flags and shale with courses of sandstone resting on massive sandstone seen to 12 ft. Flags are got from various horizons and good building-stone and road-setts from the bottom bed.

Between Hipperholme and Hove Edge the Elland Flags have been so largely quarried in the past and are being so actively exploited now that exhaustion may be said to be within sight. The quarries are owned by Brookes and Co., Ltd., Hipperholme, who have a varied output but are best known as the producers of 'Nonslip' and other artificial stone for paving (Plate VA). For this purpose only the best part of the Flagstone is used. Natural flags are also produced, and in addition setts, ashlar, sills, bricks, pipes, etc. Some of the quarries exceed 100 ft. in depth, the stone under considerable cover being the best. Quarries are being opened farther south on the outskirts of Brighouse.

Round Rastrick the Elland Flags have been quarried in the past, but were to a large extent mined by shafts and galleries. One such mine on the south side of the village is working; the shafts are round about 36 ft. deep and the good stone about 12 ft. thick. The old quarries in these beds farther south around Cowcliffe are disused.

The Elland Flags, in their type area at Elland Edge, have been very extensively quarried in the past. At the present time they are being worked in large quarries about 100 ft. deep. The upper 60 ft. consists largely of flagstone, no longer worked, while the lower 40 ft. consists of freestone or ashlar, though this bed is here and there entirely replaced by flagstones. At some places the ashlar is at present being quarried under the tips of the old and disused flagstone quarries. The bed of ashlar or freestone is very even-grained and rests directly on shaly mudstone. The material is worked as a building-stone. 'Mareballs' or 'aquaspires,' as they are termed locally (see p. 24), may render a working-face useless.

The Elland Flags were formerly worked around Almondbury to the south of Huddersfield, but their employment as a building material has now been entirely superseded either by 'Crosland Hill Stone' or bricks.

A characteristic feature of the district, especially where the Elland Flags occur, is their former extensive employment as boundary fences. This has been commented upon in the past by numerous writers visiting the district; Robert Brown in 1799 records that, "We observed some fences of a very uncommon kind in the neighbourhood. Large flagstones of three feet height, set upon their end, are fastened in the ground, which make a fence both complete and agreeable. We cannot speak to the expense, but as stones of that kind are here in plenty; we suppose a fence of this kind will be comparatively cheap."[1]

The Grenoside Rock.—The Grenoside Rock is an even-grained gritty sandstone which is well developed at Highburton and to the north of Farnley Tyas, but it is now no longer quarried in this district. There are numerous extensive quarries, however, from which the stone was formerly obtained for local building purposes. At Farnley Bank, to the south of Almondbury, the bed of sandstone below the Grenoside Rock, which consists of a bluish fine-grained freestone, is on the horizon of the Elland Flags; it is stated to have been much preferred to the Grenoside Rock itself and has been used with good effect in Almondbury.

The Clifton Rock.—The quarries in the Clifton Rock at Clifton and Bradley are disused. One near the south-eastern margin of Bradley Park, north-west of the village, shows 25 ft. of hard white evenly-bedded sandstone and produces setts and occasionally building-stone.

[1] Brown, R., 'General View of the Agriculture of the West Riding of Yorkshire,' London, 1799, Appendix, pp. 16–17.

Farther north it has been largely used for local purposes, many small disused quarries being visible: but the rock is too variable to be exploited on a large scale.

The Falhouse Rock which overlies the Blocking Coal is well developed in the Whitley district and was formerly quarried on a small scale for building purposes.

The sandstone above the Lime Coal is quarried for walling-stone on the south side of Heckmondwike, near where the Wortley Line crosses the Cleckheaton Branch Railway.

The Lepton Edge Rock is very variable in character, and has only been employed locally for walling and other minor purposes.

The Birstall Rock.—Although extremely variable in character the Birstall Rock has been somewhat extensively quarried in the past, particularly near Birstall, Batley and Batley Carr. It contains many ironstone balls which spoil the appearance of the rock and make it difficult to work; it does not weather satisfactorily and all the workings are now disused.

The Birstall Rock was formerly quarried on a small scale at Grange Moor and Flockton (see p. 111).

The Thornhill Rock.—The Thornhill Rock is one of the most important sandstones in the Coal Measures and is being worked on a large scale to the south of Bruntcliffe, around Morley and to the north of Dewsbury. In the Morley district it constitutes an excellent freestone and is quarried, often in very large slabs, for constructional and other purposes. In the Thornhill district it is no longer worked, though many of the local churches and buildings in this material suggest that if the stone is carefully chosen it constitutes an admirable and durable building-stone.

The Horbury Rock.—This bed has been quarried in the past for building, walling, etc., though it appears to be much inferior to the more massive and even-grained Thornhill stone.

Clays for Brick-making

The material employed for ordinary brick-making is usually termed a clay or shale, though more correctly it constitutes a shaly mudstone. Thick beds of mudstone occur throughout the Millstone Grits and Coal Measures, and provided they are fairly free from lime they appear to be well suited for the manufacture of common bricks. Shales in the Millstone Grits have been worked somewhat extensively for the manufacture of ordinary bricks at Linthwaite and other places in the Colne valley. At Bailey Hill, Halifax, on the east of the Hebble and opposite the railway station the shales above and below the Soft Bed Coal are ground for making red bricks. Siddal Brick Works, on the same geological horizon, one mile to the south, are now disused.

To the north of Huddersfield at Birchencliffe the shales underlying the Soft Bed Flags are also being worked for the manufacture of common bricks.

At the Elland Fireclay workings (see p. 70) the Hard Bed Band or 36 Yard Coal and fireclay is overlain by a thick series of shaly mudstones. Much of this material has to be removed as overburden in quarrying the fireclay and is extensively employed in the manufacture of common red and blue bricks.

At Brown Royd Clay Works, Mold Green, near Huddersfield, the shales overlying the 80 Yard Coal are being quarried for brick-making. To the south of Brighouse railway station, at the Brighouse Brick Company's pit, the mudstones between the upper and the main bed of the Elland Flags are being quarried and ground for a similar purpose. The thick series of shaly mudstones which overlie the Better Bed Coal appear to be eminently suitable for brick-making and are quarried in several places. One of the largest is the Spa Green Brickworks at Cowmes, near Lepton.

At Taylor Hall Brickworks, on Mirfield Moor, bricks are being manufactured from shaly mudstones immediately underlying the Wheatley Lime or Three Quarter Coal. At the Atlas Brickworks in Warwick Road, Batley, and in the Wyre Brickfields at Adwalton, shaly mudstones suitable for brick-making are being quarried in beds above the Middleton Main Coal and above the Joan Coal respectively. The shale above the Thornhill Rock occurring as overburden in some of the New Howley Park Co.'s quarries east of Howley Park is being made into red bricks.

The Glacial and superficial deposits have also been employed in several localities for a similar purpose. At the present time such material is being worked for bricks at Hillhouse to the north of Huddersfield. The valley brick-earth at Hopton, Ravensthorpe, and Thornhill Lees has also in the past been employed for brick-making.

APPENDIX I

Records of Borings

(1) Mold Green, Huddersfield.
(2) Quarmby Clough, Longwood, Huddersfield.
(3) Farnley Iron Works.
(4) Brookfoot Dye Works, Brighouse.
(5) Messrs. Patons and Baldwin's Works, Halifax.

With the exception of the last, which has been made since the map was printed, the sites of the above are shown on the one-inch geological map.

1. Mold Green, Huddersfield

A boring made for water at the Cloth Mills of Messrs. W. T. Johnson and Sons, Mold Green, Huddersfield; by Messrs. T. Matthews and Co., Imperial Iron Works, Pendleton, Manchester. The site is 1,300 yds. due east of Huddersfield Parish Church. Ht. above O.D. 250 ft. Six-inch map, Yorkshire 246 S.E.

		Thickness Ft.	in.	Depth Ft.	in.
	Dug Well			55	0
	Blue shale...	94	0	149	0
	Black shale with *Gastrioceras carbonarium* and *Pterinopecten papyraceus*	3	0	152	0
	Hard Bed Coal	1	3	153	3
	Fireclay with hard ganister rock	5	9	159	0
	Shale	38	6	197	6
	Middle Band Coal	0	6	198	0
Lower Coal Measures 348 ft. 6 in.	Sandstone	14	0	212	0
	Shales with *Carbonicola acuta*, *Carbonicola sp.* and *Orbiculoidea nitida*	38	0	250	0
	Soft Bed Coal	2	0	252	0
	Soft Bed Flags	40	0	292	0
	Shale	104	0	396	0
	Black sooty shale with *Gastrioceras* cf. *subcrenatum*, *Homoceratoides divaricatum*, *Lingula mytiloides*	4	0	400	0
	Thin seam of coal	0	6	400	6
	Fireclay with ganister rock ...	3	0	403	6
Rough Rock 116 ft. 6 in.	Flaggy gritstone, rather coarse...	26	4	429	10
	Coal	0	2	430	0
	Massive rather coarse gritstone...	90	0	520	0
	Alternating flags and sandy shale	58	0	578	0
	Shales with thin black band containing *Gastrioceras crenulatum*, *Posidoniella sp.*	2	0	580	0
	Shale	92	0	672	0

		Thickness Ft.	in.	Depth Ft.	in.
	Black shale with *Gastrioceras cancellatum, Pterinopecten elegans, Posidoniella sp., Lingula sp.*	3	0	675	0
	Soft shale	30	0	705	0
	Upper Meltham Coal	0	6	705	6
Huddersfield White Rock 45 ft. 6 in.	Ganisteroid sandstone	4	6	710	0
	Sandstone	11	0	721	0
	Sandy shale	15	0	736	0
	Coal	0	6	736	6
	Flagstone	14	6	751	0
	Black shale	89	0	840	0
Beacon Hill Flags 40 ft.	Flaggy sandstone	40	0	880	0
	Shale	88	0	968	0
	Black shale with *Reticuloceras reticulatum*, early mut. γ, *Posidoniella sp., Cordaites* ...	2	0	970	0
	Soft shale	29	9	999	9
	Coal	0	3	1,000	0
	Fireclay	4	0	1,004	0
Pule Hill Grit 50 ft.	Massive fine-grained grit ...	50	0	1,054	0
	Sandy shale	56	0	1,110	0
	Black shale with *Reticuloceras reticulatum*, mut. β, *Dimorphoceras sp., Posidoniella minor*	4	0	1,114	0
	Soft shales	16	0	1,130	0
	Coal. Trace only	—		1,130	0
Readycon Dean Series 113 ft.	Ganister rock	5	0	1,135	0
	Alternations of flaggy grit, flaggy sandstone, and sandy shale ...	108	0	1,243	0
	Black shale	97	6	1,340	6
	Black shale with fossils.—*Reticuloceras reticulatum*, mut. α predominant in upper part, and *R. reticulatum*, type form in lower part. Intermediate forms also occur. Other fossils include *Homoceras striolatum, Orthoceras sp., Dimorphoceras sp., Bellerophon* cf. *decussatus, Naticopsis brevispira, Loxonema sp., Chonetes sp., Pterinopecten speciosus, Posidoniella minor, Posidoniella spp., Nuculana stilla, Myalina* cf. *peralata, Aviculopecten carboniferus, Schizodus antiquus, Sanguinolites ovalis, Sanguinolites tricostatus, Sanguinolites sp. nov., Lingula mytiloides*	20	0	1,360	6
	Shales with plant-remains ...	3	0	1,363	6
	Thin seam of coal (about ½ in.)...	—		1,363	6
	Fireclay	1	0	1,364	6

		Thickness Ft.	in.	Depth Ft.	in.
Upper Kinderscout Grit 74 ft.	Flaggy micaceous sandstone ...	7	0	1,371	6
	Hard massive grit	67	0	1,438	6
	Shaly mudstone	2	6	1,441	0
	Thin band of black shale with *Lingula mytiloides, Myalina sp., Posidoniella sp., Sanguinolites sp., Pterinopecten sp.*	0	6	1,441	6
	Shaly mudstone	5	6	1,447	0
	Thin streak of coal	—		1,447	0
Lower Kinderscout Grit 50 ft. +	Coarse-grained massive felspathic grit	50	0	1,497	0

2. Quarmby Clough, Longwood

A boring for water made at Quarmby Clough Mills (Messrs. E. Hoyle and Sons, Ltd.), Longwood. The site is close to the southern end of Longwood Edge, and 600 yds. north-north-west of Longwood railway station (L.M.S.R.) and 2 miles west of Huddersfield. Ht. above O.D. 470 ft. Six-inch map, Yorkshire 246 S.W. Made by Messrs. T. Matthews and Co., Imperial Iron Works, Pendleton, Manchester.

		Thickness Ft.	in.	Depth Ft.	in.
	Clay, sand and grit boulders ...	7	0	7	0
	Dark shale with pyritic concretions	44	6	51	6
	Black shale with *Gastrioceras crenulatum, Pterinopecten elegans, Posidoniella sp.*	0	6	52	0
	Dark shale	96	0	148	0
	Black shale with *Gastrioceras cancellatum, Posidonomya insignis, Posidoniella sp.*... ...	2	0	150	0
	Black shale with occasional *Lingulae*	23	0	173	0
	Upper Meltham Coal	0	6	173	6
	Fireclay, with abundant *Stigmaria*	9	0	182	6
Huddersfield White Rock 101 ft. 6 in.	Fine-grained, light grey flaggy sandstone	101	6	284	0
	Dark shale and shaly bind ...	44	0	328	0
Beacon Hill Flags 63 ft. 6 in.	Flags and sandy shale	53	0	381	0
	Grey fine-grained grit	10	6	391	6
	Strong dark grey bind and shale	57	6	449	0
	Dark shale with *Reticuloceras reticulatum*, late mut. β, *Posidoniella laevis, Posidoniella sp.*	1	0	450	0
	Shale	2	0	452	0
	Trace of coal	—		452	0
Pule Hill Grit 71 ft.	Hard fine-grained felspathic grit	71	0	523	0

		Thickness Ft.	In.	Depth Ft.	In.
	Soft shale	49	0	572	0
	Shale with *Reticuloceras reticulatum*, mut. β, *Posidoniella spp.*, *Dimorphoceras sp.*	0	6	572	6
	Shale	29	6	602	0
	Coal	0	6	602	6
Readycon Dean Flags 91 ft.	Sandstone with many bands of sandy shale	66	9	669	3
	Dark grey flaggy sandstone ...	24	3	693	6
	Shales with flaggy layers ...	89	6	783	0
	Black shale	23	6	806	6
	Black shale with *Reticuloceras reticulatum*, early mut. α, in upper part and *R. reticulatum*, type in lower portion. Intermediate forms also occur. Other fossils include *Posidoniella minor*, *Orthoceras*, *Dimorphoceras sp.*, *Pterinopecten speciosus*, *Lingula mytiloides*...	9	0	815	6
	Shale with plant-remains ...	14	6	830	0
	Coal	0	6	830	6
Upper Kinderscout Grit 109 ft. 6 in.	Grey gritstone, flaggy in upper part	63	6	894	0
	Grey grit, somewhat massive and coarse-grained	46	0	940	0
	Shale with thin coal and fireclay at base	4	0	944	0
Lower Kinderscout Grit 40 ft.+	Coarse-grained massive conglomeratic grit	40	0	984	0

3. Farnley Ironworks

Information from The Farnley Iron Company and Mr. Sanderson. Six-inch map, Yorkshire 217 S.E. Ht. above O.D. about 280 ft.

		Thickness Ft.	in.	Depth Ft.	in.
	Clay and tender sandstone ...	15	0	15	0
	Shale	25	7	40	7
Better Bed	Coal	1	8	42	3
	Fireclay	1	10	44	1
	Fireclay with mica (bottom clay)	2	7	46	
	Yellow micaceous sandstone ...	10	1	56	9
	Blue-grey shale	39	0	95	9
	Grey sandstone	3	3	99	0
	Grey shale with ironstone nodules	16	3	115	3
Elland Flags	Shaly sandstone	15	6	130	9
	Shale and sandy shale	69	7	200	4
	Sandstone, chiefly flaggy ...	22	10	223	2
	Dark blue shale	7	0	230	2
	Micaceous sandstone and flags with 5 thin partings of grey micaceous shale	30	10	261	0

		Thickness Ft.	In.	Depth Ft.	In.
	Sandy and micaceous shale, with thin beds of carbonaceous shaly flags	104	9	365	9
	Dark shale	24	10	390	7
	Grey fireclay, ironstone nodules in lower part	2	6	393	1
	Clay	0	10	393	11
	Dark blue fireclay	2	0	395	11
	Black shale	18	1	414	0
? 80 Yard Band	Coal	0	3	414	3
	Grey fireclay with ironstone nodules	1	4	415	7
	Blue sandy shale...	8	8	424	3
	Dark grey shaly sandstone ...	4	0	428	3
	Dark grey sandy shale	13	9	442	0
	Sandstone with carbonaceous material on bedding planes ...	25	5	467	5
	Dark shale	21	4	488	9
	Black shale	3	0½	491	9½
? 36 Yard Band	Coal	0	2½	492	0
	Fireclay with ironstone nodules...	5	5	497	5
	Black shale	2	9	500	2
	Shaly flags	14	5	514	7
	Dark blue sandy shale	30	0	544	7
	Shaly flags	10	4	554	11
	Dark blue shale	15	1	570	0
Hard Bed	Coal	1	0	571	0
	'Hard flinty Rock' [Ganister]...	1	7	572	7
	Close-grained ganisteroid sandstone	5	9	578	4
	Grey shale	19	2	597	6
Middle Band	Coal	0	3	597	9
	Fireclay with ironstone nodules in lower part	6	3	604	0
	Blue shale...	6	0	610	0
Soft Bed	Coal	0	10	610	10
	Dark grey fireclay	1	7	612	5
	Shaly sandstone and flags ...	19	4	631	9
	Dark grey and black shale ...	53	2	684	11
Thin Coal	Coal	0	1	685	0
	Grey fireclay	4	0	689	0
	Shale with sandstone beds ...	16	3	705	3
Rough Rock	Grit	—		—	

4. Brookfoot Dye Works, Brighouse

Information from Messrs. T. Matthews and Co. (cores examined by Survey). Six-inch map, Yorkshire 231 S.E. Ht. above O.D. 200 ft.

		Thickness Ft.	in.	Depth Ft.	in.
	Clay and stones	14	0	14	0
	Sandstone	5	0	17	0
	Black shale	29	0	48	0
	Sandy shale	11	0	59	0
80 Yard Rock	Little ganister, sandstone and flags	10	0	69	0

		Thickness Ft.	In.	Depth Ft.	In.
	Shales (*Carbonicola* 87-98 ft.) ...	117	0	186	0
36 Yard Seam	Fireclay, poor below	12	0	198	0
	Ganister	6	6	204	6
	Dark shale (*Carbonicola* 208-217 ft.)	23	6	228	0
	Ganister	11	0	239	0
	Sandy shale	5	0	244	0
	Dark shale (fossiliferous nodules at base)	49	0	293	0
Hard Bed	Coal	2	6	295	6
	Fireclay	5	6	301	0
	Ganister	1	3	302	3
	Shales	31	6	333	9
Middle Bed	Coal	0	9	334	6
	Bastard ganister	3	6	338	0
	Shales (*Carbonicola* 343-358 ft.) ...	25	0	363	0
	Coal	0	6	363	6
	Shale	4	6	368	0
Soft Bed	Coal	0	9	368	9
	Ganister	5	3	374	0
	Shales (*Carbonicola* at 381 ft.) ...	34	0	408	0
	Grey micaceous sandstone ...	28	0	436	0
	Dark grey shale	41	0	477	0
	Dark shale (marine fossils) ...	2	0	479	0
	,, ,, (fish remains) ...	1	0	480	0
	Coal	0	6	480	6
	Fireclay	2	6	483	0
Rough Rock	Coarse grit	72	0	555	0
	Black shale	9	0	564	0
	Flaggy sandstone	5	0	569	0
	Grey grit and shale bands ...	21	0	590	0
	Black shale	6	6	596	6
	Sandstone	16	4	612	10
	Black shale ... ... to	15	11	628	9

5. Messrs. Patons & Baldwins, Halifax

Site at Clark Bridge Mills, beside the river Hebble. Original boring made and communicated by C. Isler & Co., depth 617 ft. Supply 6,000 galls. per hour; standing water level 4 feet. Lined with 27 ft. of 11½ inch tubes. Deepening was commenced by the same firm in 1927. Through their courtesy and that of Messrs. Patons and Baldwins the cores of the new part have been examined by the Survey from time to time and a large number of fossils has been collected. Ht. above O.D. 360 ft.

		Thickness Ft.	in.	Depth Ft.	in.
	Made Ground	7	6	7	6
	Sandstone	1	6	9	0
[Rough Rock]	Millstone Grit	84	0	93	0
[?Rough Rock Flags]	Stone and Shale	92	0	185	0
	Shale	75	0	260	0
	Slate and Fireclay	25	0	285	0
	Shale	28	0	313	0
[Warley Rock]	Sandstone with shale	20	0	333	0

		Thickness Ft.	In.	Depth Ft.	In.
	Shale with a little stone...	94	0	427	0
[? Nab End Sandstone]	Grey sandstone	71	0	498	0
	Shale with thin layers of stone ...	40	0	538	0
	Sandstone	4	0	542	0
	Coal	0	4	542	4
	Sandstone	5	0	547	4
	Shale	0	8	548	0
	Sandstone	2	0	550	0
	Shale	1	0	551	0
[Midgley Grit]	Hard grey sandstone	63	0	614	0
	Shale	3	0	617	0

From this point the Survey Officers are responsible for the description: the greater part is by Mr. A. Templeman, who collected the fossils.

		Thickness Ft.	in.	Depth Ft.	in.
	Shale, dark to grey sandy, micaceous, with indeterminate plants	47	0	664	0
	Grey sandstone, hard	1	0	665	0
	Shale, dark or grey, sandy ...	46	0	711	0
Reticuloceras reticulatum mut. β	Black shale, with *Lingula squamiformis*, *Reticuloceras reticulatum*, mut. β, *Dimorphoceras sp.*, *Orthoceras sp.*, and scales of *Acrolepis hopkinsi* M'Coy	8	0	719	0
	Grey sandstone, part shaly, part hard rooty ganister	16	6	735	6
	Black shale, sandy and coaly ...	1	0	736	6
	Coal	0	6	737	0
	Grey sandstone, partly shaly, and mostly coarse-grained, with coaly films & hard brown bands	52	0	789	0
	Dark grey sandy shale, micaceous with *Alethopteris decurrens* and *Strepsodus sp.* (scales)... ...	27	0	816	0
	Grey sandstone, shaly, with hard bands	3	0	819	0
	Dark grey sandy shale and shaly sandstone, with indeterminate plants	13	6	832	6
	Grey sandstone, hard	1	6	834	0
	Dark grey shaly sandstone and sandy shale	21	0	855	0
	Grey sandstone, hard, with vertical joint	5	0	860	0
	Grey sandstone and sandy shale	4	0	864	0
	Dark grey sandy shale with thin sandstone, *Calamites sp.* ...	13	0	877	0
	Black shale, with *Nucula sp.* ...	3	0	880	0
	Dark grey shale, with *Calamites sp.*, indeterminate plant and fish remains	10	0	890	0
	Dark-grey sandy shale, with bands of black shale, *Orbiculoidea nitida* and *Lingula squamiformis*	9	0	899	0

		Thickness Ft.	In.	Depth Ft.	In.
	Black shale, for most part with thin sandy bands with *Lingula squamiformis, L. mytiloides,* and *Aviculopecten carboniferus.*				
Reticuloceras reticulatum mut. α	Black shale with *Reticuloceras reticulatum,* mut. α (crushed), *Dimorphoceras sp., Orthoceras sp., Bellerophon* cf. *decussatus, Loxonema sp., Pterinopecten speciosus, Posidoniella minor, Nuculana stilla, N. attenuata, Sanguinolites tricostatus, Schizodus antiquus, Chonetes laguessiana, Productus sp., Lingula spp.* From 930 ft. down *Reticuloceras reticulatum* near type form (uncrushed) ...	38	0	937	0
	Shale, dark to grey, sandy and micaceous, with coaly films and indeterminate plants	5	0	942	0
	Grey sandstone, shaly and partly coarse, with *Calamites suckowi*	5	0	947	0
	Fireclay, rooty and partly sandy (without coal)	2	0	949	0
Upper Kinderscout Grit	Grey sandstone, mostly gritty and massive, but shaly in lower part. Half-inch coal in grit at 978 ft. ... ...,	45	0	994	0
	Fireclay and trace coal	8	0	1,002	0
	Shale with sandy bands and obscure plant remains ...	16	0	1,018	0
	Coarse grit	52	0	1,070	0
	Shale with *Lingula*	1	0	1,071	0
	Shale and Fireclay, with plant remains	9	0	1,080	0
? Lower Kinderscout Grit	Very coarse grit	133	0	1,213	0
	Black shale and hard sandy micaceous shale	367	0	1,580	0
	Hard dark shale with indeterminate plants				
	[*continuing at time of going to press*].				

APPENDIX II

List of the more important Quarries in Sheet 77.

Quarries marked with an asterisk (*) are standing.

6-in. Map	Name of Quarry	Products	Geological horizon
Yorks.			
230 N.W.	Brockholes Quarry	Massive sandstone ...	Kinderscout Grit
231 S.W.	Lea Wood Quarry*	Massive sandstone ...	Kinderscout Grit
245 N.W.	Wicken Hill Quarries*	Massive sandstone ...	Kinderscout Grit
245 S.W.	Derby Delph Quarries	Massive grit stone for reservoir embankments, etc.	Kinderscout Grit
230 N.E.	Scotland Quarries Midgley	Flagstones	Scotland Flags
230 N.E.	Thorney Lane Quarries	Flagstones	Scotland Flags
259 N.E.	Kitchen Clough Quarry, Slaithwaite*	Ganister rock	Readycon Dean Series
245 N.W.	Lumb Quarries, Lumb, Ripponden*	Massive sandstone ...	Midgley Grit
245 N.W.	Castle Quarries, Spa Green, Ripponden	Massive sandstone ...	Midgley Grit
245 N.E.	Hanging Stones Quarries, Ripponden*	Massive sandstone ...	Midgley Grit
245 S.E.	Wholestone Quarries, Krumlin	Massive gritstone ...	Midgley Grit
245 S.E.	Park Edge or Clock Face Quarries, Rishworth	Massive sandstone; extracted in large blocks	Midgley or Pule Hill Grit
245 S.E.	Radcliff Delph Quarries, Sowood, Stainland	Massive sandstone and flagstone	Pule Hill Grit
260 N.W.	High Wood Quarry, Golcar	Building stone ...	Pule Hill Grit
260 N.W.	Hill Top Quarry, Golcar	Building stone and flagstone	Pule Hill Grit
260 N.W.	Spring Grove Quarries, Linthwaite*	Building stone ...	Pule Hill Grit
259 N.E.	Sally Bank Quarries, Slaithwaite	Massive sandstones and flagstones	Pule Hill Grit

6-in. Map	Name of Quarry	Products	Geological horizon
Yorks.			
259 N.E.	Nether Wood Quarries Slaithwaite*	Massive sandstone	Pule Hill Grit
230 S.E.	Butts Green Quarry, Luddendenfoot	Building stone ...	Nab End Sandstone
230 S.E.	Nab End Quarry, Sowerby Bridge	Building stone and setts	Nab End Sandstone
245 S.E.	Wham Quarries, Sowood, Stainland	Flagstones ...	Beacon Hill Flags
245 S.E.	O'Cot Quarries, Worts Hill, Wholestone Moor	Flagstones ...	Beacon Hill Flags
260 N.W.	Guy Edge Quarries, Linthwaite	Building stone and flagstone	Huddersfield White Rock
245 S.E.	Clough Head Quarry, Golcar	Freestone	Huddersfield White Rock
246 S.W.	Scar Wood Quarries, Golcar*	Freestone and building stone	Huddersfield White Rock
245 N.E.	Pinfold, Slack, Delph and Cross Quarries, Barkisland*	Flagstones and tilestones	Barkisland Flags
245 N.E.	Beestonley Wood Quarries	Freestone and flagstone	Huddersfield White Rock
246 N.W.	Northwood Quarries, Blackbrook, Greetland	Flaggy sandstone	Huddersfield White Rock
260 N.W.	Heath Quarry, Linthwaite	Building stone	Huddersfield White Rock
230 N.E.	Sunny Bank Quarries, Ovenden Wood, Halifax	Sandstone and flagstone	Rough Rock and Rough Rock Flags
230 N.E.	Moorend Quarry, Mt. Tabor, Halifax	Building stone and flags	Rough Rock and Rough Rock Flags
230 N.E.	Mount Tabor Quarries	Building stone and flags	Rough Rock and Rough Rock Flags
230 S.E.	Trimmingham Quarry, West End, Halifax	Flagstones ...	Rough Rock Flags
231 N.W.	Stannary Quarry, Commercial Road, Halifax	Building stone and setts	Rough Rock
246 N.W.	Elland Wood Bottom Quarries, Elland	Building stone ...	Rough Rock
245 N.E.	Long Stone Quarry, Norland	Sandstone	Rough Rock
245 N.E.	Moor Quarries, Rochdale Road, Greetland ...	Building stones and flagstones ...	Rough Rock and Rough Rock Flags
245 N.E.	Spring Hill Quarry, Greetland	Building stones and flagstones	Rough Rock and Rough Rock Flags
245 S.E.	Rocking Stone Quarry, Wholestone Moor, Outlane	Massive sandstone	Rough Rock
246 S.W.	Gelderd Road Quarry, Longwood Edge	Sandstone ...	Rough Rock

6-in. Map	Name of Quarry	Products	Geological horizon
Yorks.			
260 N.W.	Malley Hole Quarries, Crosland Hill	Building stone ...	Rough Rock
260 N.W.	Tom Lane Quarries, Crosland Hill	Building stone ...	Rough Rock
260 N.W.	Chapel Field Quarries, Crosland Hill	Building stone ...	Rough Rock
260 N.W.	Park Quarry, Crosland Hill	Building stone ...	Rough Rock
260 N.W.	Wellfield Quarries, Crosland Hill	Building stone ...	Rough Rock
260 N.W.	Sand House Quarry, Crosland Hill	Building stone ...	Rough Rock
260 N.W.	Matlock House Quarry, Crosland Hill	Building stone ...	Rough Rock
260 N.W.	Whitefield Quarry, Crosland Hill	Building stone ...	Rough Rock
260 N.W.	Old Park Quarries, Crosland Hill	Building stone ...	Rough Rock
260 N.W.	Spinkwell Quarries, Crosland Hill	Building stone ...	Rough Rock
260 N.W.	Steam Crane and Old Spinkwell Quarries, Crosland Hill	Building stone ...	Rough Rock
246 S.W.	Mount Quarries, New Hey Road, Outlane	Building stone ...	Rough Rock
245 N.E.	Eaves Top Quarries, Stainland*	Building stone ...	Rough Rock
246 S.W.	Birchencliffe Brick Pit	Shales for brick-making	Shales above Rough Rock
231 S.W.	Bailey Hall Claypit, Halifax	Shales for brick-making	Shales above Soft Bed Coal
246 S.E.	Hillhouse Brick-works, Huddersfield	Shales for brick-making	Shales above Hard Bed Coal and Fluvio-glacial gravel
246 N.W.	New Hall Fireclay Works, Elland	Fireclay	Hard Bed Coa
246 N.W.	Woodman Hill Clay Works, Elland	Fireclay and ganister	Hard Bed Coal
231 N.W.	Beacon Hill Clay Pit, Halifax	Fireclay	Hard Bed and 36-yards Coals
231 S.W.	Cinder Hills Quarry and Fireclay Works, Halifax	Ganister and fireclay	Hard Bed and 36-yards Coals
246 N.W.	Storth Fireclay Works, Elland	Coal, fireclay, clay for brickmaking, and ironstone	Hard Bed and 36-yards Coals
231 N.E.	Storr Hill Brickworks, Wyke	Shales for brick-making	Shales above 32-yards Coal
246 N.W.	Calder Fireclay Pit, Elland	Fireclay ...	Hard Bed Band and 36-yards Coals
246 N.W.	Victoria Fireclay Pit, Elland	Fireclay, clay for brickmaking and coal	Hard Bed Band and 36-yards Coals

6-in. Map	Name of Quarry	Products	Geological horizon
Yorks.			
246 N.W.	Blackley Fireclay Pit, Elland	Fireclay, clay and coal	Hard Bed Band and 36-yards Coals
246 S.E.	Brown Royd Clay Works, Huddersfield	Shales for brick-making	Shales above 80-yards Rock and Coal
216 N.W.	Middle Lane Quarry, Clayton, Bradford	Flagstone	Elland Flags
216 S.W.	Blue Cap Quarry, Clayton	Flagstone	Elland Flags
216 S.W.	Highfield Quarry, Queensbury	Flagstone	Elland Flags
216 S.W.	Ambler Thorn Quarry, Swales Moor, Halifax	Flagstone	Elland Flags
217 N.W.	Northwood Quarry, Laisterdyke	Flagstone	Elland Flags
231 N.W.	Slack End Quarry, Swales Moor, Halifax	Building stone, flags and setts	Elland Flags
231 N.W.	Swales Moor Quarry, Halifax	Building stone and flags	Elland Flags
231 N.W.	Landemere Quarry, Shelf	Flagstone	Elland Flags
231 N.W.	Bare Head Quarry, Northowram	Flagstone	Elland Flags
231 N.W.	Northowram Hills Quarry	Flagstone	Elland Flags
231 N.W.	Green Lane Quarry, Northowram	Flagstone	Elland Flags
231 N.W.	Kirk Lane Quarry, Hipperholme	Flagstone	Elland Flags
231 S.W.	Station Road Quarry, Hipperholme	Flagstone and free-stone	Elland Flags
231 S.W.	Cromwell Quarry, Southowram	Flagstone	Elland Flags
231 S.W.	New Farm Quarries, Southowram	Flagstone	Elland Flags
231 S.W.	Baildon Quarry, West Lane, Southowram	Flagstone	Elland Flags
231 S.W.	Bolton Quarry, Southowram	Flagstone	Elland Flags
231 S.W.	Pioneer Quarry, Northcliff Lane, Southowram	Flagstone	Elland Flags
231 S.W.	Watson Quarry, Southowram	Flagstone	Elland Flags
231 S.W.	Clog Sole Quarry, Brighouse	Flagstone	Elland Flags
231 S.E.	Royd Quarry, Brookfoot L'e, S'owram	Flagstone	Elland Flags
231 S.E.	Gaubert Hill Quarries, Lightcliffe	Flagstone and artificial stone	Elland Flags
231 S.E.	Crow Nest Quarries, Lightcliffe	Flagstone and artificial stone	Elland Flags

6-in. Map	Name of Quarry	Products	Geological horizon
Yorks.			
231 S.E.	Granny Hall and Pond Quarries	Flagstone	Elland Flags
246 N.W.	Middle Delph Quarries, Rastrick	Flagstone	Elland Flags
246 N.W.	Five Acre Quarries, Rastrick	Flagstone and freestone	Elland Flags
246 N.W.	Lower Edge Quarry, Elland	Flagstone and freestone	Elland Flags
246 N.E.	New Delight Quarry, Rastrick	Flagstone	Elland Flags
246 S.E.	Almondbury Bank Quarries	Flagstone	Elland Flags
247 S.W.	Lower Hall Quarries, Lascelles Hall, Kirkheaton	Flagstone	Elland Flags
231 S.E.	Gooder Lane Brickpit, Rastrick	Shales for brick-making	Shales in Elland Flags Series
247 S.W.	Spa Green Brickpit, Lepton	Shales for brick-making	Shales above Better Bed Coal
231 N.E.	Seeds Quarry, Wyke	Sandstone	Clifton Rock
247 S.W.	Falhouse Quarry, Whitley	Flaggy sandstone...	Falhouse Rock
247 N.W.	Taylor Hall Brickworks, The Green, Mirfield	Shales for brick-making	Shales below Wheatley Lime Coal
261 N.W.	Burton Dean Quarries, Kirkburton*	Building stone ...	Grenoside Rock
261 N.W.	Cropper Gate Quarry, Grange Moor	Sandstone	Birstall Rock
261 N.E.	Cardwell Delph Quarries, Flockton*	Sandstone	Birstall Rock
232 S.E.	Atlas Brickworks, Warwick Road, Batley Carr	Shales for brick-making	Shales above Middleton Main Coal
232 N.E.	Wyre Hall Brickworks, Wakefield Road, Adwalton	Shales for brick-making	Shales above Joan Coal
232 N.E.	Finsdale Quarry, Morley	Building stone ...	Thornhill Rock
232 N.E.	Britannia Quarries, Stump Cross, Morley	Building stone ...	Thornhill Rock
232 S.E.	Cardigan Quarries, Soothill Wood	Building stone ...	Thornhill Rock
232 S.E.	Woodkirk New Quarries, Woodkirk	Building stone ...	Thornhill Rock
232 S.E.	New Bluestone Quarries, Woodkirk	Building stone ...	Thornhill Rock
232 S.E.	Caulms Wood Quarry, Upper Soothill	Building stone ...	Thornhill Rock
247 S.E.	Edge Lane Quarries, Thornhill Edge*	Building stone ...	Thornhill Rock
247 S.E.	Foxroyd Quarries, Thornhill	Building stone ...	Thornhill Rock

APPENDIX III

List of Geological Survey Photographs

(New Series One-inch Sheet 77).

Copies of these photographs are deposited for public reference in the Library of the Geological Survey, Jermyn Street, London, S.W.1. Prints and lantern-slides are supplied at a fixed tariff.

No. 3551.—Millstone Grits: Kinderscout Grit, escarpment. Blackstone Edge.

,, 3552.—Millstone Grits: Kinderscout Grit, escarpment. Blackstone Edge.

,, 3553.—Millstone Grits: Weathered Stacks of Kinderscout Grit, Blackstone Edge.

,, 3554.—Millstone Grits: Vertical erosion channels in Kinderscout Grit, Blackstone Edge.

,, 3555.—Millstone Grits: Pot-hole weathering in Kinderscout Grit, Blackstone Edge.

,, 3556.—Millstone Grits: The Rocking Stones, Rishworth Moor, about four miles S.W. of Rishworth.

,, 3557.—Millstone Grits: Gorge in Kinderscout Grit. Booth Dean, Rishworth.

,, 3558.—Millstone Grits: Middle Grits, escarpment. Cliff Hill, Rishworth.

,, 3559.—Millstone Grits: Fault seen in railway-cutting. Railway-cutting east of Triangle Station.

,, 3560.—Millstone Grits: The Ladstone, Norland Moor, Upper Greetland.

,, 3561.—Pleistocene: Peat with birch-stumps at base. Turley Holes Moor, nr. Mytholmroyd.

,, 3562.—Pleistocene: Peat with birch-stumps at base (Nearer view). Turley Holes Moor, nr. Mytholmroyd.

,, 3563.—Millstone Grits: View down Crag Clough. Turvin Mills, Crag, nr. Mytholmroyd.

,, 3564.—Millstone Grits: Base of Kinderscout Grit. Lumb Falls, Crimsworth Dean, Hebden Bridge.

,, 3565.—Millstone Grits: Millstone Grit Series, escarpments, lower part. Lower Crimsworth.

,, 3566.—Millstone Grits: Middle Grits, escarpments. Lower Crimsworth.

,, 3567.—Millstone Grits: Quarry in Scotland Flags. Scotland Quarries, Midgley, nr. Halifax.

,, 3568.—Millstone Grits.—Quarry in Scotland Flags, specimens of output. Scotland Quarries, Midgley, nr. Halifax.

,, 3569.—Millstone Grits: "Worm-castings" in Scotland Flags. Scotland Quarries, Midgley, nr. Halifax.

,, 3570.—Millstone Grits and Glacial: River-cliff of Boulder Clay and Shale. River Cliff, Brearley, nr. Halifax.

,, 3571.—Millstone Grits and Glacial: River-cliff of Boulder Clay and Shale, nearer view, River Cliff, Brearley, nr. Halifax.

,, 3572.—Millstone Grits: Coal Seam in Kinderscout Grit. Grotto Terrace, Cat i' th' Well, nr. Wainstalls, Halifax.

,, 3573.—Millstone Grits: Illingworth Fault, Lane Ends, Wainstalls, Halifax.

,, 3574.—Millstone Grits: Quarry in Rough Rock and Rough Rock Flags. Vicar Park Quarry, Highroad Well Moor, Halifax.

No. 3575.—Lower Coal Measures : One of Brooks & Co.'s quarries, showing Elland Flags. Hove Edge, Hipperholme, nr. Halifax.

,, 3576.—Lower Coal Measures : Detail of the quarry seen in photo. 3575. Hove Edge, Hipperholme, nr. Halifax.

,, 3577.—Millstone Grits : Rough Rock, escarpment. Scar Wood, Halifax.

,, 3578.—Millstone Grits : Rough Rock, escarpment, the detail. Scar Wood, Halifax.

,, 3579.—Lower Coal Measures : Workings in the 'Blue Clay,' Storth Brickworks, Elland.

,, 3580.—Lower Coal Measures : Upper surface of coal-seam showing ' cleat ' or jointing. Storth Brickworks, Ainleys, Elland.

,, 3581.—Lower Coal Measures : Section : Hard Bed Band Rock and Clay. Blackley Brickworks, Elland.

,, 3582.—Lower Coal Measures : Coal Measures, highly inclined, close to Lindley fault. Haigh House Hill, Lindley Moor, Huddersfield.

,, 3583.—Lower Coal Measures : Highly inclined strata close to fault ; Lindley Moor. Haigh House Hill, Lindley Moor, Huddersfield.

,, 3584.—Lower Coal Measures : Hard Bed Band Rock, overlain by thin seam of coal, Blackley Brickworks, Elland, nr. Huddersfield.

,, 3585.—Lower Coal Measures : ' Blue Clay ' or fireclay, overlain by black shales, etc., Blackley Brickworks, Elland, nr. Huddersfield.

,, 3586.—Lower Coal Measures : ' Blue Clay ' or fireclay, overlain by black shales, etc., Blackley Brickworks, Elland, nr. Huddersfield.

,, 3587.—Lower Coal Measures : Fault in Coal Measures ; Blackley Fireclay Works, Elland. Ainleys, Elland.

,, 3588.—Glacial ? : Pit in Fluvio-glacial (?) gravel. Castle Hill, Kirklees Park, about 2 m. S.E. of Brighouse.

,, 3589.—Lower Coal Measures : The Holme Valley ; Taylor Hill, and Castle Hill, Huddersfield. From Beaumont Park, Huddersfield.

,, 3590.—Lower Coal Measures : The Holme Valley ; Taylor Hill, and Castle Hill, Lockwood. From Beaumont Park, Huddersfield.

,, 3591.—Millstone Grits : The valley of the Holme looking south. From Beaumont Park, Huddersfield.

,, 3592.—Millstone Grits : Large quarries in Rough Rock. Wimpenny & Co., Spinkwell Quarry, Crosland Hill, Huddersfield.

,, 3593.—Millstone Grits : Large quarries in Rough Rock. Spinkwell Quarry, Crosland Hill, Huddersfield.

,, 3594.—Millstone Grits : Curved bedding in Freestone. Spinkwell Quarry, Crosland Hill, Huddersfield.

,, 3595.—Millstone Grits : Bedding of Freestone, Rough Rock Quarry. Spinkwell Quarry, Crosland Moor, Huddersfield.

,, 3596.—Millstone Grits : ' Ruttles ' in Freestone. Spinkwell Quarry, Crossland Hill, Huddersfield.

,, 3597.—Millstone Grits : Freestone sawn into blocks for sills, etc. Mason's Yard, Spinkwell Quarry, Crosland Hill, Huddersfield.

,, 3598.—Millstone Grits : Workings in lower beds of freestones, Rough Rock. Sheard's Quarry, Crosland Hill, Huddersfield.

,, 3599.—Millstone Grits : Large quarry in Freestone bed ; Rough Rock J. Shaw & Son's Quarry, Crosland Moor, about two miles S.W. of Huddersfield.

,, 3600.—Millstone Grits : Large working face of Freestone ; Rough Rock. J. Shaw & Son's Quarry, Crosland Hill, Huddersfield.

,, 3601.—Millstone Grits : Showing Freestone in Rough Rock, being quarried. Wm. Mallinson & Son's Quarry, Crosland Hill, Huddersfield.

,, 3602.—Millstone Grits : Quarry in Rough Rock. Normington & Co.'s Quarry, Crosland Hill, Huddersfield.

,, 3603.—Millstone Grits : Extensive quarries in Rough Rock, Normington & Co.'s Quarry, Crosland Hill, Huddersfield.

No. 3604.—Millstone Grits: Shows two prominent oblique joint planes. Graham & Jessop's Quarry, Crosland Hill, Huddersfield.

,, 3605.—Millstone Grits: Freestone bed; Rough Rock Quarry, Crosland Hill. Graham & Jessop's Quarry, Crosland Moor, Huddersfield.

,, 3606.—Millstone Grits: Large quarry in Freestone, Rough Rock. Thewlis Lane Quarry, Crosland Hill, Huddersfield.

,, 3607.—Millstone Grits: Large quarry in Freestone, Rough Rock. W. Boothroyd & Son's Quarry, Crosland Hill, Huddersfield.

,, 3608.—Millstone Grits: Large quarry in Freestone, Rough Rock. T. Bower & Co.'s Quarry, Crosland Hill, Huddersfield.

,, 3609.—Millstone Grits: Elizabethan mansion entirely built from Rough Rock. Crosland Hall, Crosland Hill, Huddersfield.

,, 3610.—Glacial: Fluvio-Glacial Gravel. Troydale, nr. Bradford.

,, 3611.—Middle Coal Measures: Outcrop-working in Brown Metal Coal. Howden Clough, nr. Birstall.

,, 3612.—Middle Coal Measures: Adwalton Black Bed Coal. Surface working, N.E. of Pheasant Inn, Birstall.

,, 3613.—Lower Coal Measures: Oakenshaw, or Clifton Rock, resting on thin coals 32 yards, 22 yards. Crow Brick & Tile Works, Haycliffe Hill, Bradford.

,, 3614.—Middle Coal Measures: Dressing Yard, for Quarry in Thornhill Rock. New Howley Park Park Quarry Co., S. of Morley.

,, 3615.—Middle Coal Measures: Dressing Yard. New Howley Park Quarry Co., S. of Morley.

,, 3616.—Middle Coal Measures: Thornhill Rock, and overlying shales. New Howley Park Quarry Co., S. of Morley.

,, 3617.—Middle Coal Measures: Shale above Thornhill Rock. New Howley Park Quarry Co., S. of Morley.

,, 3618.—Middle Coal Measures: Birstall Rock. Railway cutting, E. of Oakwell Hall.

,, 3619.—Middle Coal Measures: Birstall Rock. Railway cutting E. of Oakwell Hall.

,, 3620.—Middle Coal Measures: Local unconformity at base of Birstall Rock. Batley Carr Station.

,, 3621.—Middle Coal Measures: Detail of Thornhill Rock. Cutting on Midland Railway, Thornhill.

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MAPS AND MEMOIRS RELATING TO THE GEOLOGY OF THE WEST RIDING, YORKSHIRE, DERBYSHIRE AND NOTTINGHAMSHIRE.

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