THE GEOLOGY

OF THE

INGLETON & STAINMORE

COALFIELDS

by

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Thesis submitted for the degree of Ph.D. in the University of Sheffield.

The effects of burning on heather moors of the South Pennines.

The problem is dealt with under two main headings, a) the short-term and b) the long-term effects of burning.

Short-term effects.

1. On the vegetation. Calluna and the dwarf shrubs may be completely destroyed by fire, but species that are caespitose or have protected underground parts commonly survive. Regeneration of the dwarf shrubs is facilitated by their high seed-production, but they can regenerate vegetatively if not killed. The interval between successive burnings ('cycle-length'), and not fire damage, appears to be a major factor in determining the floristic composition of the vegetation.

2. On the soil. The base-status of the upper soil horizons declines through each cycle. Leaching experiments show that an increased amount of base is lost in the run-off water and leachate soon after burning. It is concluded, in view of the restriction of the rooting systems to the upper soil, that there is in this way an appreciable loss of bases from the peaty horizons at each burning.

Long-term effects.

1. On the vegetation. There is evidence that 150 years ago heather moors were considerably richer in species than they are today. It is also shown that long-continued systematic burning leads to a greater loss of species than irregular and less frequent burning.

2. On the soil. In all cases examined, woodland soils show a higher base-status than closely comparable soils under moorland, and it seems clear that the fertility of the moors is lower than it would have been had their former woodland persisted. The phytometrical use of green heather leaves substantiates these findings, and shows the fertility of old moors to be less than that of moors of recent origin.

In the final section the economic utilisation of heather moor is discussed.

Preface

The research investigation described herein was undertaken at the suggestion of Professor L.R.Moore of the University of Sheffield early in the summer of 1950. At first it was intended to restrict investigation to the Ingleton Coalfield, but as the work progressed it became necessary to visit other neighbouring areas, and during the summer of 1951 the small Stainmore Coalfield was examined. It was decided to include a systematic account of this coalfield for comparative purposes. Neither coalfield has ever been the subject of detailed and systematic study and the results of the present investigation summarized in the following pages therefore add very materially to our knowledge of the Upper Carboniferous rocks of the Pennines. These researches are embodied within the accompanying thesis, which I beg to submit to the University of Sheffield for the degree of Doctor of Philosophy of that University.

It is claimed that the researches described herein constitute a fundamental contribution to the knowledge of the geology of the North of England and, in particular, of the sequence and structure of the Upper Carboniferous rocks of the Pennines. The new facts brought to light are:-

1) A stratigraphical and palaeontological account of the Namurian sequence near Ingleton - with the description of new non-marine faunas.
2) A similar account of the Ammanian and Morganian sequence of the Coal Measures of Ingleton, embodying the first full account of floras and faunas of these beds, and their zonal subdivision based on these fossils.
3) The recognition of an Intra-Coal Measure Unconformity within the Ingleton Coalfield, ascribed to a phase of the Malvernian movements.

4) Additional information concerning the structure of the Ingleton Coalfield as a result of field-mapping and the study of mining plans and boreholes records. This information is of economic importance in the event of any further exploration of this coalfield for coal reserves.

5) A stratigraphical account of the Upper Carboniferous rocks of the Stainmore Coalfield, including the first accounts of non-marine faunas and floras of Ammanian age of that area.

6) The general correlation of Coal Measures at Ingleton and Stainmore with other British Coal-fields, in particular with those of Lancashire and Yorkshire.

7) Additional information concerning the zonal distribution of Upper Carboniferous rocks in the North of England and in particular of the rapid changes in the Namurian and lower Ammanian sediments between Ingleton and Stainmore across the region of the Craven Fault System.

The writer acknowledges with thanks the award of a Maintenance Grant from the Department of Scientific and Industrial Research which enabled these researches to be carried out over a period of two years. During this period the research investigation was supervised by Professor L.R.Moore, and the writer wishes to express his gratitude for this help and advice throughout the work.

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I. Introduction

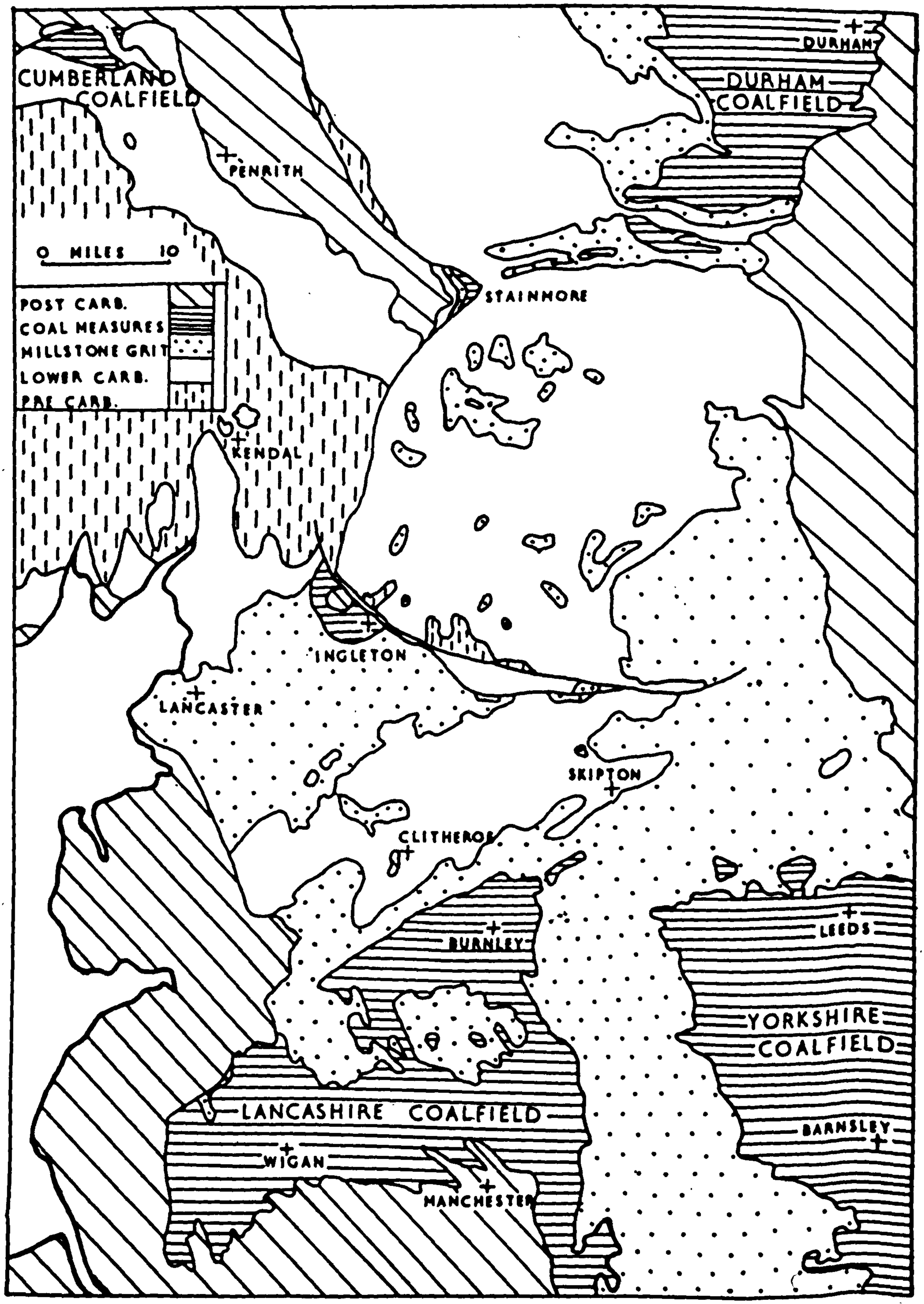
The greater part of the Ingleton Coalfield lies in the West Riding of Yorkshire, with only small areas in the adjoining counties of Lancashire and Westmoreland. It is situated some 30 miles from the nearest parts of the Yorkshire and Lancashire Coalfields, and 50 miles from the Durham and Cumberland Coalfields. (Fig. 1). Lying immediately south of the Craven Fault System it is both geographically and geologically linked to the Yorkshire and Lancashire Coalfields.

The area mapped has included the upper parts of the Millstone Grit south and west of the coalfield. Detailed mapping on a 6 inches to one mile scale has been carried out over a roughly triangular area bounded by the Craven Faults on the north east, the River Lune on the west,and the River Wenning. Of this, Coal Measures cover a roughly semicircular area based on the Craven Faults of about 28 sq. miles and Millstone Grit a further 15 sq. miles to the south and west,although it is only possible to define the boundary between the two along the southern edge of the area (Fig. 3). The area mapped falls within the boundaries of Old Series 1" Sheets 91 NE, 92 NW, 98 SE, and 99 S.W.

The greater part of the coalfield lies at altitudes of 400 feet O.D. rising to about 800 feet O.D. along the Craven Fault scarp and falling to about 100 feet O.D. in the Lune Valley. Topographically almost the whole of the coalfield is typical drumlin country, and features bear little relationship to the solid geology. Exposures of solid rock are confined to the more deeply incised rivers. Drainage is generally westerly towards the Lune, with the

Fig. 1.

SKETCH-MAP TO SHOW THE RELATIONSHIP OF THE INGLETON AND STAINMORE COALFIELDS TO OTHER PENNINE COALFIELDS



more important streams being,from north to south, Leck Beck, Cant Beck, River Greta, and River Wenning. All of these rise on or near the Craven Fault scarp and flow south-west until reaching the lower ground, when they turn due west.

No coal is at present being mined in the area, the last pit having closed in 1935. Consequently the author has been unable to examine any of the underground workings, but numerous mine plans, shaft sections and borehole records have been obtained, covering most of the known area of workings. Known workable coals are entirely confined to about 2 sq. miles in the south eastern section of the coalfield (Figs.18&19)but a few exploratory borings were sunk further west. All but one of the deeper sinkings and borings were completed before 1912 and several are incomplete either in full record of strata penetrated or in the presence or absence of fossils. It appears that there was little recourse on the part of the mining companies to reliable geological opinion. Extracts from the diary of G.T.Sergeantson, mine owner, written in the 1840's have given much valuable information regarding the older workings, for which no plans exist.

The author would like to acknowledge the help of all those who assisted in the location of widely scattered mining records, particularly the Small Mines Dept., N.C.B., Parkgate; the Opencast Prospecting Officers, N.W.Division, Ministry of Fuel and Power; and Messrs. Ord and Maddison Ltd. of Darlington. For the loan of fossil collections he is indebted to Mr.A.G.Brighton of the Sedgwick Museum, Cambridge, and to Dr.C.J.Stubblefield of the Geological Survey. For assistance in the identification of fossil faunas the author is indebted to Dr. Weir, Dr.Eagar, and Dr.Stubblefield. The author would also like to thank Prof.L.R.Moore for his help and guidance throughout this work.

II. Previous research

There has been remarkably little research in the past on the Ingleton Coalfield as such. Several of the larger works on the geology of Yorkshire give brief accounts and some give sections of the coal-bearing strata quoted from mine managers. (Phillips 1836; Davis & Lees 1878; Bird 1881; Hull 1905; Kendall & Wroot 1924). Phillips (1836) also gives a diagrammatic cross-section of the coalfield. Binney noted some Permian Breccias near Ingleton in 1855 and suggested a correlation with the Vale of Eden. Virtually the only serious work was done by Tiddeman for the Geological Survey in the early 1870's. Unfortunately the coalfield falls within the boundaries of four Old Series 1 inch maps (91 NE, 92 NW, 98 SE, 99 SW) and only two of the sheet memoirs were published (Tiddeman 1872, 1890). These give brief accounts of certain exposures but the full description was reserved for one of those which never appeared. Tiddeman also wrote a brief general account for the Coal Commission of 1871, in which he included some very optimistic figures for coal reserves. Balderston (1890) described some of the faulting. Gibson briefly described three borings in 1909 with condensed faunal lists, parts of which were recently revised by Stubblefield (in litt.). Strahan calculated the thickness of CoalMeasures (now known to be incorrect) in the Guide to the Geological Model of Ingleborough (1910). Newell Arber gave an account of the flora in 1912 based on collections made by Prof. McKenny Hughes and Miss Elles in the 1880's. The Economic Memoir on Fireclays (1920) recorded some near Burton-in-Lonsdale. Kendall & Wroot described the Permain Rocks in some detail in 1924 and in

the same year Kidston referred to three plants from Ingleton in his monograph. In 1941 Bisat and Hudson briefly described some of the Millstone Grit of the Bentham area, quoting unpublished reports by Slinger on the River Greta. Jongmans (1939) gave a revised interpretation of Newell Arber's floral list, but confused some of the horizons.

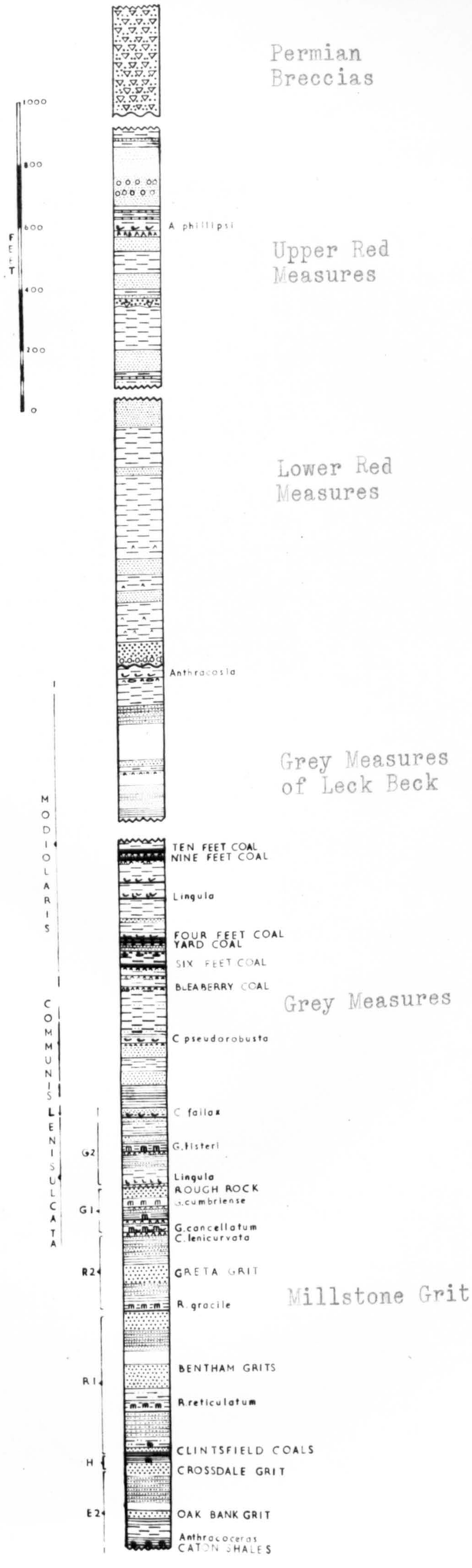
Thus there is no systematic account of the stratigraphy of the Coalfield in existence. Published sections are confined to a single mine shaft and two streams. Some work on the flora has been done but on other peoples' collections. Both Newell Arber and Jongmans correctly said that the flora was of Middle Coal Measure age. Gibson, with very little evidence, claimed a passage from red beds down into grey. Apart from the note "Anthracosia in Black Shale" on one of Tiddeman's maps no fauna has been recorded from the Coal Measures.

Several works on the regional tectonics of the North of England have included discussions of the faults which bound the coalfield on the north and north east but none have included any evidence from within the coalfield (Anderson 1947).

Within the last three years, work as yet unpublished by F.Moseley has given considerable insight into the succession and structure of the Millstone Grit to the south of the coalfield, and the author would like to acknowledge his cooperation in the field and free access given to his field notes and fossil collections. Only combined operations in the Bentham area have made it possible to elucidate the detailed structure there.

Fig. 2.

GENERALIZED SUCCESSION OF STRATA IN THE INGLETON COALFIELD AREA



III. Succession of Strata

(a) Upper Carboniferous

The general structure of the Ingleton Coalfield is that of a synclinal basin with an axis trending roughly WNW - ESE, but affected by subsidiary structures so that overall apparent simplicity may be misleading. The basin is truncated on the north east by the Craven Faults, and on the north west the relations to the Lower Carboniferous are unknown due to concealment by drift. On the south and south west the upper parts of the Millstone Grit dip beneath the Coal Measures at angles of 10 - 20°. In the centre of the basin the Coal Measures are overlain by Permian Breccias. The western part of the coalfield is almost entirely concealed by drift (Fig. 3).

i. Millstone Grit

(a) General. A succession of coarse grits, sandstones, flags and shales typical of the Central Pennines flanks the coalfield and the sequence of beds is an extension of the Lancaster Fells succession described by Moseley (M.S.1952). (Fig. 4). Beds representative of the upper part of the E zone, and the H, R, and G zones outcrop within the area mapped and the lithological subdivisions used are those proposed by Moseley. The most widespread horizon is that of the Clintsfield Coals which occur at the top of the H zone. Exposures of beds below thathorizon are widely scattered and no complete section exists within the area. For the beds between the Clintsfield Coal and the base of the Coal Measures the type section is the River Greta where there is an almost unbroken section of over 900 feet of strata.

THE GEOLOGY OF THE INGLETON COALFIELD

Permian Breccias

Carboniferous
- Red Measures (Upper / Lower)
- Grey Measures
- Millstone Grit
- Yoredale Series
- Gt. Scar Limestone
- Basal Conglomerate

Lower Palæozoic
Ingletonian

CASTERTON
KIRKBY LONSDALE
DENT FAULTS
LECK
NORTH CRAVEN FAULT
SOUTH CRAVEN FAULT
LECK BECK
BURROW
MASONGILL
IREBY
RIVER LUNE
WESTHOUSE
TUNSTALL
CANT BECK
INGLETON
RIVER GRETA
BURTON
OG
CC
LBG
UBG
GG
RR
MILL HILL SHALES
SIX FEET COAL
FOUR FEET COAL
4 FT.
LOWER BENTHAM GRIT
UPPER BENTHAM GRIT
GRETA GRIT
ROUGH ROCK
WENNINGTON
CLINTSFIELD COAL
RIVER WENNING
LOW BENTHAM
HIGH BENTHAM
OAKBANK GRIT
CATON SHALES
ROE BURNDALE GRIT

0 ½ 1 1½ 2
MILES

79 78 77 76 75 74 73 72 71 470000 69 68
360000 61 62 63 64 65 66 67 68 69 70 71 72

T.D.F. 1952

(b) Details of strata up to the Clintsfield Coal. As no complete section of these beds exists north of the River Wenning the interpretation of the isolated exposures concerned is dependent on the type sections described by Moseley in the adjoining Lancaster Fells. Marine Caton Shales are exposed in the south bank of the Wenning at Bowtham Wood (N.G.R. 34/679 684) where they yield Anthracoceras paucilobum (Phillips) and Posidoniella laevis (Brown). The base of the Caton Shales and the underlying Roeburndale Grit are seen in Adams Gill (34/688 687) where Posidonia corrugata Etheridge is abundant. In Meregill, a little further east, shales with Anthracoceras are exposed immediately north of the fault (34/704683) where they are overlain by 50 feet of sandy shale followed by at least 40 feet of flags, probably the Claughton Flags. East of the head of Meregill, near Old Butt, (34/705 687) an old quarry exposes a coarse felspathic grit, probably the Oak Bank Grit. The Caton Shales are also seen in several small streams west of Clapham station, and south of the Wenning, where they yield Anthracoceras paucilobum and Posidonia corrugata. The Claughton Flags are also seen near Wennington, in the River Greta, and in some small quarries near Melling. The Oak Bank Grit and its subsidiary upper leaf, the Crossdale Grit, are undoubtedly present north of the Wenning but cannot be differentiated owing to poor exposure.

Above the Oak Bank Grit are some 20 feet of marine Crossdale Shales which have yielded Homoceras undulatum (Brown) in the Bowland Fells. The Crossdale Shales are incompletely exposed in the Wenning (34/626702) and in the Greta (34/626720) below the Clintsfield Coals, and so far they have yielded only Lingula and fragmentary

unidentifiable Productids.

(c) Details of strata from the Clintsfield Coals to the Rough Rock. The only complete section of these beds is in the River Greta west of Burton-in-Lonsdale where for about a mile and a half the gently dipping strata are exposed in the river banks. Four subdivisions are used as follows:-

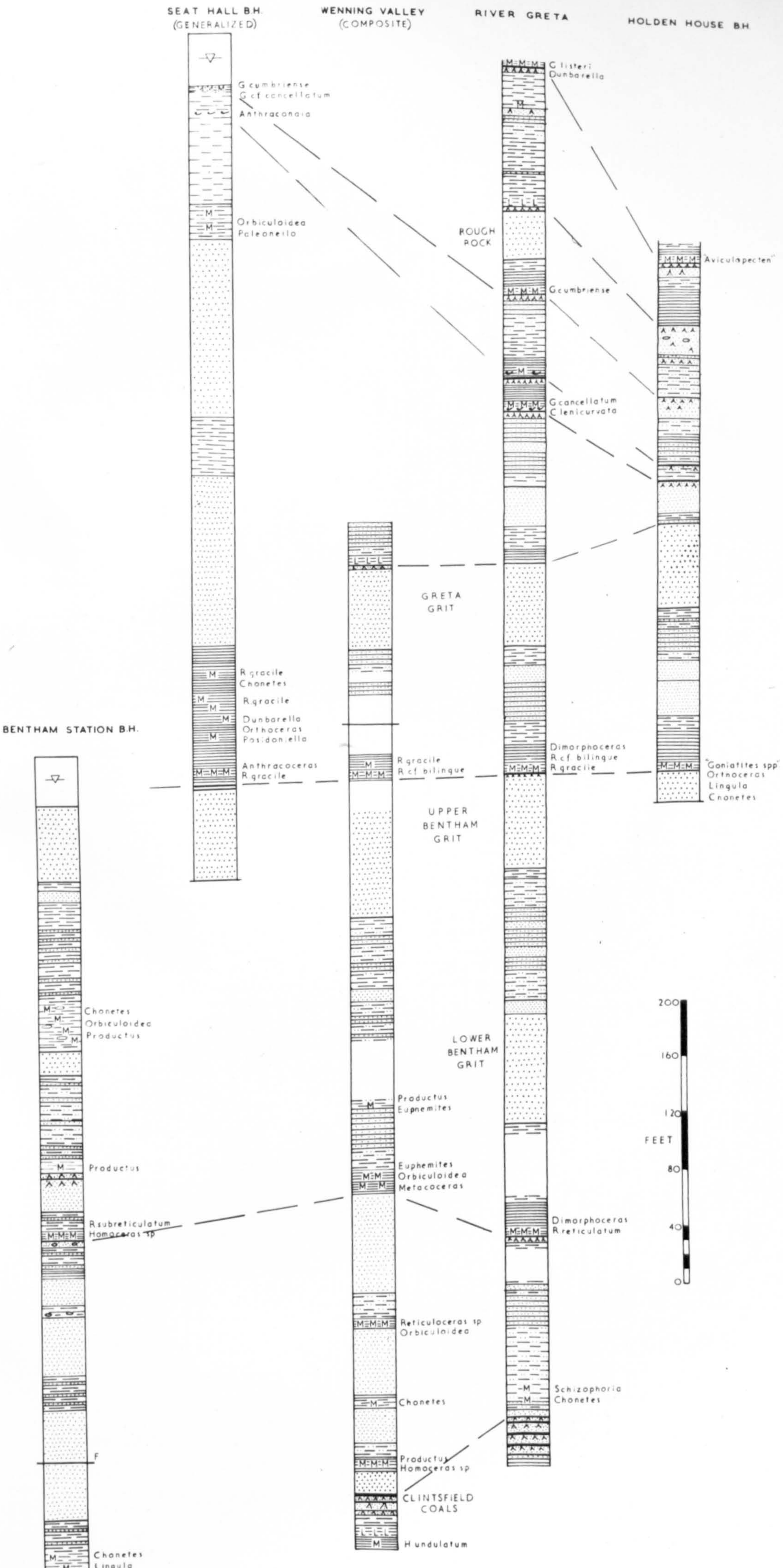
4. Rough Rock and Rough Rock Shales.
3. Greta Grit Group.
2. Bentham Grit Group.
1. Clintsfield Coals and Grit.

1). The Clintsfield Coals and Grit are placed at the top of the Homoceras stage by Moseley, who records a late form of Homoceras in the sandy shales immediately overlying the grit. The coals are three in number totalling two feet in thickness on the average. Four or more feet of sandy ganister intervene between the coals. Locally the middle or lower coals reach 18 inches in thickness and old outcrop workings and bell pits enable the outcrop to be traced intermittently from near Cantsfield S.E. across the Greta, and from near Wennington for some $3\frac{1}{2}$ miles eastwards to beyond High Bentham. The most easterly workings are near Low Linghaw Farm (34/682688) but Ganister workings on Linghaw Cross appear to be on the same strike $\frac{1}{2}$ mile to the north east. Unsuccessful attempts to work coal near Buckhaw Brow, some 4 miles further east and outside the area studied, were probably at the same horizon. The coals and the thin overlying grit total some 45 feet and are well exposed in both the Wenning and Greta. The Clintsfield Coals and Grit were considered as a lower subdivision of the Bentham Grit Group by Moseley (MS 1952) but the present author prefers to take the base of that group above the Clintsfield Grit, so that lithological and palaeontological boundaries coincide.

COMPARATIVE SECTIONS OF THE UPPER PART OF THE MILLSTONE GRIT

ADJOINING THE INGLETON COALFIELD

Fig.4



2). The Bentham Grit Group.

As developed in the River Greta the group includes two sedimentary cycles. Each contains a thick grit with an underlying series of shales and flags. (Fig. 4). The group totals 450 feet in thickness and falls into the goniatite zone R_1. Above the Clintsfield Grit are about 80 feet of sandy shales and flags with brachiopod casts. The top of these is marked by a ganister which makes a reef across the river 200 yards S.W. of Stubbing Barn, and immediately above this in the north bank are black shales with Reticuloceras reticulatum (Phillips). This is the marine band referred to by Bisat and Hudson in 1941. The black shales total about 80 feet in thickness, although the top is not seen. Above are the Lower and Upper Bentham Grits, both 80 feet thick, false bedded, coarse, pebbly, red and felspathic, with an intervening group of flags and sandy shales. A thin shaly coal occurs within the top of the Lower Bentham Grit.

Beds belonging to the Bentham Grit Group outcrop at intervals along the River Wenning. The Upper Bentham Grit is seen in the Wenning south west of High Bentham, and in several small streams draining into it. The Lower Bentham Grit is not seen in the Wenning and appears to die out southwards, as it is much reduced in thickness in the Bentham Station Borehole (34/666689) (Fig. 4). The shale with the R. reticulatum marine band in the Greta appears to split southwards and several shales with marine fossils with intervening sandstones are recorded by Moseley in Eskew Beck, Moulter Beck and Mill Lane Beck south of the Wenning. An intermediate stage is recorded in the Bentham Station Borehole, where a marine band with Reticuloceras cf. subreticulatum (Foord) is recorded at 338 feet. A marine shale in the south bank of the Wenning 10 yards west

of High Bentham Bridge occupies a similar position in the sequence although no goniatites have been obtained. The base of the shale is not exposed.

The following fauna has been collected in situ from the Bentham Grit Group:- (not including faunas recorded S. of the R.Wenning by Moseley).

Chonetes cf. hardrensis Phillips	2, 4, 5
Crurithyris urei (Fleming)	1, 2, 3, 4
Derbyia gigantea Thomas	6
Lingula mytiloides Sowerby	1
Orbiculoidea nitidea (Phillips)	4
Productus carbonarius De Koninck	6
Schizophoria sp.	1, 2
Crinoid columnals	4
Nuculana cf. attenata (Fleming)	4
Coleolus carbonarius Demanet	5
C. reticulatus Demanet	4
Glabrocingulum sp.	4
Euphemites jacksoni (Weir)	4
Pseudorthoceras sp.	1, 2
Ephippioceras aff. clitellarium (J.de.C.Sowerby)	4
Metacoceras sp.	4
Dimorphoceras sp.	1
Reticuloceras reticulatum (Phillips)	1
R. reticulatum young form	3
Rhabdoderma sp.	1

Localities:-

1. Nr.Stubbing Barn, R.Greta.
2. Above Clintsfield Grit, R.Greta.
3. Riddings Beck, E. of Wennington
4. Bentham Bridge.
5. R.Wenning, near Low Bentham
6. Nr.Gill Farm, S of Greta.

The following fauna was obtained from the Bentham Station Borehole and is in the Geological Survey Collection - (Specimen nos. W.G. 537 - 552):-

Chonetes cf. hardrensis Phillips	1, 4
Lingula mytiloides Sowerby	3, 4
Orbiculoidea nitidea (Phillips)	1, 4
Productus carbonarius De Koninck	1, 2
Crinoid columnals	1, 2, 3, 4
Aviculopecten cf. losseni (von Koenen)	1
Nuculana cf. attenata (Fleming)	3
Paleolima boltoni Demanet	3
Cleiothyridina sp.	2
Glabrocingulum sp.	3
Ptychomphalina sp.	3
Euphemites jacksoni (Weir)	3, 4
Ephippioceras aff. clitellarium (J.de.C.Sowerby)	3
Homoceras sp.	3
Reticuloceras cf. subreticulatum (Foord)	3
Forams. including Rectocornuspira	3

Localities:- Bentham Station Borehole

1. 123 - 214 feet
2. 275 - 298 feet
3. 338 - 377 feet
4. 588 - 602 feet

3). The Greta Grit Group

The base of the Greta Grit Group is taken at the Reticuloceras gracile marine band which immediately overlies the Upper Bentham Grit in the River Greta. The group contains two grits of which the lower - the Greta Grit - is a massive coarse red felspathic pebbly grit, and the upper is a finer grained white quartzitic grit (Fig. 4). The Greta Grit and its underlying sandstones and flags are well seen in the north bank above some 40 feet of black shale with Reticuloceras gracile Bisat (34/634719). The upper part of the group is exposed in both banks but is partly obscured by landslips at times. Sandy shales and flags form the bulk of this part. A thin black shale overlies the Greta Grit, and although its base is not seen in the Greta, an exposure in Nutgill Beck (34/695707) shows 2 inches of coal with Lingula in the roof shales.

The Greta Grit can be traced intermittently from the Greta towards Bentham, and is the grit upon which most of High Bentham is built, and which is incorrectly shown as Rough Rock on the Old Series Sheets 91 NE and 92 NW. The R. gracile band is exposed below this near High West End Farm, Low Bentham (34/647698) and at Belle Bank, east of High Bentham (34/677693). The Greta Grit appears to have been encountered in the Seat Hall Borehole /34/661698) although the available record is too generalized for exact correlation. As shown in Fig. 4 , this borehole can partly be correlated with the type section in the Greta by paleontological evidence. The white upper grit of the Greta Grit Group is best seen in the north bank of the Greta

near the hydraulic ram (34/639719). Some 60 feet higher at the mouth of a small tributary on the south bank is the marine band with Gastrioceras cancellatum Bisat which marks the base of the overlying Rough Rock Shales. The Greta Grit Group thus falls into the R_2 goniatite zone, and is 260 feet thick in the Greta.

The Holden House Borehole sunk in 1906 in the centre of the coalfield, two miles north of Burton-in-Lonsdale (34/658741) is believed to have penetrated the Greta Grit Group. No fauna has been preserved, and the only faunal records are those given in an unpublished report by Prof. Lebour, listed below and also shown in Fig.4 . Comparison of the record of strata penetrated with the type section in the Greta, together with the report, gives clear evidence that the boring reached the Upper Bentham Grit before being abandoned, and the R. gracile band is indicated by Prof. Lebour's reference to "at least three species of goniatite, Lingula, Orthoceras, Chonetes and several lamellibranchs in 45 feet of black shale down to 1645 feet".

The fauna collected in situ from the Greta Grit Group is as follows:-

Lingula mytiloides	Sowerby	1
Orbiculoidea nitida	(Phillips)	1
Dielasma sp.		1
Productus Carbonarius de Kininck		1
Dunbarella speciosa (Jackson)		1, 2, 3
Posidonia obliqua de Koninck		1, 2, 3
Posidoniella multirugata Jackson		2
P. vetusta (J.de. C.Sowerby)		1
P. cf. semisulcata Hind		1
Pseudamusium cf. purvesi Demanet		2,3
Orthoceras sp.		1
Dimorphoceras sp.		1
Reticuloceras gracile Bisat		1, 2, 3
R. cf. bilingue Bisat		1, 2, 3
Fish Spine		

Localities:-

1. N.Bank of R.Greta (34/635721)
2. Nr.High West End, Low Bentham
3. Belle Bank, High Bentham

The following fauna from the Seat Hall Borehole is in the collection of the Geological Survey (Specimen Nos. W.G. 440 - 441, 499 - 536)

Chonetes cf. hardrensis Phillips	4
C. laguessianus de Koninck	1, 4
Lingula mytiloides Sowerby	1, 2, 3, 4
Orbiculoidea nitida (Phillips)	1, 2, 3, 4
Productus carbonarius de Koninck	2, 4
Spirifer bisulcatus J.de. C.Sowerby	4
Dunbarella speciosa (Jackson)	2
Posidoniella cf. minor (Brown)	2
Tornquistia cf. polita (McCoy)	1
Orthoceras sp.	4
Anthracoceras sp.	4
Reticuloceras gracile Bisat	1, 2
R. gracile, old age form = R.davisi (Foord and Cricke)	2
R. reticulatum (Phillips)	4
R.cf. reticulatum (Phillips)	1

Localities in the Seat Hall Borehole:-

1. 444 - 454 feet
2. 464 - 486 feet
3. 490 - 499 feet
4. 515 - 525 feet

4). The Rough Rock and Rough Rock Shales.

Between the top of the Greta Grit Group and the Rough Rock are 110 feet of dominantly shaly beds, with subordinate flags. These are exposed only in the River Greta, and are best seen in the south bank between the Chalybeate Springs (34/643719) and the small tributary some 300 yards downstream.

At the base is a marine band with the following fauna:-

Lingula mytiloides Sowerby
Orbiculoidea nitida (Phillips)
Productus carbonarius de Koninck
Nuculana sharmani Etheridge
Anthracoceras sp.
Gastrioceras cancellatum Bisat
G. cf. lineatum Wright
Gastrioceras sp.
Megalichthys sp.

The marine shells are confined to one inch of fine black shale. Coarser shale contains Lingula alone for half an inch above and below. Two inches of coarse shale between the marine band and a thick ganister below contain large but

poorly preserved non-marine lamellibranchs which include:-

Carbonicola lenicurvata Trueman
C. cf. lenicurvata Trueman
C. aff. pseudacuta Trueman
C. cf. deansi Eagar
C. cf. obliqua Wright
? C. cf. protea Wright

It is possible to obtain slabs of shale less than one inch thick with marine shells on one side, non-marine on the other, and Lingula between. The non-marine shells are in considerably coarser and more micaceous shale. Twenty five feet higher is a thick black rootlet shale and two inches of coal overlain by a grey shale with poorly preserved small shells doubtfully referable to cf. Carbonicola lenicurvata Trueman and cf. C. pseudacuta Trueman. These shales are incompletely exposed and appear to pass up into a thin series of flags capped by a hard ganister, and the shales above this contain scattered Gastrioceras cumbriense Bisat. One band one inch thick contains abundant fragments of G. cumbriense and other shells. The fauna obtained from this band is as follows:-

Lingula mytiloides Sowerby
Orbiculoidea nitida (Phillips)
Productus carbonarius de Koninck
Aviculopecten cf. gentilis Sowerby
Dunbarella speciosa (Jackson)
Posidoniella rugata Jackson
Metacoceras sp.
Dimorphoceras sp.
Gastrioceras cumbriense Bisat
G. cf. cancellatum Bisat
G. cf. crencellatum Bisat
Fish Scales including Cladodus sp.
Cordaites sp.
Diplotmema sp.

Twenty three feet above this band is the sharply defined base of the Rough Rock, a coarse felspathic grit 27 feet thick. Bands of pyrite nodules near the top, which are exposed in the river bed, probably weather to give rise to the Chalybeate springs on the south bank. A small fault repeats the Rough Rock and G. cumbriense band, so that the latter is exposed four times - twice in each bank. The best locality for collecting is in the south

bank 10 yards N.E. of the Chalybeate springs.

The Rough Rock shales are not exposed elsewhere in the coalfield but have been penetrated in two boreholes. The Seat Hall Borehole commenced just above the G. Cumbriense band, and at 60 feet depth this penetrated a grey shale with non-marine lamellibranchs, probably to be correlated with the band with small cf. Carbonicola lenicurvata in the Greta, 25 feet above the Gastrioceras cancellatum band. The latter is possibly represented by the occurrence of Orbiculoidea nitida (Phillips) and Paleoneilo sp. at 120 - 145 feet, though this may represent the Lingula band above the Greta Grit.

The fauna of the Seat Hall Borehole in the Rough Rock Shales in the Geological Survey collections is as follows:-

Lingula mytiloides	Sowerby	1, 3
Orbiculoidea nitida	(Phillips)	3
Productus carbonarius	de Koninck	1
Nuculana sharmani	Etheridge	3
Palaeoneilo sp.		3
Anthraconaia sp.		2
Carbonicola sp.		2
Gastrioceras cumbriense	Bisat	1
G. cf. cancellatum	Bisat	1

Localities in the Seat Hall Borehole:-

1. 40 feet
2. 56 - 100 ft. (one specimen labelled 60 ft).
3. 120 - 145 feet (Specimen Nos. W.G. 435 - 9, W.G. 483 - 498).

The Holden House Borehole also passed through the Rough Rock and shales. No fauna is recorded although Prof. Lebour refers to the occurrence of marine fossils. The lithological record shows a close similarity to the succession in the Greta although thicknesses are much reduced, the Rough Rock itself being only 10 feet thick (Fig. 4)

Summarizing, the Millstone Grit sequence in the Greta totals 900 feet from the Clintsfield Coals up to the Rough Rock. Other sections available for comparison are confined to the three boreholes, Bentham Station, Seat Hall,

and Holden House, and to scattered outcrops in the Wenning Valley. All the available data is brought together in Fig. 4 and it is evident that there is a marked attenuation from south to north, at least in the upper zones, and probably throughout. The thickness from the Reticuloceras gracile band to the Rough Rock is now shown to be 400 feet. Bisat and Hudson (1941) quoted Slinger (unpublished, 1936) as giving a thickness of 150 feet.

ii. Coal Measures

(a) General. The Coal Measures fall naturally into two groups; a lower group of dominatly grey measures which contains the workable coals, and an upper group of dominantly red measures without workable coals. The two groups are separated by an unconformity described below (p. 34). Previous workers have not introduced any clear-cut terminology, only provisional correlations to the Middle and Upper Coal Measures of the Yorkshire and Lancashire successions. Lower Coal Measures have not been recognised previously. The conventional terms of Lower and Middle Coal Measures are not used owing to the lack of a definite limiting horizon which does not introduce ambiguity when compared with other coalfields. For the sake of convenience the two groups are described as Grey Measures and Red Measures respectively. The latter is subdivided into an Upper and a Lower series for reasons given below (p. 28). The Upper portion of the Grey Measures, which contains the workable coals will occasionally be referred to as Productive Coal Measures. It must be realized that some red-coloured beds do occur within the Grey Measures, presumably due to secondary staining and oxidation, and some grey beds also occur within the Red Measures. Coal Measures are well exposed in the River Greta south of Burton-in-Londsdale and an ascending sequence is seen as

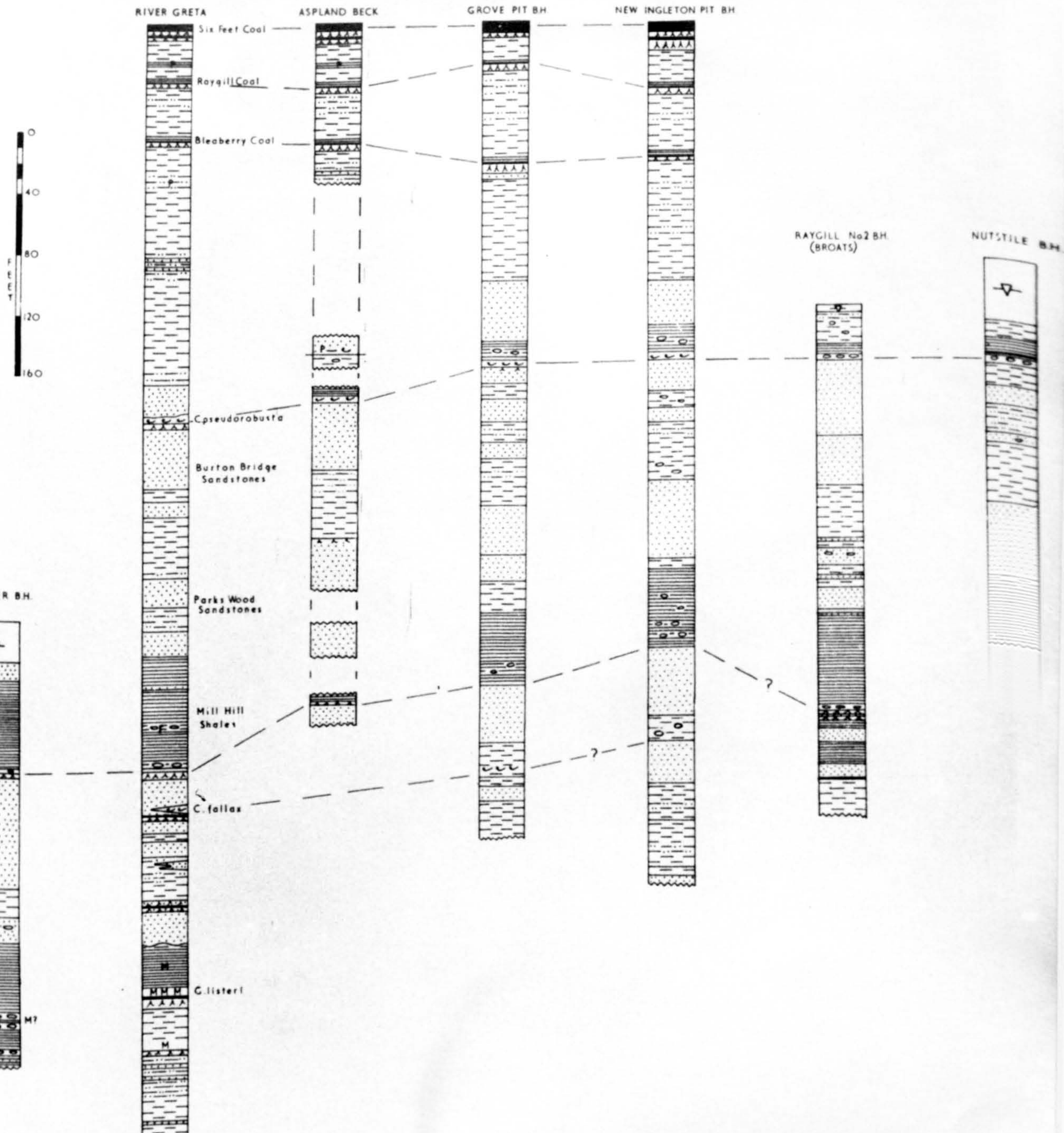
the river is followed upstream to Ingleton. The River Greta thus presents an almost complete succession of the Coal Measures as developed in this area and consequently forms the type section. In the northern end of the Coalfield Leck Beck gives a long and somewhat complicated section of both Grey and Red Measures. No single horizon has definitely been recognized in both Leck Beck and the River Greta and correlation is based on palaeontological evidence.

(b) Details of Grey Measures.

1) Grey Measures - Rough Rock to Six Feet Coal.

Continuing the section in the River Greta upstream from the Rough Rock there is almost unbroken exposure of some 900 feet of beds up to the base of the Red Measures at Parkfoot (34/672718) all with a gentle northeast to northerly dip. The workable coals are confined to the uppermost 150 feet, and of these the lowest, the Six Feet Coal, makes a useful horizon for mapping and subdivision of the succession (Fig. 5). Above the Rough Rock in the south bank is a thick fireclay followed by dark grey marine shales with Lingula mytiloides Sowerby, Orbiculoidea nitida (Phillips) and fragments of Productus carbonarius Demanet. In the coarse shales which follow are occasional cf. Anthraconaia bellula (Bolton) and above a flaggy development is a thin ganister, coal smut and sandy shale with Dunbarella papyracea (J.Sowerby). Some 30 feet higher is a thick ganister with two inches of coal overlain by 18 inches of laminated black shale with abundant D. papyracea and goniatites. The latter are mostly crushed and slickensided but ornament of the Gastrioceras listeri group is sometimes preserved. Also present are Lingula mytiloides and fish scales including Rhabdoderma and Rhadinichthys. The band is exposed in the south bank, about 80 yards west of the remains of a small weir (34/644721).

COMPARATIVE SECTIONS OF STRATA BELOW THE SIX FEET COAL, INGLETON



Some 25 feet above the G.listeri band is a transgressive sandstone with a 6 inch coal near the top. A cycle of shale, flags, sandstone and ganister follows but the base of the shale is obscured by the concrete of the weir. A thick sandstone overlies the ganister, which has been worked in both banks, and appears to split near the mouth of Clifford Gill. The intervening shales are exposed in a tunnel mouth on the south bank close to the mouth of the gill (34/648717) where they yield abundant non-marine lamellibranchs including:-

Anthraconaia cf. lenisulcata Trueman
A. cf. bellula (Bolton)
Carbonicola fallax Wright
C. aff. fallax (elongate form)
C. cf. protea Wright

At this locality the non-marine shale rests directly on the lower leaf of sandstone, but southwards, up Clifford Gill the shale increases in thickness, and south of a small fault a thin Lingula band, thin coal and black rootlet shales are seen below the non-marine shale (34/648714).

Above the sandstones is a ganister, formerly mined for brick-making, and then 70 feet of blue-black shale, the Mill Hill Shales, with rare fish scales and Calamite fragments. This section is well exposed in a bluff east of the lower reaches of Clifford Gill. In the north bank of the river opposite Greta House the Mill Hill Shales are seen to pass up into two groups of coarse red, yellow and purple false-bedded sandstones separated by grey micaceous sandy shales. The lower group makes a prominent bluff at Parks Wood (34/649719) and the upper forms the foundations for the old weir below Burton Bridge (34/652719).

Immediately overlying the Burton Bridge Sandstones is a fireclay followed by 8 feet of black shales with abundant fish debris and non-marine lamellibranchs in a thin band at the base. The band is exposed in the river bed close to the south bank 20 yards west of the Bridge, but the

lamellibranchs are commonly replaced by pyrite bands. Better collecting may be had in Aspland Beck (see below). The fauna collected from this band clearly indicates an horizon in the communis zone and includes:-

Carbonicola pseudorobusta	Trueman
C. aff. pseudorobusta	Trueman
C. communis	Davies and Trueman
C. aff. communis	Davies and Trueman
C. aff. crista-galli	Wright
C. cf. robusta	(J.de C.Sowerby)
Acanthodes sp.	
Acrolepis hopkinsi	McCoy
Elonichthys aitkeni	Traquair
Rhabdoderma aldingeri	Moy-Thomas
Rhizodopsis sauroides	(Williamson)

Overlying these shales is a thick development of light grey shales and sandy shales with subordinate sandstones and two thin coals. About 280 feet thick this constitutes the remainder of the succession up to the Six Feet Coal. Plant debris occurs at several horizons and pinnules of Neuropteris gigantea Sternberg are not uncommon. Lyginopteris sp. was found near the top of these beds. In Aspland Beck (34/677710) the lower part of these beds yielded Anthraconauta minima (Hind). 75 feet below the Six Feet Coal is the Bleaberry Coal, 4 to 8 inches thick, with a thick white fireclay which was extensively worked west of Bleaberry Hill for earthenware manufacture. The coal is overlain by 9 inches of black shale with rare fish scales including Acrolepis sp. and Rhizodopsis sp. The Raygill Coal is 40 feet higher and is 2 inches thick, with another thick white fireclay. Fragments of Lepidodendron are frequent in the immediate roof shales, and some 6 feet higher. The following were collected:-

Neuropteris obliqua	(Brongriart)
Lepidodendron loricatum	Arber
L. wortheni	Lesquereux
Calamites paleaceus	Stur
Cordianthus sp.	
Rhizodopsis scales.	

These thin coals are best seen in Aspland Beck, being generally obscured by the tip of the old Waterside Pottery

where they outcrop in the bank of the River Greta (34/677714).

The section in the River Greta totals 750 feet in thickness from the Rough Rock to the Six Feet Coal. Beds belonging to this series are also exposed in Aspland Beck, which joins the Greta at Parkfoot. For nearly a mile to the south east there is in Aspland Beck a descending succession of beds on going upstream. The lowest horizon seen is the Ganister at the base of the Mill Hill Shales. All the major lithological divisions above this can be recognized although exposure is far from complete. The shales with C. pseudorobusta are well exposed close to the footbridge by Dumb Tom's Barn (34/677709). The Six Feet, Raygill, and Bleaberry Coals are exposed immediately west and south of Raygill Farm. The discontinuous nature of the section makes detailed comparisons of thickness of individual members of the succession impossible, but there does not appear to be any major change between Aspland Beck and the Greta.

Several boreholes penetrated strata below the Six Feet Coal and in all cases the lithological succession shows close agreement with the sequence in the Greta as shown in Fig.5 . No faunas were recorded but the presence of fossils is noted at horizons corresponding to the C. pseudorobusta band in borings sunk from the pit bottoms at Grove Pit (34/693715) and New Ingleton Pit (34/695723). Fossils are also recorded at about the C. fallax horizon in the Grove Pit borehole. In the others, Raygill No.2 (34/686712), Nutstile (34/694714) and Thornber (34/671701), "bullets" or "iron balls" are recorded at equivalent horizons. There is a slight suggestion of northeasterly thinning from the Greta to New Ingleton Pit. The Holden House Borehole is believed, for reasons given below (p. 38) to have penetrated

only the lowest part of this series. 18 inches of shale with abundant "Aviculopecten" are recorded by Lebour at 1266 feet, and probably are to be correlated with the Gastrioceras listeri marine band. The succession down to the Rough Rock in the borehole resembles that in the Greta.

The following plants from 270 feet depth in Grove Pit borehole are in the Geological Survey Collection (W.G. 470).

Mariopteris sp.
Calamites sp.
Myriophyllites sp.

It is not clear however whether depth was measured from the top of the boring which started from the shaft bottom, or from the surface.

2) Grey Measures - Six Feet Coal to the highest Grey Measures, R.Greta.

The exposed productive coals are four in number, of which the Six Feet (or Deep) Coal and the Four Feet (or Main) Coal are the most extensively worked. The Yard Coal, close below the Four Feet Coal, is of poorer quality and presents difficulties in working as only soft fireclay lies between the two. The Crow Coal, 15 to 18 inches thick lies between the two main seams and has only been worked on a limited scale, although the fireclay was worked for pottery. The Six Feet Coal may reach 8 feet in thickness when the dirt between it and an underlying 12 inch coal dies out. Otherwise it averages 5 feet 10 inches. The Four Feet Coal maintains the thickness by which it is named throughout the area. The Yard Coal is somewhat variable; generally less than a yard thick it may decrease to 23 inches, although in New Ingleton Pit a local thickening to 5 feet 9 inches is recorded. Detailed sections of coals, extraced from mining records are given in Fig. 7 . Relative positions in the succession are given in Fig. 6 . There do not appear to be any significant variations between the type section in the Greta and those in shafts and borings.

COMPARATIVE SECTIONS OF THE PRODUCTIVE COAL MEASURES

INGLETON

Scale of Feet

40 20 0 40 80 120

Coal — Plants P P

Cannel coal — Shells

Thickness of coal seams given in inches

LECK BECK

BOGG BECK

BARNOLDSWICK B.H.

GRETA-PARKFOOT & ASPLAND BECK

NEWFIELD PIT

WILSON WOOD PIT

WINNING PIT

NEW INGLETON PIT

No 3 B.H.

GRETA-STEPHENS WOOD

BASE OF MEASURES

BARREN RED

undifferentiated strata

undifferentiated strata coloured red on shaft section

coloured grey on shaft section

Four Feet Coal

Yard coal

Six Feet Coal

Bleaberry Coal

<10° dip

>10° dip

FEET 120 80 40 0

Fig. 6

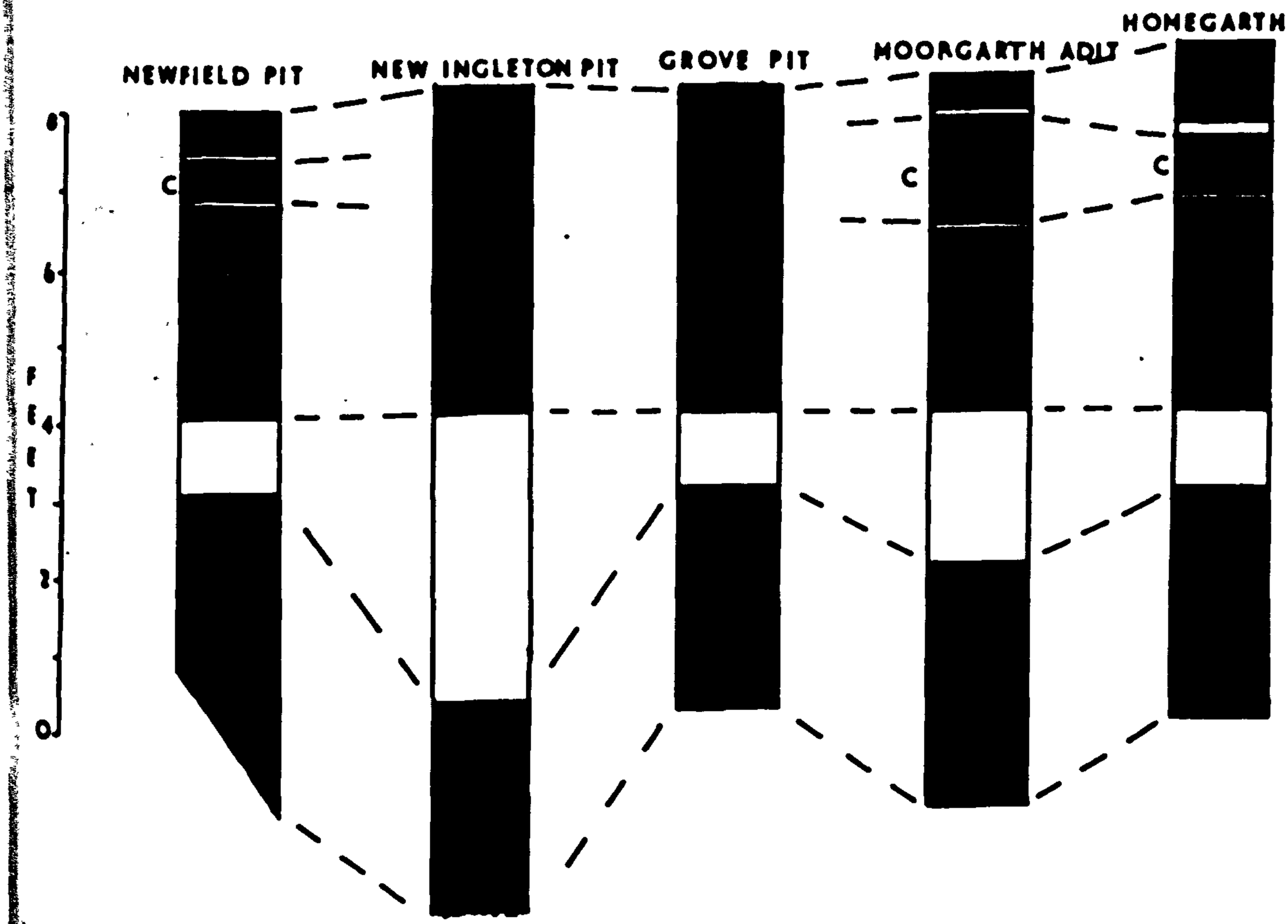
In the River Greta the Six Feet Coal is exposed in the river bed at the site of the old toll bridge near Greta Bank Pottery (34/664717) and abundant plant remains occur in the light grey roof shales and in some ironstones scattered through these shales. The following flora was collected in situ:-

Sphenopteris nummularia Cyctbier
S. obtusiloba Brongniart
Renaultia gracilis Brongniart
Diplotmema furcatum (Brongniart)
D. sturi (Gothan)
Diplotmema sp. (cf. sturi)
Zeilleria avoldensis (Stur)
Mariopteris cf. acuta Brongniart
M. muricata (Schlotheim)
M. nervosa (Brongniart)
Mariopteris sp. (cf. coarctata)
Alethopteris davneuxi Brongniart
A. decurrens (Artis)
A. valida Boulay
Alethopteris sp.
Asterotheca miltoni ? (Artis)
Sphenophyllum aff. majus Bronn
S. cuneifolium (Sternberg)
S. cuneifolium forma saxifragaefolium (Sternberg)
Lepidodendron cf. aculcatum Sternberg
L. loricatum (Arber)
L. cf. obovatum Sternberg
Lepidophloios acerosus (Lindley and Hutton)
L. cf. laricinus (Sternberg)
Lepidophyllum triangulare Zeiller
L. minus Goode
Lepidostrobus spp.
Sigillarophyllum sp.
Calamites cf. suckowi Brongniart
Asterophyllites equisetiformis (Schlotheim)
Cyclopteris sp. (trichmanoides?)
Samaropsis sp.
Pinnularia capillacea Lindley and Hutton
Cordaites sp.
Spirorbis sp.

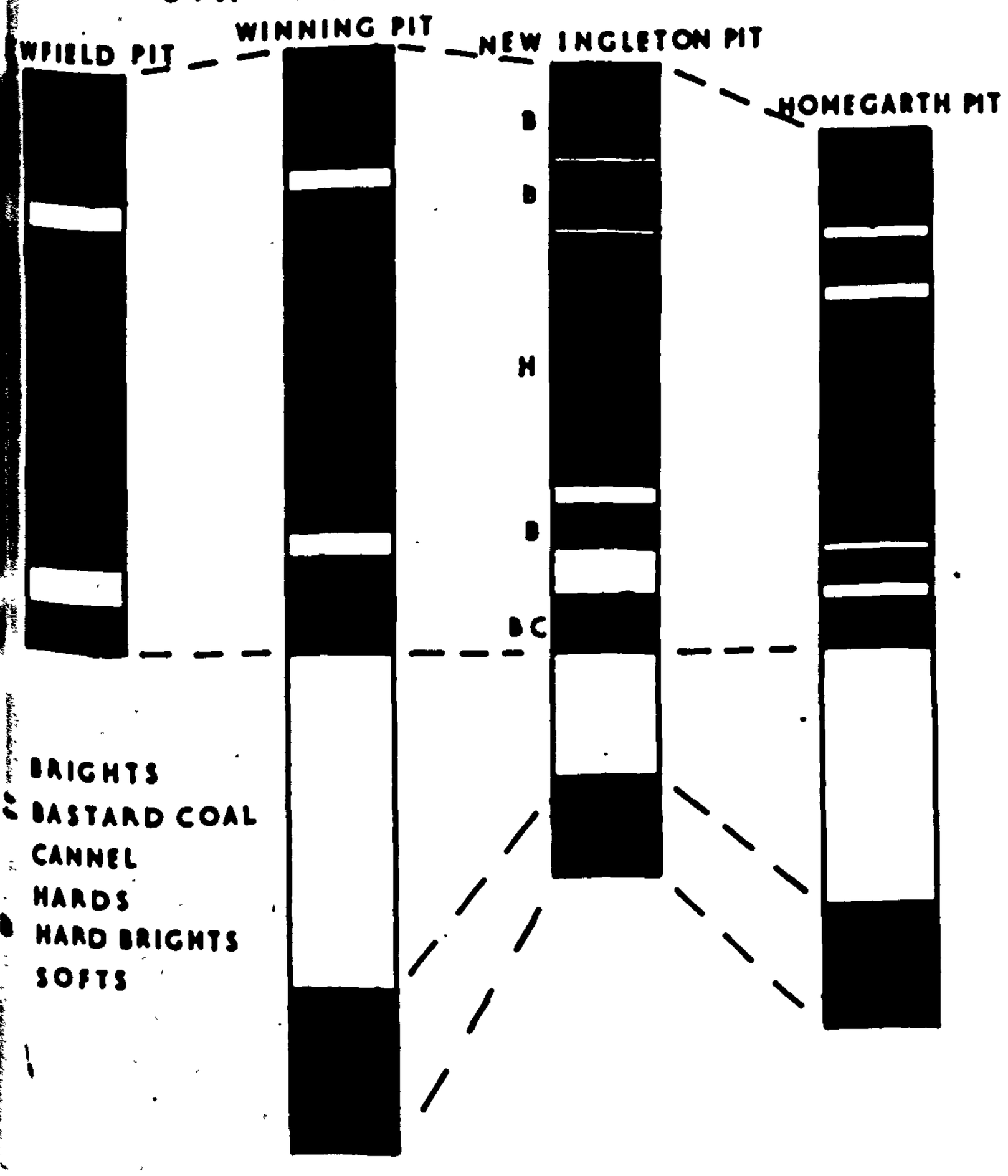
In addition the author has examined collections now in the Sedgwick Museum, Cambridge, and in the Geological Survey Museum, made by Prof. T.McKenny Hughes and Miss G. Elles in the 1880's, and a collection in the Geology Department, University of Sheffield made by Prof. Fearnsides in 1915. A few plants mentioned by Kidston in his monograph (1924) are also included. The following list includes plants believed to occur at this horizon but not found in situ by the author.

COMPARATIVE SECTIONS OF INGLETON COALS

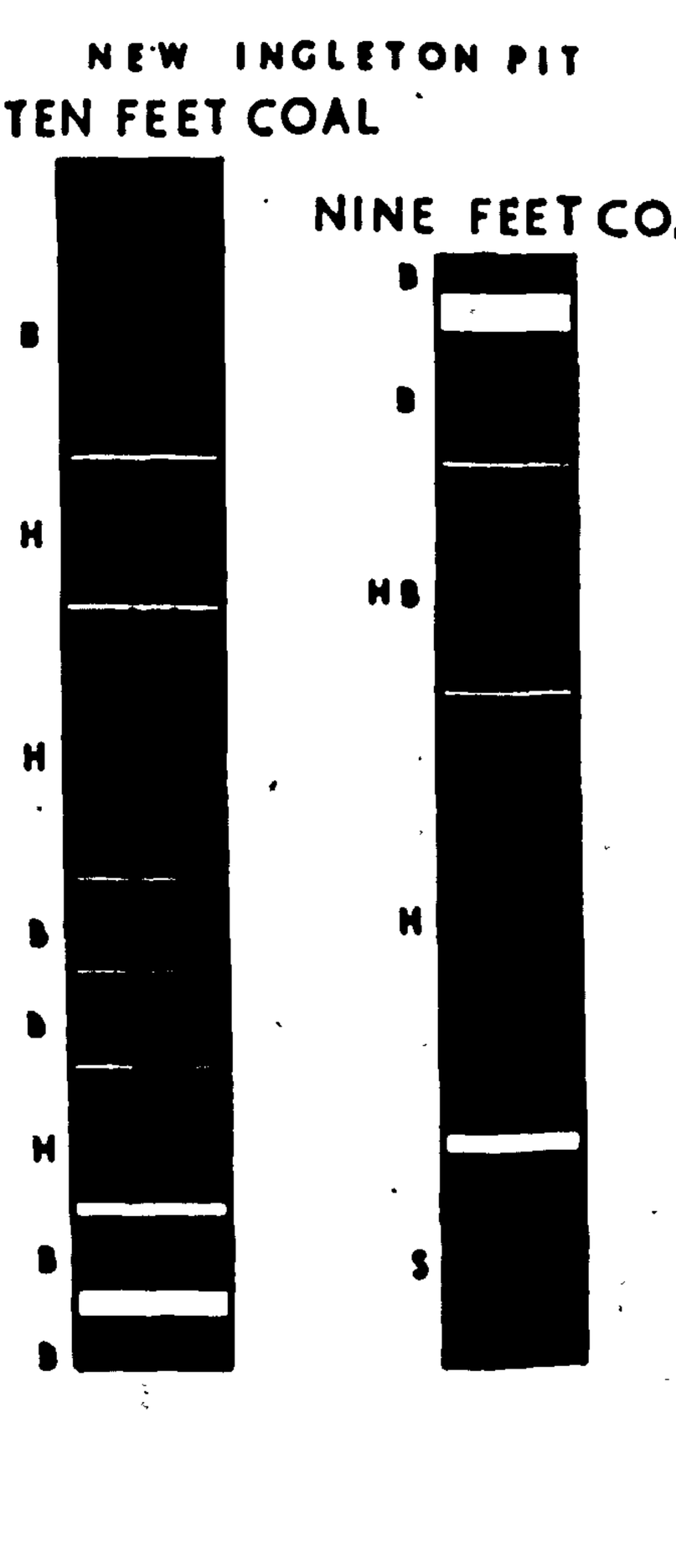
FOUR FEET & YARD COALS



SIX FEET COAL



TEN FEET COAL



Sphenopteris bella (Stur)	K	
S. laurenti Andrae	S	
Alethopteris lonchitica (Schlotheim)		GS
A.valida Boulay	S	
Neuropteris gigantea Sternberg		F
N. heterophylla Brongniart	F	
N. obliqua (Brongniart)	S	
N. obliqua forma impars Stockman		S
N. tenuifolia (Schlotheim)	F	
Lepidodendron obovatum Sternberg		GS
L. simile Kidstone	S	
L. cf. lanceolatum Lesquereux	S	
Bothrodendron sp.	S	
Lepidophyllum sp.	S	

S = Sedgwick Museum (Specimen Nos. W 1114, W 1360, W 1361, E 2178-92, I 2194-2203, I 2205-6, I 2208-9), G.S. = Geol. Surv. (Specimens Nos. RC 2689-90, 2701-10), F = University of Sheffield, K = Kidston. Fearnsides' specimens were obtained from workings in New Ingleton Pit. Of the others the Lycopods and some pteridosperms were found in situ, the remainder being from Newfield Pit (34/689715). In the case of the colliery specimens no horizon is given but the Six Feet Coal is the only worked coal at this pit known to carry plants in its roof, and the lithology of these specimens is identical with that of those obtained in situ.

The plant bearing shales pass up into light grey sandy shales and soft sandstone. Solid and upright casts of tree trunks occur frequently in these beds, particularly about 10 to 15 feet above the Six Feet Coal. A good example is seen under the north bank at the west end of Stephens Wood (34/661720). Cannel is recorded at a similar horizon at Grove Pit but is not present at outcrop. 30 to 40 feet above the Six Feet Coal are two prominent bands of large ironstones. These take the form of large oval concretions some 7 feet long by 4 feet wide and high, and some have strong cone-in-cone structures on the red outer surface. Locally the concretions pass into beds one to two feet thick and extending 50 feet or more. Their secondary origin is shown by small-scale false-bedding in the surrounding sandy shale passing into the

the ironstone with little or no break. The ironstones are well exposed in the River Greta at several points between Bleaberry Hill and Parkfoot. Just above the ironstones and six feet below the Crow Coal is a second fine grey shale with abundant plant remains - the Crow Coal Shales. These are exposed below the Crow Coal in the north bank, 220 yards North-east of Faccon Farm (34/670717). The flora is similar to that above the Six Feet Coal but less rich, and the relative abundance of some plants is somewhat different. Small ironstones in the shales contain lycopods only. The following plants were collected in situ:-

Mariopteris coarctata Stur
M. hirta (Stur)
M. cf. hirta (Stur)
M. muricata (Schlotheim)
Corynepteris sp. (cf. sternbergi)
Alethopteris davreuxi Brongniart
Neuropteris cf. grangeri Brongniart
N. obliqua (Brongniart)
N. obliqua forma impars Stockman
N. cf. osmundae (Artis)
Sphenophyllum cuneifolium (Sternberg)
S. cuneifolium forma saxifragaefolium (Sternberg)
Lepidodendron obovatum Sternberg
Lepidophloios acerosus (Lindley and Hutton)
Lepidophyllum acuminatum Lesquereux
Calamites carinatus Sternberg
C. undulatus Sternberg
Annularia radiata Brongniart
Asterophyllites charoeformis Sternberg
A. equisetiformis (Schlotheim)

Estheria (Estheriella) striata Munster
Ostracod

The roof of the Crow Coal is a thin yellow sandstone which passes upwards into a succession of thin dark sandstones and dark sandy shales which contain thin bands of dark micaceous shale rich in Calamite fragments and pinnules and fronds of pteridosperms. These, the Parkfoot Shales, are exposed in the north bank of the Greta opposite the mouth of Aspland Beck. The following plants have been obtained in situ:-

Sphenopteris pseudofurcata Kidston
Alethopteris lonchitica (Schlotheim)
Neuropteris gigantea Sternberg

N.heterophylla Brongniart
N. cf. hollandica (Jongmans)
Neuropteris sp.
Calamites carinatus Sternberg
C. suckowi Brongniart
C. undulatus Sternberg
Cordaites sp.

The Parkfoot Shales, 25 feet thick, pass up into the fireclay below the Yard Coal. This and the Four Feet Coal lie 90 feet above the Six Feet Coal and are partly exposed above the Parkfoot Shales in the river bed (34/671718) but the detailed section is obscured by old outcrop workings and tips. The Four Feet Coal is overlain by a few feet of blue-black shale with abundant small ironstone concretions. Some of these contain several small non-marine lamellibranchs, others are single shells on their own, and the shale itself contains impressions of still more. Collecting is poor at this exposure as most of the shells are badly weathered, but the tips of all the collieries known to have worked the Four Feet Coal provide good specimens and part of the band, badly weathered, is seen in the railway cutting SE of Moorgarth (34/701715). No shells have been obtained from pits which did not work the Four Feet Coal. A selection of the shells were examined by Dr. Weir. The fauna indicates an horizon at or near the base of the modiolaris zone and includes:-

Anthraconaia williamsoni (Brown)
A. cf. williamsoni (Brown)
cf. Anthracosphaerium boltoni (Wright)
Carbonicola rhomboidalis Hind
C. cf. rhomboidalis Hind
C. subconstricta (J. Sowerby)
C. cf. subconstricta (J. Sowerby)
C. cf. acuta (J. Sowerby)
C. cf. robusta (J.de.C.Sowerby)
cf. C. crista-galli Wright
C. cf. martini (Trueman and Weir)
C. cf. obtusa Hind
Naiadites sp.

The Anthraconaias have been found as shale impressions only. The same horizon has yielded at the Grove Pit to only, abundant fragmentary Naiadites sp. and remains of the Arthropod Palaemysis sp., both as shale impressions.

Small ironstones on some of the tips particularly Grove Pit, have yielded plants, and although none have been found in situ, they are probably from about the same horizon. The plants include:-

Alethopteris lonchitica (Schlotheim)
A. cf. lonchitifolia Bertrand
Mariopteris cf. nervosa (Brongniart)
Neuropteris gigantea Sternberg
N. heterophylla (Schlotheim)
N. cf. tenuiøfolia (Schlotheim)

In addition the following plants from an unknown locality but probably from this horizon are preserved in the Sedgwick Museum (Specimen Nos. I 2193, 2204, 2207)

Neuropteris rarinervis Bunbury
Neuropteris sp. (cf. N.heterophylla - N.scheuchzeri)
Spirorbis sp.

3) Grey Measures - Unexposed beds above the Four Feet Coal.

Between the Four Feet Coal and the base of the Red Measures in the River Greta only about 40 feet of hard white sandstones and sandy shales are seen. But all the shafts and boreholes to the north east, i.e. nearer Ingleton, record higher Grey Measures beneath the Red Measures. Of these sinkings New Ingleton Pit gives the most complete section, totalling 330 feet between the Four Feet Coal and the base of the Red Measures (Fig. 6). No fauna has been obtained or recorded, but "Carbonicola acuta" is recorded by Gibson (1909) at several horizons in the adjoining No. 3 B.H. (S.E. of Ingleton Station 34/696724). These shells have not been preserved, nor has the "Lingula" recorded (Gibson 1909) at 922 feet in the same boring, at an horizon roughly 100 feet above the Four Feet Coals. The latter may indicate the presence of the Joan Coal Marine Band of Yorkshire. A small flora from 860 feet depth has been preserved in the Geological Survey Collections (Specimen Nos. W.G. 426-430, 457-467) and includes:-

Alethopteris decurrens (Artis)
Mariopteris cf. nervosa (Brongniart)
M. muricata (Schlotheim)
Mariopteris sp.
Neuropteris gigantea Sternberg
N. heterophylla (Schlotheim)
N. obliqua (Brongniart)

Also at 800 feet (W.G. 431-3)

Sigillaria principis (Weiss)
Calamites sp.
Lepidodendron sp.

Several thin coals, one reaching 38 inches in thickness, are recorded in the sinkings through these beds (Fig. 6) but none have been worked. In New Ingleton Pit alone two coals 10 feet and 9 feet thick were encountered and worked over a limited area at the top of the unexposed Grey Measures. The greater part of the unexposed Grey Measures are grey sandy shales with ironstone nodules. Subordinate bands of fireclay, black shale and thin sandstones are also recorded (Fig. 6).

4) Grey Measures - Leck Beck.

At the northern end of the Coalfield Leck Beck flows in a south-westerly direction from the Silurian rocks near the Dent Fault across the Craven Fault and down to the River Lune. For about a mile in its middle reaches Coal Measure strata are exposed, with a general southerly dip, modified by small east-west folds and at least two faults of unknown throw. There are many breaks in exposure and spring floods are liable to move large quantities of alluvial pebbles so that exposures change in size and character at almost every visit. There appears to be considerably more exposed now than when Tiddeman described the section in 1872.

The dominant colour of the Coal Measures in Leck Beck is red, and the division into true Red Measures and Grey Measures is taken, largely on palaeontological grounds, at a conglomerate a few yards north of Springs

Wood Footbridge, exposed in the north west bank (34/646779). The contact of Grey Measures with Silurian rocks at the Craven Fault is not exposed, there being a gap of about 10 yards between the nearest outcrops of the two. South westwards, downstream, there is an ascending sequence of Grey Measures, broken by at least one fault, close to the Craven Fault. Between these two are a few feet of dark grey sandy shales, a fireclay and about 10 feet of heavily slickensided black shales which have yielded from the stream bed Mariopteris acuta Brongniart and Diplotmema sp. The relations of these beds to those on the downthrow (south-west) side of the fault are unknown. South west of this fault is a coarse grey grit which passes upwards into a succession of nearly 500 feet of coarse red sandstones, fine purplish grey sandstones and grey sandy shales, all dipping roughly southwards at angles from 35° to 50°. A white ganister occurs near the middle of the section, which is broken by several gaps in exposures. In the south east bank about 30 yards upstream from the Springs Wood Footbridge there is a mottled red and white fireclay overlain by about 2 feet of fine grained pink shales. Above these are about 10 feet of coarser pinkish grey shales containing brick red ironstone nodules with calcite veining. With heat treatment solid shells of Anthracosia spp. can be extracted. Purple impressions and occasional solids occur in the pink shales. The fauna includes:-

Anthracosia ovum Trueman and Weir
A. cf. ovum Trueman and Weir
A. caledonica Trueman and Weir
A. cf. caledonica Trueman and Weir
A. aff. phrygiana (Wright)
A. aff. aquilina (J.de.C.Sowerby)
A. cf. aquilinoides (Tchernyshev)
A. cf. retrotracta (Wright)
Anthraconaia of modiolaris group (?cf. curtata Brown)
Naiadites sp.
Spirorbis sp.

That these clearly indicate a faunal horizon high in the modiolaris zone has been confirmed by Dr.Weir. The coarse shales pass up into light grey micaceous sandy shales, and 20 feet above the fossiliferous beds is the sharp base of the conglomerate taken as the base of the Red Measures.

It is suggested that these 500 feet of beds, of which the top belongs to the highest part of the modiolaris zone, lie stratigraphically above the Grey Measures of the River Greta and New Ingleton Pit, in which at least the base of the modiolaris zone is present, and which may include some of the middle part of the modiolaris zone. The nature and amount of the gap between the two series remains unknown.

(c) Details of Red Measures.

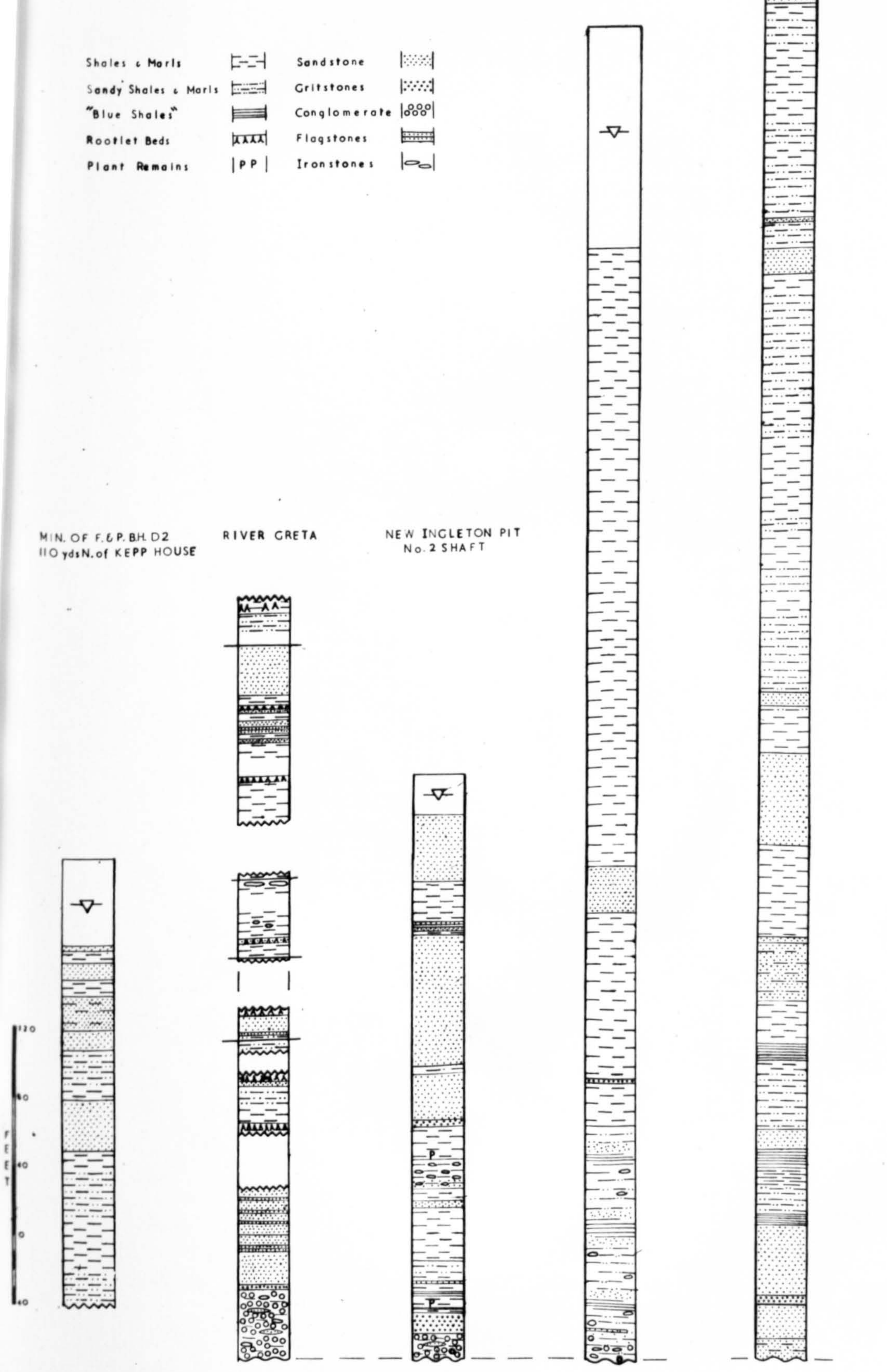
The Red Measures are divided naturally into two distinct parts, an Upper and a Lower group. The Upper Red Measures are seen in contact with Permian breccias but are separated from other Coal Measure rocks by faults of unknown throw, and by wide areas of drift. They are here designated ~~by~~ the Upper Red Measures since they are lithologically distinct from the Lower Red Measures, which alone are seen in contact with Grey Measures.

1) Lower Red Measures - River Greta.

Continuing up the type section in the River Greta, the Lower Red Measures are exposed from Parkfoot up to the Ingleton rubbish tip $\frac{1}{4}$ mile south of the main road bridge (34/686726). The section totals some 350 feet of pink and grey sandy shales and shales with fireclays (Fig. 8). Red and purple ironstones are not infrequent, and bands of deep purple shale occur sporadically throughout. Sandstones are almost entirely confined to the lower part of the section.

COMPARATIVE SECTIONS OF THE LOWER RED MEASURES OF THE INGLETON COALFIELD

Shales & Marls
Sandy Shales & Marls
"Blue Shales"
Rootlet Beds
Plant Remains
Sandstone
Gritstones
Conglomerate
Flagstones
Ironstones



The base of the Lower Red Measures consists of 40 feet of conglomerate, largely made of rounded pebbles of indurated shale and ironstone up to 6 inches long in a shaly matrix. Locally, hard sandstone channel infillings with impressions of pebbles on the sides occur as reefs in the river. At the mouth of Jenkin Beck the conglomerate is overlain by 8 feet of coarse red and yellow grit, and above this by hard pink quartzitic sandstones, with bands of coarse conglomerate. Pebbles in the latter are up to a foot in length. The sandstones and grit are also well exposed in the south bank at Stephens Wood where the grit thickens to 30 feet at the expense of the conglomerate, here reduced to less than 10 feet. Hard pink sandstone and some grit are also seen in Bogg Beck, east of Burton-in-Lonsdale (Fig. 6 & 10).

The sandstones pass up through flags into a cyclic sequence of shale, sandy shale, thin sandstone (sometimes) fireclay, shale. Except for the complete absence of coal the rhythm is the same as normal coal measures. Stigmarian rootlets are abundant in the fireclays, and casts of large roots occur occasionally in the sandstones. Ironstones are most common in the finer bands. Several small faults and gaps in exposures obscure the full sequence, and no faunal or floral horizons have been found.

2) Lower Red Measures - Mining evidence.

The 350 feet of beds seen in the Greta appear to be only the lowestpart of the Lower Red Measures as nearly 400 feet are recorded in New Ingleton Pit, 700 feet in No.3 Borehole, and 900 feet in the Holden House Borehole (Fig. 8). The records are somewhat generalized and it is difficult to determine the exact base in the last, and the last two may include part of the Upper Red Measures although there is nothing in the boring records

to suggest the presence of the "Spirorbis" limestones or breccias of the exposed Upper Red Measures. Plant remains are recorded about 50 feet above the base of the Red Measures in New Ingleton Pit, and specimens collected from an unknown horizon during the sinking, which cannot be correlated lithologically with any other known horizon, include abundant:-

Linopteris brongniarti (Grand Eury)
L. neuropteroides (Gutbier)
L. neuropteroides var. major Potamie

(Now in Sedgwick Museum Specimen Nos. I 1364, 1367, 1368, 1370, 1371).

Plants from a depth of 660 feet in No. 3 B.H. in the Geological Survey Collection (Specimen Nos. W.G 420-5, 442-454) include:-

Mariopteris sp.
Neuropteris tenuifolia (Schlotheim)
Neuropteris sp. ? cf. N. macrophylla (Brongniart)
Aulacopteris vulgaris (Grand Eury)

3) Lower Red Measures - Leck Beck.

The Lower Red Measures of Leck Beck are in general similar in lithology to those of the Greta, although no direct comparison can be drawn except that both have coarse sandstones and conglomerate at the base. At least two faults of unknown throw, break the Leck Beck succession. Features not present in the Greta are a coal half an inch thick overlain by four inches of black coaly shale and a few inches of green shale. This is exposed in the south bank 100 yards north west of Leck Mill (34/645771).

Above the conglomerate and coarse sandstone at Springs Wood footbridge are flags with sandy shales and thin sandstones. Unidentifiable fragments of pteridosperm fronds are scattered through the finer bands, which have weathered to a very crumbly condition. The steep dip decreases downstream and the beds are cut off by a strong east-west fault, with a smash belt 4 feet wide. South of

this fault a cyclic succession of beds similar to that seen in the Greta occurs in two small folds which cross the stream. Parts of at least five cyclothems are seen, the Leck Mill Coal forming the top of the middle one. In the lowest complete cyclothem seen the shales are strongly variegated, mottled and stripped with red and grey, clearly due to secondary alteration, as some of the stripes cut obliquely across the bedding although minute adjustment faults which break the stripes probably indicate the penecontemporaneous nature of the alterations. The variegated shales are exposed in both banks $\frac{1}{4}$ mile north of Leck Mill. A few feet above these, in the sharp bend in the river, a band of sandy ironstones, locally passing into coarse purple shale contains abundant pinnules of:-

Alethopteris sp. (of lonchitica - lonchitifolia group)
Neuropteris cf. gigantea Sternberg
N. tenuifolia (Schlotheim)
N. aff. flexuosa (Sternberg)
N. rarinervis Bunbury
cf. Linopteris sp.

Pink shales below the Leck Mill Coal have yielded casts of the ostracod Geisina arcuata (Bean) and higher in the sequence the shales above the Leck Mill Coal yielded a single shell from an ironstone in the north bank west of Leck Mill. The shell was identified by Dr.Weir as cf. Anthraconauta wrighti (Dix and Trueman), and probably indicates the basal portion of the phillipsi zone. Further careful search at this exposure yielded only fragments of plants in ironstone nodules, including:-

Neuropteris tenuifolia (Schlotheim)
N. cf. rarinervis Bunbury
Calamites carinatus Sternberg

West of Old Leck Parsonage a fault of unknown throw crosses the stream bringing coarse red, yellow and purple false-bedded sandstones against pink shales. These sandstones pass up into sandy shales and a fireclay. Pink shales above the fireclay have yielded fragments of

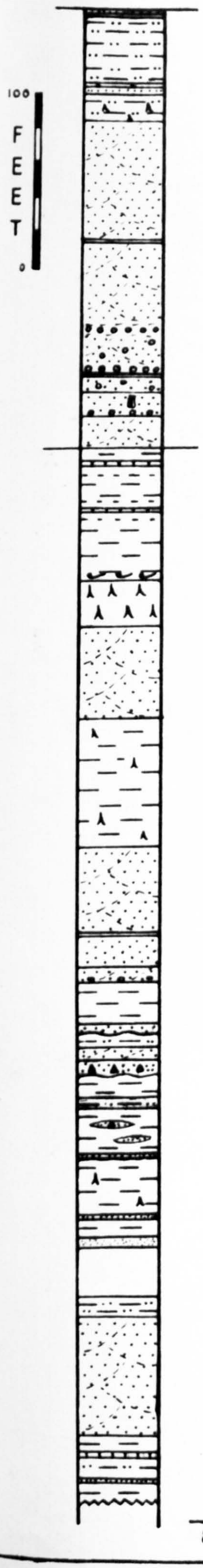
Neuropteris sp. and Calamites sp. in the foundations of some small breakwaters. These, in turn, are overlain by coarse red and purple false-bedded sandstones which are the highest beds seen in the section. These disappear under boulder clay opposite Park House (34/641769).

4) Upper Red Measures:

These beds are exposed in the type section of the River Greta close to Ingleton village, between the Hollintree Fault and a point just above the confluence of the Twiss and Dale Becks. As this lies between the two road bridges over the Greta at Ingleton it is referred to as the Between Bridges Section. The dip is steeply to the south west - the opposite of the Lower Red Measures and Grey Measures exposed downstream - becoming vertical near the base of the section under the railway viaduct as the Craven Fault is approached. A total of 850 feet of beds is exposed. The Upper Red Measures are dominantly sandy and contain breccias and coarse shale conglomerates at several horizons. Details of the succession are given in Fig. 9 . Three limestones are exposed. The lowest is a hard red calcareous rock outcropping at the base of the section in the north west bank of the Dale Beck 50 yards north of the viaduct (34/694733). The other two are close together in the middle of the section, outcropping in the northwest bank a few yards south of the farm buildings (34/692730). Both are highly dolomitized. Spirorbis has not been found in them but has been recorded in pebbles in the Permian breccias a mile to the west (Binney 1855). The two limestones are cut off by a fault which runs obliquely across the river.

The whole of the Upper Red Measures are dominantly red in colour with abundant green reduction spots. Fireclays with stigmarian rootlets occur at several horizons and there is some tendency towards cyclicity in the deposits. However

UPPER RED MEASURES BETWEEN BRIDGES, INGLETON.



		Hollin Tree FAULT
7'		Red & grey sandy shale & fine red shale
39'		Purple & grey sandy shale
2'		Red & green spotted clay with some roots
5'		Hard pink sandstone & shale
18'	3"	Soft purple micaceous sandy shale with some roots
70'		Purple false-bedded sandstone
1'		Soft red clay
52'		Red & purple strongly false-bedded sandstone
26'	3"	Sandstone with red & green shale conglomerate
2'	6"	Laminated green & purple shale
10'		Sandstone with scattered shale pebbles
13'	2"	Sandstone with calamite stems & shale conglomerate
20'		Coarse false-bedded sandstone
		FAULT
2'	4"	Mottled red & grey limestone & 5' lime-enriched shale
26'		Pink silty shale with lime-enrichments top & bottom
2'	2"	Mottled red & grey limestone with enrichments
34'		Pink, purple & light grey laminated silty shale with 1" SHELL BED near base
27'		Light grey & purple shales and rootlet beds
55'		Massive false-bedded red & purple sandstone
76'		Red, pink, purple & yellow clay shales with ferruginous joint enrichments & some roots
50'		Massive pink & purple false-bedded sandstone
	6"	White, yellow and chocolate clay
19'		Alternating hard & soft pink sandstone
8'	6"	Massive red false-bedded grit with shale pebbles
26'	6"	Coarse purple shale
6'		Coarse false-bedded sandstone with pebble bands
8'		Purple shale with sandy bands
8'	6"	Mottled false-bedded sandstone with stems & pebbles
7'	6"	Coarse false-bedded sandstone and breccias,
14'		Red clay shales with green spots and patches
7'		Purple laminated sandy shales with rare plants
26'	7"	Hard red clay shales with some breccia & sandy lenses
2'		Pink false-bedded sandstone with an irregular base
31'	7"	Red clay shales with green spots & some roots
1'	9"	Hard red micaceous sandstone
11'		Hard red caly shales with green spots & yellow bands
7'		Fine pink sandstone with red specks
25'		Ga[illegible]
10'	9"	Alternating fine & coarse purple & red shale
60'		Soft purple false-bedded micaceous sandstone
11'		Coarse purple micaceous shale
1'		Hard red calcareous rock
13'	6"	Sandy shale & fine shaley sandstone
12'		Red& purple laminated micaceous shale with plant debris
858'	4"	

the coarse members of each cycle are generally at the base and show evidence of rapid deposition. Opposite the old Slaughter House a fireclay is overlain by a shale breccia a foot thick which passes up into coarse sandstone with lenses of breccia and finally into sandy shales. In some higher cycles the place of the fireclay is taken by a few inches of leached yellow and white rubbly material - possibly a fossil soil, rather than a rootlet clay. In the higher parts of the section the cycle is sometimes reduced to alternations of coarse shale conglomerate and coarse false bedded sandstone. The conglomerate bands are up to 4 feet thick and commonly contain slabs of shale a foot or more in length. No lower Carboniferous or older rocks have been found in the conglomerates.

Quiet conditions intervened near the middle of the section, between the series with breccias and that with conglomerates. Shales containing a thick rootlet bed underlie the two limestones, and immediately below the manure heap on the west bank, about 30 feet below the lower limestone, the rootlet bed is overlain by 1 inch of fine red shale with large green reduction spots and which contains non-marine lamellibranchs including:-

Anthraconauta phillipsi (Williamson)
A. aff. phillipsi (Williamson)
A. cf. tenuis (Davies and Trueman)

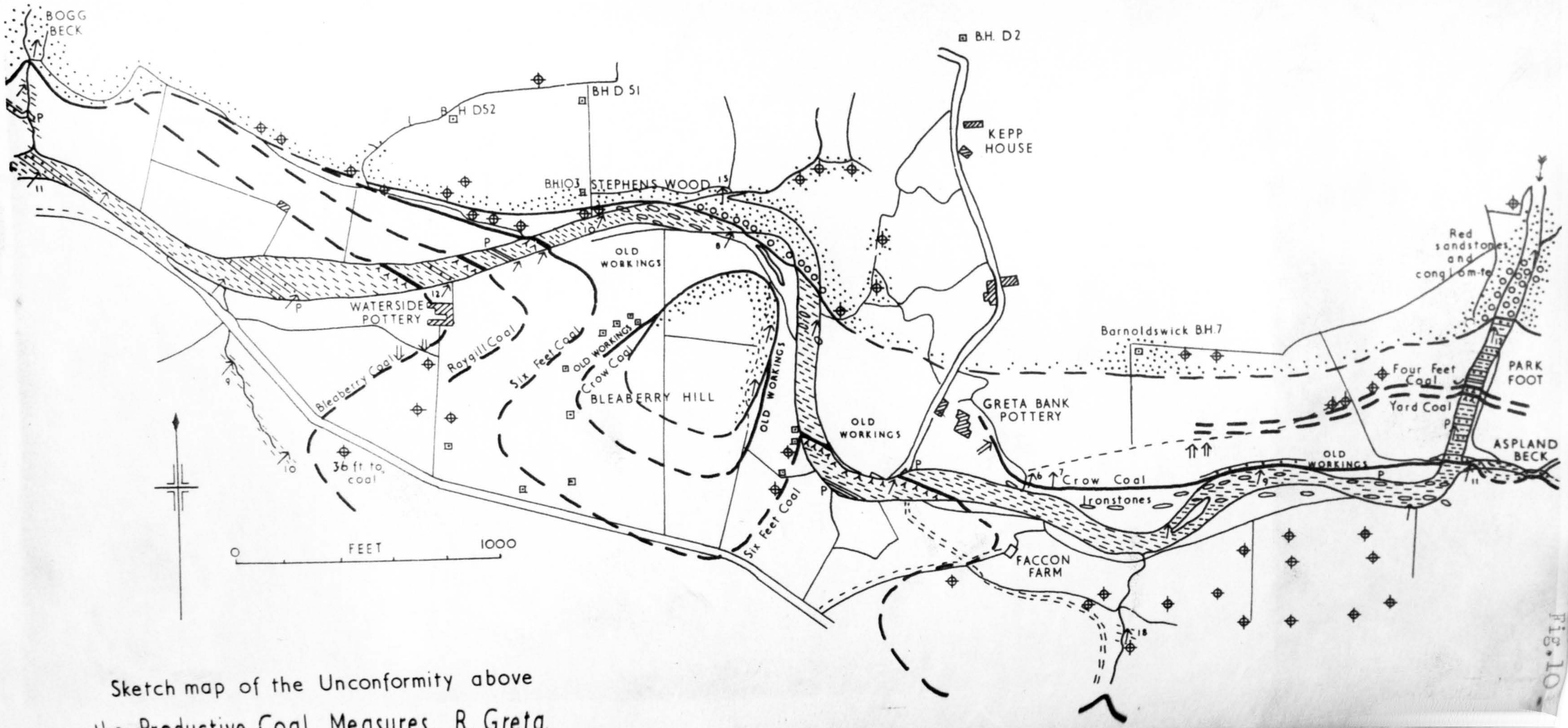
The largest shells reach 10 m.m. in length, but there are large numbers of spat, 1 to 2 m.m. long, on some bedding planes.

A section of Upper Red Measures lithologically similar to the lower third of the Between Bridges Section, is exposed below the unconformable base of the Permian breccias in Westhouse Gill about a mile to the north west (34/675747). The only fossil obtained, other than stigmarian rootlets, was a pinnule of Cyclopteris sp.

Summarizing, the Red Measures fall into two natural groups, an upper group of definitely phillipsi age and possibly as high as the lower part of the tenuis zone, and a lower group for which the available evidence is disappointingly small, i.e. a single shell, cf. Anthraconauta wrighti (Dix and Trueman) from Leck Beck, and Linopteris brongniarti (Grand Eury) in New Ingleton Pit. This is not inconsistent with the lower part of the phillipsi zone, as discussed below (p. 63). There is no definite evidence of the existence of the similis-pulchra zone in the coalfield, although the above may range as low as the top of this zone. Lithologically the Lower Red Measures are similar to the Etruria Marls of the Midlands, and the Upper Red Measures to the Newcastle and Keele groups, a comparison which agrees with the palaeontological evidence.

(d) The Intra-Coal-Measure Unconformity

The relationship between the Grey Measures below and the Red Measures above is considered to be unconformable. The key exposures for the demonstration of this unconformity occur in the banks of the River Greta for a distance of about one mile between Parkfoot and Burton-in-Lonsdale (Fig. 10). Detailed mapping on a 24 inches to one mile scale shows that the basal beds of the Red Measures step down westwards from an horizon 40 feet above the Four Feet Coal to one somewhat below the Bleaberry Coal, i.e. 240 feet of Grey Measures are overstepped in a distance of one mile. Evidence from mine plans, shaft and borehole sections (Fig. 6.) suggests similar relationships between these groups and extends the knowledge of the unconformity within the coalfield. Thus, relationship similar to that seen in the River Greta exists towards the northwestern limit of the Ingleton colliery workings where the coals are said to be cut out by "Red Rock". East of Parkfoot the general rise of the plane of unconformity brings in a further 300 feet of Grey Measures



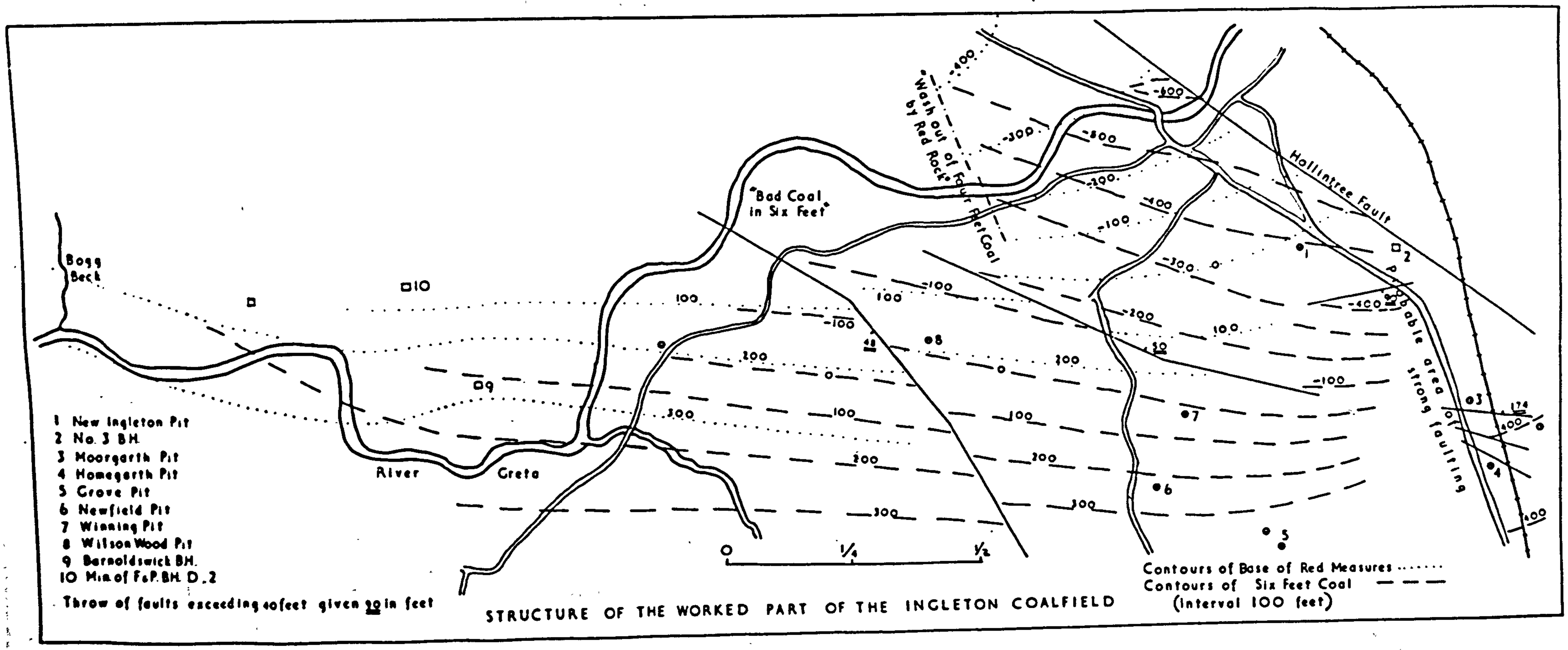
Sketch map of the Unconformity above the Productive Coal Measures, R. Greta.

Fig. 10

below the unconformity and proved in New Ingleton Pit (Fig. 6).

In the River Greta at Parkfoot the base of the Red Measures rests on white sandstone 40 feet above the Four Feet Coal. Workings in this coal can be traced westwards along the outcrop for some 250 yards to some old adits 300 yards east of Greta Bank Pottery, but no further. At the Barnoldswick Borehole some 250 yards north of this a thin coal a few feet higher than the white sandstones of Parkfoot was recorded just below Red sandstones. The outcrop of Crow Coal (which is confused with the Four Feet Coal Outcrop on O.S. Sheet 98 S.E.) 30 feet below the Four Feet Coal, can be traced to an old adit just behind the Greta Bank Pottery, but 200 yards to the north west in the north bank opposite Bleaberry Hill (34/64718) massive red sandstones are seen resting on an horizon just above the large ironstones and below the Crow Coal. Two sinkings marked near Kepp House in Tiddeman's maps (6" O.S. Yorks. W.R. CXII NE) with Four Feet Coal at 60 feet bear no relation to local structure and could not be found on the ground. The site of one is now occupied by a bungalow; and a boring (Ministry of Fuel and Power D 2) 100 yards north of Kepp House (34/666722) by opencast prospectors within 10 yards of the other sinking was still in Red Measures when abandoned at a depth of 261 feet. It seems probable that Tiddeman incorporated inaccurate local information.

Several sinkings between Kepp House and the river to the west reached the Six Feet Coal (60 feet below the Crow Coal) after penetrating basal Red Measures. The tips give no evidence of Four Feet or Crow Coals or the intervening strata. The unconformity thus has an irregular base rising slightly from the river at Parkfoot to the Barnoldswick Borehole, and then falling again to the river west of



STRUCTURE OF THE WORKED PART OF THE INGLETON COALFIELD

Fig. 11.

Kepp House and northwards to Borehole D 2 (Fig. 11).

West of the river, on Bleaberry Hill, outcrop workings in both Crow Coal and Six Feet Coal can be traced on the steep eastern and northwestern slopes, but in the case of the Crow Coal the line of workings stops sharply against the base of the Red Measures, exposed a few feet above. On Bleaberry Hill the Red Measures have a steeper dip than the underlying productive measures and the Crow Coal is over-stepped before reaching the river. On the north bank at Stephens Wood massive red and yellow sandstones, with limonite-rich springs at the base are seen to cut across the horizons of large ironstones 30 to 40 feet above the Six Feet Coal. Further west the feature made by the red sand-stones and the outcrop workings of the Six Feet Coal converge and finally the Six Feet Coal disappears below the Red Measures. Phillips (1836) quoted the mine manager as saying"the Six Feet Coal thins rapidly to 18 inches and disappears near Burton-in-Lonsdale," and comments: "It is strange indeed that in this remote area the miner's tag of red rock cutting off the coal has penetrated". Further west in Bogg Beck red sandstones are seen within 10 feet of light grey shales and sandy shales with plant fragments, the red sandstones having a steeper dip. The latter can be correlated with beds outcropping at the western end of the Waterside Pottery tip, some 10 feet below the Bleaberry Coal, and 85 feet below the Six Feet Coal. Limonitic springs and the strong feature upon which Burton-in-Lonsdale is built suggest a continuation of the Red Measures westwards but evidence is completely concealed by drift.

In the whole of this section it must be emphasized that there is no trace of faulting, other than a minor displace-ment of 3 feet in the Crow Coal outcrop east of Greta Bank Pottery, almost continuous outcrop can be followed throughout the section.

East of Parkfoot, towards Ingleton, a number of mine shafts give evidence of the rising base of the Red Measures (Fig. 6). In Wilson Wood Pit, ½ mile east of Parkfoot strata up to a thin coal 40 feet above the Four Feet Coal are recorded and the remaining 200 feet above this are undifferentiated. In Winning Pit, nearly ½ mile further east, two thin coals, respectively 50 and 100 feet above the Four Feet Coal are recorded and on the old chart examined the strata above this are coloured pink, those between and below grey. This suggests that in both pits most of the strata above the thin coals recorded were Red Measures.
At New Ingleton Pit complete shaft sections for both upcast and downcast shafts are available, and several other thin coals are recorded in 330 feet of Grey Measures between the base of the Red Measures and the Four Feet Coal. 30 feet below the Red Measures occurs the top of the Ten Feet Coal and eleven feet below this is the Nine Feet Coal. Both coals were worked over a very limited and roughly circular area 250 yards in diameter. On the north east they are cut off by the Hollintree Fault but over the rest of the perimeter they are recorded as dying out in "faulty ground" with "rock rolls". The coals were said to be highly oxidized and liable to spontaneous combustion and the soft roof and floor were frequently susceptible to bulging. In No. 3 Borehole, 250 yards to the north east, the available record is somewhat generalized and it is difficult to give the exact horizon of the base of the Red Measures. It is however, certainly between 380 and 400 feet above the Six Feet Coal, (only fragments of the Four Feet Coal were recovered) i.e. somewhat lower than in New Ingleton Pit.
A change of dip is recorded about this level. The Ten Feet and Nine Feet Coals were not found in the boring, nor are they known elsewhere in the coalfield. Thus these coals

are considered to be preserved in this small area partly by reason of their being in the centre of a pitching syncline and partly by an irregularity in the plane of unconformity such as has already been demonstrated in the Greta and the Barnoldswick Borehole. It may be noted here that blocks of coarse conglomerate, identical with that seen in the Greta, have been found on the tip at New Ingleton Pit. At the western limit of the Four Feet Coal workings at New Ingleton Pit the coal is recorded as being cut off by "Red Rock" in the form of a "wash-out". A heading was driven 60 yards into the "Red Rock" without penetrating it.

Other important evidence of the unconformity is provided at the Holden House borehole. There the base of the Red Measures is uncertain in the lithological record for grey and red beds are recorded for about 200 feet in somewhat irregular alternation. Strata from the bottom of the borehole at 1666 feet up to just above the "black shale with Aviculopecten" (equivalent to the G. listeri marine band) at 1266 feet can be correlated directly with the Greta as shown in Fig. 4 . In the Greta this horizon is 650 feet below the Six Feet Coal. Higher than this there is no direct correlation with the Greta section and the base of the Red Measures is taken at 1262 feet. The boring contractors recorded "Red and grey sandstone, strong, with marl joints" just above this horizon. This interpretaion is in agreement with statements made by Prof. Lebour in an unpublished report to the colliery owners in 1907. Accompanying this report was a diagrammatic section showing how, in his opinion, the Red Measures could step down northwards onto lower coal measure horizons. If this interpretation is adopted the Red Measures rest unconforably on an horizon 650 feet below the Six Feet Coal roughly in the centre of the coalfield.

Further northwest, in Leck Beck the relationship between Red Measures, which have yielded evidence of their age (low phillipsi) and partly red-stained Grey Measures, which have yielded a fauna indicative of the top of the modiolaris zone, are uncertain. The latter are overlain by a conglomerate and coarse red sandstone, but these are cut off from the former by a fault of unknown throw. Reasons have already been given for regarding this conglomerate as the equivalent of that at the base of the Red Measures in the Greta (p. 30) and if this interpretation is correct the Red Measures of Leck Beck rest on a younger horizon of Grey Measures than in any part of the Greta or the collieries. This would imply that the northward transgression of Red Measures onto lower horizons of Grey Measures from the Greta to the Holden House Borehole is not maintained north of the latter. It is suggested that there may be gross and irregular transgression across the underlying beds, a structural complexity within the underlying group prior to the deposition of the unconformable series, or a combination of both.

The only other exposures giving evidence of the relations of Red Measures and Grey Measures is in Cant Beck, west of Collin Holme. Two short sections $\frac{1}{2}$ mile apart (34/633747 and 34/623739) contain no recognizable horizons but lithologically resemble Grey Measures and Red Measures respectively. Assuming no faults intervene in the mile of unexposed ground between Cant Beck and the Greta the lower of these sections may be uppermost Millstone Grit or lowest Coal Measures, while the upper section may be Red Measures (or possibly red-stained Grey Measures). The general relations would then compare favourably with those in the Holden House Borehole, 1 mile to the east.

Summarizing, the unconformable base of the Red Measures can be shown to step down westwards from above the Ten Feet Coal of New Ingleton Pit to below the Bleaberry Coal in Bogg Beck, Burton-in-Lonsdale, a thickness of about 500 feet of strata. North of Burton-in-Lonsdale the overstep appears to be continued nearly down to the Gastrioceras listeri marine band in the Holden House Borehole, thereby transgressing a further 570 feet of beds. To the north, however, the overstep is reversed in direction and some 500 feet of beds younger than the productive measures of New Ingleton Pit appear below the unconformity.

(b) Post-Carboniferous Deposits

i. Permian

Rocks provisionally referred to the Permian occupy a roughly circular area between the Greta and Leck Beck, about 2 miles in diameter, and bounded by the Craven Faults on the north east. Only in one place is the contact with the underlying Carboniferous seen and that is in Westhouse Gill, about 1 mile northwest of Ingleton. This section was briefly described by Binney (1855) and later by Tiddeman (1872) and Kendall and Wroot (1924). Some 300 feet of breccia are seen resting on the lower part of the Upper Red Measures, both with a steep south westerly dip decreasing downstream. Various other small exposures occur in the vicinity of Westhouse and further west. The Ingleton and Kirkby Lonsdale Railway crosses the outcrop and several cuttings penetrated the breccia which was then used for bridges and walls, but no in situ exposures remain along the railway.

Kendall (1924) described two distinct types of breccia which he said were stratigraphically distinct. The lower type, in Westhouse Gill, consists largely of pebbles of Carboniferous Limestone in a matrix of quartz sand stained red by haematite. Occasional Upper Carboniferous and Lower Palaeozoic pebbles occur. In exposures along the railway the latter are more frequent. At Todgill, (34/652762) the most northwesterly outcrop the sandy matrix is dominant with only a few pebbles - from all sources. In Ireby Beck near Masongill (34/665759) there is a good section in breccia made almost entirely of Lower Palaeozoic Pebbles, with some of gritstone, in sandy matrix. The breccia is however highly porous, contains casts of pebbles and shows the general characters of decalcification

The beck has its sources in peat not far away. Blocks in which Carboniferous Limestone and Lower Palaeozoic pebbles are about equal in number occur around Ireby, and are seen in situ north of Wiregill Bridge (34/647755).

The general lithology of the breccias is closely comparable with the Brockrams of the Vale of Eden. Kendall (1924) suggested that the incoming of Lower Palaeozoic pebbles was due to the progressive uncovering of the Barbon and Howgills Fells. There is no direct evidence of this and the two types of breccia may have been derived from their respective sides of the Dent Fault line contemporaneously, becoming mixed within the present area of outcrop.

The southern and western boundaries of the area of outcrop are concealed by drift, and the limit was drawn by Tiddeman immediately south of the known outcrops close to the railway. The drumlins along this line are higher than those further south west and there is some suggestion of a buried scarp. However the Holden House borehole only ¼ mile north of this line records breccia down to 361 ft. with almost horizontal dip. The adjacent exposures show dips ranging from 8 - 12° N. This suggests that the Permain outcrop extends considerably further south than shown on the Old Series map (98 S.E.). There are no exposures of solid rock for nearly two miles to the south. In this connection the Kepp House (or Burton No.2) boring record would be valuable were its location known. It is recorded as being at an altitude of 325 ft O.D. on one of the drumlins east of Burton-in-Lonsdale - possibly one of those north west of Kepp House, Barnoldswick. This boring penetrated 50 feet of "coarse conglomerate" before passing into "red marls". This suggests that the Permian outcrop may extend nearly to Burton-in-Lonsdale. A site suggested by Prof. Lebour to the coal-owners before the

hole was drilled was further north near Low Threaber. This is more in line with known facts, but could hardly be described as "near Kepp House" as in one of the records.

Summarizing, the Permian breccias cover about 6 sq. miles in the north centre of the coalfield, with amaximum known thickness of 350 feet at Holden House. Whilst Carboniferous Limestone Pebbles form the greater part of the breccias Lower Palaeozoic rocks become more important to the north and west. Upper Carboniferous rocks also are known. The breccias are known to rest on the lower part of the Upper Red Measures in Westhouse Gill, and probably rest on Lower Red Measures in the Holden House and Kepp House Boreholes. There is thus unconformity below the breccias, but its full extent remains unknown.

ii. Superficial

Almost the whole of the Ingleton Coalfield is covered by boulder clay, largely in the form of drumlins. Exposures of solid rock are confined to the larger streams which have cut through the boulder clay. The constituent boulders are chiefly Lower Palaeozoic rocks from the Barbon and Howgill Fells, Ingleton/ian (Pre-Cambrian) from Chapel-le-dale, and Carboniferous Limestone. Sandstones and ironstone nodules which may be Upper Carboniferous in age are seen occasionally. Coal fragments occur in the boulder clay immediately north of the Upper Red Measure outcrops in the River Greta by the viaduct, and in Aspland Beck some 300 yards south of Raygill. There is an abortive trial sinking on the bank near the latter. Blocks of Permian Breccia occur throughout the Greta but are only rarely seen in Leck Beck which lies to the north west of the outcrops. The thickest boulder clay is at No. 3. B.H. east of Ingleton Station, where 129 feet 6 inches of drift is recorded. Well over 100 feet occurs in the middle reaches of Leck Beck, and 40 to 50 feet is seen in bluffs near Ingleton road bridge.

An attempt to analyse the direction of elongation of drumlins proved rather inconclusive. A glance at a topographic map shows most of them to be circular in plan. South easterly elongation northwest and northeast of Bentham seems to be a reflection of the strike of the underlying grits, suggesting that the boulder clay overlies buried scarps. The drumlins known to cover the Permian breccias are generally higher than those over the coal measures and when viewed from the west or south give the impression of an escarpment.

The matrix of the boulder clay is generally grey, but in the area believed to consist of Red Measures it commonly takes on a pink colouring, with development of very fine grain - e.g., Cant and Ireby Becks, east of Collin Holme. In the region of the Permian breccias the boulder clay becomes reddish and sandy.

In the extreme south east of the coalfield are mounds of fluvioglacial gravels, possibly representing the outfalls of englacial rivers during a temporary halt in the retreat. The best of these is at Old Butt, roughly midway between Bentham and Clapham. The mound here is 50 feet high and about 100 yards in diameter and exhibits current bedding inclined in a general south easterly direction. This is seen also in gravels near Newby Cote. High in the West bank of Aspland Beck 300 yards south of Raygill about 6 feet of semi-consolidated gravel is seen resting directly on boulder clay. Frequently "Old Gravel Pit" is seen marked on Ordnance Survey Maps near the tops of drumlins. Few of these show any exposure now, but those which do, show boulder clay. The boulders were apparently used by local farmers for road-making and walls.

Alluvium occurs in wide spreads along the River Greta, south of Ingleton and the Wenning near Clapham, in both cases above points where hard rocks outcrop in the rivers. The Lune Valley has alluvial flats a mile wide throughout. The Alluvium is almost entirely derived boulder clay and without good exposures it is sometimes difficult to differentiate between them. Terraces occur up to twenty feet above the alluvial flats in the Lune Valley at Burrow, and in the Greta Valley, south of Ingleton etc. Sometimes these are cut directly into boulder clay, elsewhere they are covered by alluvium. In the Lune Valley the terraces pass imperceptibly into low drumlins. Between the drumlins

of the central part of the coalfield are local patches of fine alluvium with or without peat. Patches of peat also occur on the gritstone moors near Clapham. A few of the hollows between drumlins around Masongill and Ireby are considerably sharper and deeper than others and may be segments of spillway channels.

IV Structure

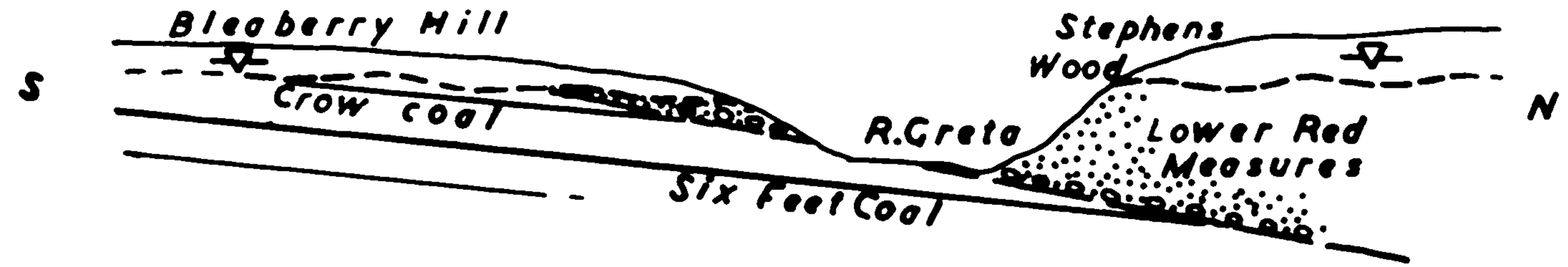
The overall picture of the structure of the Ingleton Coalfield is that of an asymmetrical synclinal basin with an axis trending WNW - ESE. Examined in detail the structure is more complex. The coalfield is bounded on the north-east by the Craven Fault system, and as might be expected this has had a marked effect on the development of the coalfield. Movements have taken place several times during the Carboniferous period and afterwards.

(a) Folding.

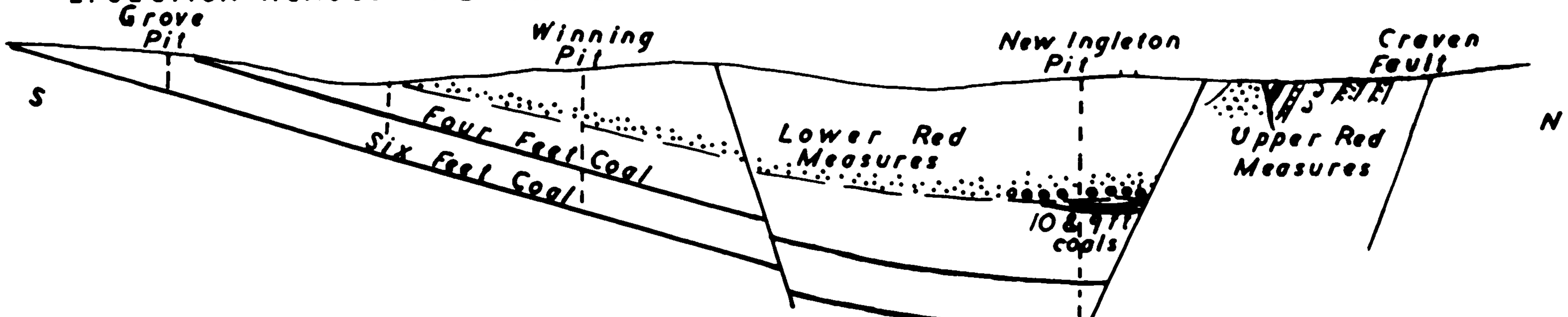
The southern part of the coalfield is the best known so far as detailed structure is concerned. On ascending the Greta section from west to east there is a very gradual change of dip from northeast in the lower part to north north east and north in the higher parts near Parkfoot. The angle of dip averages 10° throughout this section. The same change of strike is seen in the River Wenning two miles to the south, with northeasterly dips near Wennington swinging to almost due north near High Bentham. To the east the Wenning Valley is crossed by a strong northeast southwest anticline with a north easterly pitch. The northwest flank is not well exposed but dips of 25° or more are seen on the east flank in Meregill. The anticline affects the lower parts of the Millstone Grit in the Wenning Valley and appears to affect higher grits and possibly Coal Measures to the north where exposures are few and far between.

Briefly then the southern part of the coalfield consists of a broad shallow syncline, pitching northeast through Bleaberry Hill, and flanked by a sharp anticline on the east. These affect strata up to the Lower Red Measures, and probably come of the Permain. To the North, near the Craven Faults, there is a marked change. In the Between Bridges Section of

1. SECTION ACROSS THE GRETA VALLEY NORTH OF BLEABERRY HILL



2. SECTION ACROSS THE WORKED PART OF THE INGLETON COALFIELD



3. SECTION OF STRUCTURES IN LECK BECK

Diagrammatic Sections of Structures in the Ingleton Coalfield.

Fig. 12.

Greta south-westerly dips of 45-90° occur in Upper Red Measures, and similar dips on the same strike are seen in Yorlsber Gill to the southeast, and Westhouse Gill to the northwest. This area of strong southwesterly dips is separated from that of a gentle dip ~~dip~~ on the southwest by the Hollintree Fault. Taken together these areas give the impression of an asymmetrical syncline with a faulted axis, and there is some evidence from the Holden House Borehole and Permian outcrops that the strata near the centre of the coalfield are nearly horizontal. It is possible that the broad syncline pitching north through Bleaberry Hill dies out. Similarly, the low dips of Permian rocks in Ireby Beck on the same strike as the steeply dipping beds of Westhouse Gill, less than a mile away, suggest a flattening of structures. Southeasterly dips at Todgill (34/652762) suggest that the Permian rocks occupy an almost circular basin.

Structures in the northwest of the coalfield bear little relation to the rest. In Leck Beck Coal Measures are seen with steep south to south-south-west dips decreasing downstream and modified by at least two small anticlines crossing the stream on approximately east-west axes. Less than a mile to the southeast the Permian dips southeast, and a similar distance to the northwest Yoredales and Carboniferous limestone dip in the same direction. The relations of the latter to the Millstone Grits to the south remains hidden by the alluvium of the Lune Valley, but it is quite certain that there is no room for a complete sequence of Yoredales, Millstone Grit and Coal Measures southeast of Kirkby Lonsdale, as shown on O.S.Sheet 98 SE

(b) Faulting

Comparatively few faults are known in the Coalfield area, and most of these were shown on the Geological Survey maps. The dominant directions are NE-SW, and NW-SE, with a few

approximately E-W. The most powerful fault in the Coalfield is the Hollintree Fault which strikes NW-SE, parallel to the Craven Faults. First discovered in the 1880's by Balderston (1890) this is seen only occasionally after spring floods have removed alluvial boulders from the exposure in the Greta. When the New Ingleton Pits were worked the fault was proved over a distance of nearly a mile in workings.Study of mine plans has shown that the fault hades to the southwest by about 10°. As the downthrow is to the northeast by at least 1000 feet, it is thus a reversed fault. The fault is not seen along the strike to the northwest in Westhouse Gill and so may be pre-Permian in age. The steep dips on the downthrow side appear to be later in origin so the fault may have been quite a low angle thrust rising to the northeast at that time. Between the Hollintree Fault and the South Craven Fault is the oblique Yarlsber Fault, described by Tiddeman, although there is now no sign of it at the point he described. However coal workings and Red Measures, probably Upper Red Measures, are juxtaposed. An eastwest fault seen cutting off the Spirorbis Limestones in the Greta appears to cut across the Hollintree Fault to bound the New Ingleton Pit workings near Thorngarth. Downthrow is by an unknown amount to the south.

Other faults parallel to the Hollintree Fault occur in the southeast of the coalfield and in the Greta west of Burton-in-Lonsdale. The latter throws the Rough Rock 30 feet fown to the southwest while the former is less clear in its effects. Shown on O.S.Sheet in a position where only a local thinning of coal is shown on plans of Grove Pit, it is now thought to be a fault with a throw of 48 feet somewhat to the west of Wilson Wood and Winnings Pits, which probably is contiguous with the powerful fault in the Wenning Valley and Bowland Fells.

Among the northeasterly faults the strongest, of which little is exposed, displaces the outcrop of the Clintsfield Coals by half a mile between the Greta and the Wenning; downthrow is to the southeast. This fault dies out against a northwesterly fault. At Bentham a fault striking east north east throws the Upper Bentham Grit down to the north west.

Of the westerly faults the strongest appears to be an arcuate development of a northwesterly fault near Winning Pit. This swings to almost east-west near Moorgarth, and the throw appears to increase eastwards. Several parallel faults close together at Moorgarth caused difficulties in mining, and it appears, from the discrepancies in the strike of the coals in Grove and Moorgarth Pits, and from the difference of 300 feet in the depth to the Six Feet Coal in New Ingleton Pit and the adjacent No.3. B.H., that the structures around and east of Moorgarth are cut off by a north-north-west fault parallel to, and about 1/3 mile west of the railway. This fault is not exposed, nor is it recorded in mine plans.

A fault, or "rock roll" with a throw of 12 feet forms the southern boundary of the New Ingleton Pit workings. Its hade of 45° to the south, probably means that it is the same fault as that seen in the Greta to the west, where the throw cannot be determined.

In Leck Beck there are several E-W and ESE-WNW faults, all except one apparently downthrowing to the south by unknown amounts. Working downstream a small fault is seen in the east bank about 50 yards from the Craven Fault, and is probably an off-shoot of it. About 100 yards south of Springs Wood Footbridge a major fault, with a smash belt 4 feet wide crosses the river almost east-west, and it is notable that this is on the same strike as the Kirkby Lonsdale Fault which affects the Lower Carboniferous rocks

to the west. Two small faults, only one of which is exposed, break the axes of the small folds between Springs Wood and Leck Mill. West of Leck Mill a further major fault crosses the river almost east-west. Its smash belt is only occasionally seen in the river bed.

(c) Structural History

The development of the structure of the Ingleton Coalfield is undoubtedly founded on the intermittent movements which have taken place along the Craven Fault Line. At least as early as the later Lower Carboniferous times it was the dividing line between sedimentary facies and as a result of late Sudetic movements deposition was subsequently limited to the south side of the line for much of Millstone Grit times, and part of Coal Measure times. Later Coal Measures probably spread across the line, but uplift of the Craven Block relative to the Craven Lowlands during the Malvernian movements exposed Coal Measures to erosion and Red Measures now overstep Grey Measures northwards through much of the coalfield. At this time the Grey Measures of the Greta would have had a gentle southerly dip. The gentle flexure developed along the Craven line at the end of Ammanian times was, however, not simple, as is shown by the structures in Leck Beck. The apparent reversal of the direction of overstep may be explained in several ways. The simplest is that the flexure may have split fanwise westwards into two folds with a syncline between - now the site of Leck Beck. Alternatively there may have been post-Ammanian pre-Morganian block faulting along the axis of the flexure, and a block of Grey Measures so let down was later covered unconformably by Red Measures. Or it is possible that there may be a combination of both factors.

In the Variscan orogeny either the Craven Block or the adjoining Howgill Fells region was uplifted and faulting rather than flexuring took place, and the block was exposed

to erosion and became the source of the Permian breccias. The breccias appear to lie unconformably on both Upper and Lower Red Measures, and this is largely due to pre-Permian faulting.

The main period of folding in the Ingleton Coalfield area was post-Permian, probably Tertiary in age. The southwest - northeast folds in the southern half of the coalfield affect both Carboniferous and Permian rocks. The steep dips close to the Craven Faults are seen in both Coal Measure and Permian rocks, and are undoubtedly related to major movements of the Craven Faults in Tertiary times. It is during this period that the major part of the coalfield received its northerly tilt towards the Craven faults.

V. Palaeontological Notes and Correlation

(a) Marine Faunas

In recognizing the major marine subdivisions of the Central Pennines much that has already been said applies to the Ingleton area also. Evidence of the E_2 and H stages in the area has already been given. Their identication depends more on direct correlation with known strata in the Bowland Fells than on contained faunas. The Homoceras stage is particularly thin, and the succeeding lower Reticuloceras stage contains few goniatites, apart from the R. reticulatum band in the Greta. The succession of sub-zones listed by Bisat and Hudson (1941) is limited to a maximum of 80 feet of strata in the Greta. These are mainly sandy beds containing brachiopods and are probably equivalent to the Cayton Gill Beds of Nidderdale (Tonks 1925). The R. reticulatum band contains abundant fragmentary goniatites and there is some variation in their ornament. The author, however, does not feel justified in using some of the varietal names proposed by Bisat and Hudson (1941), although a specimen from the Bentham Station borehole was identified as R.cf. sub-reticulatum (Foord and Crick) by Stubblefield.

The goniatites of the Reticuloceras gracile band are similarly fragmentary, and there was some doubt at first regarding nomenclature as many appeared to be intermediate between R.gracile (Bisat) and R.bilingue (Bisat). As more specimens were examined it became clear that the domiant form was nearer R.gracile (late mut. ∝ in Bisat's nomenclature). The specific names R. bilingue and R. reticulatum have been used to indicate the range of variation of the ornament within the community. Stubblefield has compared some adult specimens with R. davisi (Foord and Crick), a name which was used for forms in a sub-zone of the Lower Reticuloceras stage (R_1) by Bisat and Hudson.

The fauna of the Gastrioceras cancellatum band is much smaller than the preceding bands, both in numbers of species and numbers of individuals, and it is not surprising that it was not recognised in the Seat Hall and Holden House boreholes. The band is only an inch thick in the Greta. Lingula occurs at top and bottom while the middle part contains productids and scattered goniatites. These are dominantly G.cancellatum Bisat with occasional variants.

The fauna of the Gastrioceras cumbriense band contrasts strongly with that of the G. cancellatum band. Goniatite remains are prolific in their numbers. Variants, which takem individually would be named G. cancellatum and G.crencellatum occur sporadically. Nautiloids referred to Metacoceras sp. are present but rather poorly preserved. Posidoniella rugata Jackson is also common.

Regarding the Upper Gastrioceras stage two marine bands corresponding to the Pot Clay and Ganister Marine bands of Yorkshire have been found but the former has only Lingula and a few other brachiopods, while in the latter the goniatites are badly crushed and ornament of the G. listeri group only can be recognized. The latter are associated with, though not on the same bedding planes, abundant Dunbarella papyracea, a feature common in many parts of the Yorkshire Coalfield. Occasional Dunbarella papyracea occur at an intermediate horizon 30 feet below the G. listeri band. The G.listeri band is the highest fully marine horizon found in the coalfield, although Lingula has been found beneath the Carbonicola fallax bed about 100 feet higher, and is also recorded at an horizon low in the Modiolaris zone in No.3. Borehole.

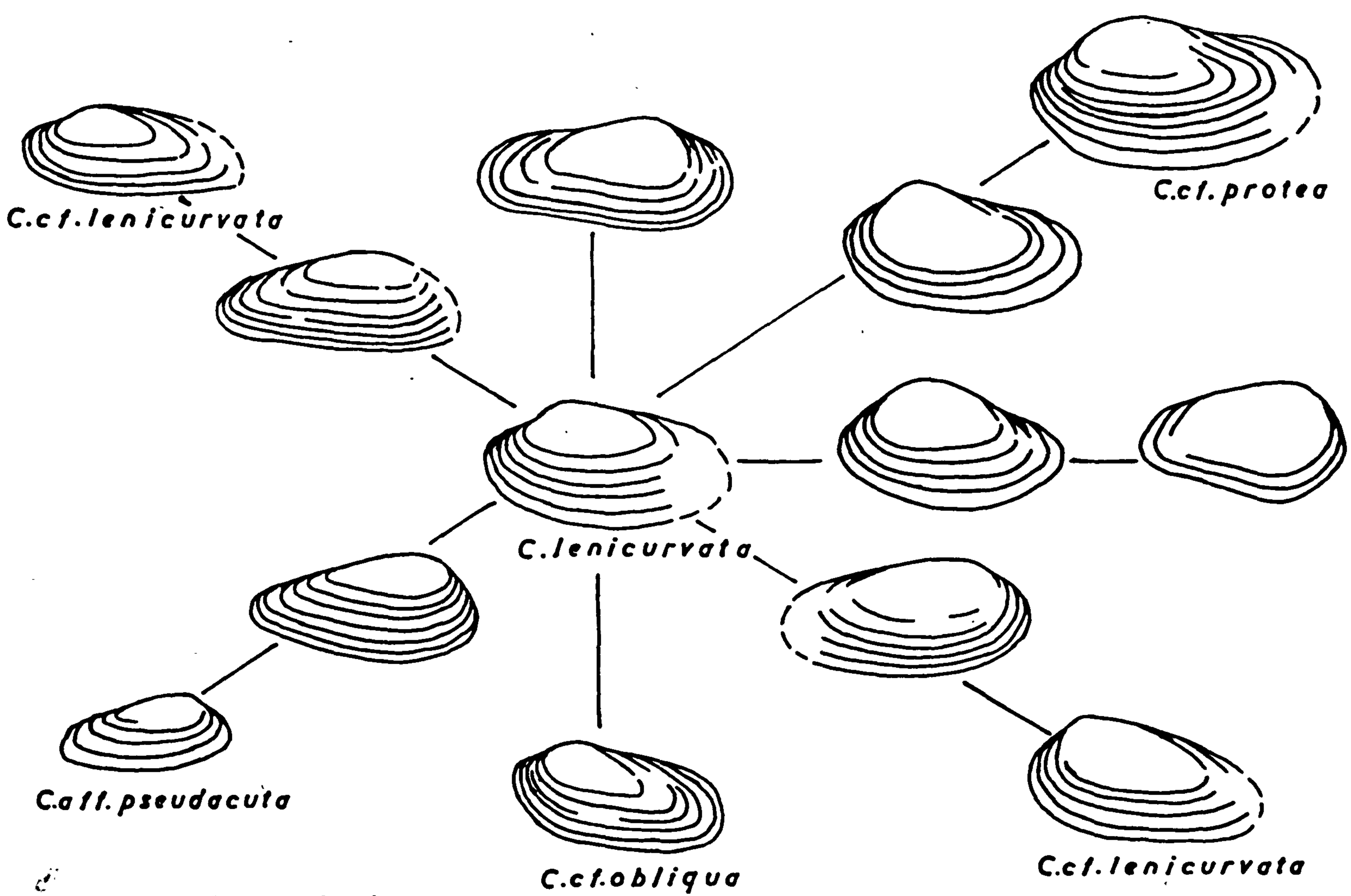
The zonal subdivision;adopted have been indicated earlier in this paper and it is clear that there is no significant departure from the zonal scheme proposed by Bisat in 1924, nor are there any notable gaps in the sequence.

(b) Non-marine faunas

Five well-developed faunas of non-marine lamellibranchs have been found at widely separated horizons within the coal-field, and also a few scattered shells at other horizons. Up to 60 specimens have been obtained from each of the five bands listed earlier but as most of these are from river bank exposures or from weathered material on old colliery tips the state of preservation has not been good enough for reliable statistical studies. However some work on variation has been done and the results are described below. The accompanying variation diagrams are based on visual arrangement of the shells in such a way as to show both the extent and direction of variation and the number of variants involved. The dominant form is taken as the norm of each diagram and is as close as possible to the mean of the standard scatter diagram. Outside this, however, arrangement is largely arbitrary although with some reference to the scatter diagram. The shells are shown in natural size in the diagrams.

(i) Carbonicola lenicurvata assemblage (Fig. 13)

The lowest non-marine lamellibranch fauna is that of Carbonicola lenicurvata Trueman and its variants. It occurs immediately below the Gastrioceras cancellatum band at the base of the G_1 stage. The shells are preserved as impressions in a crumbly coarse micaceous shale and growth lines are indistinct. Posterior ends are often damaged either before or during collecting. The shells are large, 45-50m.m long, umbones fairly prominent and well forward. Ventral margins are straight or gently curved. Posterior ends are truncate or bluntly rounded in some specimens, tapering in others. Decreasing height and tapered posteriors show a tendency for some specimens to resemble C.pseudacuta. Others have increased height and blunt posteriors and have



Variaton in the Carbonicola lenicurvata community. River Greta.

Fig.13

a poor resemblance to C.protea. One shell, which may have been distorted by crushing resembles C.obliqua. Two small and very poorly preserved shells, which do not fit into the variation diagram are referred to C.cf. deansi Eagar. On the whole the fauna is probably closely related to that described from an horizon 27 feet below the G.cancellatum band at Bingley (Trueman and Deans 1933, Eagar 1949).

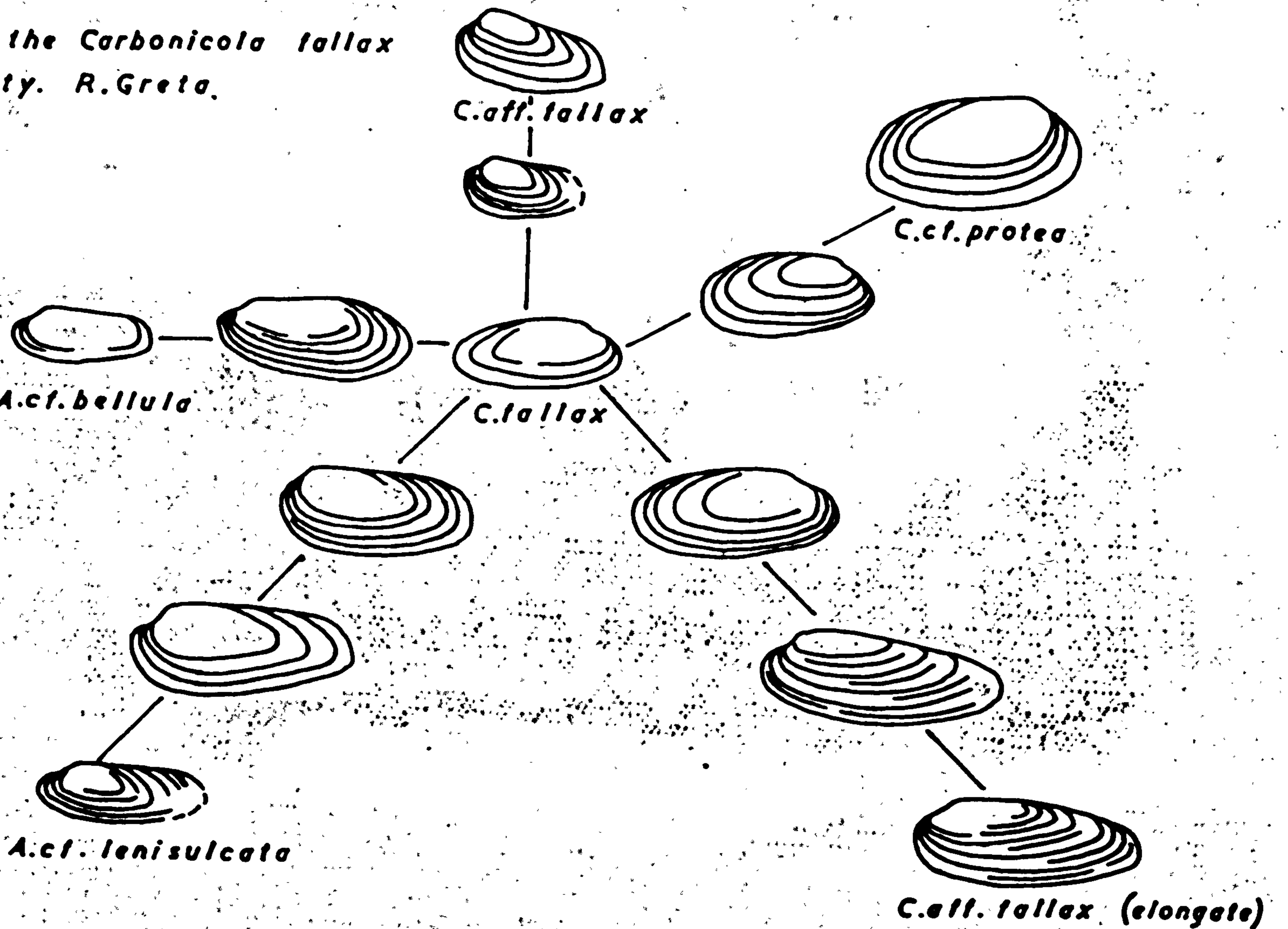
Some 25 feet higher a few very poorly preserved shells similar in shape to the above but much smaller, were found in a fine grey shale. The tapered form, C.cf.pseudacuta, seemed to be more common, but no statistical studies were attempted. At what is believed to be the same horizon in the Seat Hall borehole, a few very small Carbonicola sp. and some specimens of Anthraconaia were found, and are inthe Geological Survey collections (Specimen Nos. WG 439, WG 488). The Anthraconaias are a very elongate form, similar to the A. pruvosti group of the Upper Coal Measures, and it is understood that they are shortly to be referred to a new species by the officers of the Geological Survey.

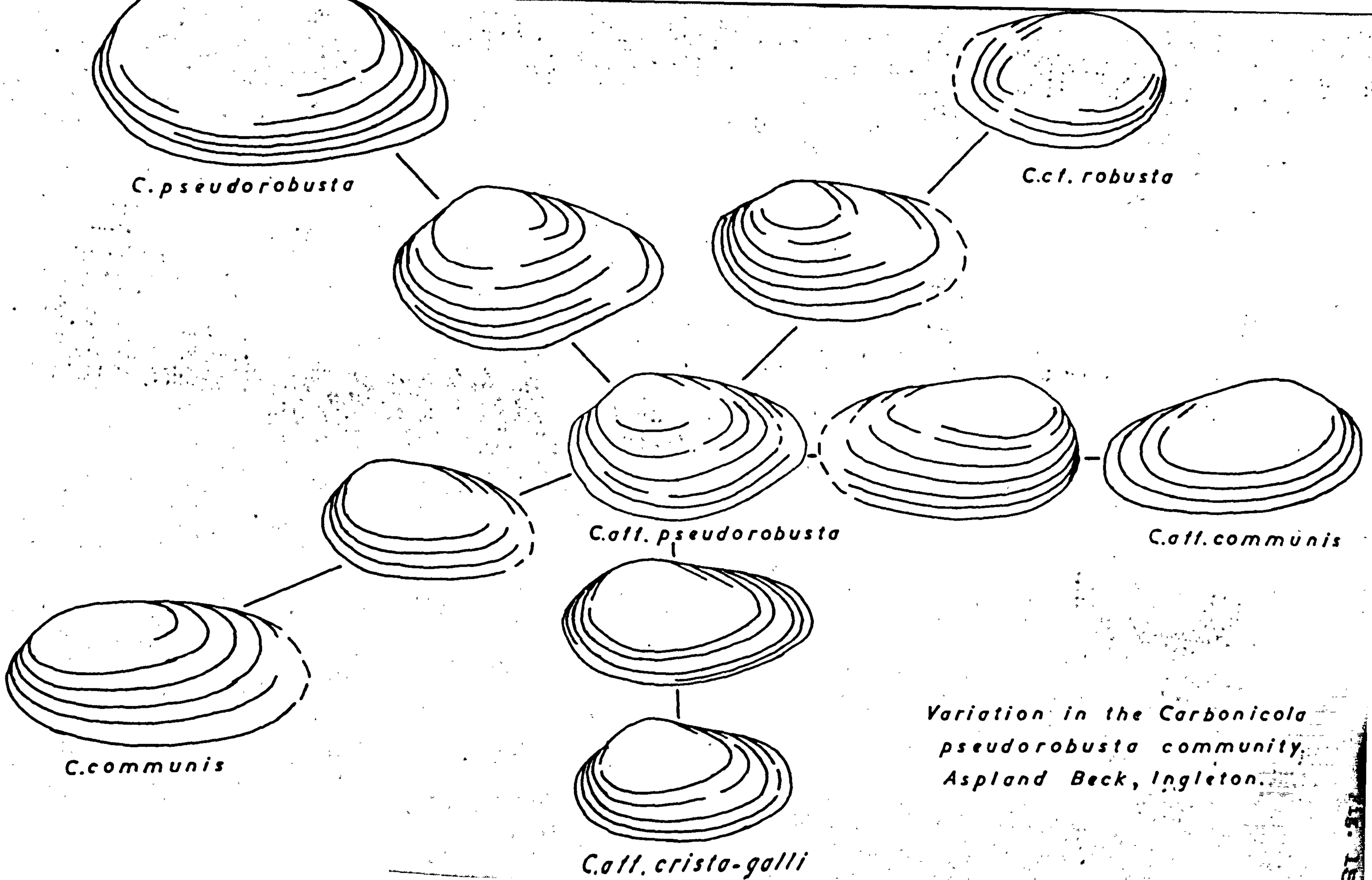
The widespread shell beds above the Soft Bed Coal, described by Eagar (1951), have not been found at Ingleton, althouth two isolated specimens doubtfully referred to cf. Anthraconaia bellula have been found at about the equivalent horizon.

(ii) Carbonicola fallax assemblage (Fig. 14)

The shellsof the Carbonicola fallax fauna are preserved as impressions in a medium-grained shale. Some of the shells are fragmented but good specimens are obtainable. Dr.Eagar has agreed with the interpretation that the fauna is the same as that upon which he has been working in Lancashire during the last few years. The norm is close to the holotype of C.fallax Wright, an elongateoval shell with low umbones and gently curved margins. In some variants

Variation in the Carbonicola fallax community. R.Greta.





Variation in the Carbonicola pseudorobusta community, Aspland Beck, Ingleton.

the hinge margin is progressively straightened, until the shells become Anthraconaioid, and the names A. cf. lenisulcata and A. cf. bellula have been applied to extreme variants. A direction of variation present in this fauna and noted elsewhere by Eagar is towards extreme elongation. A few other increase in height until they resemble C. protea. This fauna occupies a position towards the top of the lenisulcata zone in the Yorkshire and Lancashire Coalfields.

(iii) Carbonicola pseudorobusta assemblage (Fig. 15)

The only non-marine lamellibranch fauna definitely in the communis zone is that of Carbonicola pseudorobusta. The norm is however closer to C. aff pseudorobusta Trueman as figured in Trueman and Weirs' monograph (Plate IX. Fig. 3). These large shells are found in a fissile black shale as somewhat crushed solids, sometimes with a pyritous infilling and occasionally with calcareous shelly material still preserved. There is a strong tendency for the posterior ends to break off during extraction and few complete specimens have been obtained. Growth lines are often obscured by pyritous growths. Variation is comparatively limited and most of the 30 specimens obtained can be referred to C.pseudorobusta or C.communis. A few extremes tend towards C.crista-galli and C.robusta.

(iv) Four Feet Coal Assemblage (Carbonicola rhomboidalis etc.)

The roof of the Four Feet Coal has provided the largest non-marine lamellibranch fauna, mainly from colliery tips.(Fig.: Variation is wide but no significant differences have been found between different tips. The majority of the shells are preserved as small ironstone solids, frequently with the posterior and damaged, and sometimes with the margins worn all round. A few shells occur as impressions in the black shale surrounding the ironstone. Among the latter are the only two specimens of Anthraconaia williamsoni (Brown) and

C.subconstricta

C.cf.subconstricta

C.cf.robusta

C.cf.acuta

C.rhomboidalis

cf.A.boltoni

C.cf.martini

C.cf.obtusa

C.cf.crista-galli

C.cf.rhomboidalis

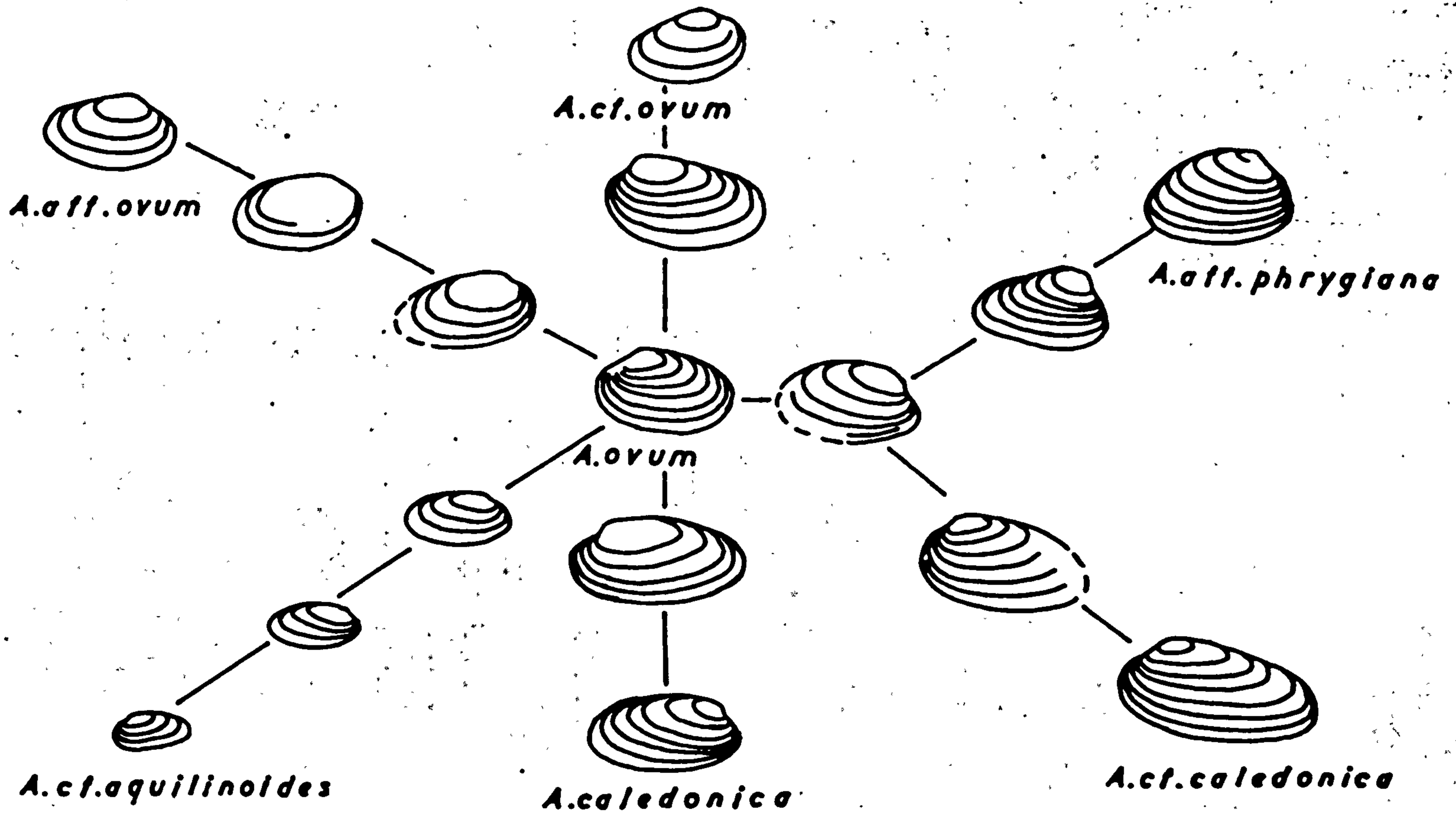
Variation in the Carbonicola rhomboidalis community above the Four Feet Coal, Ingleton.

Fig.16.

fragments of Naiadites sp. The remainder of the fauna may be considered as Carbonicola rhomboidalis Hind and variants. Several specimens have the same shape and proportions as C.rhomboidalis but are considerably smaller than the holotype and Dr.Weir has suggested that these may be young or dwarfed forms. The norm is a somewhat more rounded form than the holotype of C.rhomboidalis and variation lies in several directions. Reduced height and elongated posterior ends give forms such as C.subconstricta (J.Sowerby) and C.martini(Trueman and Weir). While in the other extreme increased height and reduced posteriors give almost circular shells referred to cf. Anthracosphaerium boltoni (Wright). Other variants tend towards C.cf. acuta (J.Sowerby) C.cf. crista-galli Wright, C.cf. robusta (dwarfed form) (J.de.C Sowerby), and C.cf. obtusa Hind. The fauna as a whole shows affinities with both communis and modiolaris zone faunas and the band probably lies at the boundary of these two zones. Indeed it would not be surprising if the band and its important coal below were on the same horizon as the thick New Hards Coal of Yorkshire and the Oldham Great Mine of Lancashire, both of which have similar faunas in their roofs and are taken as zonal boundaries.

(v) Anthracosia assemblage Leck Beck (Fig. 17)

In Leck Beck a rich non-marine lamellibranch fauna was found in secondarily red-stained ironstone nodules with calcite veining and in the surrounding pink shale. The former are solid but are very difficult to extract whole owing to calcite veins passing through the shells. A selection has been examined by Dr.Weir and referred to Anthracosia ovum Trueman and Weir and Anthracosia caledonica Trueman and Weir together with variants towards A.aff. phrygiana (Wright) A. aff. aquilina (J.de.C.Sowerby)



Variation in the Anthracosia ovum community.
Leck Beck, near Ingleton.

A.cf.aquilinoides (Tchernyshev) and A.cf.retrotracta (Wright). A single specimen of an Anthraconaia of the modiolaris group (A.cf.curtata?) was obtained, also fragments of Naiadites sp. with attached Spirorbis sp. Dr.Weir commented on the small size of some shells. While this may be due to stunting in adverse conditions it is thought that the red staining is largely secondary. The tendency to obtain a preponderance of small shells is partly due to larger specimens, some of which were seen in the field, breaking up completely on extraction. That the fauna clearly indicates an horizon in the modiolaris zone has been confirmed by Dr.Weir.

(vi) Other horizons

Scattered non-marine lamellibranchs have been found at several other ~~parts of the~~ horizons. Of these the small shells in the Upper Red Measures of the Between Bridges Section in the Greta are the most important. The shells are found as impressions in a red shale with large green spots about half an inch thick. The largest shells are undoubtedly Anthraconauta phillipsi (Williamson) and reach 10 m.m. in length. Spat, 2 or 3 m.m.long, are abundant on some bedding planes. Some shells of intermediate size are somewhat elongated when compared with the large shells and are referred to A.cf.tenuis (Williamson). This fauna is evidence of at least the higher part of the phillipsi zone and may even be low in the tenuis zone.

At a lower horizon, in Leck Beck, a single shell in an ironstone was identified by Dr.Weir as cf.Anthraconauta wrighti (Dix and Trueman). The range of this species is imperfectly known in Britain but is generally confined to lower phillipsi or uppermost similis pulchra age. On the basis of floral evidence the former is considered more likely.

In Aspland Beck Anthraconauta minima (Hind) has been found among plant debris some distance below the Bleaberry Coal. "Carbonicola acuta" was recorded by Gibson (1909) in the unexposed Grey Measures of the No.3. Borehole, but no specimens were preserved.

Non-marine faunas other than lamellibranchs consist of fish remains and arthropods including ostracods and Euestheria. Fish teeth, spines and plates are abundant on a few bedding planes in the black shale with Carbonicola pseudorobusta. Scattered scales occur in the shales above the Bleaberry Coal, and rare scales are found in the Marine beds of the Millstone Grit and lower Grey Measures. Slabs of black shale with abundant remains of arthropods among the shells in the roof of the Four Feet Coal were found on Grove Pit tip. Some of these in the collection in the Dept. of Geology, Sheffield University were identified as Palaemysis sp. by F.L.Kitchin . Occasional Euestheria sp. occur among the plants in the Crow Coal shales, and if, in accordance with the lamellibranch zonation indicated above, these are placed near the top of the communis zone, it is significant that an Euestheria band has recently been recognized at a similar position in the Yorkshire Coalfield (Goosens 1952). The Ostracod Geisina arcuata (Bean) occurs in the Lower Red Measures of Leck Beck.

(c) Floras

The greater part of the floras of the Ingleton Coalfield have been obtained from the hundred feet of Grey Measures which contain the productive coals. Below the Six Feet Coal the only identifiable plant remains were Diplotmema sp. among the marine shells of the Gastrioceras cumbriense band, which may indicate the relative proximity of land, and Neuropteris obliqua and lycopods above the Raygill Coal. A single pinnule of N. gigantea and some poor specimens of Lyginopteris sp. were obtained below the Bleaberry Coal and may indicate the presence of Floral zone C.

A rich flora has been obtained in situ from four horizons associated with the productive coals, the roof of the Six Feet Coal; the Crow Coal Shales, about 40 feet higher; the Parkfoot Beds, 20-30 feet higher; and the roof of the Four Feet Coal. To these have be added collections made some 70 years ago partly in situ in the Greta, and partly from the same horizons in collieries. There is little significant difference between the floras at these horizons, although the relative proportions vary considerably with the sedimentary environment. The two lower horizons are in fine grey shale with some in nodules, the third in coarse micaceous shale and the highest in ironstone nodules. The general impression is that the group belong to Flora D of Dix (1934) with some elements of Flora E coming in. In the lower beds Mariopteris spp. and Sphenophyllum cuneifolium are dominant, with some Sphenopteris and Alethopteris but rare Neuropteris. The upper two horizons are dominantly Neuropteris spp. with some Alethopteris spp. The important elements of Floral zone D present are Sphenophyllum cuneifolium and its variety saxifragaefolium, Neuropteris grangeri, N.heterophylla, and N. gigantea, Alethopteris decurrens, Sphenopteris obtusiloba and Lepidophloios acerosus.

Neuropterid pinnules close to N. tenuifolia are present but where larger fronds are obtainable the plant appears to be a form intermediate between that and N. heterophylla, similar to N.hollandica Jongmans. Among the Alethopterids, A.decurrens and A.lonchitica are the most common. A.davreuxi, generally a higher form, is uncommon, and in the ironstones above the Four Feet Coal a form almost indistinguishable from A.serli, has been referred to A.cf. lonchitifolia Bertrand. Lepidophloios acerosus (Lindley and Hutton) is particularly common among the lycopods, with only a single specimen doubtfully referred to L. cf. laricinus. Renaultia gracilis and Zeilleria avoldensis are important among the Sphenopterids. That the flora does not belong to Zone E or higher zones is indicated by the absence of such forms as Lonchopteris, Neuropteris scheuchzeri, and Asterotheca miltoni. A single specimen very doubtfully referred to the last was found, and in the nodules above the Four Feet Coal neuropterid pinnules with the venation intermediate between N.gigantea and N.scheuchzeri are common although the villose character of the latter is not seen. Lyginopteris and Neuropteris schlehani are not present. Thus, the Flora occupies a position near the top of Floral zone D, and this is in accordance with evidence from non-marine lamellibranchs, which place these beds at or near the base of the modiolaris zone.

A small flora obtained from a depth of 860 feet in No.3 Borehole (see page 26) at an horizon about 150 feet above the Four Feet Coal does not add to the floras described above.

The Lower Red Measures have yielded a small number of plants at several horizons. Those collected in situ have all been from Leck Beck. The lowest of these was in a band of sandy ironstone nodules which contained an abundance of detached Neuropterid pinnules referred to N.cf.gigantea and N.tenuifolia. Some variations of the latter have stronger venation showing affinities with N.flexuosa. Other

pinnules with rarer venation, strongly branched are referred to N.rarinervis. In some cases bifurcation of veins is strongly marked both near the midrib and near the margin and thus some close set veins have the reticulate character of Linopteris. Thus, although few diagnostic species are present, there are signs of the important development of the Neuropterid stock such as might be expected near the top of Floral zone F or more likely within Floral zone G.

A little higher in the sequence nodules from the beds which yielded the lamellibranch shell cf. Anthraconauta wrighti contain fragments of Neuropterids and Calamites similar to the above.

The conclusions reached from these collections in situ are to some extent confirmed by those found during boring and sinking operations. Ironstones from an unknown horizon in New Ingleton Pit Shaft, and probably from a point 50 feet above the base of the Red Measures where the records merely state "Plant Remains" contain abundant well preserved pinnules of Linopteris brongniarti (Grand Eury) and L.neuropteroides (Grand Eury). These,again, are usually abundant only at or near the base of Floral Zone G.

At a depth of 660 feet in No.3. Borehole a rich flora of Neuropterid pinnules, purple-stained in pink shale, was obtained. N. tenuifolia is dominant, but some show the closely packed, many-branched venation of N.macrophylla, although without the lateral lobe.

As the Upper Red Measures have yielded only Calamite casts the above constitutes the total flora of the Red Measures. The only forms truly diagnostic of the higher floral zones are unfortunately not localized accurately i.e. Linopteris spp. but the general impression is that the Lower Red Measures belong to Floral Zone G, or less likely to the top of Floral Zone F. This is in accordance with the evidence afforded by the single lamellibranch,

cf. Anthraconauta wrighti, obtained from Leck Beck, which is commonest at or near the base of the phillipsi zone.

VI Mining History

The earliest available record of coal-mining at Ingleton is in ~~this~~ 1648. The coal-bearing area was then, as now, divided between two Manors, one Ingleton and Bentham Moor, and the other Burton-in-Lonsdale. In 1657 the whole of the collieries in the former were sold for £230. The boundary of the Manors follows the River Greta for much of its course so that the greater part of the coal-bearing area lies in the former manor. The early pits were located on the Burton bank of the Greta near Barnoldswick. Disputes were frequent, and pits changed hands several times, finally coming into the hands of the Sergeantson family in 1736, who maintained a controlling influence until the late 19th century. The heyday of mining was about 1820 - 1840 with recrudescences in the 'sixties and the early 'twenties. By 1828 crop workings extended at intervals from Parkfoot to Moorgarth in both Four Feet and Six Feet Coals. Workings near Yarlsber in 1828 penetrated 9 feet of coal but this can no longer be located. Near the River Greta work was in progress near Faccon Farm and Stephens Wood, and outlines of old pillar and stall workings can still be seen in the river bed at Greta Bank. 700 yards of drainage level probably with an outfall by the mouth of Clifford Gill, were driven about this time. By 1830 there were pits at Moorgarth, Burton, Foredales, Winning Engine Pit, and Bleaberry. In 1833 work commenced on the Clintsfield Coal near Bentham, and a vain attempt to reach coal at Pemberton ($\frac{1}{2}$ mile S. of Ingleton Bridge) was made. Winning Pit was sunk in 1834.

In 1837 the Lancaster Mining Co. attempted to find coal near Westhouse, opposite Halsteads, and on Newby and Bentham Moors, and a report on their lack of success was written by Phillips (1837). The company soon went bankrupt. By 1842 the Wilson Wood Pit had reached the Six Feet Coal, and

Raygill Pit was worked out. The Clintsfield Colliery closed in 1845

Soon afterwards the construction of railways in the district gave a new lease of life to the pits. New Pits were sunk near Foredales and later Grove Pit, with its own branch railway. Much of its coal went to the dockyards at Barrow-in-Furness.

By about 1880 virtually all the coal between the River Greta at Parkfoot and the Ingleton-Settle railway south of a line through Wilson Wood House and Moorgarth Hall had been worked. The Grove Pit was reopened later and finally abandoned in 1914 (Figs. 18 & 19).

In this period, about 1890, J.Barker, successor to Sergeantson and Hodgson (manager of the Burton Collieries) obtained opinions from various mining engineers and received a variety of ideas for working coal which was supposed to exist between Burton and Westhouse. A network of drifts starting from a point near Greta Bank Pottery and several shafts near the Ingleton-Burton road were proposed, with railways from Wennington and Bentham. Several exploratory boreholes were proposed but there is no record of their being sunk, nor plans of any workings north of the river.

Not until the sinking of the Holden House bore in 1906 was a geologist called in to advise and examine the cores - Professor Lebour. He suggested an unconformity existed and proposed a further boring to ascertain its extent. This, the Kepp House Bore, was sunk, and confirmed his conclusions, but no record of its exact location was kept. Two bores near Bentham were sunk in vain (Gibson 1909) but one near Ingleton station (No.3.B.H) was more successful and in 1910 the New Ingleton Pit was commenced. Rather unexpectedly two unknown thick coals were found - the Ten Feet and Nine Feet Coals - over a limited area. They were worked and

Fig.18.

WORKED AREAS
INGLETON SIX FEET COAL

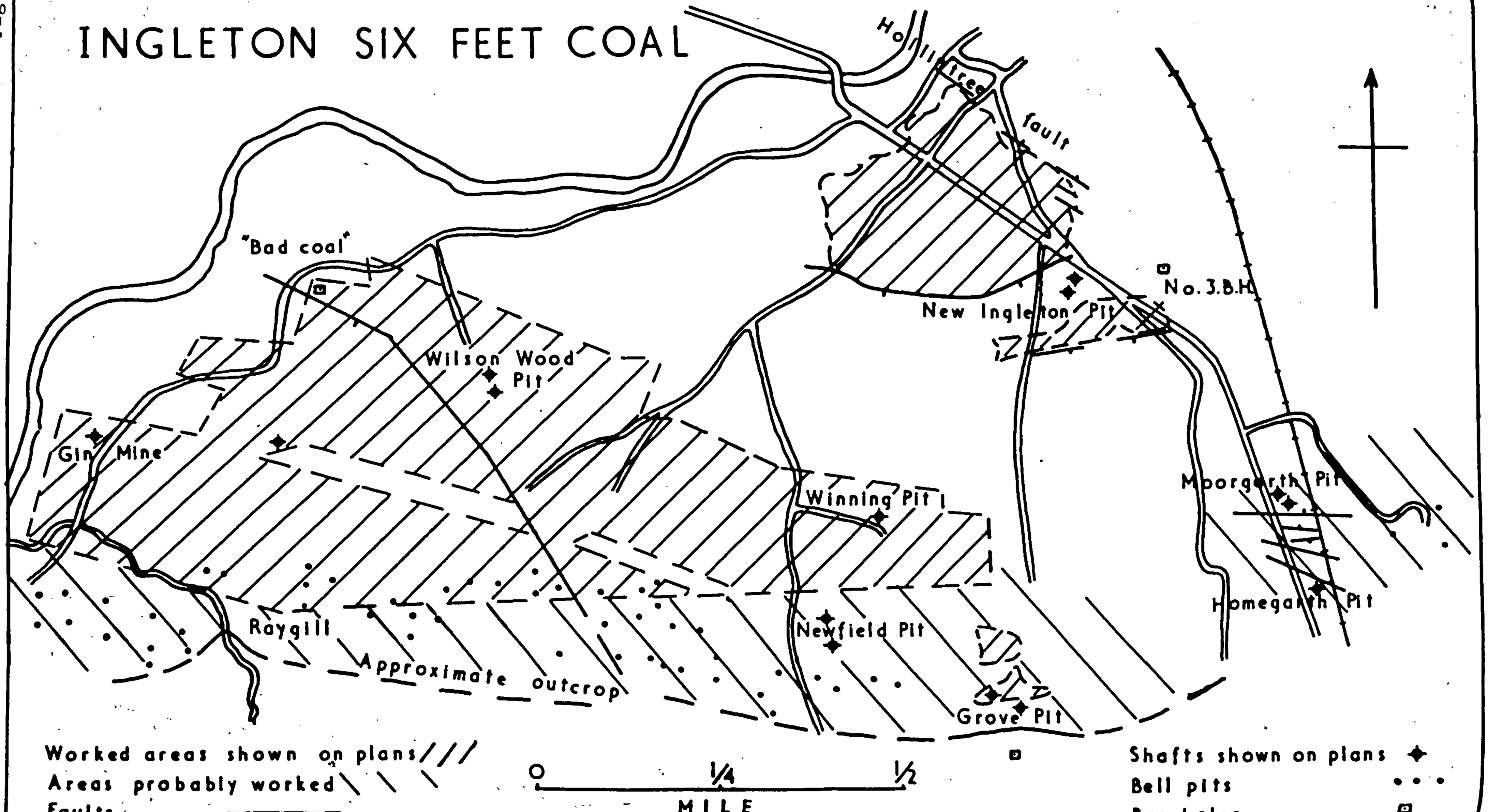
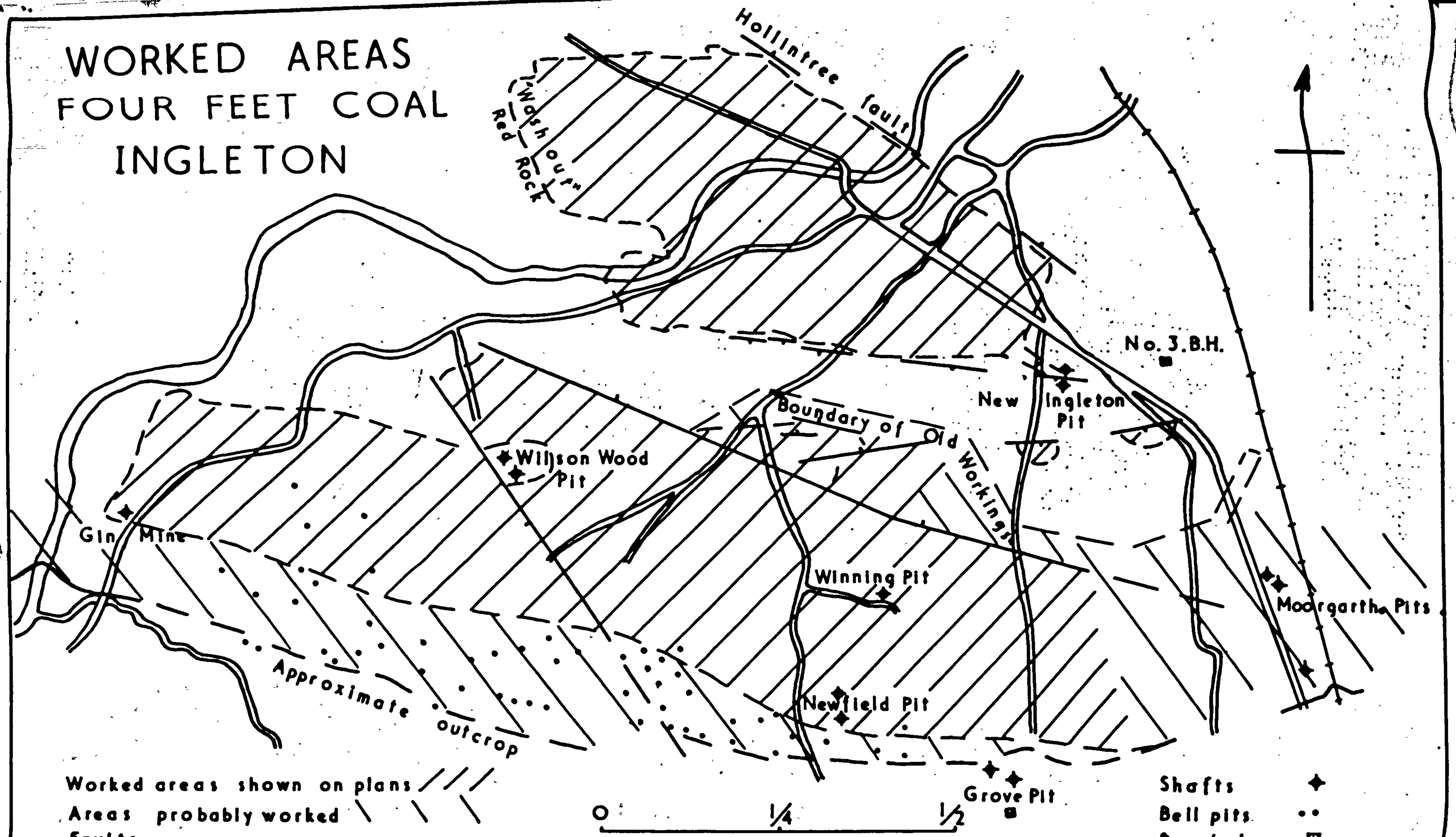


Fig.19

WORKED AREAS
FOUR FEET COAL
INGLETON



abandoned by 1919. The Four Feet and Six Feet Coals were worked over a large area and the pit closed in 1928, reopened in 1933 and was finally abandoned in 1935. In the Four Feet Coal "Red Rock" cut off the coal to the west and faults or old workings on all other sides. A large area, about ½ sq. mile of Six Feet Coal remains untouched below Four Feet Coal workings and probably beyond them to the west. (Figs. 18 & 19)

In 1945-6 about 60 shallow and 3 deep boreholes were sunk by open-cast prospectors around Bleaberry Hill and Stephens Wood - without success. 40 feet of boulder clay precluded all hope of successful opencasting over the area concerned. No prospecting was done further east near New field and Grove Pits where boulder clay may be thinner but where old workings are to be expected.

At present no mining of any kind is being carried on at Ingleton. For the future at least ½ sq. mile of Six Feet Coal is untouched under the river west of New Ingleton Pit. This area may be extended as a narrow strip ¼ mile wide down the river towards Barnoldswick. There is no record of any workings north of High Barnoldswick House on the north bank of the river. The Four Feet Coal is probably cut out by unconformity in this belt, but the Six Feet Coal will probably extend further than the known workings which are partly limited by manorial boundaries. The 38 inch coal and other thin coals recorded in the New Ingleton shaft are completely unworked and their extent is unknown.

As Tiddeman said in 1871 "the western end of the coalfield has never had a fair trial". 4 inches of coal was found in a shallow bore west of Collin Holme probably in the Millstone Grit. Other than the above no workable coal can be expected in any part of the coalfield except the northern end of Leck Beck. The occurrence here of Grey Measures palaeontologically related to the productive

measures but younger than the known seams indicates the possibility that the latter may lie under Leck Beck. If the coals are there they will have steep dips, frequent faults and are very unlikely to exceed one square mile in area.

Fireclays and pottery clays have been worked extensively around Burton but records are very scanty. Six potteries were at work in and around Burton in the early 19th century. The shales and seat-earths associated with Six Feet, Raygill and Bleaberry Coals were worked both opencast and underground. The Bleaberry Clay Mine, south of Waterside Pottery worked as recently as 1935. Ganister was mined at Mill Hill (immediately below the Mill Hill Shales) and near the G. listeri marine band, north of Clifford Hall. Sand for glass-ware was worked at one time - probably in Sand Quarry Wood, north of the latter.

PART II

THE STAINMORE COALFIELD

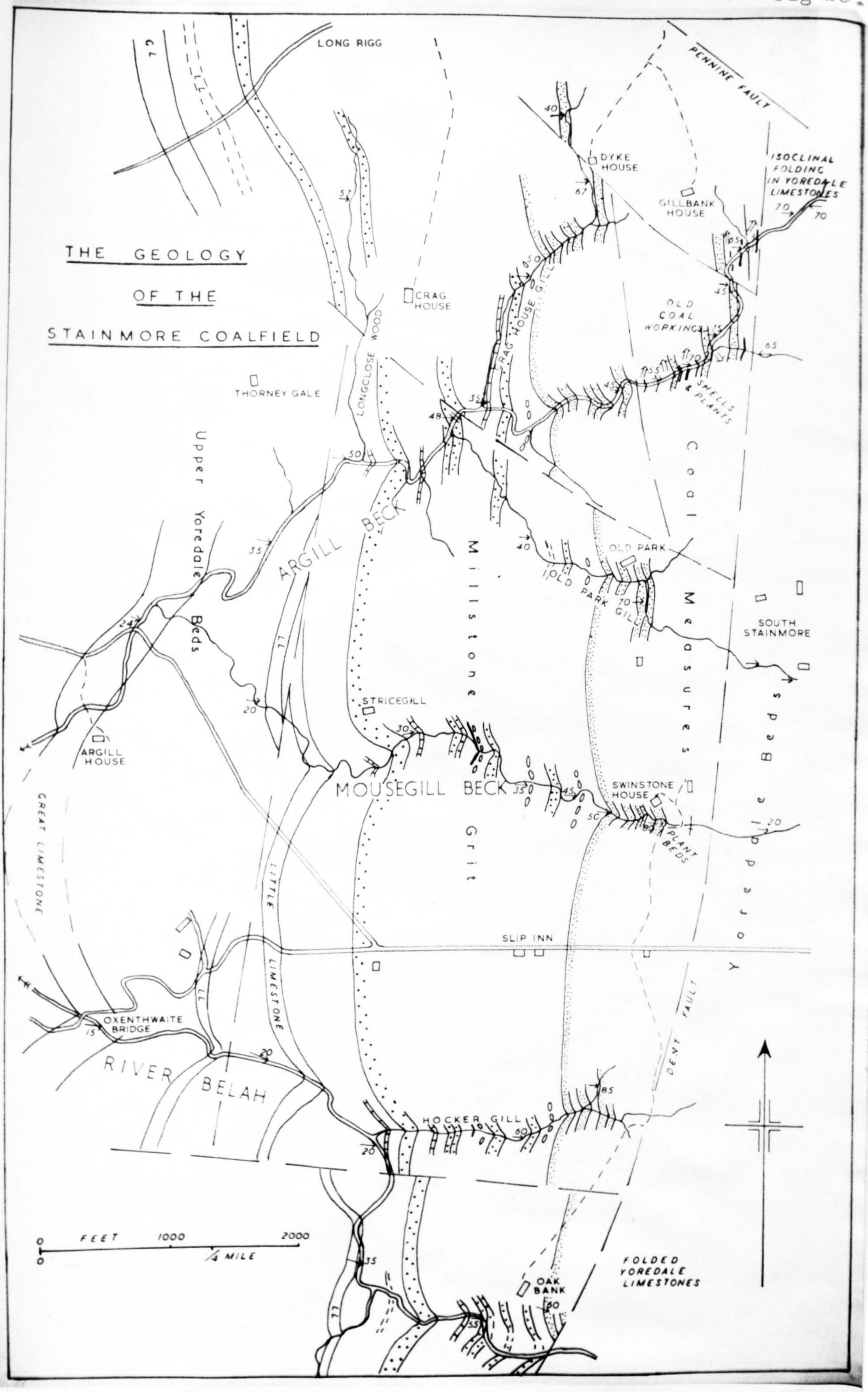
I. Introduction

Lying at the western end of the Stainmore Gap through the Pennines the Stainmore Coalfield covers an area of only two square miles, and is the only outcrop of Coal Measures in Westmorland (Old Series 1" Sheet 102 SE)(See Map in Part I.) The coalfield consists of a crescent shaped strip of undulating country from 400 to 1000 feet O.D. roughly four miles long from north to south, and less than a mile across at its widest. It is bounded on the north east by the Pennine Fault system and on the south east by the Dent Fault System, both of which throw Yoredale Series against the highest part of the local Coal Measures. On the western side of the coalfield older Carboniferous rocks, Yoredales and Millstone Grit, crop out from beneath the Coal Measures. A few miles to the west these are overlain unconformably by Permo-Triassic rocks.

The Coalfield is drained by a number of sub-parallel streams flowing to the west. These are incised as much as a hundred feet, with interfluve areas thickly covered with boulder clay especially in the north. Exposures are confined to these streams but sections are by no means continuous. Coal-bearing strata outcrop in one stream only, Argill Beck, and mining has been on a very limited scale by small adits driven into the river banks south and south west of Gillbank House. Basal Coal Measure sandstones and the underlying Millstone Grit outcrop in the adjoining Argill Beck, Mousegill Beck, Intake Gill, and in the River Belah (Fig. 20).

The terminology adopted in the present account is similar to that proposed by Chubb & Hudson (1925) for the Tan Hill

THE GEOLOGY OF THE STAINMORE COALFIELD



district some 5 miles to the south east. There the Upper Yoredales include beds from the Great limestone up to the lowest of the coarse grits, considered by the writer to be the equivalent of the Tan Hill Grits. The top of the Millstone Grit is taken at the base of a higher grit with a conglomeratic base which seems to be linked to the sedimentary cycles of the Coal Measures rather than to those below. Discontinuities in sedimentation thus delimit the three subdivisions of the Upper Carboniferous rocks. The Millstone Grit of this terminology includes beds equivalent to those included in the Upper Yoredales by Carruthers (1938), and which are similarly unconformably covered by Coal Measures in Durham. In the past there has been considerable confusion in the nomenclature and correlation of these beds between the Great Limestone and the lowest of the Productive Coals in Durham. The term Millstone Grit has been applied to some or all of these beds by writers from Phillips (1836) onwards. No type sections were adequately described until Hudson and his co-workers applied Bisat's Goniatite zonal scheme in Swaledale. Diagnostic fossils are few and far between and much detailed correlation still remains to be done.

II. Previous Research

The existence of Coal Measures in this area was apparently unknown until their discovery by J.G.Goodchild during the primary survey in 1870. No memoir was ever published for this sheet (102 SE) but Goodchild wrote a report for the landowners in 1872 giving details. This report has not yet been located by the writer but it is referred to in a later paper by Goodchild (1890) when dealing with the former extent of the Coal Measures.

In 1935 J.Selwyn Turner described the tectonics of the western end of the Stainmore Gap, and published a map showing the approximate outcrops of strata referred to the Millstone Grit and Coal Measures, and gave diagrammatic cross-sections which included the Coal Measures as a whole although they were not differentiated into individual beds. The structural history of the coalfield, as part of a wider area, was described by Turner but no details of the stratigraphical sequence of Millstone Grit and Coal Measures were given. Thus no detailed account of the succession of Upper Carboniferous rocks of this area has been published, and Goodchild's unpublished account is not known to exist today. Mining information is negligible.

This account presents the details of the Millstone Grit and Coal Measure succession together with a brief notice of the underlying Upper Yoredale Series and the structural history of the area. During this investigation the discovery of hitherto unrecorded faunal and floral horizons in the Coal Measures has enabled the age of these beds to be ascertained. The faunas and floras described below are entirely the present author's collecting.

III. Succession of Upper Carboniferous Strata

(a) General

The most complete succession in the area is that in Argill Beck, in which an ascending sequence of beds is crossed on going eastwards upstream from Argill Bridge (Fig. 20). As there are several faults crossing the stream, and also some large gaps in exposure reference must be made to the tributary stream Mousegill Beck, about½ mile to the south, to establish a complete succession (Fig. 21). The Upper Yoredales, 300 feet. thick are exposed in both streams from Argill Bridge eastwards for a 1/3 mile, dipping at 20° - 30° to the east. Dips increasesteadily upstream, with the Millstone Grit dipping at 30 - 45° to the east, and the Coal Measures at 45° to vertical. The Millstone Grit follows, with a discordant base, although no major unconformity has been detected within the area. Its total thickness is 630 feet, and it contains a few thin limestones or bands of calcareous nodules between the grit bands. The Coal Measures contain strong grit bands in the lower portion of the sequence. These rest with discordance upon the Millstone Grit. Only in the higher portion do workable coal seams appear. These are seen at outcrop only in Argill Beck where they persist to within a few yards of the Dent Fault Line, 30 yards east of the footbridge near Gillbank Farm (N.G.R.35/841137). Approximately 800 feet of Coal Measures are exposed. About 700 feet outcrop in Argill Beck and the remaining 100 feet are cut out of Argill Beck by a fault, are seen in Mousegill Beck. There are several gaps in exposure in the upper part of the Argill Beck section.

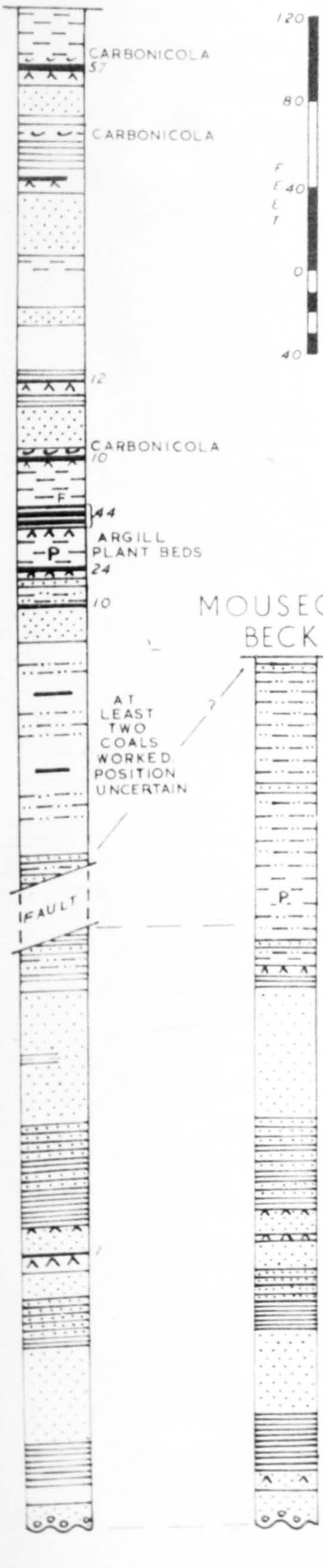
No diagnostic fossils have been obtained from either Upper Yoredales or Millstone Grit during the present work, indeed the only fossils seen were fragmentary productids and crinoid ossicles. By comparison with the neighbouring Tan Hill Area some 5 miles to the south east it is probable that both

Fig.21.

SECTIONS OF STRATA IN THE STAINMORE COALFIELD

Coal Measures

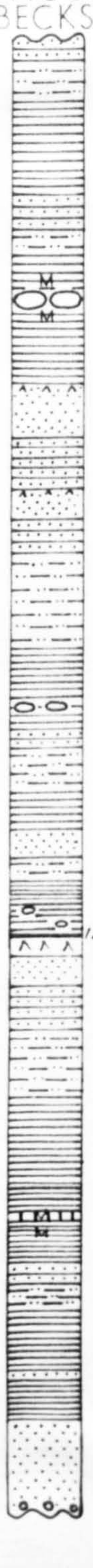
ARGILL BECK

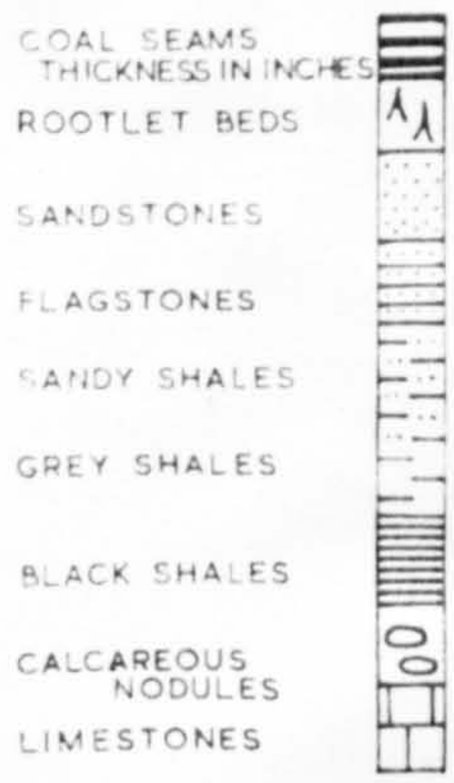


MOUSEGILL BECK

Millstone Grit

ARGILL & MOUSEGILL BECKS





Upper Yoredales

probably fall within the Eumorphoceras stage (E) although the Millstone Grit may range up into the Homoceras stage. The Coal Measures have yielded a good non-marine lamellibranch fauna and floras at two horizons; these suggest that the workable coals occur at or near the base of the modiolaris zone.

(b) Details

(i) Upper Yoredales Series. The Series consists of some 300 feet of sandstones, shales and limestones exposed in Argill and Mousegill Becks in the River Belah and its tributaries (Fig. 20) and in Augill Beck (Not shown on map. About 1 mile N.W. of Argill Beck). The base of the Series is taken at the Great Limestone, upon which Argill and Oxenthwaite Bridges are built. It consists of some 60 feet of coarse crinoidal limestone, thinly bedded towards the top and partly haematized in places, e.g. Augill Beck. Above it a marine shale development passes up through sandy shales and flags into fine grained massive sandstones, which form a prominent bluff about $\frac{1}{4}$ mile north east of Argill Bridge (35/827131). These are capped by the Little Limestone, some ten feet of thin bedded, sometimes nodular argillaceous limestone with crinoid ossicles. The Little Limestone is faulted out of Argill Beck, but is repeated by faults in Mousegill Beck west of Stricegill Farm, and in the Belah. The cycle of dark shales passing up through flags into fine grits is repeated and capped by the foot thick Crow or Crag limestone, about 80 feet above the Little Limestone. The Crow limestone occurs as bands of close-set nodules where the Intake Gill and Hocker Gill join the River Belah and as a thin dark limestone a few yards east of the mouth of Longclose Gill, in Argill Beck (35/831133). Thick black shales passing up into flags in places follow, and are discordantly overlain by the conglomeratic base of the millstone Grit, the thick Mirk Fell Beds of Swaledale

being cut out by westward outstep of the Tan Hill Grits

(ii) Millstone Grit. The strata referred to as Millstone Grit in this area are probably equivalent to the Upper part of the Upper Yoredales of Carruthers (1938), his application of the term "Millstone Grit" being to the grits in the lower parts of the Coal Measures in the Durham Coalfield. In the Stainmore Coalfield area the Millstone Grit consists of some 600 feet of sediments built up in cycles similar to the underlying Yoredales, except that the limestones are rarely more than a few inches thick and are generally represented only as bands of nodules. (Fig. 21)

The Millstone Grit is well exposed in Mousegill for about 1/3 mile east of Stricegill Farm. The dip is eastwards at angles from 30° - 60°, increasing upstream towards the Dent Fault. The base of the Series is marked by a massive coarse felspathic grit, often pebbly or even conglomeratic towards the base. This makes the marked feature on which Stricegill Farm is built (35/830126) and makes waterfalls some 30 feet high near the mouths of Hocker Gill (35/831117) and Intake Gill (35/830110). The conglomeratic base is well exposed in Augill Beck and in Coldkeld Beck in Amersber Wood.

The basal Millstone Grit is followed by at least 6 sedimentary cycles of limestone, shale, sandy shale, grit, shale, limestone. Some of the grits have rootlet markings at the top, but only in one case is there a rootlet bed and coal above the grit i.e., at the east end of High Wood, Mousegill Beck. The individual grits are about 12 - 20 feet thick, medium grained and massive. The lowest of the limestones is about a foot thick and occupies a position similar to the Hearne Beck Limestone of Shunner Fell. (Chubb & Hudson 1925). It is exposed in Argill Beck due south of Crag House (35/833133) in Mousegill at the east end of Snouthill Wood (35/833126), and in the River Belah near the Cattle ford (35/832112). Nodule beds only occur in the higher cycles except for the highest, in which occurs a bed a foot thick which splits into

two near the mouth of Crag House Gill. In Mousegill Beck, 200 yards west of Swinstone House (35/836125), the bed is somewhat broken up, to give the appearance of large bullions close together. Productid remains and crinoids occur in the shales below in both sections. It may be noted that in the case of the two limestones in Argill Beck, near the mouth of Crag House Gill, they were interpreted by Turner (1935) as a faulted inlier of Fell Top Limestones, i.e. part of the Upper Yoredales cut out by the unconformity at the base of the Millstone Grit less than half a mile away.

There is no direct evidence of the age of these beds but the general succession is similar to that described by Chubb & Hudson (1925) in the Tan Hill area some 5 miles to the south east. Thus it may be that the beds with shell fragments near the top of the Millstone Grit as described above may be the equivalent of the Cayton Gill Beds of Nidderdale (Tonks 1925) which are of Lower Reticuloceras age, or more likely, the Shunner Fell Beds of Swaledale.

(iii) Coal Measures. Strata of Coal Measure age total some 800 feet in thickness and are exposed in Argill and Mousegill Becks. (Fig. 21) Neither of these, exhibits an unbroken section, and only the former contains the workable coals. However a fault separates these from the lower arenaceous beds in Argill Beck and the highest beds in Mousegill Beck are not seen in Argill Beck owing to their being cut out by this fault. The Coal Measures can be separated into two groups, a lower dominantly sandy division without coals about 300 feet thick and an upper dominantly shaly division with at least ten coals visible at outcrop. Goodchild (1890) mentions 20 coal seams but some are no longer exposed, and their approximate position is indicated only by old adits and tips. The arenaceous group outcrops also in Crag House Gill, Old Park Gill, and in Hocker Gill.

The base of the Coal Measures is marked by a coarse felspathic grit some 15 feet thick, with shale conglomerate bands towards the base. In Argill Beck it overlies a few inches of rubbly ganister, probably the remains of a fossil soil, while in Mousegill Beck, just below Swinstone Bridge (35/836125) the base is seen to transgress some 4 feet of the underlying sandy shales at the top of the Millstone Grit. Above the basal grit are a few feet of dark shale and a thick grit. A cycle of shale, sandy shale, flags, grit, seat-earth follows, the top of the grit containing strongly developed bands of pock-marking due to the rolling of pellets of semiconsolidated sand and mud. The seat earth contains abundant rootlets through a thickness of 9 feet, but is separated from the overlying grit by less than one ich of soft coal. The grit, 14 feet thick, has rootlet beds at the top and is followed by a thick shale development, passing up into further grits at the top. These in turn are followed by a thick sandy shale and flaggy group with scattered plant debris only partly exposed in the stream bed. These beds are here cut off by the fault mentioned above, and the succession is continued in Mousegill Beck immediately south of Swinstone House. The flaggy beds with plant debris here make a small crag on the south bank opposite the farm and the overlying grit outcrops in the stream bed. It is capped by a white fireclay. No coal is seen and after a few feet without exposure sandy shales are seen below a thick development of light red shales passing up into sandy shales for about 100 feet as far as the Dent Fault Line. Some 20 - 25 feet above the fireclay are several horizons with plant remains. These may be collected near water level in the south bank, close to the bend in the farm road (35/837124).

The following plants were obtained from the Mousegill Beck Plant Beds:-

Mariopteris sp.
Alethopteris sp. (? cf. A.davreuxi)
Neuropteris gigantea Sternberg.
Neuropteris sp. (? cf. N.tenuifolia)
Neuropteris sp. (? cf. N.obliqua)
Sphenophyllum cuneifolium (Sternberg)
S.cuneifolium forma saxifragaefolium (Sternberg)
Bothrodendron punctatum Lindley and Hutton
Asterophyllites equisetiformis (Schlotheim)

The plants occur as impressions in fine-grained light red or lilac shales.

About 100 feet of pink-tinged sandy shale and flaggy beds are exposed in Mousegill Beck above the Plant Beds and it is not clear how much of this is cut out by the fault in Argill Beck or whether still more beds are missing. East of the Fault in Argill Beck little is exposed for some 200 yards. A few feet of sandy shale outcrop in places and the presence of at least two thick coals is suggested by tips outside old adits (now blocked) driven along the strike in the north bank. Higher upstream in the south bank (35/838135) is a good exposure of about 100 feet of steeply dipping strata containing several coals (Fig. 20). A sandstone with a 10 inch coal above it are followed by flaggy beds and then 2 feet of coal. Above this are about 15 feet of coarse light grey shales with abundant plant remains at several horizons. These, the Argill Plant Beds, have yielded the following plants:-

Mariopteris muricata (Schlotheim)
M. cf. coarctata Stur
M. cf. acuta Brongniart
Mariopteris sp. (? cf. M.nervosa)
Diplotmema sp.
Neuropteris heterophylla Brongniart
N. cf. tenuifolia (Schlotheim)
N. cf. gigantea Sternberg
N. cf. heterophylla Brongniart
Lepidophyllum sp.
Cyclopteris orbicularis
Myriophyllites gracilis
Cordaites principalis (Germar)

The Argill Plant Beds pass up imperceptibly into thick

rootlet beds below a thick composite coal. The whole seam section totals some 8 feet but the thickest leaf of coal is less than 2 feet. Bands of pyritous ironstone and crushed black shale make up the remainder. This is probably the coal referred to by Goodchild (1890) as 8 feet thick. A few inches of black shale forming the immediate roof material contain occasional fish scales and fragments of plant stems referred to as Lyginodendron sp. About 20 feet higher a 10 inch coal is overlain by 18 inches of slickensided black shale with abundant non-marine lamellibranchs, forming in parts a mussel-band. Many of these shells are crushed but a considerable fauna of uncrushed and identifiable shells was obtained. A representative fauna from this band was examined by Dr.Weir, who places the horizon at the base of the modiolaris zone. The fauna collected includes:-

Anthraconaia cf. curtata (Brown)
A. cf. williamsoni (Brown)
? Anthracosphaerium boltoni (Wright)
Carbonicola aff os-lancis Wright
C. cf. os-lancis Wright
C. cf. antiqua (Brown)
C. cf. bipennis (Brown)
C. cf. polmontensis (Brown)
C. cf. martini Trueman and Weir
Carbonicola sp. (? cf. rhomboidalis)
? C. cf. rectilinearis Trueman and Weir

The shell bed is capped by a thin sandstone close to the mouth of a small tributary, where adits have been driven for a 12 inch coal seen in the bed of Argill Beck, and for another higher in the sequence and seen in the tributary. For about 100 yards up Argill Beck exposure is poor until a landslip scar on the south bank shows some 20 feet of shales. A few poorly preserved and unidentifiable Carbonicola spp. were found in weathered ironstones in the debris below the scar but the source was not found.

Among the highest beds in the coalfield is a coal 4 feet 9 inches thick worked from an adit in the north bank 10 yards west of Gillbank footbridge (35/840138). The coal dipped at 65° E in the workings, but is no longer seen at

outcrop. The tip, now being eroded by the stream, yields blocks of very poor quality powdery coal, and occasional non-marine lamellibranchs in ironstones. These are very poorly preserved and can only tentatively be referred to Carbonicola cf. acuta (J.Sowerby). The coal is overlain by some 25 feet of shale which is seen crushed and faulted under the footbridge. Between this and the Dent Fault some 10 yards upstream the last coal and the associated shales appear to be repeated, with almost vertical dips to the west. An adit a few yards north of the footbridge has a tip yielding large blocks of coal with a powdery brecciated appearance probably caused by movements of the closely adjacent Dent fault. Beyond the Dent Fault Yoredale limestones are seen isoclinally folded and much faulted.

Summarizing, the Coal Measures consist of about 800 feet of beds with all three fossil horizons fairly close together towards the top of the succession. The shells indicate an horizon at the base of the Modiolaris zone while the floras, though less conclusive, indicate a position towards the top of Floral Zone D. Thus it may be said that the arenaceous beds at the base of the Coal Measures are probably of communis age, and that the highest beds known to exist in the Coalfield probably belong to the modiolaris zone.

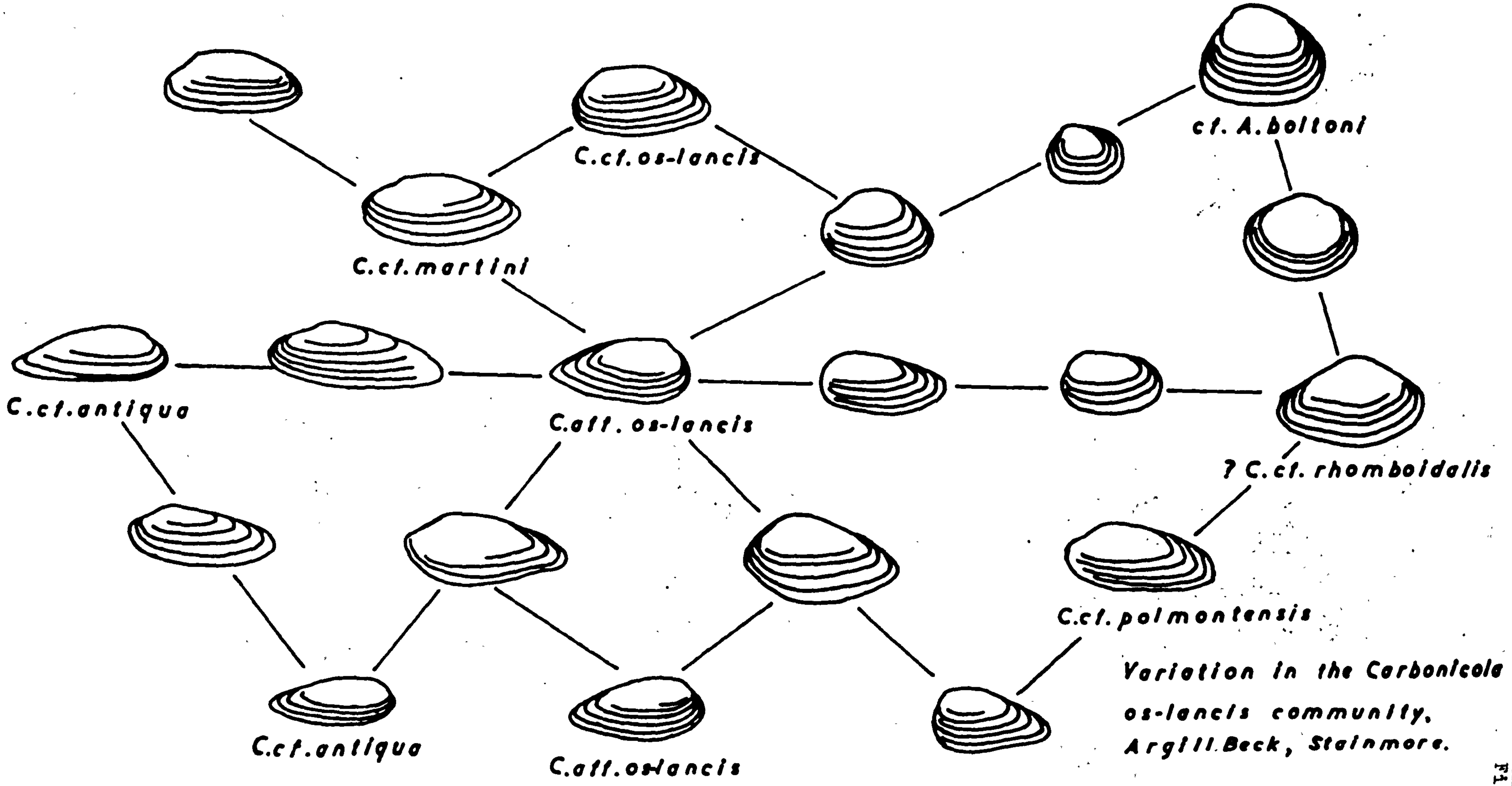
IV. Palaeontological Notes

(a) Non-marine lamellibranchs

The community of lamellibranchs in the Argill Shell Bed shows a wide degree of variation in shape and size (Fig. 22). This is partly due to crushing and slicken-siding after burial. The dominant form, and generally the best preserved, has been referred to Carbonicola aff. os-lancis Wright. In proportions there is close similarity but the Argill shells are generally much smaller than the forms described by Wright and by Trueman and Weir. Dr.Weir has also commented on some of them being elongated and resembling Carbonicola antiqua (Brown), a direction of variation not previously recorded. Small shells, referred to C. cf. bipennis (Brown) are not uncommon, and other variants resemble C. rhomboidalis and C. martini. A number of small shells appear to be close to Anthracosphaerium boltoni (Wright) although their state of preservation is not all that could be desired. A few large Anthraconaia spp. are scattered through the community. Thus elements of both communis and modiolaris faunas are present in roughly equal numbers and an horizon close to the base of the modiolaris zone is indicated. The poor specimen doubtfully referred to C. cf. rectilinearis cannot be regarded as diagnostic of any lower horizon.

(b) Floras

Two floral horizons occur, one in red shale in Mousegill Beck and one in grey shale in Argill Beck. The exact relationships of the two are not known with certainty but it is probable that the latter lies about 150 - 200 feet above the former. Both contain large numbers of individuals although relatively few species are present. In Mousegill pinnules of Neuropteris gigantea and Sphenophyllum cuneifolium make up most of the flora. These indicate (Floral Zone D but elements of Zone E are beginning to appear i.e. the poorly preserved ?Alethopteris davreuxi and ? Neuropteris tenuifolia.



Variation in the Carbonicola os-lancis community, Argill Beck, Stainmore.

Fig.22.

In Argill Beck Neuropteris gigantea is almost absent, and N. heterophylla, in small fronds is extremely common and makes up most of the flora. Mariopteris spp. are also common but difficult to identify specifically in the coarse shale. Variants of N. heterophylla show tendencies towards N.tenuifolia and N. grangeri. The only other plant at all common is Diplotmema sp.

The band with fish scales a few feet higher contains fragments of Lyginodendron sp. Thus the Argill Plant Beds contain some forms which become dominant towards the top of Floral Zone D.

PART III

THE REGIONAL SETTING OF THE INGLETON AND STAINMORE COALFIELDS

I. Introduction

The Upper Carboniferous Rocks of the North of England have long been regarded as falling into two distinct provinces. The Central Pennine Province, which includes the Yorkshire and Lancashire Coalfields and the wide areas of Millstone Grit between and north of them, is characterized by a thick and complete representation of Millstone Grit and Productive Coal Measures. The Northern Pennine Province embraces the Northumberland and Durham Coalfields together with the relatively limited flanking areas of Millstone Grit, and is characterized by a much thinner succession containing distinct breaks in sedimentation. Whilst the Central Pennine Province presents a complete sequence of goniatite and non-marine lamellibranch zones, the Northern Pennine Province presents a restricted succession in which the goniatite zones H, R, & G, and the non-marine lamellibranch zone of Anthraconaia lenisulcata are absent, except in West Cumberland where a minor incursion of the G zone is recorded. The major coalfields of the two provinces are 60 miles apart at their nearest points on the eastern flank of the Pennines and nearly 100 miles apart on the western flank. In the latter area the Ingleton and Stainmore Coalfields form outliers roughly 30 miles apart, and respectively about 30 miles from the major coalfields of the two provinces. However Parts I and II of this thesis show that the successions at Ingleton and Stainmore are very different. These differences are commensurate with those observed between the larger coalfields of the Central and Northern Pennine Provinces, so that the Ingleton and Stainmore Coalfields may be considered as

belonging respectively to those provinces. The establishment of this fact means that the limits of the two provinces are brought nearer together, in fact the distance between them is now reduced to 30 miles. This change of outlook becomes significant when it is appreciated that the changes from one depositional province of the Upper Carboniferous to another take place within a region which is much more closely related to observed structural features.

The North of England was divided into two provinces as early as late Avonian times by changes in sedimentary facies approximately along the line of the Craven Faults, the Askrigg Block to the north being uplifted relative to the Craven Lowlands to the south. These differences were accentuated by the Sudetic movements, during which the Craven Faults were initiated. The difference persisted throughout Millstone Grit times, and it is here shown that along somewhat comparable lines changes in Coal Measure sedimentation took place. The Ingleton Coalfield lies immediately south of the Craven Faults while the Stainmore Coalfield lies some 30 miles to the north. The latter, however, does not lie on the uplifted block as it is developed today, but is on the downthrow side of the Dent-Pennine Fault system. Whilst some sedimentary changes took place near this line in Lower Carboniferous times they seem to have been less important than those along the Craven line, and do not appear to have persisted into Upper Carboniferous times. The development of this fault system seems to have been entirely post-Carboniferous.

A comparison of the successions in the Ingleton and Stainmore Coalfield areas, stage by stage, follows and illustrates the differences in sedimentation in the two provinces. Correlation with the larger coalfields is largely on a palaeontological basis, although some direct lithological correlations can be made in the lower parts of the successions.

II. Namurian

(a) General

The Namurian rocks of the North of England have recently been reviewed by Trotter (1952). They may be considered under two lithological headings, Millstone Grit and Yoredale Series. Each consists of a cyclic repetition of facies, although the facies differ in the two groups. In the Millstone Grit a cycle from marine shale, through non-marine shale, sandstone, to deltaic grit, with or without the remains of vegetation on its top, and so back to marine shale is dominant. In the Yoredale Series the marine element is more important, the cycle being limestone, marine shale, shelly grit, sometimes deltaic grit and rootlet bed, and so back to limestone. In each type of cycle the proportionate thicknesses of the different facies may vary considerably. So far as the lowest parts of the Namurian are concerned the two types of cycle are confined respectively to the Central and Northern Pennine Provinces but later there seems to have been a combination of the two types of cycle in the Northern Pennine Province. Thus there is the "Millstone Grit" of Northumberland and Durham, in which deltaic grits become more important and the limestones less important than in the typical Yoredale cycle. At times either or both may be absent from this cycle. Palaeontologically the Millstone Grit marine strata contain largely planktonic faunas, including goniatites and lamellibranchs, while those of the Yoredales contain benthonic faunas, mainly brachiopods and corals. The preponderance of deltaic grits in what may be considered a basin of relatively deep water in the Central Province, and of marine shelly grits in the shallow water of the Northern Province may seem somewhat anomalous, but it may be that the thin deltaic grits locally present in the Yoredale cycles represent, in part, the distributary channels

CORRELATION OF THE MILLSTONE GRIT OF THE INGLETON & STAINMORE COALFIELDS

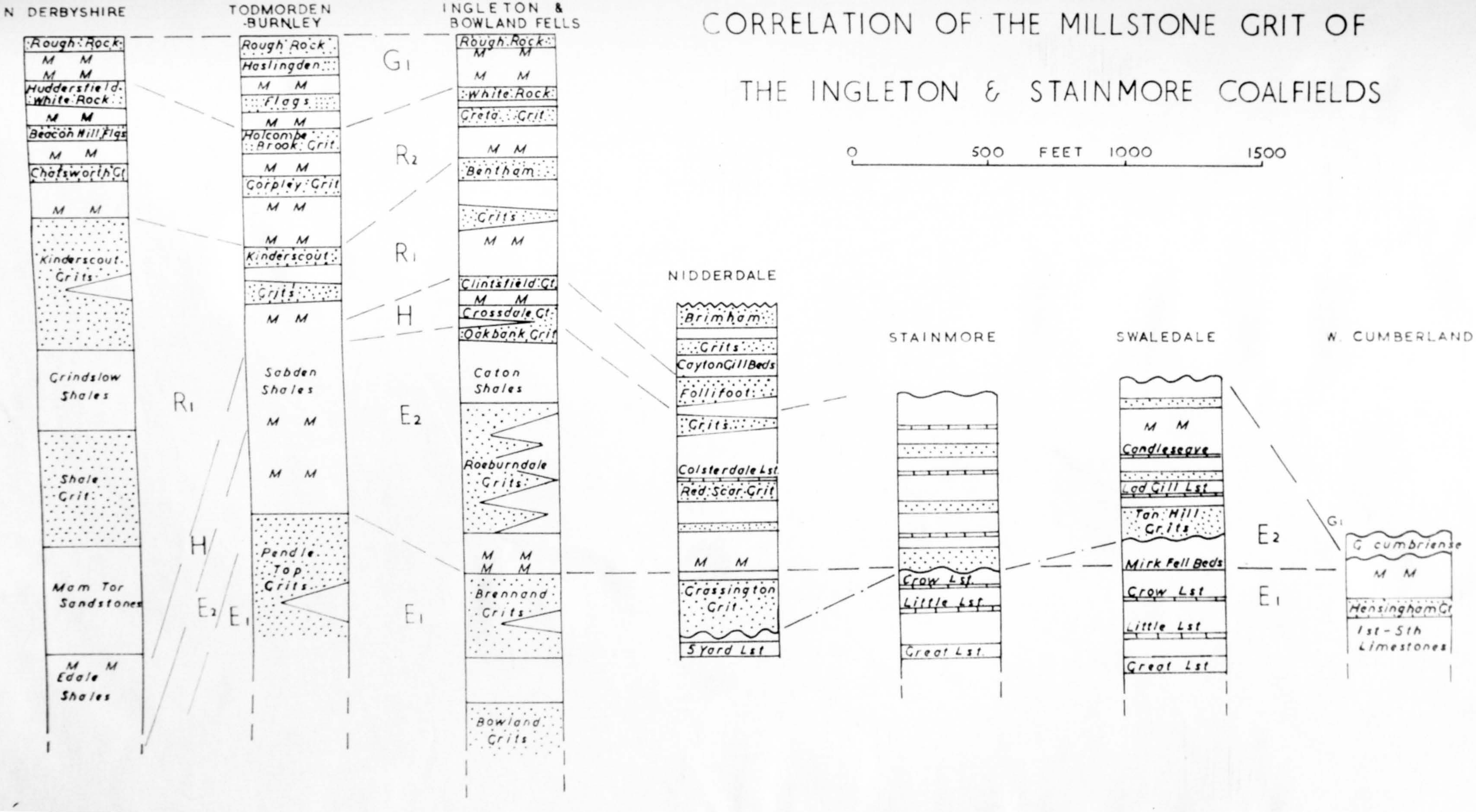


Fig. 23

of the larger deltaic grits to the south. This applies to the lower Namurian stages E_1 and E_2, in the Northern Province and probably applied throughout the higher zones although no representative of these now exists, owing to a period of erosion followed by unconformity below the Coal Measures north of the Craven Fault Line.

(b) Details

1) Lower Eumorphoceras stage. In the Central Pennine Province this consists of some 2300 feet of deltaic Pendle grits and marine Bowland Shales. These are partly exposed in the Docker Moor area some 4 miles south west of the Ingleton Coalfield but are not seen within the area mapped. In Swaledale their place is taken by some 900 feet of alternating limestones, shales and grits, the Yoredale series. Near the top of these is a group of marine strata, the Mirk Fell Beds which can be accurately placed at the base of E_2 (Hudson 1941). These are however cut out by unconformity in the Stainmore Coalfield area, and Millstone Grit, probably of higher E_2 age, rests on strata of upper E_1 age (Fig. 23). This unconformity has been shown to step down southeastwards towards Grassington, and strata of E_1 age rest unconformably on Lower Carboniferous rocks there. Northwards Carruthers (1938) has shown that the plane of unconformity rises diachronously across the Alston Block.

2) Upper Eumorphoceras stage. In the Lancaster Fells about 1000 feet of deltaic grits and marine shales occur in what must have been the area of greatest subsidence at this time. There is considerable thinning to the south and some attentuation to the north (Moseley 1952). Immediately south of the Ingleton Coalfield continuous sections are not available but some 900 - 1000 feet of strata probably fall into this zone. In Swaledale some 500 - 700 feet of Millstone Grit lie unconformably on Upper Yoredales of Upper E_1 - Lower E_2 age. In the

Stainmore Coalfield 670 feet of "Millstone Grit" rest on strata close to the top of the E_1 stage. In this region however the age of the upper part of the Millstone Grit is in doubt owing to the scarcity of diagnostic fossils. Chubb and Hudson (1925) considered the higher beds (Shunner Fell Beds) equivalent to the Cayton Gill Beds of Nidderdale of low R_1 stage (Tonks, 1925), but Trotter (1952) and others consider them equivalent to the Colsterdale Marine Beds of Upper E_2 age. Throughout the Northern Pennine Province these beds are overlain unconformably by grits of Coal Measure age.

3) Homoceras stage. Beds of this stage are thin throughout the Central Pennine Province and are absent from the Northern Province. Rarely reaching 150 feet in thickness, the stage is dominantly marine shale throughout the Central Province but in the Ingleton area a series of coals and ganisters, the Clintsfield Coals, come in at the top and have been traced some distance to the east.

4) Lower Reticuloceras stage. The thick deltaic grits of this stage are a prominent feature of the Central Pennine landscape from Derbyshire to the Craven Faults, but there is no representative of this stage north of the latter. The two Bentham Grits flanking the Ingleton Coalfield are approximately equivalent to the Kinderscout Grits further south. A marine shale incursion with Reticuloceras reticulatum occurs below the grits, and at the base of the zone are flags and sandstones with brachiopods which Trotter (1952) has likened to the marine grits of the Yoredales. These occur in the Lancaster Fells south of Ingleton but show some attenuation west of the coalfield (Fig. 4). They are approximately equivalent to the Cayton Gill Beds of Nidderdale (Tonks 1925). The marine shales with a succession of early Reticuloceras spp. described by Hudson (1943) flanking the Burnley Coalfield are not developed at Ingleton though there is some suggestion of their appearance south of Bentham. The stage as a whole is

thickest in the south of the Province, i.e. the centre of the basin southwards moved.

5) Upper Reticuloceras stage. As in the lower part of this stage thick deltaic grits characterize the whole province. The GretaGrit of Ingleton is approximately of the same age as the Chatsworth Grit to the south of the province, while the white grit above it at Ingleton may be the equivalent of the Huddersfield White Rock. There is a general tendency for northerly attenuation, and the marine bands with late mutations of Reticuloceras reticulatum are represented only by R. gracile at the base and by Lingula at a higher horizon at Ingleton.

6) The Lower Gastrioceras stage. As shown in the last two stages there is an increasing degree of uniformity throughout the Province. Marine and non-marine shales alternate in the lower parts of this stage, which is capped by the wide-spread Rough Rock. The strong development of flags of the Lancashire Coalfield is not present at Ingleton. The wide-spread marine bands with Gastrioceras cancellatum and G. cumbriense are both present. The non-marine lamellibranchs (Carbonicola lenicurvata etc) recorded 27 feet below the former near Bradford (Trueman and Deans 1934) are immediately below it at Ingleton; thus the northerly attenuation in the lower stages is again indicated. The marine incursion with G. cumbriense in Cumberland is not seen in the Stainmore area.

III. Ammanian

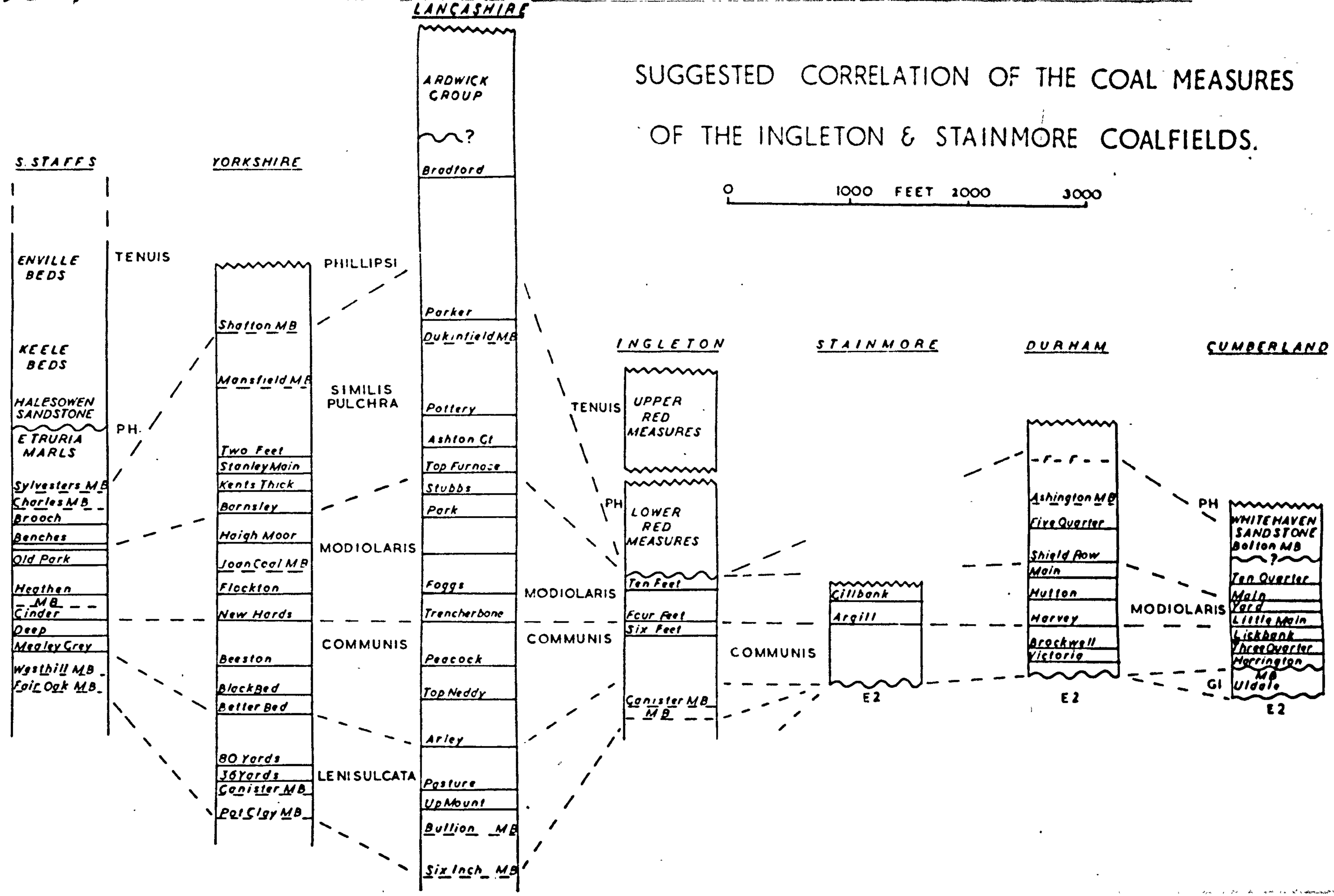
(a) General

By far the greater majority of workable coal seams in both Central and Northern Pennine Provinces occur in the Ammanian. The overlying Morganian strata are chiefly red beds with rare coals generally towards the base, whilst the underlying Namurian strata contain good coals only in the Northern Pennine Province. Each coalfield has, in the past, used its own lithological subdivision of the Coal Measures, but for comparative purposes it is necessary to apply the non-marine lamellibranch zones proposed by Davies and Trueman (1927). These have been applied successfully on a broad scale in all the Pennine Coalfields, but much detailed work remains to be done, particularly in the Northern Pennine Province. In every case the majority of the workable coals occur in the modiolaris and similis pulchra zones. The underlying communis zone has several coals in the Central Province, but relatively few occur in the Northern Province. The Ingleton and Stainmore Coalfields are no exception to this general rule. In both the thickest coals present occur at or near the base of the modiolaris zone, higher zones being largely absent, or in the restricted areas where they may occur, covered by drift. Although coals occur in both areas at about the same horizon, with some hundreds of feet of barren strata below, the lithological successions and the contained faunas are markedly different. This is a reflection of the differences well known to exist between the larger coalfields of the two provinces. Indeed it is only above the base of the modiolaris zone that successions in the latter begin to show any resemblance. One point of significance is that in all the coalfields the communis-modiolaris and modiolaris — similis - pulchra zonal boundaries appear to occur at especially thick and widespread coal seams, and it raises

Fig.24.

SUGGESTED CORRELATION OF THE COAL MEASURES OF THE INGLETON & STAINMORE COALFIELDS.

0 1000 FEET 2000 3000



the question whether these coal seams can be regarded as the remnants of coals once continuous throughout the whole of both provinces. The workable coals of Ingleton and Stainmore and their associated strata suggest that this may not be the case, although the available evidence is not conclusive.

In comparing the successions of the Ingleton and Stainmore Coalfields with those of the surrounding larger coalfields it is at once obvious that the story outlined above during Namurian times continued well into the Ammanian. At Ingleton the sequence is condensed compared with the great coalfields of Yorkshire and Lancashire, but when the South Pennine Coalfields are considered it is evident that the story of southerly attenuation towards a land-mass in the Midlands is repeated in a northerly direction also, and that, during lenisulcata and early communis times the site of the Stainmore Coalfield, was part of the Northern land-mass. The probable correlation of the two coalfields with the larger coalfields is given in Fig. 24 .

(b) Details

1) The Lenisulcata zone. Beds belonging to this zone are present only at Ingleton, and in them most of the well-known horizons of the Lower Coal Measures of Yorkshire and Lancashire can be recognised. (Fig.24). The number of cyclothems is reduced however, and in those present the thin coals of Yorkshire and Lancashire are still further reduced in thickness. The Ganister Coal at Ingleton still has its thick seat-earth and overlying marine bed with abundant Dunbarella papyracea, but the coal is the thickest in that part of the succession at 4 inches. The thickness from the Rough Rock to the Ganister Coal remains much the same as in the larger coalfields but the thickness of the zone as a whole is much reduced. The top of the zone at Ingleton cannot be fixed

accurately but it can safely be said that it is probably less than half the 800 - 1000 feet present in W. Yorkshire and Lancashire, and northerly attenuation can be demonstrated within the coalfield.

2) The Communis zone. Some 300 - 400 feet of beds at both Ingleton and Stainmore fall into this zone although the lower limit is difficult, if not impossible, to define. The upper limit is taken at about the Four Feet Coal at Ingleton, and at the lowest of the thick coals at Stainmore. During Communis zone times the two Pennine Provinces probably became linked by Coal Measure sedimentation spreading across the uplifted block. Coarse grits and sandstones occur at the base of the Coal Measures in Northumberland and Durham, i.e. low in the communis zone, and it is significant that coarse sandstones occur in the Ingleton succession at a comparable horizon (the Burton Bridge and Parks-Wood Sandstones). Although occuring at a slightly lower zonal horizon the widespread Elland Flags of the Central Pennine Province may be related to this extension of the area of sedimentation. The details of the succession may be different in the two areas but it may be noted that in both beds with abundant plant remains occur towards the top of the communis zone.

3) The Modiolaris zone. In neither the Ingleton nor the Stainmore Coalfield is this zone completely represented. At Stainmore some 200 feet of beds referrable to the Lower part of the modiolaris zone are the highest beds in the area. At Ingleton some 300 feet of beds in a similar zonal position in the south east of the Coalfield are overlain unconformably by beds believed to be of phillipsii age, and beds of the higher part of the same zone are similarly overlain by beds of phillipsii age in the north west. In neither coalfield is the sequence of beds present clearly exposed so that detailed comparison with other coalfields is not possible. As has been

observed above the only coals thick enough to be profitably workable occur towards the base of the zone in both areas, and in both areas rich non-marine lamellibranch assemblages occur close to these thick coals. The total assemblages are however somewhat different although similar forms are present in both areas. The sedimentary environments are different and the differences in the assemblages may be related to this fact. Both show a wide degree of variation, and it is significant that similar widely-varying assemblages have been noted above the New Hards, Trencherbone, and Harvey Seams of Yorkshire, Lancashire and Durham respectively. In the latter case abundant arthropod remains are recorded, and they are also abundant at Ingleton. The Joan Coal (Clay Cross) Marine Band of Yorkshire may be present at Ingleton for Lingula was recorded about 100 feet above the Four Feet Coal in a bore-hole.

4) The Similis-Pulchra Zone. No beds higher than the modiolaris zone occur at Stainmore, and at Ingleton no beds of this age are known to exist, although the base of the Red Measures may occur within the top of this zone. Arguments for the opposite view have been advanced in Part I.

IV. Morganian

(a) General

Taking the Top Marine Band of Yorkshire, and its equivalents elsewhere as the base of the Morganian, and also the phillipsii zone it is evident that the Morganian is approximately equivalent to the Upper Coal Measures of the Pennine Coalfields. These are present in all the Pennine Coalfields as dominantly red strata with few coals, and with Spirorbis limestones in places, but are rarely seen in clear exposures, and, on the whole, are imperfectly known. In Yorkshire and Durham only a few hundred feet of Morganian beds are believed to rest conformably on the Ammanian. The phillipsii zone has been recognized in both, but not the tenuis zone. In Lancashire both zones are represented in over a thousand feet of Upper Coal Measures. The relations with the underlying Ammanian are however obscure. Until recently the relations were thought to be conformable except in certain small anticlinal areas (e.g. Edge Green (Jones 1938) where gross unconformity was believed to exist. This has recently been questioned by Trotter (Presidential Address to the Yorkshire Geological Society, 1952). In Cumberland strata of not only Morganian but also of presumed uppermost Ammanian age (the Whitehaven Sandstone Series) are undoubtedly unconformable on Lower Ammanian strata. The placing of the lowest Whitehaven Sandstone Series on the uppermost Ammanian depends on the interpretation of the sequence in a single stream section through badly faulted and poorly exposed ground, and has been questioned by Trueman (1947). Some 1500 feet of Red Measures at Ingleton are of Morganian age almost certainly representing both phillipsi and tenuis zones and possibly a part of the upper similis pulchra zone. Present knowledge of the successions in the North and Central Pennine Provinces is unsatisfactory for comparative purposes

and it is only in the South Pennine or Midland Province that a more perfectly known succession of Morganian strata is present.

It is at once evident that the Malvernian movements originally described from the Coalfields of Southern Britain, and which were doubtless responsible for widespread unconformities in the Midlands, were also effective in the Ingleton Coalfield. This does not imply that the movements were necessarily synchronous in both these regions for the lack of conclusive evidence from the Ingleton succession precludes such finality. Unconformity at or near the base of the Morganian has thus been recognized on both the North and southern borders of the Central Pennine Province. In the centre of this region i.e., Yorkshire and Lancashire, there is apparent conformity over most of the area. It therefore appears very probable that the Craven Fault belt, the scene of important uplifts during the Sudetic and Mid-Namurian movements, was again the scene of uplift for the Malvernian movements; as in the case of the Sudetic movements the centre of the Central Pennine basin was not affected to the same extent. It is unfortunate that no Morganian strata are preserved at Stainmore to continue the story northwards, but it may be noted that unconformities are developed on the margins of uplifted areas in West and East Cumberland, but not in the more central area of the Durham Coalfield.

(b) Details

The Phillipsii - Tenuis zones. The succession of Morganian strata at Ingleton comprises at least 1500 feet of beds lithologically and structurally divisible into two groups, whose interrelationship is unknown. Of these the lower group contains elements of the phillipsi zone fauna and flora near its base while the upper has elements of the tenuis zone fauna coming in near the middle. Lithologically the lower group is dominantly sandy shales and marls, while the

upper contains sandstones, breccias, shale-conglomerates and "Spirorbis" limestones. These two groups are thus, undoubtedly closely comparable with the Etruria Marls and Keele Groups of the Midlands respectively, both lithologically and palaeontologically. Available evidence suggests that the coarse sandstones and conglomeratic beds of the latter are less strongly developed in Lancashire.

V. Post-Morganian

Overlying Coal Measures at Ingleton are at least 360 feet of coarse breccias with subordinate sandy incursions. Lower Carboniferous and older rocks figure largely among the included fragments and from their similarity to the Permian Brockrams of the Vale of Eden they have always been regarded as Permian in age. Permo-Triassic sandstones occur faulted against low horizons in the Millstone Grit near Lancaster some 15 miles to the south west, and in Morecambe Bay and further south they overlie Millstone Grit unconformably. A small outlier of Permian sandstone occurs near Clitheroe. The Brockrams of the Vale of Eden occur in a marginal position north and east of the Lake District - Howgill Fells massif. Kendall (1924) suggested that the breccias at Ingleton were contemporaneous with those of the Vale of Eden and that, like the latter, they passed into sandstones away from the massif. Recently Versey (1952) has questioned Kendall's view on several grounds. Versey claims that the proportions of the constituent pebbles at Ingleton and in the Vale of Eden are different, more Upper Carboniferous and fewer Lower Palaeozoic fragments being present at Ingleton. Also the sand grains in the matrix of the breccias at Ingleton are said to be more angular than in the Vale of Eden. The present writer considers these claims to be invalid. A greater thickness of Upper Carboniferous rocks at Ingleton contributed to the breccias and considerable differences in proportion of constituents can be found in different parts of the Vale of Eden or at Ingleton. Greater angularity of grains merely suggests a shorter distance of travel. The tectonically disturbed breccias at Ingleton are unique in the Permian system in Britain but it must be remembered that it is not often that Permian beds are associated with faults such as the Craven Faults, and there

is little doubt that considerable movements took place along this line during Tertiary times. It has been shown above (Part I) that some of the folding and faulting of the Coal Measures took place before the breccias were deposited. The view put forward by Versey that the Ingleton breccias are possibly equivalent to the Enville Beds of the Midlands remains a possibility, but is considered unlikely by the writer.

VI. Red and Reddened Beds

The occurrence of red strata in both Coal Measures and Millstone Grit at both Ingleton and Stainmore has already been noted in Parts I and II, but some account of their distribution and origin seems necessary and is given below.

Red colouring in sedimentary rocks may be due to the conditions of original deposition or to secondary alteration. In either case the colour is probably largely due to the presence of ferric rather than ferrous oxide. Most of the Red Measures of the Ingleton Coalfield owe their colour to the conditions at the time of deposition or immediately afterwards. As was pointed out in Part I plant remains and occasional non-marine lamellibranchs are present in these beds, which also exhibit a cyclic character essentially similar to the underlying Grey Measures. The sediments themselves were undoubtedly laid down in water and the red colouration does not provide the evidence of arid or desert climates in the present case. The essential difference between conditions of deposition of grey and red Measures is that during the latter sedimentation frequently overtook subsidence and that minor uplifts took place - as forerunners of the Hercynian movements. The result of this was that during Grey Measure times newly deposited sediments were permanently below the water table while the Red Measures were not, and oxidation of the iron content could and did take place. The change in conditions from Grey to Red was not sudden, as the Lower Red Measures with their alternating grey and red beds show. The higher in the succession the more prominent does the red colour become. In the Lower Red Measures the coarser beds usually show the greater degree of colour, and it is suggested that the fall in water-table and the consequent onset of oxidizing conditions was limited in duration and that only the coarser and more porous beds

were affected in the time available. The least oxidized beds usually occur close to the position in the cycles at which coal would have occurred in Grey Measures and it is suggested that vegetable debris did accumulate above the rootlet-beds present but that it was oxidized in preference to the iron in the overlying shales.

Secondary reddening of sediments can take several forms. In the Ingleton and Stainmore Coalfields gritstone beds of Namurian and Ammanian age are sometimes bright red although adjacent shales show little or no trace of red colour. While this may in part be due to localized and temporary falls in the water-table, it has been suggested that subsequent to the deposition of these beds after folding and erosion the water-table fell to a great depth and oxidation took place through several hundred feet of coarser-grained beds. This may have happened in pre-Morganian times at Ingleton or during Permo-Triassic times at Ingleton and Stainmore. An alternative explanation is that iron-rich ground-waters may have circulated through these beds and deposited their iron as coatings on each grain. The Permo-Triassic rocks have been suggested as the source for this iron, but as many of these were derived from Carboniferous rocks the ultimate source remains something of an enigma.

Secondary reddening also occurs as enrichments in joints as nodules frequently in the Red Measures and quite commonly in the Grey Measures. Segregation and deposition of iron oxides by slowly moving ground-waters in joints causes no difficulties, but red or purple nodules in grey shales are a problem. These nodules commonly contain plant or animal remains, e.g. Leck Beck Mussel Band. In the primarily Red Measures these are usually the cause of a reduction in the ferric iron content, for example the grey-green shales at the position of the coal in the Red Measure cycle, and the green reduction spots of the red shales of the Upper Red

Measures. The iron rich nodules are thus somewhat anomalous. The presence of carbonaceous plant remains in some is evidence that penecontemporaneous oxidation did not take place, and the fact that they are solids and not impressions is evidence that the formation of the nodules was not long after deposition. It is suggested that sulphur liberated by the vegetation during decay may combine with iron in surrounding shales to form pyrites which in turn are oxidized and more pyrites formed. Oxidation in this case may take place during seasonal falls of water-table. Without such falls the pyritous nodules common at some other horizons would be formed.

Summarizing, it may be said that the colour of the Red Measures is largely primary and is due to a gradual change of conditions of sedimentation prior to the Hercynian uplift. The localized red colour in lower beds is partly due to enrichments by percolating ground-waters or deep oxidation during Permo-Triassic times, and partly to temporary and local fluctuation in the height of the water-table. Local oxidation of Ammanian and probably also Namurian may also have occurred at Ingleton prior to the deposition of the unconformable cover of primarily red Morganian strata.

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Key to Plates 1 & 2 Non-marine lamellibranchs from the Ingleton And Stainmore Coalfields.

1. Carbonicola cf. lenicurvata Trueman, R.Greta near Burton

2. C. aff. lenicurvata Trueman, R.Greta near Burton-in-Lonsdale

3. C. cf. protea Wright (?) Locality as above.

4. C. Aff. lenicurvata Trueman " " "

5. C. fallax Wright, mouth of Clifford Gill, Burton-in-Lonsdale

6. C. aff. fallax Wright, " " " "

7. C. aff. fallax Wright, elongate variant, " "

8. C. aff. fallax Wright, elongate Anthraconaioid variant "

9. Anthraconaia cf. lenisulcata Trueman " "

10. Carbonicola pseudorobusta Trueman, Aspland Beck, Ingleton

11. C. aff. crista-galli Wright " " "

12. C. aff. communis Davies & Trueman " " "

13. C. cf. acuta (J.Sowerby) Roof of Four Feet Coal, Ingleton Coll.

14. C. aff. rhomboidalis Hind, dwarf variant, " "

15. C. cf. obtusa Hind, " " "

16. C. cf. subconstricta (J.Sowerby) " "

17. cf. Anthracosphaerium boltoni (wright) " "

18. Carbonicola aff. rhomboidalis Hind " "

19. C. cf. rhomboidalis Hind " "

20. Anthracosia aff. caledonica Trueman & Weir, Leck Beck

21. A. cf. phrygiana (Wright) Leck Beck, near Ingleton

22. Anthraconaia cf. curtata (Brown) (?), Leck Beck.

23. Anthracosia cf. caledonica Trueman & Weir, Leck Beck.

24. A. ovum Trueman and Weir, Leck Beck

25.& 26. Anthraconauta phillipsi (Williamson), below Viaduct, Ingleton

27,& 28. A. cf. tenuis (Davies& Trueman), below Viaduct, Ingleton

29. Carbonicola aff. os-lancis Wright, Argill Beck, Stainmore. (elongate variant):

30. C. aff. os-lancis Wright, Argill Beck, Stainmore.

31. C. aff. antiqua (Brown), " " "

32. C. cf. rhomboidalis Hind (?) dwarf variant, "

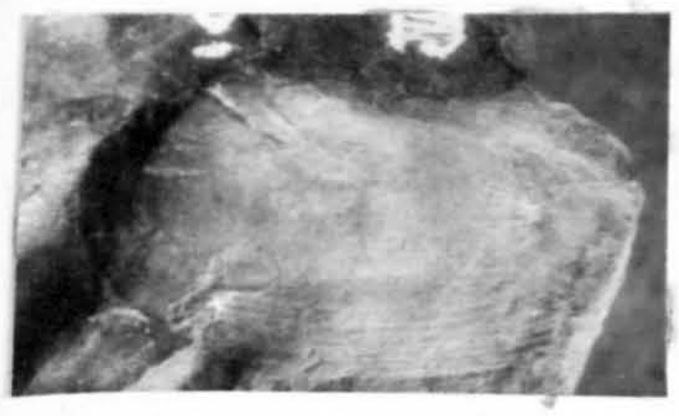
33. cf. Anthracosphaerium boltoni (Wright) "

34. cf. A. boltoni (Wright), Argill Beck, Stainmore

35. Anthraconaia cf. williamsoni (Brown), Argill Beck, Stainmore.

36. Anthraconaia cf. curtata (Brown), Argill Beck, Stainmore.

NON-MARINE LAMELLIBRANCHS FROM THE INGLETON COALFIELD



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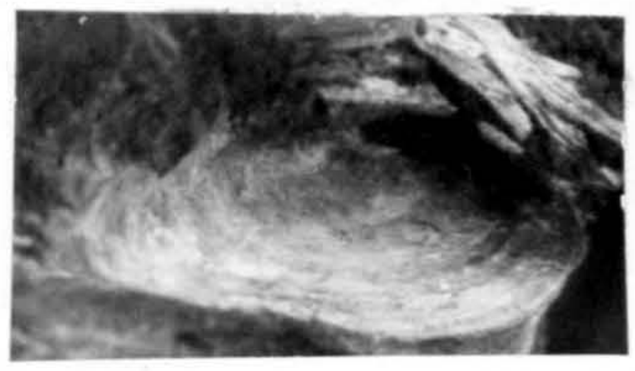

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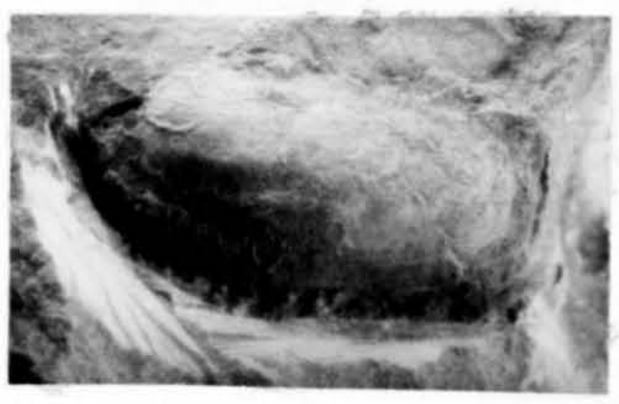

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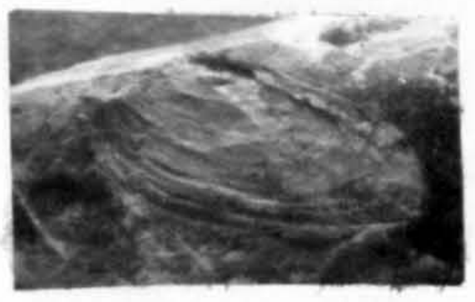

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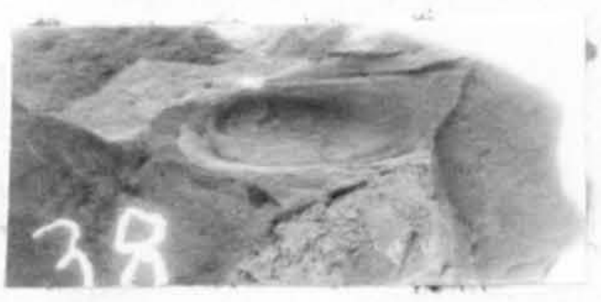

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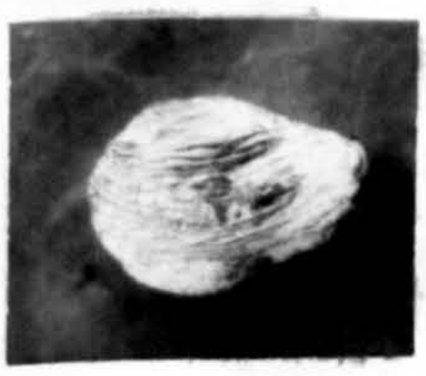

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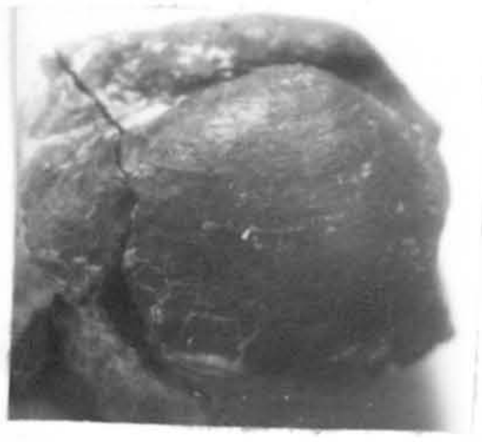
NON-MARINE LAMELLIBRANCHS FROM THE INGLETON COALFIELD



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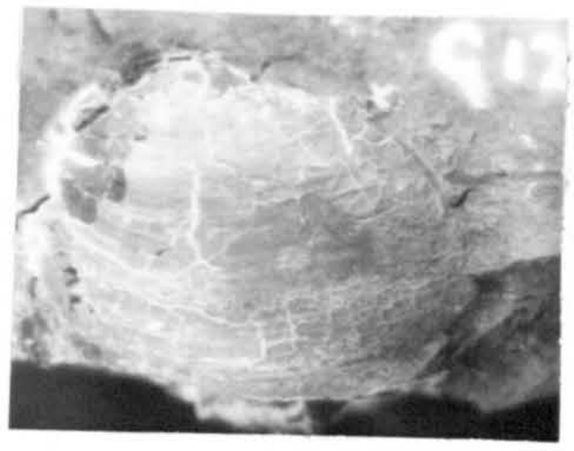

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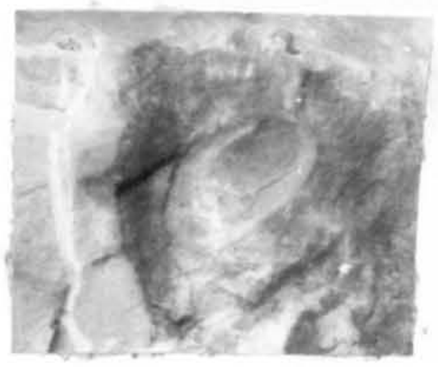

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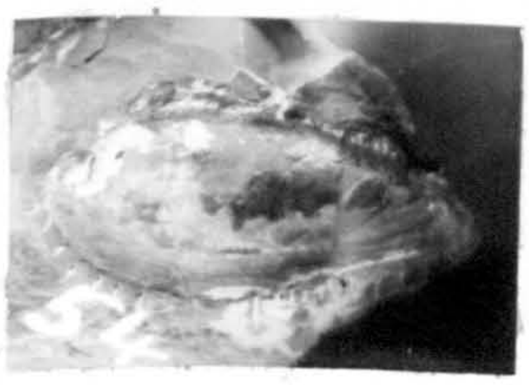
NON-MARINE LAMELLIBRANCHS FROM THE STAINMORE COALFIELD



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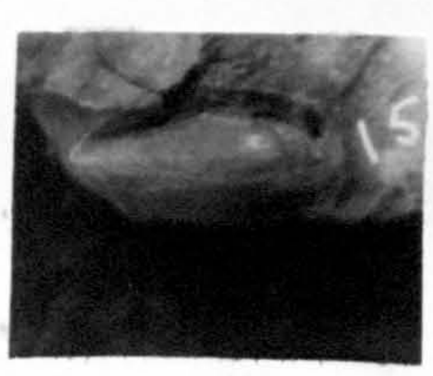

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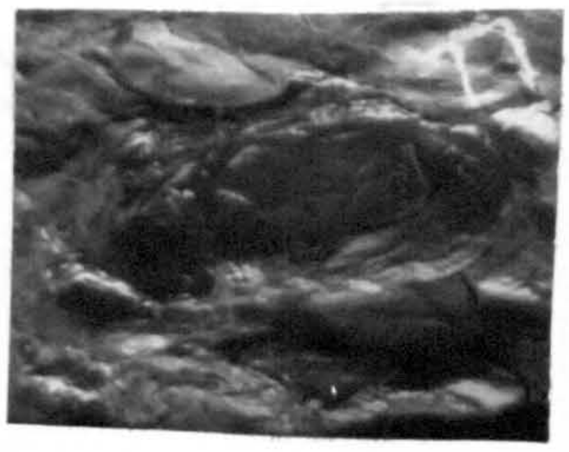

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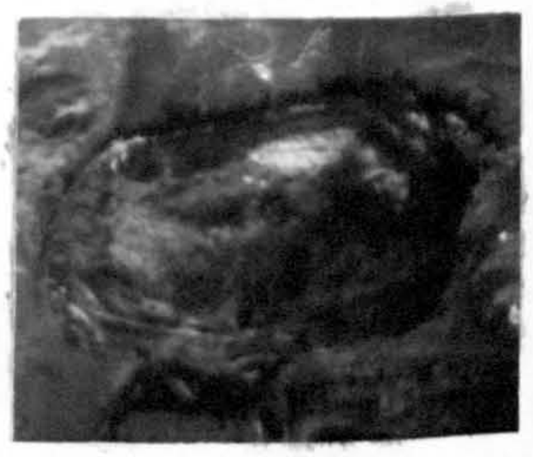


36.

1. Outcrop of Clintsfield Coals, Ganisters, and Grit, River Wenning, near Wennington.

2. Pyrites nodules in the Rough Rock, River Greta, near Burton-in-Lonsdale.

3. Fossil tree-stump above the Six Feet Coal, Stephens Wood, River Greta.

4. River Greta at Greta Bank, seen from Bleaberry Hill.

5. Large ironstones below Crow Coal Shales, near Parkfoot, River Greta.

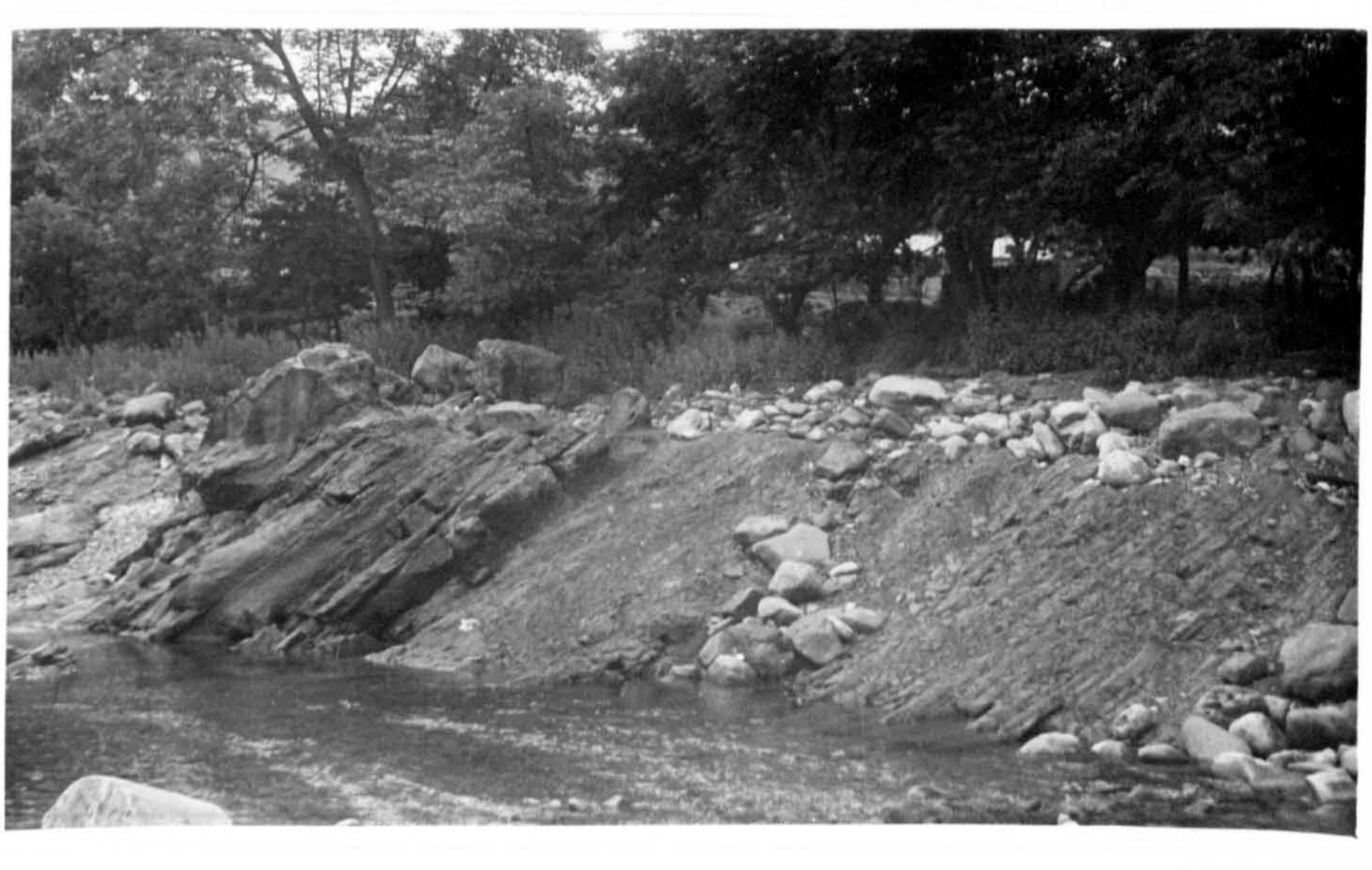
6. Parkfoot Beds, opposite the mouth of Aspland Beck, River Greta, Parkfoot.

7. Basal Red Measure sandstones in the River Greta near Parkfoot.

8. Basal Red Measure sandstones in the River Greta north of Bleaberry Hill.

Conglomerate bands at the base of the Red Measures River Greta near Parkfoot.

10. Contorted red and grey shales under drift, Lower Red Measures, River Greta.



11. Red sandstones and shales of the Upper Red Measures, River Greta, Ingleton.

12. Breccias and sandstones of the Upper Red Measures, River Greta, Ingleton.

13. Permian Breccias in Ireby Beck, Masongill, near Ingleton.

14. Basal Coal Measure Grits in Argill Beck, Stainmore.

15. Pock-marked surface of basal Coal Measure sandstone in Argill Beck, Stainmore.