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THE GEOLOGY

of the

COUNTRY BETWEEN MASHAM AND GREAT WHERNSIDE

by

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

VOLUME II

A Thesis presented for the degree of Doctor of Philosophy

in Durham University (Durham Division)

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CHAPTER 13

THE COLSTERDALE MARINE SERIES

In 1890, Dakyns made reference to the 'Tesselated Limestone'. This is now called the Colsterdale Limestone, following Bisat (1914), who named the shales with limestone above the Red Scar Grit the Colsterdale Marine Band. Because of their thickness the term 'Band' is hardly appropriate, and the beds are here referred to as the Colsterdale Marine Series.

The first mention of this horizon was by Phillips (1836 pp. 209-212) who recorded five marine fossils from Colsterdale on the authority of Danby. Dakyns (1891) mentioned the occurrence of the Tesselated Limestone resting on, or near the top of, the Red Scar Grit. Bisat (1914) recorded numerous exposures of the Colsterdale Marine Band from Colsterdale and Upper Nidderdale, and southwards down the borders of Nidderdale and Wharfedale. Bisat said "The fossiliferous group thickens to the N.E. in Colsterdale mainly owing to grit bands coming in". This statement is in a sense correct; the Colsterdale Marine Series does in fact thicken to the N.E., but the incoming of a fossiliferous phase in the Red Scar Grit gives an additional thickness of marine strata which are not here referred to the Colsterdale Marine Series as explained in Chapter 12. Thus the thickness of 80' allotted to the Colsterdale Marine Series of Colsterdale includes about 34' of beds here referred to as the Colsterdale Marine Series and over 40' of beds now referred to the Red Scar Grit.

Tonks (1925) recorded a section from "Intake Barn Beck

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1550 yd. N.W. of Scar House". Though this beck is not named on the map, Tonks appears to refer to Tops Gill (056776). Here he recorded the Colsterdale Limestone as resting on the Red Scar Grit. This is demonstrably not the case in Tops Gill, and indeed in Stand Syke, 670 yds. N.N.W. of this point, the limestone is seen to be at least 7' above the Red Scar Grit. Tonks followed Dakyns in saying that the Colsterdale Limestone becomes encrinital on Braithwaite Moor. This misinterpretation appears to be based upon the incoming of a fossiliferous phase in the Upper Red Scar Grit of Braithwaite Moor. Exactly how this horizon was confused with the Colsterdale Limestone, a horizon appreciably higher in the succession, is a matter for conjecture. In the record of the Geological Association meeting in Upper Nidderdale, Hudson (1938) gives a fauna from the exposure in Tops Gill, which was visited by the party.

Stratigraphy

Within the limits of the area the Colsterdale Marine Series are defined as fossiliferous shales with a blue limestone 1' thick carrying <u>Cravenoceratoides nitidus</u> (Phillips), which overlie the Red Scar Grit and underlie the unfossiliferous Nar Hill Beds. The thickness varies from at least 34' to 12'6" and this variation is apparently due almost solely to a thickening of the beds below the Colsterdale Limestone in the N.E. part of the area. In the south of the ground these beds are abnormally thin (under 5') and are also little developed in Backstean Gill south of the present ground (Bisat,1914).

Lithologically the series may be divided up into four

subgroups which are here detailed in ascending sequence:

(i) Dark grey or purplish shales with chalybite nodules carrying a nuculid-gastropod fauna in both shale and nodules. These beds occur only in Colsterdale and under the moors to the north of this dale; they vary from nothing to over 26' in thickness. This development is entirely absent in the S. of the present ground and in the areas further south.

(ii) Grey-black, compact, brittle shales with a fauna of smooth goniatites (Anthracoceras paucilobum and Dimorphoceras sp.), species of Posidonia and Posidoniella and orthocone nautiloids. The thickness varies from 3' to 9', with its minimum in the south of the ground.

(iii) Blue calcite mudstone (the Colsterdale Limestone) with a little angular quartz sand, weathering to a gingerbready rottenstone and about 1' thick. The rotten, weathered material yields a prolific fauna, the predominant form being Cravenoceratoides nitidus (Phillips) together with Anthracoceras paucilobum and Dimorphoceras sp., species of Posidonia and Posidoniella, orthocone nautiloids and fish remains. The goniatite fauna and the nautiloids are preserved in bas-relief.

(iv) Dark grey shales with smooth goniatites and pelecypods, chiefly Posidonia and Posidoniella, and similar in lithology and fauna to the shales which underlie the Colsterdale Limestone. The thickness of these shales varies from 3' to 12'6". The thinnest development of beds below the Colsterdale Limestone is in the south of the area where they are often about 3' thick. These beds are also very thin in Backstean Gill, 3 miles south of the present area (Bisat, 1914), but appear to thicken again

further south to a probable 7' in Cockhill Adit (Dunham and Stubblefield, 1945) and to about 21' at Simonseat (Hudson, 1939).

The Colsterdale Marine Series is not exposed very frequently in sections and for miles of outcrop its presence may not be indicated. On Great and Little Whernside a slight feature with a spring line on the impervious Colsterdale shales aids mapping of this division. The measured sections are stream sections and landslip scars which provide the bulk of useful records in this series.

Details

The several exposures are described in some detail in the following pages to bring out the considerable faunal and lithological variation which occurs in this group of beds.

North and east sides of upper Nidderdale. The exposures are detailed from west to east.

In Stand Syke (051779) the following section is visible (see also Plate 28):

-	Nar Hill Beds
3'6"	chips of dark, soapy shale
1'	Colsterdale Limestone, weathered to a yellow, fossiliferous rottenstone, parting readily and yielding a prolific fauna of goniatites and pelecypods preserved in bas-relief
7'	scree in dark, soapy shale
6'	unexposed, probably Upper Red Scar Grit
-	Upper Red Scar Grit.

The section in Tops Gill (056776) shows the following section:

4'	black soapy shale (top not seen)
3'	unexposed
1'	soapy shale
-	Upper Red Scar Grit.

The Colsterdale Limestone probably occurs above the observed beds, but may possibly be in the unexposed 3'.

Soapy shale chips are picked up at several points on the N. side of Nidderdale between Tops Gill and Thrope Edge, indicating the continuity of this marine horizon.

Thrope Edge landslip scar shows an excellent section through the complete Colsterdale Marine Series and is the only full section of these beds in the present area. The two sections in the landslip scar (106759) are figured in Plate 29. It will be seen that the southerly section shows two limestones, the upper one only being represented by a nodule. It is interesting to note that in the northerly section, 50 yards away, there is only one limestone and this is at the same height above the top of the Red Scar Grit as the nodule in the southerly section. It is thus probable that limestones can be locally developed at either, or both of these levels. Unfortunately none of the limestone was sufficiently weathered to yield a fauna. The shales above and below the lower limestone yield smooth goniatites and pelecypods with one specimen of Eumorphoceras bisulcatum, but the bulk of the shales are poor in fossils. The upper beds of the section vary appreciably in thickness between the two exposures and this may be due to erosion prior to the deposition of the Nar Hill Beds.

At three points S. of Thrope Edge, small exposures occur along a spring line on the Colsterdale Marine Series, whilst chips of shale from the marine band occur in the tip of a coal shaft at 106750.

Backstone Gill, near Lofthouse (110740) (Plate 29), gives a clear section of the lower part of the Colsterdale Marine Series. A 6" rotten bed of calcareous shale 1'6" above the base of the series may be a degenerate representative of the Colsterdale Limestone. The sequence consists of soapy, dark shales with Posidonia, Posidoniella and a few smooth goniatites, which are never very abundant, but are most prolific at a horizon 6' above the supposed Colsterdale Limestone.

South side of Nidderdale - The exposures are detailed from east to west.

Woodale Scar (Plate 29) shows three incomplete sections in which the Colsterdale Limestone overlies 6' of shale. The beds above the limestone are appreciably thinner than in the Thrope Edge landslip scar, and consist of soapy shales with a sparse fauna. At the west end of the scar the Colsterdale Marine Series appears to have been cut down to 1' of grey, soapy shale, by a transgression of the sandstones of the Nar Hill Beds.

At Foggyshaw Gill (090762) the basal shales of the Colsterdale Marine Series are seen but here they are soapy shales without a fauna. An old trial for coal at 080754) shows soapy shale chips, indicating the presence of the marine series on the south side of Rainstang. A moor top exposure in a channel on Scar House Moss (061757) shows about 2' of soapy, rotten shale which has yielded an indeterminate pelecypod.

East Gill Dike (037743) shows the lower part of the marine series with the limestone (see also Plate 29) here only 3'

above the base. The shales immediately above the limestone have yielded Eumorphoceras bisulcatum.

Stone Beck (012741)(Plate 28) shows only 4' of beds above the base of the series, between the Red Scar Grit and the Colsterdale Limestone. This compares well with similar, low thicknesses in the south of the present area. The beds above the limestone are black, compact shales with a sparse fauna of smooth goniatites and posidoniellids, except for the lowest 1' which is soft and black, and contains Eumorphoceras bisulcatum, immediately above the Colsterdale Limestone.

The section in Blackfell Scar (012748) shows:

3'	soapy shale chips (top of these beds not seen)
1'	rotten limestone (Colsterdale Limestone)
3'	soapy shale chips resting on Red Scar Grit

A scar on the N.W. face of Great Whernside overlooking Hem Gill Shaw (002760) shows chips of soapy shale above and below the limestone, here an orange rottenstone with a prolific goniatite-pelecypod fauna. The data from this section are given on Plate 28. Traces of the Colsterdale Marine Series are seen at intervals on the west flank of Great Whernside along the outcrops facing out onto Whernside Pasture.

Little Whernside (021774) shows a partial section in 10' of soapy shales below the Colsterdale Limestone. The limestone is here in a rotten condition and is overlain by soapy shale chips.

On the east side of Coverdale, further down the valley, outcrops are absent for a long distance at this horizon, though

these marine beds appear to be about 20' thick in Lead Up Gill, as estimated from outcrops in the beds above and below them. At Greystone Gill (076818) a gap of approximately 20' again occurs at this horizon, with some chips of soapy shale.

Along the line of an old portage track near Roova Pot Hole (078820) the Colsterdale Marine Series appear to be nearly 35' thick, but unfortunately the lowest 20' of beds are unexposed and the limestone was not located. It is possible that this apparent extra thickness is here due to thickening of the beds below the Colsterdale Limestone as in Colsterdale, but this cannot be established with any certainty.

Ulfers Gill (093827) shows the most northerly section in the Colsterdale Marine Series of the area, this excepting the records from coal pits on Braithwaite Moor which unfortunately lack detail. The section seen in Ulfers Gill is (see also Plate 28):

4'	flaggy sandstone of the Nar Hill Beds
6'	unexposed, but are probably fossiliferous shales
2'	black, fossiliferous shale
1'	Colsterdale Limestone, weathering to an orange mud, surrounding cores of blue calcite mudstone with scattered detrital silt grains and crushed goniatites preserved in calcite. Streaks of organic carbon occur parallel to the perceptible bedding of the limestone, along which it tends to split roughly. Goniatites are preserved in bas relief in calcite (specimens of Ct. nitidus are seen in the fresh rock; this being the only locality where fresh material yielded a good fauna) whilst a rhizodont scale was preserved in pyrite
3'	blue shale with posidonids and smooth goniatites
5'	green, soapy unevenly splitting shale with rare fossils
-	Upper Red Scar Grit.

Unfortunately the slopes overlooking the River Ure east of Flamstone Pin do not provide evidence of the Colsterdale Marine

PLATE 27 A

The E. side of Coverdale, looking N.N.E. from Great Bank (076818) along the slopes of Scrafton Moor. The line of tips (centre and in diagonal line, bottom left) is in the Woogill Coal above which is the thin, resistant Upper Red Scar Grit forming a scar (centre). The Colsterdale Marine Series are partially exposed in the sides of the lower part of the pony track, centre right. The lower Follifoot Grit forms Roova Crag (sky-line). The break in slope at the base of the Grassington Grits and Shales at the foot of the hill is well seen.

PLATE 27 B

Dip slopes at the head of Colsterdale, viewed from the head of Beldin Gill, looking S.E. to South Haw across Steel House Moor. The bulk of the peat covered plateau is in Ganister Beds. South Haw is a large outlier capped by Libishaw Sandstone with steep bounding features on Libishaw Shale. In the distance is the Main outcrop of the Libishaw Sandstone in Brown Ridge whose terminal feature is seen on the sub-sky-line ,left. The conical hill just visible, centre left is Throstle Hill, an outlier on the Capelshaw Shales.

Series, except from the information provided by shafts, which is considered at the end of this section.

Colsterdale - All exposures of the Colsterdale Marine Series thus far described, with the exception of that near Roova Pot Hole, show an overall thickness of approximately 15', with a persistent limestone never more than 10' above the base of the series. This tends to approach nearer to the top of the Red Scar Grit as the series isttraced south in the direction of Meugher (044704). The exposures seen in Colsterdale and the mine records from the moors north of Colsterdale all point to an overall increase of thickness of the Colsterdale Marine Series to the north east which is due to thickening of the beds below the Colsterdale Limestone, accompanied by a local, distinct lithofacies and biofacies development in these lowest beds, namely that of shales with chalybite nodules carrying a nuculid-gastropod fauna at restricted horizons.

The section in Long Gill (100799) shows these relations best (Plate 28).

-	Nar Hill Beds
2'	shale with sparse posidonids
3'6"	black shale, tending towards a rotten limestone in its lower part
8"	Colsterdale Limestone - a compact, blue calcite mudstone weathering to a rottenstone
8'6"	black, brittle, compact shale with posidonids and smooth goniatites
6'6"	unfossiliferous, brittle blue shales with chalybite nodules
5'6"	gap to top of Upper Red Scar Grit (presumed to be shales with chalybite nodules)

The thickness of beds above the limestone is comparable with that seen elsewhere, but that of those below the limestone is about 20'6" and therefore over double that commonly seen in ground

to the south of Colsterdale.

The section in Thorny Grane Gill (112796) is similar (see also Plate 28):

-	Nar Hill Beds
1'3"	soapy shales without fossils
2'6"	black, compact, finely micaceous shales with posidonids and smooth goniatites
9"	compact, blocky blue calcite mudstone with goniatites and weathering to a rotten orange crust
6"	silty, olive shale
2'6"	unexposed; probably fossiliferous shales
3'	compact, black finely micaceous shale with posidonids and smooth goniatites
6"	compact finely micaceous, grey shale, splitting with difficulty the fauna includes nuculids
6'	dark grey apparently unfossiliferous shales
2'6"	shale with scattered chalybite nodules
6'	approx gap to Upper Red Scar Grit

In Spruce Gill a section occurs with the lowest beds unfortunately obscured (135803) (see also Plate 28):

-	Nar Hill Beds
1'	brittle dark grey shale with fossiliferous traces
2'6"	dark grey, slightly rotten shale with smooth goniatites and posidonids
9"	blocky limestone, weathering to an orange coloured rottenstone and carrying a prolific fauna of goniatites and pelecypods on the bedding planes, along which it splits readily
6'6"	dark, slightly platy carbonaceous shale with posidonids and smooth goniatites
2'4"	bluish grey, finely micaceous shale with irregular fracture
2'	blue, slightly soapy shale
8'	approx. estimate gap to Upper Red Scar Grit (these beds may include shales with chalybite nodules)

The lowest beds of the Colsterdale Marine Series are seen at Gollinglith Foot (153809) (Plate 28). The outcrop shows over 20' of beds, identical with similar ones underlying the Colsterdale Limestone elsewhere in Colsterdale. The upper part of the section shows 16'6" of grey-blue moderately soapy shales without fossils and with chalybite nodules which

are usually scattered, but also occur in numbers along one 3" zone. Fossils occur in the beds which underlie these shales; these consist of 3' grey finely micaceous shale which carries a nuculid-gastropod fauna preserved in relief. In the middle of these shales a horizon occurs with nodules of pale grey, banded chalybite carrying a nuculid-gastropod fauna preserved in relief in calcite, which is only obtainable when the rock is somewhat weathered.

A partial section of the Colsterdale Marine Series occurs in Barnley Beck (105822) (Plate 28) where beds a few feet above the base of the series are exposed. They are ash grey rather blocky shales with fine mica plates and with heavy limonite staining, with casts of nuculids and gastropods in a similar preservation to that seen in the shales at Gollinglith Foot. These shales carry three bands of compact, black chalybitic shale with numerous small nodules, under 1 cm. in size, which are possibly coprolites. These bands carry small Nuculopsis gibbosa and gastropods preserved as casts, in a preservation similar to that seen at Gollinglith Foot. Some 3' of black, soapy shale chips which yielded a fragment of a posidonid pelecypod overlie the shales with the nuculid-gastropod fauna, but the Colsterdale Limestone is not exposed; probably it occurs just above the beds described above.

The dump from a shaft sunk to the level of the Woogill Coal on Braithwaite Moor (115847), has yielded debris which is of considerable interest; this includes fragments of soapy, dark shale and a chalybite nodule. The nodule in thin section

consists of microgranular chalybite of grain size about 12 microns, containing some angular detrital quartz of 50 microns diameter. The fossils in the nodule, which are preserved in calcite, are nuculids, probably referable to Nuculopsis gibbosa (Fleming), embedded in a dark grey matrix of chalybite which has weathered to a russet crust of limonite on the surface of the rock. The occurrence of nuculids in clay ironstone at this point extends the limits of the probable area with a nuculid fauna in the Colsterdale Marine Series some distance to the north of the known outcrops in Coverdale. The record of 48' of shale overlying the Red Scar Grit in West Pit on Braithwaite Moor is interesting as it may indicate that the Colsterdale Marine Series is abnormally thick here owing to a thick development of shales with chalybite nodules, in the lower part of the marine series under Braithwaite Moor. However, in the absence of fossil records from this pit section it is not possible to prove that all these shales above the Red Scar Grit are of fossiliferous facies and therefore part of the Colsterdale Marine Series.

The record of 34½ of shales above the Red Scar Grit from Brown Beck Pit (133827) is probably a measure of the thickness of the Colsterdale Marine Series, since the shales below the limestone at Gollinglith Foot are apparently at least 26' thick giving a probable total thickness at this last locality of about 34'.

Two other records are of interest from debris of shafts sunk to the Woogill Coal in the vicinity of Gollinglith Foot.

A tip below Agra Crags (157811) yielded Colsterdale Limestone, containing fossil wood, palaeoniscid scales and obscure goniatites, indicating that the Colsterdale Limestone still persists here. This is useful evidence since the Colsterdale Limestone was not seen in the exposure in the bank of the River Burn at Gollinglith Foot. A tip of a shaft at Healey Pasture (157809) yielded clay ironstone nodules in the lower part of the Colsterdale Marine Series.

Palaeontology

The chief fossil of zonal importance in the Colsterdale Marine Series is Cravenoceratoides nitidus (Phillips) which is restricted to the Colsterdale Limestone in the present area. This species is widely known from the middle of the Arnsbergian (E_2) beds and was first recorded from the present area by Tonks (1925) from the Colsterdale Limestone. Hudson (1944) summarised the knowledge relating to the E_2b beds which had been previously designated the Cravenoceratoides nitidus subzone by Hudson and Cotton (1943). A limestone with Ct. nitidus has been recorded from Greenhow (Dunham and Stubblefield, 1945), Simonseat (Hudson, 1939) and the Lancaster Fells (Moseley, 1954) and this fossil was also found in the Alport borehole (Hudson and Cotton, 1943). Ct. nitidus was not found in the Harrogate, Beamsley or the Bradford and Skipton districts by the several workers on these areas, though faunas known to overlie and underlie Ct. nitidus were found in a series of marine shales, part of which are broadly correlated with the Colsterdale Marine Series on this account.

In the records from Greenhow, Simonseat and the Lancaster

Fells there are in common with the present area shales with a fauna of Anthracoceras and Dimorphoceras, which are larger, more laterally compressed and less strongly ornamented goniatites than Cravenoceratoides. These forms are found both above and below the limestone with Ct. nitidus, in dark shales with an accompanying fauna of posidonids and rare orthocone nautiloids.

The nuculid-gastropod beds - the fauna of this phase of the Colsterdale Marine Series was first recorded by Bisat (1914) from the spoil of trial in 1904. Though no mention is made of the exact stratigraphical position of this fauna, which is not typical of the Colsterdale Marine Series as a whole, a large list of fossils is given, including some which may come from the Colsterdale Limestone and associated shales. Hudson (1939), in putting forward the correlation of the Shunner Fell Marine Beds and the Colsterdale Marine Series, maintained that the fauna recorded from Gollinglith Foot is intermediate in character between the Shunner Fell Limestone and the typical Colsterdale development. The lists given by Chubb and Hudson (1925) for Shunner Fell and by Bisat (1914) for Gollinglith Foot show that Schizophoria resupinata, Lingula sp. orthotetids and species of Productus are records held in common. Collection during the present work took place in situ at a locality near the Gollinglith Foot trial holes and yielded a fauna which excluded all the forms above, excepting Lingula. The forms which were found to be most abundant were the nuculids and the gastropods, neither of which figure in the lists from Shunner Fell. It follows that the present in situ

collecting does not confirm any faunal parallel and the one quoted above is not very marked either. Records from the equivalents of the Colsterdale Marine Series described from the areas to the south of the Rigid Block and from Greenhow fail to show a faunal assemblage similar to the nuculid-gastropod phase developed in Colsterdale. Actually this fauna most closely resembles that of the Mirk Fell Ironstones which are however certainly at a lower stratigraphic level.

The fauna here recorded from the nuculid-gastropod bed is derived from both chalybite nodules and shale. The best preserved specimens were found in chalybite nodules at Gollinglith Foot where they yield a profusion of internal casts of nuculids and Glabrocingulum. A minority of specimens show external markings. Nautiloids occur in unusual abundance and include several specimens of Liroceras and orthocone nautiloids preserved in full relief. The records include rare fossils of Yoredale aspect, Crurithyris, Dielasma and Hyalostelia. Goniatites are very rare and all are fragmentary and therefore doubtful determinations. The best preserved form is an internal cast of a juvenile form with a suture resembling that of Homoceras more closely than that of Cravenoceras.

Above the nuculid-gastropod beds the fauna has been collected from three different levels, the Colsterdale limestone and the shales above and below this horizon.

The goniatite fauna of the shales consists entirely of smooth forms which are in some bands fairly abundant, but do not appear ever to crowd the bedding planes as in the cases

described by Moseley (1954). The dominant species is Anthracoceras paucilobum with rarer Dimorphoceras and occasional orthocone nautiloids, together with a moderate profusion of posidonids, which are the most abundant fossils. Posidonia cf. corrugata and forms similar to it, referred to P. sulcata and P. trapezoedra, dominate over the smaller Posidoniella which is however occasionally abundant. Specimens referred to these former species cover a large number of variants in which the chief variable factors are the intensity of the concentric ornament, the presence in some instances of radial ornament and variation in relative dimensions. Posidonia aff. membranacea is a rare record in contrast with the relative abundance of this form in the shales of the Cockhill Marine Band. The Colsterdale limestone is characterised by a profusion of Ct. nitidus preserved in bas-relief with numerous specimens of Anthracoceras paucilobum and Dimorphoceras which together are about half as abundant as Cravenoceratoides. Rare orthocone nautiloids are also recorded together with fish remains which, though rare, show considerable variety and appear to be entirely absent from the shales with smooth goniatites above and below the Colsterdale Limestone. Posidonids are comparatively rare and are not numerically dominant as in the shales above and below the limestone: they are chiefly Posidoniella rather than Posidonia which is the most abundant form in the shales. Eumorphoceras bisulcatum Girty has been recorded from immediately above the Colsterdale Limestone during the present work (this form has been previously recorded by Hudson et al. (1938) from Tops Gill in the

present area, from the Colsterdale Limestone of Greenhow, by Dunham and Stubblefield (1945) and from the Colsterdale Limestone of Simonseat, by Hudson (1939), but appears to be restricted to the south of the present area and has never been found in Colsterdale).

The frequency with which drifted plants are recorded throughout the Colsterdale Marine Series is noteworthy; they occur commonly at all horizons and are recorded from about half the localities. In one instance several individuals of Spirorbis occur attached to a piece of drift wood and it is thus inferred that the Colsterdale Marine Series was laid down close to a landmass, though the goniatites and pelecypods point to a marine environment of deposition.

The absence of Cravenoceratoides from the Series as a whole apart from the limestone is noteworthy. Hudson (1943) considered that the smooth goniatites, Anthracoceras and Dimorphoceras, and the lirate cravenoceratids preferred differing salinity conditions and since the latter forms occur chiefly in limestones, it was assumed that they were the more marine ones. The present records indicate that the smooth forms must have been tolerant of a wider range of conditions than the lirate forms since they are also common in the Colsterdale Limestone whilst the reverse does not apply i.e. the lirate forms are not abundant in the shales; in fact they are entirely absent.

Moseley (1954) gives the following percentages of forms in the limestone with Cravenoceratoides nitidus: Cravenoceratoides, 86 Anthracoceras, 3 Posidonia, 4. Records from the Colsterdale Limestone in the present ground gave the following

corresponding percentages: 45, 33 (with Dimorphoceras), 21 (with Posidoniella), plus 1% orthocone nautiloids. It is possible that these figures indicate less marine conditions on the Rigid Block at the time of the formation of the Colsterdale Limestone, since there is a greater proportion of smooth goniatites.

The posidonids appear to have exerted some preference for the shale environment since they are not abundant in the Colsterdale Limestone. In addition P. corrugata appears to be more common in the shales than the limestone where Posidoniella is a more common record. It follows from this that the more coarsely ornamented forms appear to have been more abundant in the shale environment. It is therefore possible that individual with a coarse ornament were best adapted to the least marine conditions.

Comparisons with the faunas from equivalent horizons - Lengthy faunal lists are now available from the Shunner Fell Marine Beds (Scanlon, 1955, King, 1914, Chubb and Hudson, 1925) which are regarded as the approximate equivalent of the Colsterdale Marine Series by Scanlon, following his discovery of Tylonautilus nodiferus Armstrong at this level, confirming the earlier correlation put forward by Hudson (1939) which was based on the discovery of Anthracoceras glabrum by King (1914) which is now re-named A. paucilobum (Phillips)(G.S.M. No. 37664-665) by Bisat. Both the above mentioned forms are restricted to the E. zone and T. nodiferus has been previously recorded from the shales above the limestone

with Ct. nitidus in the Lancaster Fells by Moseley (1954) whilst A. paucilobum is known from the Colsterdale Marine Series of the present area, Greenhow and Simonseat. The record of Posidonia membranacea from the Shunner Fell Beds is also held in common with the Colsterdale Marine Series. Certain forms are also recorded in common in the Shunner Fell Marine Beds and the nuculid-gastropod beds; these are Fenestella sp., Euphemites sp. and Glabrocingulum. The remaining fauna has some parallels in the Upper Red Scar Grit of the present area and in the several R_1 shell beds, since it includes several forms commonly found in the Yoredale facies of sedimentation, most of which are animals with long ranges such as Spirifer, Chonetes and productids.

Comparison with the fauna of the High Seat Marine Beds (Rowell, 1953), which is correlated with the Shunner Fell Marine Beds, shows little faunal similarity with the forms recorded from the Colsterdale Marine Beds, but finds more numerous parallels in the R_1 shell beds of the present area.

The records from the Botany Limestone (Garwood, 1912, Reading, 1954) regarded by Reading as the probable equivalent of the Shunner Fell Marine Beds, differ considerably in fauna from that horizon and quite radically from the Colsterdale Marine Series owing to the presence of numerous subgenera of Productus and also corals. Some of the forms recorded, since they are long ranged fossils of Yoredale aspect, are also found in the R_1 shell beds and the Red Scar Grit of the present area.

Whilst the beds correlated with the Colsterdale Marine Series to the north show little faunal resemblance to this horizon, the numerous records from the area south of the Craven Faults show a great faunal similarity with those from the present area, since they also consist of a goniatite-pelecypod fauna with orthocone nautiloids and fish remains, indicating that an environment suitable for goniatites extended on to the Askrigg Block, but to the north of the present area was absent and probably replaced by a fauna of Yoredale aspect with rare goniatites recorded from the Shunner Fell locality. Ct. nitidus, Anthracoceras and Dimorphoceras are recorded from numerous localities south of the present area together with a pelecypod fauna in which the dominant forms are perhaps Posidonia corrugata and Posidoniella laevis. Orthocone nautiloids figure in most of the existing records and also fish remains which are rare finds, the most important of which in the present work was of Listracanthus, known also from the Cockhill Limestone at Greenhow (Dunham and Stubblefield, 1945) which is its lowest known occurrence in Great Britain and from the Ct. stellarum beds at Netherby (Stephens et al. 1942). The present record is intermediate between the two given above.

Faunal Lists of Colsterdale Marine Series

nuculid-gastropod beds. ('s' denotes specimen in shale- all un-named specimens are preserved in chalybite)

Drifted plants, 1,4,

Hyalostelia smithii Young and Young, 1s

Crinoid stems, 3

Fenestella sp.,1
?Rod cryptostome, 1

Crurithyris urei (Fleming), 1,1s
Dielasma sp. (Fleming), 1
Lingula mytiloides J. Sowerby, 1
Leda attenuata (Fleming), 1, 1s, 3
?Lithophaga sp., 1s
Nuculana undulata (Phillips), 1s
Nuculopsis gibbosa (Fleming), 1, 1s, ?2, 3, 4s
Posidonia corrugata (R. Etheridge jun.), 1s, 4s
---------- cf. wapanuckensis (Girty), 1
Scaldia sp., 3

Bellerophon anthracophilus Frech, 1
Bellerophon sp., 1,1s
Euphemites sp.,1s, 3
Glabrocingulum aff. interstrialis (Phillips)1, 1s, 3
---------- sp. indet., ?4s
Naticopsis sp., 1
Turbonellina cf. lepida (de Koninck), 1
---------- sp. indet., 3

Anthracoceras paucilobum (Phillips), 4s
---------- sp., 1, 1s
Cravenoceras holmesi Bisat, ?4s
Cravenocerasp., ?3
cf. Homoceras sp. juv., 1

Liroceras cf. lunense Turner, 1
Orthocone nautiloids, 1,3, 4

Ostracods, 1, 1s, ?3

Palæoniscid scales, 3, 4

Index of localities for the above:

1. Right bank of the R. Burn, Gollinglith Foot, Colsterdale (153809)
2. Tip of old coal pit, Braithwaite Moor (115847)
3. Right bank of Barnley Beck, Colsterdale (105822)
4. Left bank of Thorny Grane Gill, Colsterdale (112796)

<u>Anthracoceras</u> shales below the Colsterdale Limestone

Plants, 1

?Nuculopsis gibbosa (Fleming), 3
Posidonia corrugata (R. Etheridge), 1, 2
---------- aff. membranacea (McCoy), 3
---------- cf. wapanuckensis (Girty), 3
Posidoniella laevis (Brown), 1, 3
---------- minor (Brown), 1, 2, 3
---------- aff. sulcata Hind, 1, 3
---------- variabilis (Brown ms.) Hind, 1

Anthracoceras paucilobum (Phillips), 1,2
---------- sp., 1
?Dimorphoceras sp., 1
?Dolorthoceras sp., 1
Orthocone nautiloid, 2,3

Index of localities for the above:

1.	Left bank of Thorny Grane Gill, Colsterdale	112796
2.	Left bank of R. Burn, above Dawson House, Colsterdale	100799
3.	Right bank of Spruce Gill, Colsterdale	135803

Colsterdale Limestone

Carbonised wood, 1,2,3

Myalina sp., 1
Posidonia corrugata (R. Etheridge jun.), 1,3
---------- aff. wapanuckensis (Girty), 3
Posidoniella laevis (Brown), 1
---------- minor (Brown), 2,3,4
---------- cf. minor (Brown), 1

Spirorbis sp., 2

Anthracoceras paucilobum (Phillips), 1,2,3,4
Cravenoceratoides nitidus (Phillips), 1,2,3,4,5,6
Dimorphoceras sp. 1,?3,?4
cf. Dolorthoceras attenuatum (Fleming), 4
Orthocone nautiloid 2,3,5

Listracanthus sp., 1
Palaeoniscid scale, 1,5,6
Rhizodont scale 1,4

Index of localities for the above

1.	Stand Syke, Nidderdale	051779
2.	Right bank of Spruce Gill, Colsterdale	135803
3.	N.W. slopes of Great Whernside	002760
4.	Right bank of Ulfers Gill, Coverdale	093827
5.	Left bank of Thorny Grane Gill, Colsterdale	112796
6.	Right bank of Armathwaite Gill, Nidderdale, blocks from glacial drift	074749

Anthracoceras shales above the Colsterdale Limestone

Plants, 1,2,3,4

Crinoid ossicles, 2

Limatulina sp., 1
Posidonia cf. corrugata (R. Etheridge jun.), 1,2,3,4,5,6,7,
---------- aff. membranacea (McCoy), 3
---------- trapezoedra Ruprecht, 1

Posidonia cf. wapanuckensis Girty, 1
Posidoniella laevis (Brown,)1
---------- minor (Brown) 1,2,3,4
---------- sulcata Hind 1,3
---------- cf. sulcata Hind, 2
---------- variabilis (Brown ms.) Hind, 1

Anthracoceras paucilobum (Phillips), 1, 2,4,5
Dimorphoceras sp., ?1, 2, 3, 4, 5
Eumorphoceras bisulcatum Girty, 3,7
---------- bisulcatum Girty gerontic form, 1
?Orthocone nautiloid, 3

Index of localities for the above:

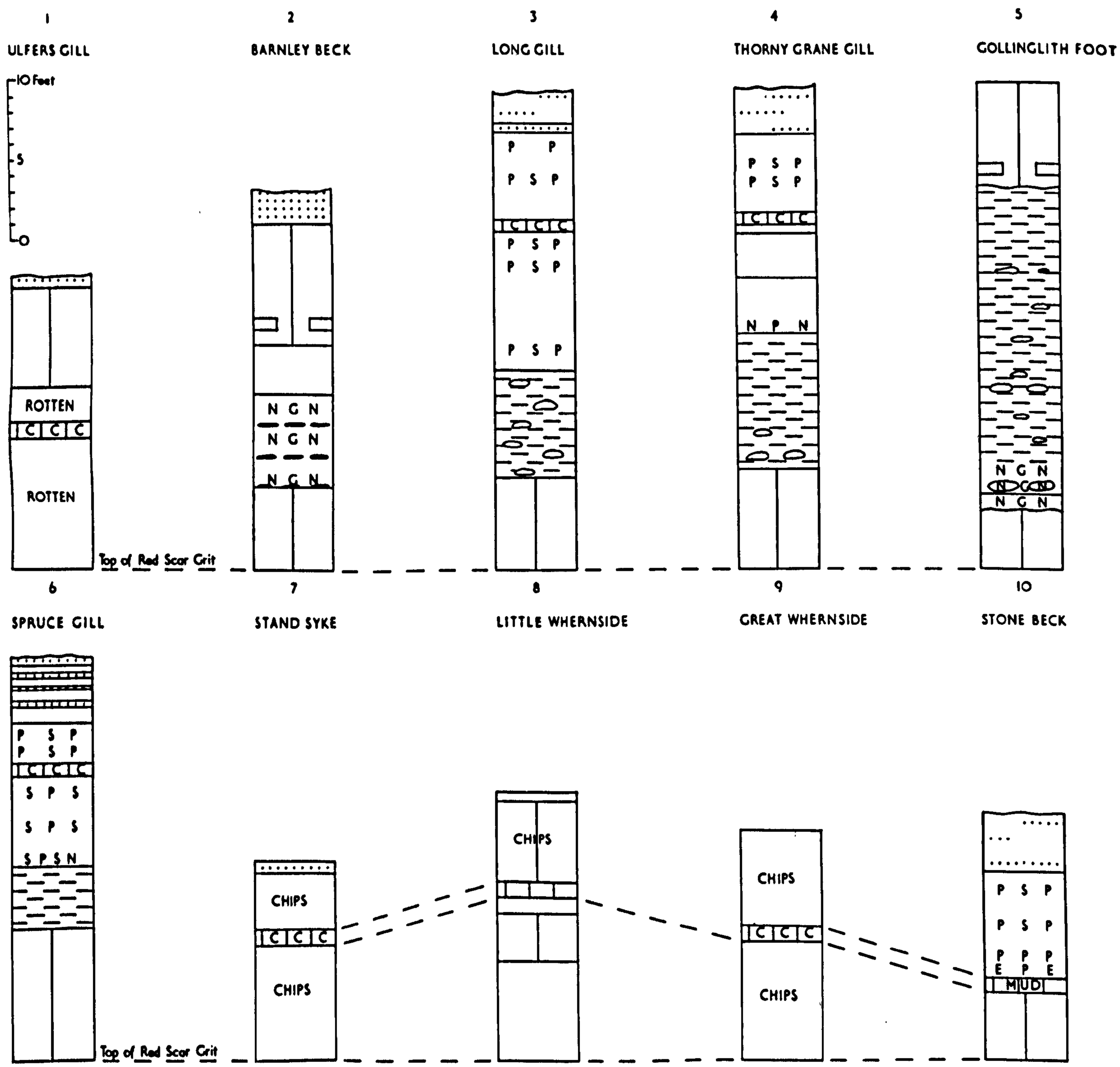
1.	Thrope Edge landslip scar, Nidderdale	106759
2.	Backstone Gill nr. Lofthouse, Nidderdale	110740
3.	Right bank of Stone Beck, Nidderdale	012741
4.	Left bank of R. Burn, above Dawson House, Colsterdale	100799
5.	Left bank of Thorny Grane Gill, Colsterdale	112796
6.	Right bank of Spruce Gill, Colsterdale	135803
7.	Left bank of East Gill Dike, Nidderdale	037743

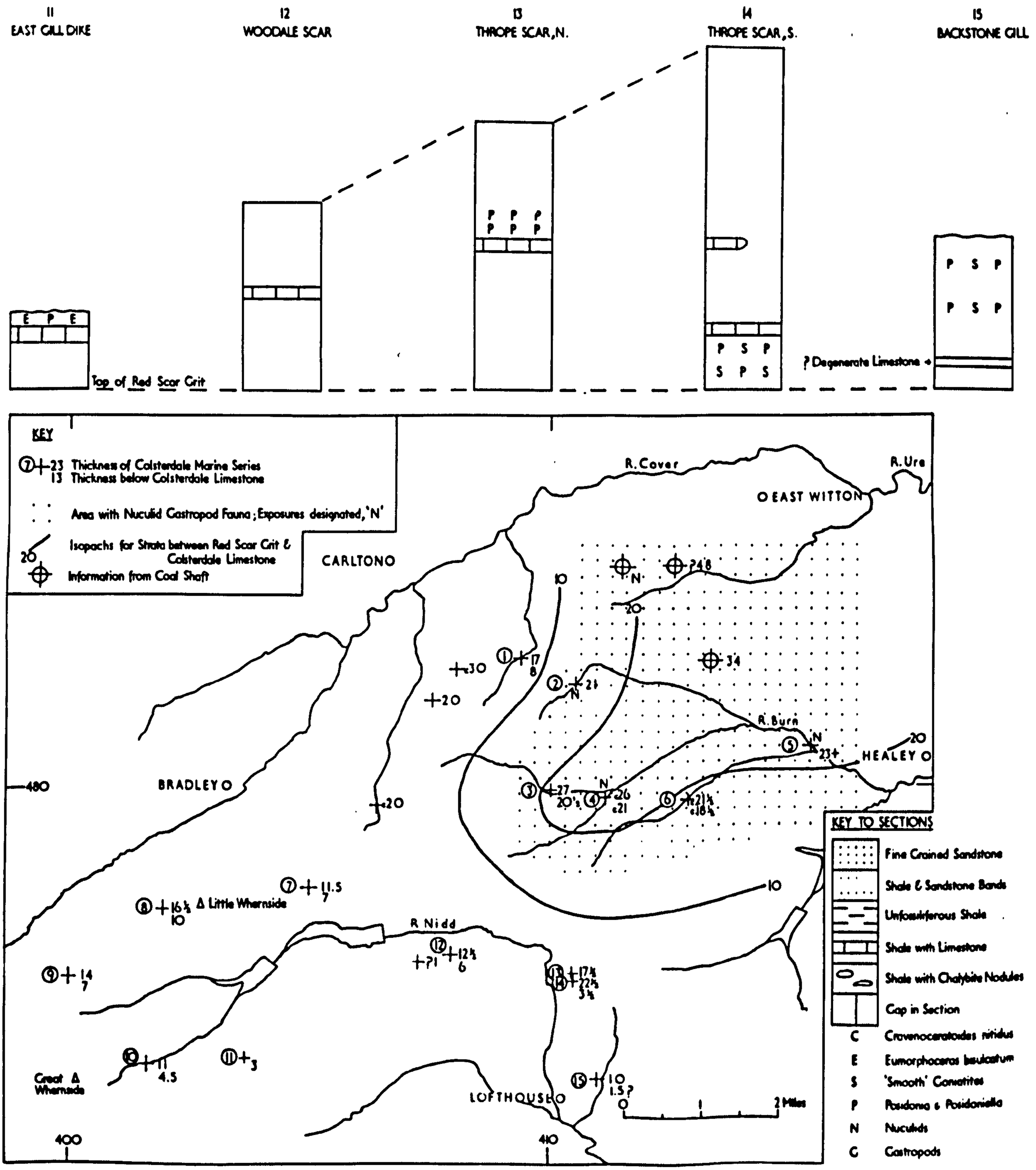
PLATE 28

Comparative sections in the Colsterdale Marine Series

PLATE 29

Comparative sections in the Colsterdale Marine Series with a key map for Plates 28, 29. The key map gives locality numbers and thickness and facies data.


1
ULFERS GILL
10 Feet
5
0
ROTTEN
C C C
ROTTEN
Top of Red Scar Grit
2
BARNLEY BECK
N G N
N G N
N G N
3
LONG GILL
P P
P S P
C C C
P S P
P S P
P S P
4
THORNY GRANE GILL
P S P
P S P
C C C
N P N
5
GOLLINGLITH FOOT
N G N
N G N
6
SPRUCE GILL
P S P
P S P
C C C
S P S
S P S
S P S N
Top of Red Scar Grit
7
STAND SYKE
CHIPS
C C C
CHIPS
8
LITTLE WHERNSIDE
CHIPS
9
GREAT WHERNSIDE
CHIPS
C C C
CHIPS
10
STONE BECK
P S P
P S P
P P P
E P E
M U D


11
EAST GILL DIKE
12
WOODALE SCAR
13
THROPE SCAR, N.
14
THROPE SCAR, S.
15
BACKSTONE GILL
E P E
Top of Red Scar Grit
P P P
P P P
P S P
S P S
P S P
P S P
? Degenerate Limestone
KEY
7 23 Thickness of Colsterdale Marine Series
13 Thickness below Colsterdale Limestone
Area with Nuculid Gastropod Fauna; Exposures designated, 'N'
Isopachs for Strata between Red Scar Grit & Colsterdale Limestone
Information from Coal Shaft
CARLTONO
BRADLEY O
R. Cover
R. Ure
EAST WITTON
R. Burn
HEALEY O
Δ Little Whernside
R Nidd
Great Δ Whernside
LOFTHOUSE O
2 Miles
KEY TO SECTIONS
Fine Grained Sandstone
Shale & Sandstone Bands
Unfossiliferous Shale
Shale with Limestone
Shale with Chalybite Nodules
Gap in Section
C Cravenoceratoides nitidus
E Eumorphoceras bisulcatum
S 'Smooth' Cowlitites
P Posidonia & Posidoniella
N Nuculids
G Gastropods

CHAPTER 14

THE NAR HILL BEDS

The first name given to the beds between the Colsterdale Marine Series and the Lower Follifoot Grit was the Upper Washburn Grits and Shales, by Hudson (1939). The term 'Washburn Grits and Shales' referred to a group of strata described by Hudson, with its base 75' below the Red Scar Grit and top at the base of the Lower Follifoot Grit, the stratigraphic term quoted above being taken from this group terminology. Since the Washburn Grits and shales already include previously recognised lithological names which Hudson allowed to stand, it is considered bad terminology to associate the group name with a newly named lithological unit. In fact Hudson did give a special name to the sandstones at this level (which are not 'Grits' in any sense); he called them the 'Nar Hill Sandstones', a term which specifically excluded any shales. The naming of the beds between the Colsterdale Marine Series and Lower Follifoot Grit in the present area is, I believe, clarified by the use of the modified term 'Nar Hill Beds', which includes both sandstones and shales at this level.

Dakyns (1892) gave little detail for the Follifoot Grits, or for the Nar Hill Beds, though he correlated the top Grit of Great Whernside with the Lower Follifoot, which is a correct correlation in the opinion of the present author. In the key of Geological Survey 1" sheet 97 S.E., New Series 51 only one Follifoot Grit is listed, and a series is recognised below it

which is not given a name.

Bisat (1914) included the Nar Hill Beds with the Lower Follifoot Grit of the present work in his 'Barren Beds'. He examined these formations chiefly in the dam trench at Leighton, at that time under construction, and stressed the fact that these rocks, like the Lower Follifoot Grit were without a fauna. Tonks (1925) tabulated the Nidderdale succession, which has since been quoted with modifications by several authors. In it he shows 90' of shales above the top of the Red Scar Grit, with an impersistent sandstone. These beds are overlain by a sandstone which he calls the 'Lower Follifoot Grit'. It is now established by the discovery of H. beyrichianum above the Upper Follifoot Grit of Tonks that this is in reality the Lower Follifoot Grit, above which H. beyrichianum occurs in areas further south. The Lower Follifoot Grit of Tonks, which belongs to the Nar Hill Beds, when mapped into Coverdale is seen to be very impersistent. It is replaced laterally by strata which are predominantly shales. This sandstone is fine grained, in contrast with the typical Lower Follifoot Grit of the areas further south which appears to be a medium to coarse grained sandstone, always referred to in the literature as a 'grit'. Tonks tabulation of the strata is also in disagreement with that given on the published map Sheet 97 S.E. (New Ser. 51.) which gives only one and not two Follifoot Grits in the present area. This is in nearly every available section the correct interpretation and it is

thus unfortunate that the later source (Tonks, 1925) has often been quoted with some little modification. Hudson (1938, 1939), Jones (1943), Dunham and Stubblefield (1945), Rowell (1953) and Scanlon (1955) effect correlation in this manner with the succession in upper Nidderdale, the type section in E_2 beds of the main outcrop of the Millstone Grit facies sediments of the Askrigg Block.

Stratigraphy

The Nar Hill Beds are a variable group of silty shales, siltstones flaggy sandstones and blocky, fine grained sandstones. The arenaceous beds, characteristically of lenticular shape, are least frequent on the E. fringe of Coverdale where the beds are predominantly shaly and most frequent near Scar House in Nidderdale and in Upper Colsterdale. The farthest N.E. of all the exposures, that in How Gill Plantation, shows a predominantly shaly sequence, though arenaceous beds appear to figure strongly in the records of the old coal pits on Braithwaite Moor to the W. of this point. It is thus possible that the zone of maximum development of sandstones in the Nar Hill Beds is in a N.E.-S.W. belt from Braithwaite Moor in the north via upper Colsterdale and Scar House to the S.E. slopes of Great Whernside. There is a decrease in the proportion of arenaceous beds to the west and east of this zone, though the evidence for these changes of lithology is not complete. (Plate 30 incorporates all available records).

The arenaceous beds of the sequence are characteristically blocky weathering and when deeply weathered tend to show rounded edges. The grain size is almost invariably between 125 and 200 microns and only very rarely are coarser beds seen. Exceptionally, medium grained feature-forming sandstones occur at a level which is apparently in the upper part of the Nar Hill Beds. Beds of this lithology are treated in conjunction with the Lower Follifoot Grits which they lithologically resemble. In the two sections of Plate 30 where they occur, namely at Spruce Gill and Thrope Edge, they are omitted and incorporated with the sections on Plate 33 in the Lower Follifoot Grit. These sandstones may be regarded as channel fillings which heralded the incoming of the Lower Follifoot Grit spread of medium grained sand, but are themselves more localised than the persistent Lower Follifoot Grit.

The Nar Hill Beds are almost devoid of traces of organisms; the single exception is the occurrence of worm trails in flaggy sandstone in Beldin Gill, Colsterdale, indicating conditions of emergence at the time that these beds were being laid down.

The group is so variable that it was almost never possible to map horizons within it. Sandstones are very rarely feature-formers, this despite Tonks' erroneous statement to the contrary (1925, p. 250). Since they vary much in thickness, they are not mapped separately because the available information is rarely sufficient to map contacts except in totally exposed

sections. An examination of the variation encountered in the excavation for the Leighton Dam Trench, a plan of which is set out in Plate 32A, provides ready proof of the exceedingly rapid thickness and lithological variation in these beds, which renders mapping of lithological units hazardous and unscientific.

Details

N. and E. side of Nidderdale from Dead Mans Hill to the Lofthouse Fault - Stand Syke (051781) shows a partial section in this group. The uppermost 45' are silty shales. Beds lower in the sequence include several sandstones. A hand specimen of one was a fine grained, moderately feldspathic sandstone with specks of organic carbon. At intervals the section is obscured, but there appear to be numerous shale partings.

Tops Gill (056777) shows exposures in the upper beds which are silty mudstones, whilst the lower beds, though discontinuously exposed, appear to be chiefly sandstones It seems that the proportion of sandstone to shale increases in an easterly direction along the north side of Nidderdale, and indeed in the quarries to the E. the sandstones form the bulk of the middle and lower parts of the Nar Hill Beds.

The large quarries on the S. slopes of Carle Fell (062776) show a section in a group of sandstones with thin partings of mudstone and flaggy mudstone. The arenaceous beds are chiefly massive, fine grained feldspathic sandstones which tend to

weather into rounded forms. The thickest sandstone is 53' thick and includes a washout 35 yd. across inside it (see Plate 31A). The washout is in a medium grained feldspathic sandstone, of coarser grain than the normal sandstones in the Nar Hill Beds, which contains 50% of large, angular siltstone fragments. Some of the fragments show flexuring due to compaction and were evidently transported when in a fairly plastic state and subsequently crushed by the superincumbent load of sediment. The lower surface of this cut-and-fill structure is undulose whilst the upper surface intertongues with the overlying massive sandstone, which shows a gentle large scale flexuring, probably as a result of compaction. The dominantly arenaceous nature of the beds was also confirmed in the log of the trial borehole sunk before exploitation of the rock of this quarry commenced; this log was used to supplement the evidence of the exposures when constructing the section given on Plate 30. As in the previous section quoted, the upper beds, below the Lower Follifoot Grit are silty shales. They are seen in a somewhat inaccessible position in the top of the upper level of the quarry. A small quarry further to the E. (068776) shows 15' flaggy mudstone overlying 48' massive sandstone. This in turn rests on a considerable thickness of mudstone which does not appear to be represented in the quarry to the west, except by thin partings.

Woo Gill shows extensive exposures in these beds, but the stream section is too long to permit of satisfactory measurement

and many gaps occur in the section. Shales are strongly developed in the middle of the Nar Hill Beds in a position where the strata are principally sandstones in the quarries on Carle Fell, to the west.

East of Woo Gill occasional small exposures and fairly abundant blocks of sandstone occur on the lower part of the outcrop, indicating that the Nar Hill Beds here include arenaceous horizons.

Thrope Edge landslip scar (106759) shows a clear section of the lower beds of the group which consist of sandstones and mudstones in alternation. The thicker sandstones tend to be blocky and rather massive feldspathic, fine grained sandstones with a little muscovite. The upper beds are unexposed and include in their topmost part an impersistent medium grained sandstone, described in the next chapter in conjunction with the Lower Follifoot Grit.

Exposures are lacking below Thrope Edge and the next good exposure seen going in a southerly direction is in the scar of of the Backstone Gill landslip (112743) in which the upper strata of the Nar Hill Beds are exposed. They are flaggy mudstones and mudstones and resemble the beds below the Follifoot Grit of most sections in being virtually free of arenaceous horizons. Blocks of sandstone occur on the outcrop of the lowest of the Nar Hill Beds immediately above the Colsterdale Marine Series in Sandscar Wood in this same locality. The scar of a landslip at Massey edge (115733) shows

sandstones and shales which appear to vary in thickness (12' only are seen).

Rainstang and Great Whernside - Rainstang is a somewhat ill-exposed outlier with its upper slopes in the Nar Hill Beds. The best sections are in a large quarry on the N.W. slopes of the hill (175763) (Plate 30) which shows an alternation of sandstones and thin shale partings. The lower strata of the Nar Hill Beds are predominantly sandstones in this quarry and in the top of Woodale Scar. A specimen from the lowest beds on Woodale Scar was a fine grained sandstone with flecks of limonite and showing slightly rounded edges on the weathered surfaces. Specimens taken from two levels in the quarry were fine grained sandstone, one of which was fairly feldspathic, the other with only rare feldspars. The highest beds of the series on Rainstang are seen in occasional exposures in channels cutting through the peat near the head of Foggyshaw Gill (085761). They are shales or flaggy mudstones with occasional thin bands of flaggy sandstone.

The Nar Hill Beds are infrequently exposed in the Great Whernside outlier. The best sections are in the several head streams of Stone Beck (011741) (Plate 30) which show a fairly complete section, but with a sufficiently large number of gaps in the lower beds to make it impossible to tell with certainty how predominant the frequent sandstones are. The upper strata are more continuously seen and are chiefly silty mudstones with a bed of 13' blocky medium to coarse grained sandstone near

the top of the sequence in a position where arenaceous horizons are rarely developed at other localities. The highest of the Nar Hill Beds form a succession of gulleyed stream valleys beneath the Lower Follifoot Grit. A further gulley is seen below Blackfell Top showing the upper 35' of beds, here shales with no evidence of the sandstone which occurs at this level in the Stonebeck drainage further south.

A scar on the N.W. slopes of Great Whernside (002760) (Plate 30) shows a good section in the lowest beds of the group. Whereas blocky sandstones are abundant in Stone Beck at this level, the exposure here shows a predominance of shale, with only thin sandstones. Southwards further scars occur with shales and flaggy sandstones, but it is not possible to correlate individual beds in these exposures. At Black Dyke Hole (997752) a flaggy sandstone scree occurs above the horizon of the Colsterdale Marine Series and it is probable that sandstones figure more largely in the lower part of the Nar Hill Beds than they do further north.

Little Whernside to Witton Fell - A gulley section on the N.W. slopes of Little Whernside (021774) shows 30' of shales immediately overlying the Colsterdale Marine Series. This section compares with that described from the N.W. slopes of Great Whernside where the lowest strata of the Nar Hill Beds are also predominantly shales. A gulley on the S.E. slopes of the mountain (031775) shows 70' of silty mudstone without sandstone bands underlying the Lower Follifoot Grit. There

are no sections on Little Whernside in the middle part of the Nar Hill Beds and it is possible that they include some sandstones. The available evidence is summarised on Plate 30.

The outcrop on the E. side of Coverdale is ill-exposed, but occasional good sections occur. The upper 90' of these beds are partially exposed in a gulley on the W. slopes of Carle Fell (058797) where they are shales and flaggy mudstones with thin bands of sandstone.

Tributaries of Lead Up Gill draining off Carle Fell show silty shales with the development of blocky, fine grained sandstones in the lowest 25' of the beds. The strong development of shales in the middle of the Nar Hill Beds contrasts with the thick development of sandstones at this horizon in the Carle Fell quarries 1¼ miles of this point. The whole series appears to be over 60' thinner than at Carle Fell; this may be due to the greater compaction of shales than sandstones.

Scattered exposures in Greystone Gill provide some additional data about these beds which are only very partially seen, but include shale and fireclay. A section at 076815 shows:

6"	fireclay probably overlain by 5' more fireclay
4"	ganister
2'6"	fireclay

The development of fireclay is not parallelled elsewhere in the group in the present area. Exposures are lacking on East Scrafton Moor, though there are some indications of the presence of a sandstone in this group.

The section in Ulfers Gill is discontinuous, but it is apparent that the lower beds include a fair proportion of sandstones . Shales occur in the middle of the group which appears to be less than 150' thick, and therefore considerably thinner than in Nidderdale where sandstones are more fully developed. The uppermost part of the Nar Hill Beds is exposed in gulleys located on old pony tracks on East Scrafton Moor (085823 and 093827) and are flaggy mudstones seen to a thickness of 20' below the Lower Follifoot Grit. The Nar Hill Beds are unexposed along their outcrop on the slopes of Flamstone Pin and on Braithwaite Moor with the exception of a single exposure of fireclay at Wharrel Crags (111846).

The slopes of Witton Fell are ill-exposed, but a small exposure of shale with sandstone blocks was seen low in the Nar Hill Beds (131851) and 6' of sandstone are seen higher in the succession at 141850. Exposures in Sowden Beck (130845) show flaggy sandstones, siltstones and shales which appear to underlie a medium grained sandstone high in the Nar Hill Beds, here considered in conjunction with the Lower Follifoot Grit (Chapter 15).

How Gill (158842) provides an important, but somewhat incomplete section in which the visible strata are predominantly shales (see Plate 30) together with thin beds of sandstone. It is probable that the bulk of the unexposed beds are also shales. It seems that the rocks in this section are much more argillaceous than those recorded from the old coal pits on

Braithwaite Moor and it is thought probable that the Nar Hill Beds become more shaly to the N.E.

Colsterdale - The Nar Hill Beds form a valley inlier of complex shape in the upper part of the dale. Though sections are usually difficult to measure because of the near coincidence of the dip values and long profiles of the valleys, these are a few good sections in these beds which are seldom exposed in stream sections in either Coverdale or Nidderdale.

The coal pits to the north of Colsterdale provide important evidence (set out on Plate 30). The figured records are derived from the published 6" sheets of the Geological Survey. Whilst the nomenclature used is vague in some respects, especially in beds which involve repetitions of sandstones and shales, it appears that sandstones are strongly developed in the sequence at Brown Beck Pit and West Pit. The overall thickness which was recorded in Brown Beck Pit is considerably thinner than it is to the S. in Nidderdale. At the extreme head of Scale Gill, on the col between Colsterdale and Coverdale, blocks of sandstone occur. These belong to a sandstone high in the Nar Hill Beds which is overlain by shales which are imperfectly exposed, but appear to be very silty, and immediately underlie the Lower Follifoot Grit.

The section seen in Barnley Beck (103820) is not accurately measurable and includes several major gaps, but the results of careful levelling have been incorporated in a partial section in Plate 30. Whereas the section in Ulfers Gill to the W.

showed only minor exposure in sandstones, there appears to be a stronger development in Barnley Beck. Immediately above the Colsterdale Marine Series sandstones occur, above which a considerable, but not accurately measurable, gap occurs in the section. The sections above the gap are fairly consecutive and shows a rapid alternation of sandstones and shales, with very few sandstones of a quality or thickness which would fit them for quarrying as has been carried out on their equivalents in Nidderdale. Silty shales with thin flaggy sandstones which underlie the Lower Follifoot Grit are seen in the walls of an old pony track (108818). On the broad spur between Barnley Beck and Birk Gill there are many indications of sandstones, in the form of surface blocks distributed on the hillside in such a way as to suggest an interleaving with shale, a conclusion verified by examination of the section in Barnley Beck.

Examination of Long Side (115826) yielded boulders for a long distance uphill, suggesting that sandstones are well developed on the hillside. Blocks of similar lithology, namely a fine grained, blocky sandstone, also were seen shortly above the top of the Colsterdale Marine Series. Backstone Gill and Brown Beck both show a few exposures which are in shales and sandstones in fairly equal amounts.

An exposure in How Gill Plantation (152818) shows the beds immediately underlying the Lower Follifoot Grit which are here about 25' of mudstone. These are underlain by 10' flaggy mud-

stone, below a 10' gap in the section. Here, as at most other exposures, arenaceous sediments are rare in the 40' or so of beds underlying the Lower Follifoot Grit.

Feeders of the River Burn above Colsterdale Hamlet - Steel House Gill (786092) shows a well exposed, but somewhat disjointed section in which shale partings are common in the visible sandstones. The uppermost strata are chiefly shales and the Lower Follifoot Grit rests on 10' of shales. Beldin Gill combined with the lower part of Steel House Gill provides a measurable section, which is probably the most complete one now visible in the Nar Hill Beds of the present area. The beds immediately above the Colsterdale Marine Band are blocky fine grained sandstones (100799). Blocky sandstones at a slightly higher level form cliffs in Steel House gill near High Engine Pit and on the upthrow side of a small fault, in Beldin Gill. An alternation of shales and flaggy sandstones overlie these beds. At two levels in the middle of the Nar Hill beds in Beldin Gill evenly and thinly bedded fine grained flaggy sandstones occur with numerous worm trails here referred to as Crossopodia sp. The largest trails are ribbons ½" wide with a central furrow. These trails are the only indisputable evidence of emergent conditions during the formation of the Nar Hill Beds, though it seems highly likely that the whole series was deposited in extremely shallow water. The upper beds of the series are silty shales with lenticular sandstones which show marked variation in lithology and thickness

within the limits of the gorge in Beldin Gill. One of the thicker sandstones shows rounded weathering, a feature of the more deeply weathered sandstones of this series, and also the development of Liesegang rings. The uppermost beds are 10' of silty shales which directly underlie the Lower Follifoot Grit.

The section in Long Gill is inadequately exposed, but the lower part of Backstone Gill, just below its confluence with Long Gill (095805) shows a good section in the highest beds of the group:

24'	thin bedded flaggy sandstone
11'	shale
30'	fine grained sandstone
10'	approx. shale (base not seen)

Though the uppermost beds are faulted against the Lower Follifoot Grit, it seems probable that the highest beds tabulated above almost directly underlie the Lower Follifoot Grit. Blocks of fine grained sandstone occur on the north slopes of Long Gill. It is probable that they are derived from the thick sandstones seen in Backstone Gill, which is broadly correlated with the highest sandstone seen in the section at Beldin Gill. Sandstones low in the Nar Hill Beds are spasmodically exposed in the stream section in Long Gill.

The slopes of the Burn valley north of Thorny Grane Moor show occasional blocks and exposures in the Nar Hill Beds whilst similar blocks occur scattered on the N. slopes of the valley. Exposures on the N. side of the Burn valley are rare, but a

limited section is visible in New House Gill in 14' of massive, blocky sandstone.

Thorny Grane Gill (110795) provides a large number of exposures which are not, however accurately measurable. Fine grained blocky sandstones are abundant, but at several levels show shale partings. It appears that arenaceous beds are more fully developed than in Beldin Gill to the west. Sandstone bands appear to persist to the top of the series, but exposures are inadequate to test the relative proportions of shales to sandstones.

Spruce Gill and Lower Colsterdale - The spur on the N. side of Spruce Gill shows indications of sandstone at several points on its south side. Pieces of fine grained, blocky sandstone are especially abundant in a ploughed field at 147808. On the N. side of the spur the sandstones have been worked in old stone pits, the largest of which shows 10' of sandstone. Blocks occur at several points on the N. side of the spur indicating thick sandstones in the Nar Hill Beds.

Slee House Gill (125802) gives an incomplete section in which the visible beds are chiefly blocky, fine grained sandstones. The nearby section of House Gill shows intermittent exposures in fine grained sandstone. The highest ones are in a medium grained sandstone a short distance below the Lower Follifoot Grit. These beds are considered in conjunction with the Lower Follifoot Grit in the chapter which follows and appear to be of the same lithology as sandstone boulders S.W. of Gin Coal Pit

(108802) which probably belong to the same horizon.

The section in Spruce Gill (130798) is not readily measured, but an approximate section has been incorporated in Plate 30. Sandstones appear to be here as abundant as in the quarries on Carle Fell and shale partings are rare. The lowest beds, like those in the middle of the group, appear to be almost exclusively blocky, fine grained sandstones without shale partings. In the upper beds the thickest shale parting was only 4', a strong contrast to the sections further west where shales are much more important (Beldin Gill and the Coverdale sections). The Nar Hill Beds are overlain in Spruce Gill by a medium grained sandstone which appears to be at a lower horizon than the Lower Follifoot Grit, but is considered in conjunction with that latter horizon in the next chapter.

The S. side of Spruce Gill is badly exposed and little is seen to the east except for two very small exposures near Breary Bank. Sections occur sporadically in the R. Burn, however, and the lowest beds of the series are seen at 156806 where they are 4' blocky, fine grained sandstone. Further exposures are seen downstream at 164804 where a steeply dipping alternation of shales and sandstones is exposed for a thickness of 17'. 50 yd. downstream from this last exposure blocks of massive sandstone occur, pointing to a further development of arenaceous beds at this horizon.

The most easterly of all exposures in the Nar Hill Beds in Colsterdale is in a scar in the right bank of the R. Burn at Hall Wood (175800). The section there shows 20' silty mudstone

overlying 10' of silty flagstones. Though the Lower Follifoot Grit is not here seen, its base probably occurs only a few feet above the top of the beds seen in the section.

Grimes Gill and the valley of Pott Beck - Grimes Gill shows a disjointed dip stream section in sandstones and shales. A more complete picture can be built up in Hopper Gill and the exposures in Grimes Gill near the bottom of Hopper Gill (141789) (Plate 30). The section seen is in the upper part of the group and shows a large thickness of silty mudstone underlying the Lower Follifoot Grit. These mudstones overlie sandstones with shale partings.

The valley of Pott Beck has several large scattered outcrops in the Nar Hill Beds, the largest of which is at 170797 showing 18' of sandstone overlying 30' of silty flagstone. Other exposures further upstream show a predominance of silty mudstone, with silty flagstone and some thin, blocky fine grained feldspathic sandstones. As a consequence of the construction of reservoirs in Pott Beck, two excellent sections were available in the dam trenches which penetrated the bulk of the thickness of the Nar Hill Beds. The records from these show vividly the rapid lateral variation at this level. The Leighton trench record shows that the uppermost 110' of strata are poor in sandstones and all arenaceous horizons appear to lense out within the limits of the section. 60' of beds underlying these show a strong development of sandstones with shale partings. These also show variation and rest on 30' of blue, sandy shales in the

valley bottom which appear to have been affected by cambering (Plate 30 summarises the section). The Roundhill trench (Plates 30, 32A) shows more spectacular variation than that at Leighton. The upper beds are 32'-43' of shales, like the beds under the Lower Follifoot Grit of most localities. The shales rest on a sandstone and a shale which persist through the limits of the section. These overlie very variable sediments with a sandstone 50' thick which lenses out to zero with great rapidity.

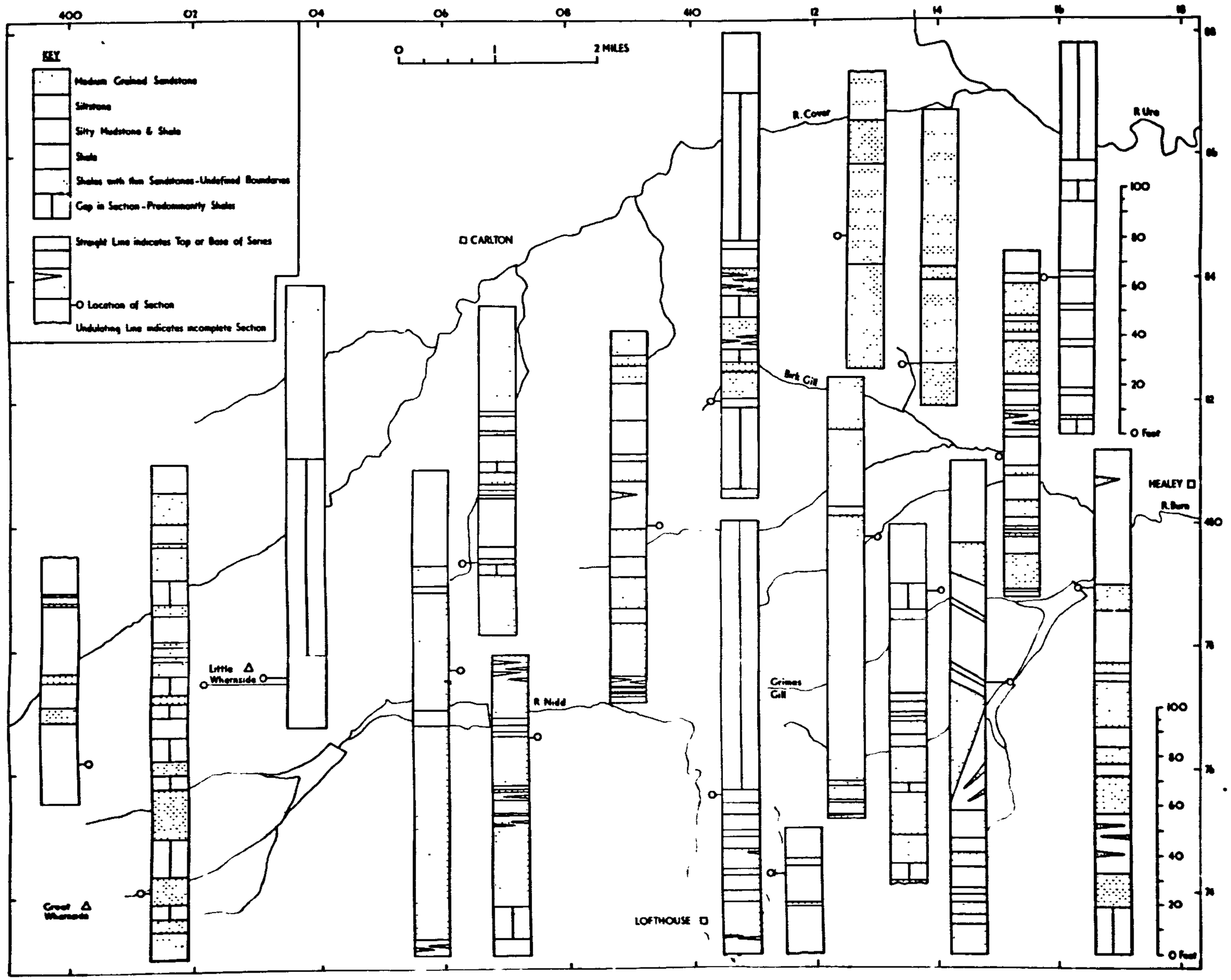
PLATE 30

Sections diagram for the Nar Hill Beds. The diagram incorporates all available measured sections throughout the area.

The concentration of the thickest sandstones along a S.W.-N.E. line through Scar House and upper Colsterdale is apparent in this diagram. The shaley nature of the beds along the eastern flank of Coverdale is apparent.

KEY

N.W. slopes of Great Whernside (lowest beds only)	002760
Stone Beck (all series)	011741
Little Whernside (all series)	031775
Carle Fell Quarries (incl. Trial Bore) (all series)	062776
Lead Up Gill (all series)	063793
Rainstang Quarry (lowest beds only)	076764
Beldin Gill (all series)	095800
Barnley Beck (all series)	104820
Thrope Edge (all series)	104756
Backstone Gill (upper beds only)	112742
West Pit (mine record) (all series)	124847
Spruce Gill (all series)	130798
Brown Beck Pit (all series)	134826
Grimes Gill and Hopper Gill (upper beds only)	141789
Gollinglith Foot trial boreholes (all series)	151811
Roundhill Dam trench (nearly all series)	153774
How Gill (all series)	158840
Leighton Dam trench (nearly all series)	164789


KEY
Medium Grained Sandstone
Siltstone
Silty Mudstone & Shale
Shale
Shales with thin Sandstones - Undefined Boundaries
Gap in Section - Predominantly Shales
Straight Line indicates Top or Base of Series
Location of Section
Undulating Line indicates incomplete Section
0 1 2 MILES
CARLTON
R. Cover
R Ure
Burk Gill
HEALEY
R. Burn
Little Whernside
R Nidd
Grimes Gill
LOFTHOUSE
Great Whernside
100
80
60
40
20
0 Feet

CHAPTER 15

THE LOWER FOLLIFOOT GRIT

The key of the Geological Survey 1" sheet 97 S.E. (New Ser. 51), covering the present area, names the horizon under discussion, the 'Follifoot Rock', which is synonymous with the 'Middle Grit' of Phillips. Present work shows that this horizon is equivalent to the Lower Follifoot Grit of the areas to the south and accordingly this name is here used. Bisat (1914) included this horizon in the upper part of his 'Barren Beds', a term which is not used here. Tonks (1925) asserted that there were two Follifoot Grits present in upper Nidderdale, a view at variance with that of the Geological Survey, and he held further that they were both persistent horizons. The present work has shown that the lower of these sandstones is not persistent, but dies out almost completely to the W. and N.E. The section given by Tonks (Fig. 8) shows that this sandstone has its base 90' above the top of the Red Scar Grit; the name 'Lower Follifoot Grit' is given to this horizon. During the present work the true Lower Follifoot Grit has been recognised by the presence of the <u>Homoceras beyrichianum</u> fauna from the shales which overlie it. This horizon is the 'Upper Follifoot Grit' of Tonks whilst the 'Lower Follifoot Grit' of that author is in reality the Nar Hill Beds (broadly equivalent to the Nar Hill Sandstone and the accompanying shales in the Simonseat area of Hudson, 1939).

Stratigraphy

The Lower Follifoot Grit is a variable series of medium or

coarse grained, sometimes massive and frequently current bedded feldspathic sandstones, locally containing some shaley partings which permit the local differentiation of upper or lower leaves of Grit, in addition to the main leaf. Outcrops of the Grit occur along the fringes of the main area of Millstone Grit facies strata on the Askrigg Block. Plate 47 shows the escarpment edge of this outcrop which is capped by the Lower Follifoot Grit forming Great Whernside, Little Whernside and the easterly flank of Coverdale to Flamstone Pin, where the outcrop turns through a right angle and runs along the south flank of Wensleydale which is seen in the far distance. The two Whernsides are outliers and the main outcrop of the Lower Follifoot Grit turns east into Nidderdale at Dead Mans Hill and flanks the dale on its north side, and then of on its E. side where the Nidd turns and runs south. In Colsterdale the Lower Follifoot Grit forms a complex pattern of outcrops and gradually falls in level to the E., where it occupies the valley bottoms and finally plunges below the bed of the R. Burn near Swinton Castle.

The main mass of the Lower Follifoot Grit varies from about 11' to 75' in thickness and is never absent along its anticipated line of outcrop in the present area. In Nidderdale, below Thrope Edge, in Spruce Gill and Sowden Beck a distinct lower leaf is developed which is separated from the main leaf by 32'-52' of shales; these are however very infrequently exposed. The lower leaf resembles the main leaf lithologically since it is a medium or coarse grained feldspathic sandstone. In all the three cases this local development of a lower leaf of Grit

appears to die out rapidly (Plate 34). The abnormal thickness (122') of the Lower Follifoot Grit in Grimes Gill, Colsterdale is probably due also to the development of a lower leaf. Whilst at least 4' of shale occur in a parting in part of the section it seems likely that it lenses out. This shale is probably the equivalent of that exposed between the main leaf of the Grit and the lower leaf in Spruce Gill 1 mile to the N.W. As in the instances cited above where a lower leaf is present, the extra thickening of the Grit (in Grimes Gill) rapidly reverts to normal (about 40') in half a mile to the E. When the lower leaf of Grit is seen it seems that its presence is coupled with a thinning of the Nar Hill Beds beneath it and it appears likely that it bears a channelled relationship to the underlying beds. It is possible to argue that these lower developments of coarse to medium grained sandstone should be grouped with the Nar Hill Beds since they appear near the top of that division. The conspicuous grain size difference between the fine grained Nar Hill Beds and the local, medium to coarse grained sandstones make it more natural to refer these sandstones to the Lower Follifoot Grit in the opinion of the present author; in addition there is the probability that the two leaves are merged in Grimes Gill. There is some suggestion that the several developments of thick sandstone at this level lie on a north-south course which may possibly be a channel cutting into the Nar Hill Beds. The absence of any known medium grained sandstone on the north slopes of Colsterdale about Brown Beck is however a factor which is against this reconstruction, since the channel, if such a

feature exists, must run through this hillside.

The main leaf of the Lower Follifoot Grit is usually about 40' thick, but thins in upper Colsterdale around Beldin Gill and Steel House Gill and also appears to be thin to the south, on Woogill Moor. This is overlain at scattered localities by an upper leaf of the Grit. This is seen on Great Whernside (the summit plateau), on West Scrafton Moor, above Lobley Crags (Colsterdale), in Spruce Gill and at Gladstones (on Carle Fell, Nidderdale). At the first three of the above-named localities slump structures and steep foreset bedding are common. The slumps rarely show overturning of beds, but take the form of corrugations. Whilst this upper leaf of the sandstone cannot be proved to overlie shale, it seems likely that a shale is in many instances present. This shale is probably thickest on Great Whernside, but appears to lense out to zero in a southwards direction on the mountain.

The Lower Follifoot Grit tends to form plateaus, together with the Ganister Beds which overlie it; the most extensive of these is on the N. of Colsterdale which is exclusively in the Grit. Due to the number of scars and the presence of a marked plateau edge on these beds at numerous points the base of the Grit can be usually accurately mapped. Mapping is somewhat less easy at the head of Colsterdale where the horizon is thinnest and there is little tendency for it to form topographic features. The most difficult beds to map accurately are the shales which separate the leaves of the Grit since they are almost never exposed; this aspect is therefore almost entirely reliant on the interpretation of features. Whilst the upper

PLATE 31 A

Washout in the Nar Hill Beds, quarries on Carle Fell, Nidderdale (061776). The channel is filled with sandstone carrying very numerous shale pebbles. The undulation of the bedding planes in the cliff, partly as a result of compaction is well shown. The slopes above the cliff are in silty shales underlying the Lower Follifoot Grit. The ruler (right) is 6' long and its base rests on the cone of debris.

PLATE 31 B

Slump hitches in the upper leaf of the Lower Follifoot Grit of West Fell, Coverdale (074811). The block is 4' high and is in situ on a low feature.

limit of the Lower Follifoot Grit is more nearly a time-line than the base, the contact is seldom exposed, but can be approximately located due to the incoming of the ganisters and flaggy, fine grained sandstones which are characteristic of the Ganister Beds. In the south of the area where thick developments of fine grained sandstone locally occur immediately above the Lower Follifoot Grit, these have been referred to the Ganister Beds which they lithologically resemble (see Chapter 16 for a further discussion of this topic).

Details

The outliers of Great Whernside and Little Whernside - The Lower Follifoot Grit shows one of its thickest developments in the present area on Great Whernside (Plate 34). The lower leaf of the Grit is a coarse grained feldspathic sandstone which is exposed in a gulley at 006748. The lower part of this leaf is also seen in several of the gulleys at Stone Head Top. The prominent line of crags round the summit of the mountain, in the upper leaf of the Grit, is adjudged on the basis of features to be separated from the lower Grit by an unexposed shale restricted to the N.W. face of the summit plateau of Great Whernside. The upper leaf is a current bedded medium to coarse grained sandstone exposed through a thickness of 20'. It frequently shows slump structures along the length of Little Crags and Long Crags, flanking the Great Whernside plateau on the W. side (Plate 47 is an air view showing these scars). The upper surface of the upper leaf is laid bare on the summit plateau at 005740 due to the erosion of the soft shales of the Ganister Beds, here a thin

veneer on the Lower Follifoot Grit. This surface of sandstone shows slump waves which have not suffered erosion prior to the deposition of the Ganister Beds. A further capping of Lower Follifoot Grit is seen on the north end of the Great Whernside massif above Nidd Head allotment. It seems probable that a shale parting is developed within the Grit, but this suggestion is based solely on weak features. It is therefore not certain if the inferred shale parting below Blackfell Crags at the N. end of the summit plateau of the mountain continues so far north as this point.

Little Whernside (029777) is capped by the Lower Follifoot Grit which gives this hill its very flat top (Plates 33A, 38B, 47 are views of this mountain from various angles). The Grit is seen to a thickness of 30' and forms a prominent line of scars on its N.W. face.

<u>The edge of the main outcrop on the E. side of Colsterdale Dead Mans Hill to East Scrafton Moor</u> - The Lower Follifoot Grit is well exposed in a line of crags on the N.W. edge of Carle Fell facing out on to Colsterdale (057796) (Plate 25B), where the thickest single exposure shows 18' of current bedded sandstone, which is probably about 45' thick. Further exposures occur round the head of Lead Up Gill where the Grit appears to be still in one leaf. On West Scrafton Moor, however, two separate leaves are developed, as in Great Whernside (Plate 34). The lower leaf is ill-exposed, but the feature which it forms carries sandstone boulders. The upper leaf forms a clear feature which attains a maximum height of 15', is well exposed and broken by

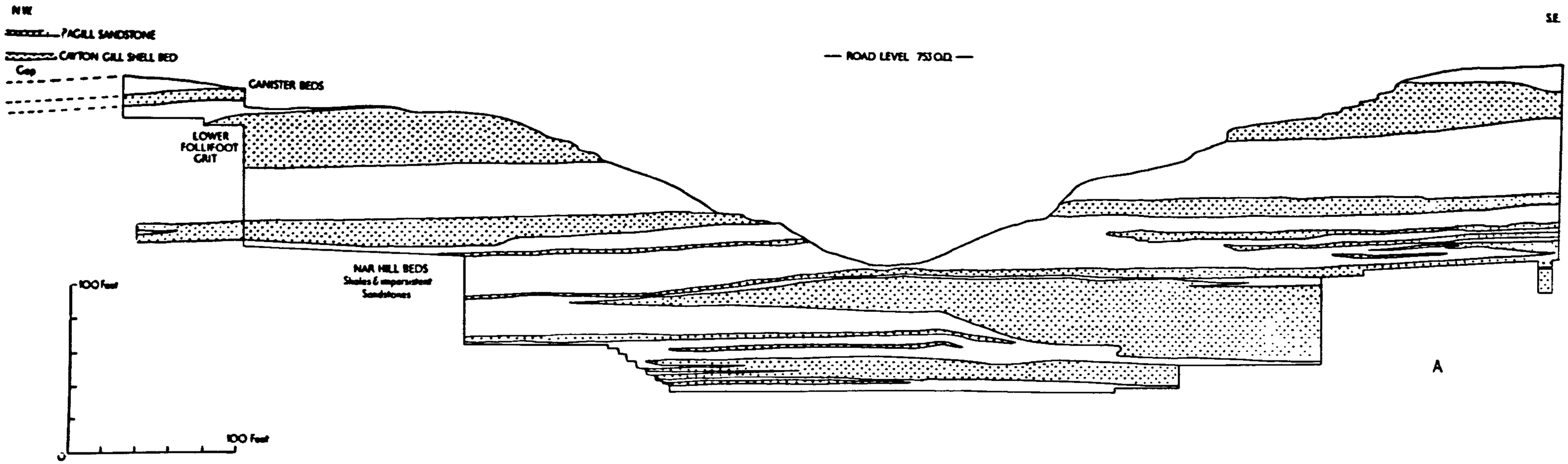
two faults. At several points along it the sandstone shows slump structures and wavy bedding (Plate 31B), also characteristic of a similar, upper leaf on Great Whernside. This upper leaf is not exposed north of Jonaman (075814) and appears to die out to the north as well as the south.

The Lower Follifoot Grit, with apparently only one leaf developed, forms the prominent scars of Little Roova Crag and Great Roova Crags. 20' of massive medium grained feldspathic sandstone, unusually rich in microcline and with some current bedding is seen in Great Roova Crags (082824).

Outcrops round the head of Colsterdale, south of Birk Gill - An extensive plateau on the Lower Follifoot Grit forms Colsterdale Moor, East Scrafton Moor and Barnley Moss; the grit is probably over 40' thick here and occurs in a single leaf. Blocks and boulders of medium grained sandstone are abundant where the peat has been eroded away and frequently a line of scars marks the edge of the outcrop on the borders of the plateau: Over Stones, High Crags and Hanging Stones are such crags, whilst elsewhere a simple feature marks the base of the Lower Follifoot Grit. The absence of a good feature at this level on the south flank of Colsterdale Moor makes this horizon hard to fix. It is thought that this is due to a medium grained sandstone high in the Nar Hill Beds, with a grain size and resistance to weathering closely comparable with that of the Lower Follifoot Grit. It is possible that this is a similar development to that seen below the main body of the Lower Follifoot Grit of Spruce Gill, Colsterdale.

PLATE 32 A Plan of the dam trench for the Roundhill Reservoir, Colsterdale. The information is taken from the Engineers' plan by courtesy of Harrogate Corporation ; all drift deposits have been omitted for the purposes of clarity. The section involves no linear exaggeration of scale. The Cayton Gill Shell Bed and Agill Sandstone were encountered during the digging of a subsidiary trench and are shown in their correct positions. The lensing out of the sandstone in the Nar Hill Beds within the limits of the section illustrates the extreme variability of these beds and appears to be an excellent example of a cut-and-fill washout channel.

PLATE 32 B View of Penhill Crags across the landslip derived from the scar, looking south. The overlap of the thick sandstone in the Nidderdale Shales on the West end of the cliff in an eastwards direction appears to be due to transgression at the level of a sandstone leaf which cuts across the bedding of the main mass of the sandstone and is followed by a thickness of shales which appear to bear a washout relationship to the sandstone towards the E. end of the cliff. The base of the thick sandstone is not seen at any point owing to overburden. The view is taken from a photograph taken some distance away which has been so enlarged as to give the impression that the cliff is viewed from the landslip below it.


N.W.
S.E.
?ACGILL SANDSTONE
CAYTON GILL SHELL BED
Coal
CANISTER BEDS
— ROAD LEVEL 753 O.D. —
LOWER FOLLIFOOT GRIT
NAR HILL BEDS
Shales & impersistent Sandstones
100 Feet
100 Feet
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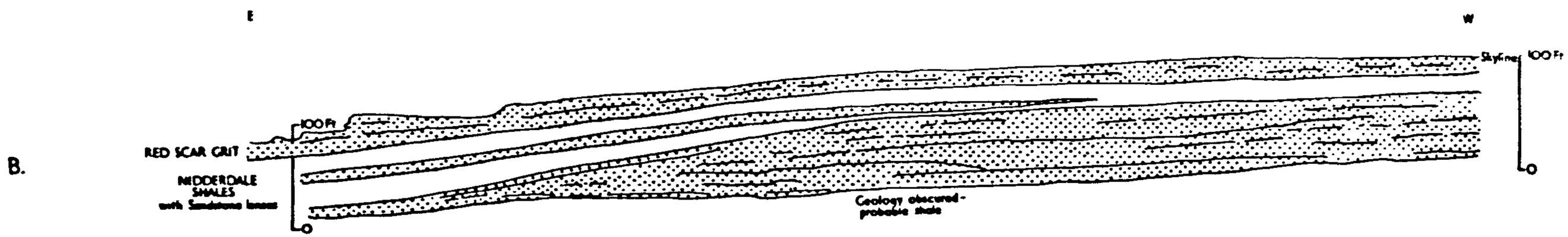

E
W
Skyline
100 Ft
100 Ft
RED SCAR GRIT
NIDDERDALE SHALES
with Sandstone lenses
Geology obscured - probable shale
0
B.

In upper Colsterdale, around Backstone Gill (095806), Beldin Gill (092800) and Steel House Gill (089795) a drastic thinning of the Lower Follifoot Grit takes place. In this area the Grit does not exceed 22' in thickness and is a massive medium grained sandstone occasionally forming boulder-strewn features. The small thickness appears to be maintained on Thorny Grane Moor and in Thorny Grane Gill (102789) where the horizon is perhaps about 40' thick. The spur of Gollinglith Ridge is capped by this horizon which appears to be at least 40' thick here and forms prominent scars at Gollinglith Crags (127804) (a view of this spur and the crags is given on Plate 43B). A maximum of 20' of massive sandstone is exposed and large quantities of sandstone debris cover the summit of the spur.

<u>N. and E. sides of Nidderdale from Dead Mans Hill to the Lofthouse Fault</u> - The outcrop of the Lower Follifoot Grit is marked by sandstone boulders on the S. side of Carle Fell and there is a partial exposure in Tops Gill. An upper leaf of the Grit is exposed in a feature forming Gladstones (061779) which appears to die out to the E. and W. This latter development is reminiscent of the features seen high in the Grit on Scrafton Moor, since they too are 10' high and are overlain by blocks of the Ganister Beds. In Woo Gill (070787) the Lower Follifoot Grit shows only a single leaf which is well exposed, but can only be approximately measured since the section is a long one; the entire Grit is only about 25' thick here however. The underlying strata are variable since a shale 20' thick is cut out within the limits of the section; these rest on 22' of fine

grained ganisteroid sandstone which is not similar to the usual softer and more feldspathic sandstones of the Nar Hill Beds (Plate 34). It thus seems possible that this horizon should be considered as a lower leaf of the Lower Follifoot Grit, though this is only a tentative suggestion and it little resembles other developments of sandstone below the level of the main leaf of the Grit.

On Woogill Moor the Lower Follifoot Grit fails to make a feature for some distance, but above Bull Brae the feature resumes and can be traced intermittently along the slopes of the valley. It appears that the Grit is here thin as in Colsterdale; the height of the feature suggests a figure in the vicinity of 20'. The most complete exposure is in Whin Pasture Crags where 15' of sandstone are visible.

South of the Lofthouse Moor Fault two sandstones are developed along Thrope Edge, of which the lower one is impersistent since the feature which it makes dies out suddently S.S.W. of Thrope Edge shooting box. Exposures occur in 17' of medium grained feldspathic sandstone in which the chief feldspar is microcline; also interstitial silt is quite plentiful in thin section. 40' of beds above this horizon are probably shales which are overlain by 27' of medium to coarse grained feldspathic sandstone. This leaf appears to be the persistent, main leaf of the Grit and is again well exposed at Thrope Plantation (106747) where exposures show it is at least 35' thick. Further exposures occur round the spur into Backstone Gill where the base of the Grit is seen. As in Woo Gill, a markedly transgressive base occurs which cuts down into flaggy mudstones. Occasional

further exposures are seen to the south which suggest that the Grit is thick, perhaps of the order of 50'.

Colsterdale from Spruce Gill to Swinton - The section in Spruce Gill shows the development of a lower leaf of sandstone similar to that of Thrope Edge (see ante). The mapping indicates that it lenses out to the N. (Plate 34, key map), but the extent to the S. is unknown. The base of the sandstone is exposed and is a medium grained rock except in the lowest 2' which show small quartz pebbles. It appears to cut down into sandstones of the Nar Hill Beds which are by contrast fine grained. Evidence from exposures and features suggests that this horizon is 34' thick. The overlying beds are shales which are partially exposed; this is one of the exceedingly few exposures in shales within the Lower Follifoot Grit. The section is as follows:

-	main leaf of Lower Follifoot Grit
20'	gap
8'	greenish silty shale
0-9"	silty micaceous mudstone
1'	gap approx.
34'	lower leaf of Lower Follifoot Grit (approximate figure)

The main leaf of the Grit can be shown to be continuous with that of Gollinglith Ridge which is part of the main outcrop of the Lower Follifoot Grit in upper Colsterdale. The main leaf develops an impersistent upper feature which is reminiscent of similar developments elsewhere. It is possible that this feature rests on an unexposed shale horizon (this possibility is expressed in Plate 34 which does not show the lower leaf of Spruce Gill, because this is not fully developed at the point where the upper leaf is seen). The main portion of the Lower Follifoot Grit forms a

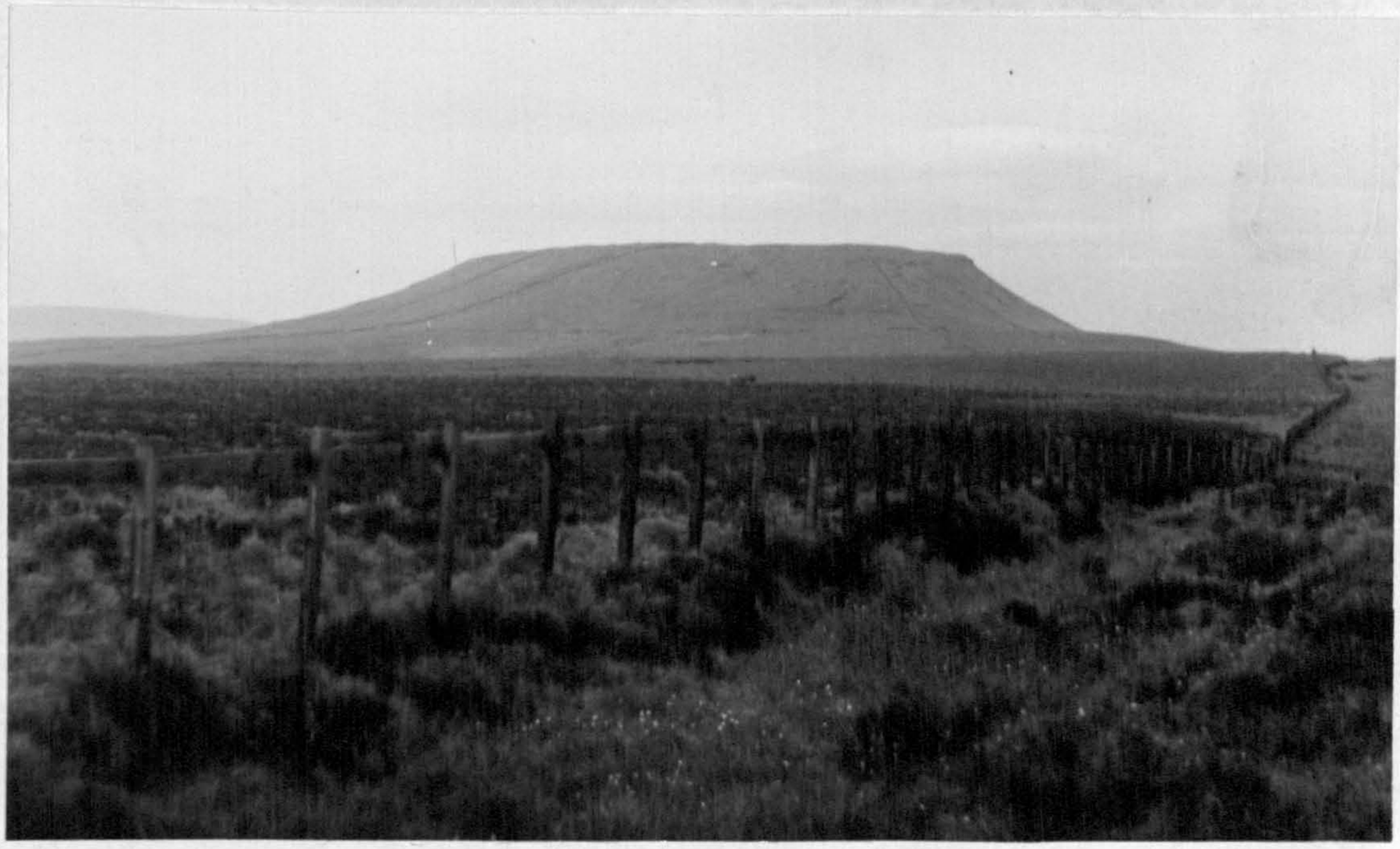


PLATE 33 A

Little Whernside from the slopes of Dead Man's Hill. The low ground in the fore and middle-ground is in Red Scar Grit forming the col between the above named hills. The feature with the Colsterdale Marine Beds is seen at the base of Little Whernside, whose summit plateau is in the Follifoot Grit , overlying steep slopes in the Nar Hill Beds. The N. end of Great Whernside is in the background (left).

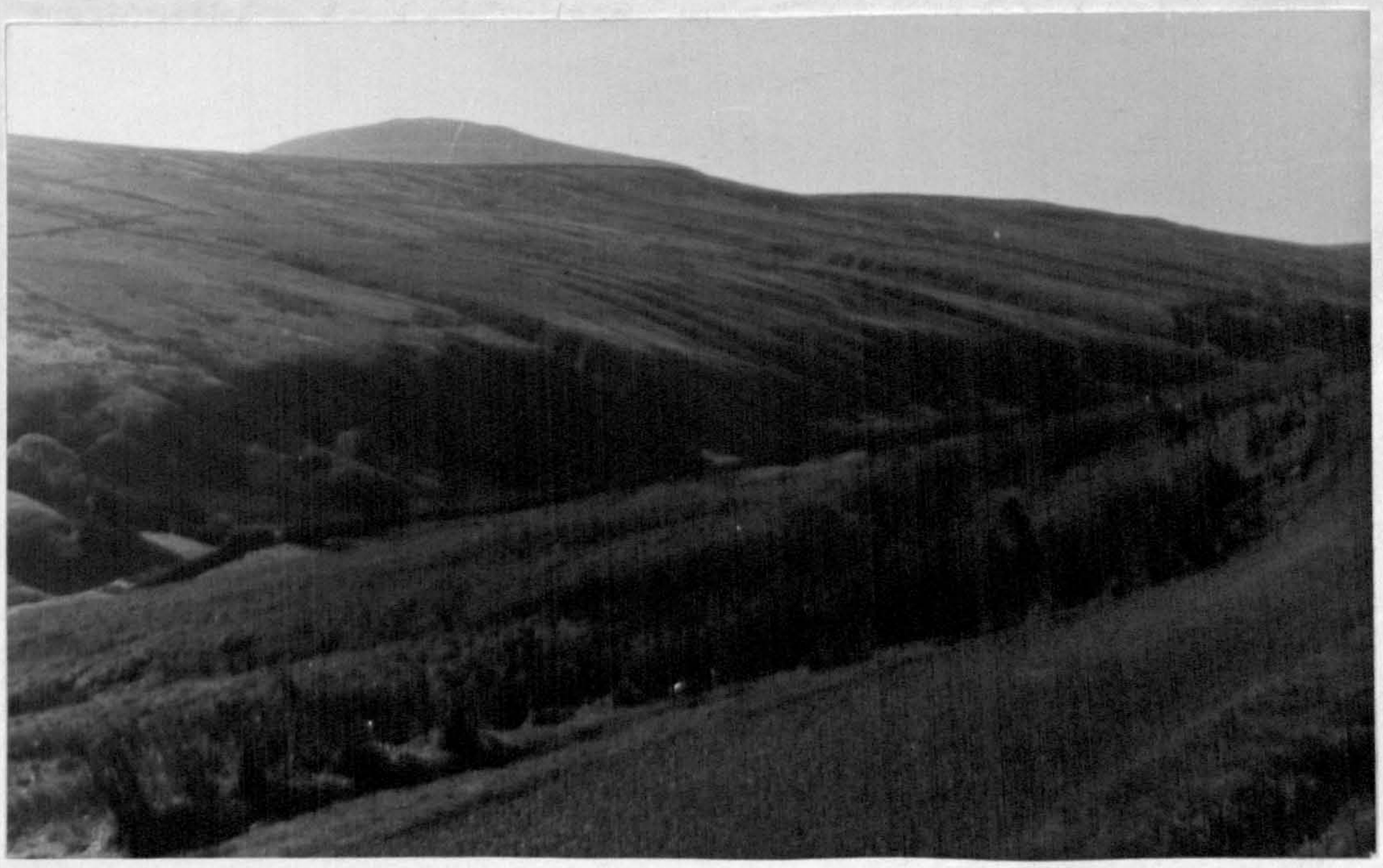


PLATE 33 B

Great Whernside and Coverdale from the road S.W. of Woodale. The R.Cover runs from right to left; the confluence with Lords Gill is on the extreme left. The gulleyed mature of the boulder clay mantling the sides of the dale is well seen. The two darker patches below the sky-line, centre and centre right are the steep slopes on the outcrop of the Grassington Grit which here cuts out the Main Limestone which is present on the valley side as far to the right of the view as the parallel walls which run up the side of the dale.

clear feature north of Hambleton Lith. It is apparent however that the lower part of the Grit dies out, in this case to the E., but a portion of it persists along the N. side of the spur on which Towler Hill Farm is situated. Intermittent outcrops occur on a distinct feature which dies out eastwards under the cover of drift on the end of the spur near Leighton. In the puddle field at Leighton Reservoir (156788) 28' of medium to coarse grained feldspathic sandstone with oligoclase, orthoclase, perthite and microcline are seen. In the Leighton trench 700 yd. E. of this point the total thickness of this horizon is 33' (Plate 34). Hopper Gill, tributary to Grimes Gill, has an exposure in 17' of medium grained sandstone. The total thickness of the Grit does not appear to be much in excess of 30' here. In 700 yd. to the S.W. of this point the Follifoot Grit thickens greatly to an estimated 122'. The grain size here is somewhat variable and includes some fine grained beds low in the sequence (Plate 34). A shale parting occurs on the N. bank of Grimes Gill (135782) where the section seen is as follows:

4'	flaggy sandstone
4'	gap (possibly shale)
4'	flaggy mudstone

Since this shale is about 75' below the top of the Grit it seems possible that it is equivalent to the shale exposed in Spruce Gill, 1 mile N.W. of this point. If this is the case the lower sandstones which appear to merge downstream with the upper beds are equivalent to the impersistent lower leaf of the Grit which is seen in Spruce Gill. On the S. side of Grimes Gill the mapping indicates that the beds thin rapidly to the E. as they do on the N.

side of the valley. Occasional outcrops occur on the spur below Pott Hall, but the best record is that of the Roundhill Dam Trench (Plate 32A, 34) where it is 37' thick. The upper beds of the Grit are exposed in a valley inlier above the reservoir in Agill where a maximum of 20' of sandstone are exposed.

Down-valley from Leighton exposures of the Grit are seen in stream courses below Healey and in the R. Burn near Healey Saw Mill. In thin section a specimen from this locality was a fine grained sandstone with microcline and oligoclase. Owing to faults in the Burn valley the Grit is again exposed further downstream W. of Shaws Farm (204804) where 15' of medium grained current bedded sandstone are seen.

Exposures north of Birk Gill and the R. Burn - On the N. side of Colsterdale the Follifoot Grit forms extensive plateau areas in the region of Jenny Binks Moss and Brown Rigg, on the interfluve between Colsterdale and Wensleydale. The crags facing on to Colsterdale run for several miles intermittently and form picturesque features on the N. side of the valley. These crags extend from Wet Shaw Crags in the west via Hanging Stones, Brownbeck Crags and Slipstone Crags to Agra Crags. Medium to a coarse grained current bedded sandstones are excellently exposed and thicknesses of up to 25' are seen. Current bedding often occurs; sometimes the rock is very massive and resembles the Brimham Grits, this being especially noticeable at Slipstone Crags. The sinking at Brown Beck Pit, Agra Moor (133827), penetrated 51'6" of sandstone which is almost the entire thickness of the Lower Follifoot Grit, in view of the fact that the line of

the plateau dipslope on which the pit is situated plunges beneath the Ganister Beds of Agra Moor Top, 400 yd. E. of the pit. Above Lobley Crags (122831) a feature with 5' of steeply current bedded sandstone showing minor slump structures is seen at a higher level than the main leaf of the Grit. Whilst there is little evidence for a shale parting here, the appearance of a separate feature with slump bedding is reminiscent of similar developments elsewhere in the area, at Scrafton Moor and Great Whernside. Healey Pasture Quarry shows the most complete exposure of the Grit on the N. side of Colsterdale (160809). Here there are exposed 35' of massive medium grained sandstone which in thin section is markedly feldspathic, with oligoclase, perthite, microcline, microcline micropethite and orthoclase. A little scattered clacite cement occurs, but the bulk of the grains are sutured together, due to secondary growth of quartz in optical continuity.

The N. side of the outcrop of the Lower Follifoot Grit N. of Colsterdale is often feature-bounded. These features and a few exposures allow of the mapping of the involved shape of the outcrop in the area round Farmery Mires. The plateau round Brown Rigg shows abundant sandstone blocks where the peat is thin or absent. Witton Fell is an outlier on the main leaf of the Grit which is exposed in a line of scars on the N. side of the plateau summit of this hill, where a maximum of 20' of current bedded sandstone are seen (133851). In Sowden Beck a lower leaf of coarse, feldspathic sandstone is developed about 50' below the main leaf of the Lower Follifoot Grit which appears to

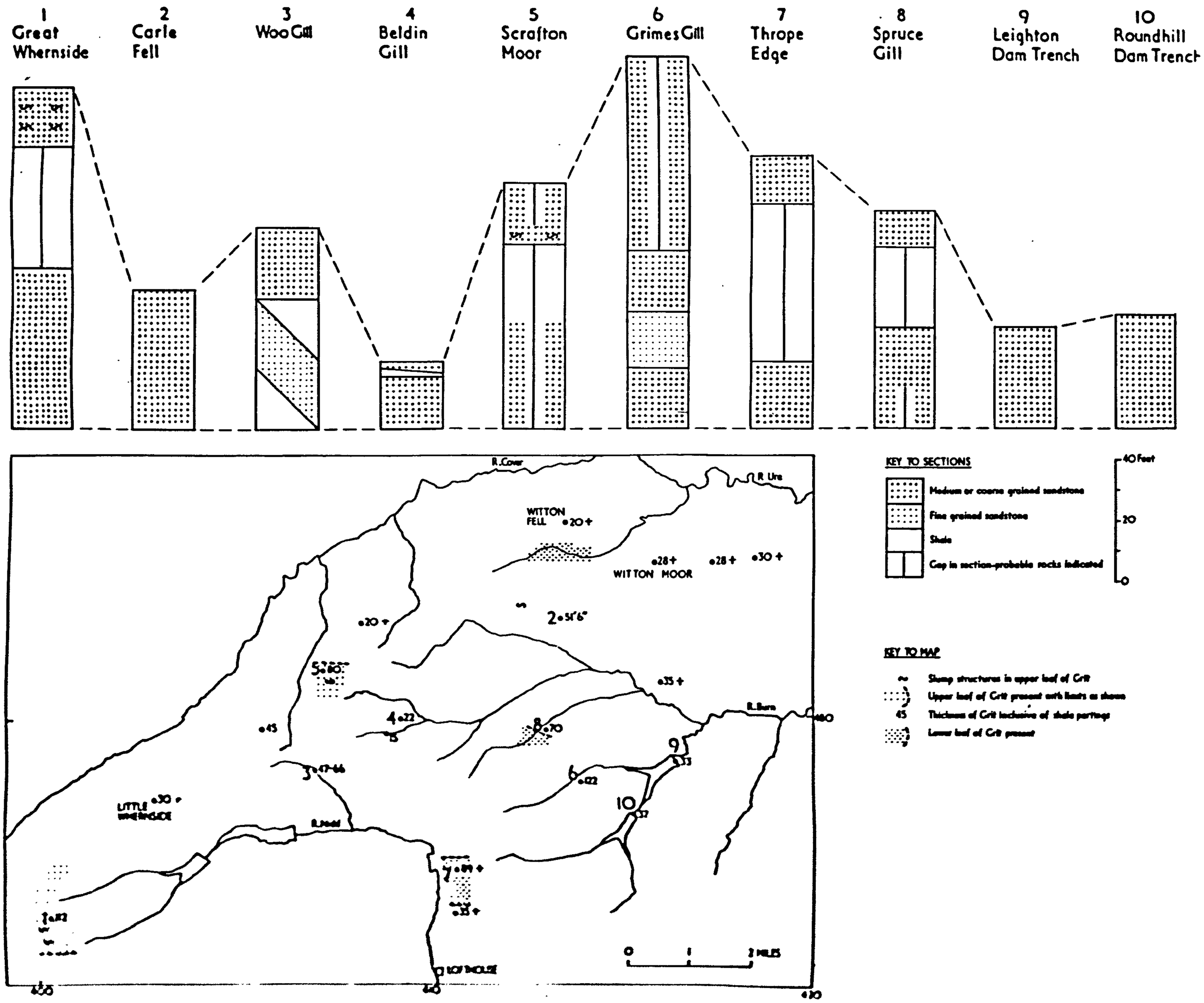
stand in the same relation to it as does the upper to the impersistent, lower sandstone of Thrope Edge, Nidderdale. The lower sandstone cannot be recognised on the N. face of Witton Fell nor can it be seen further E. than Tom Claypham Beck (138841). It is therefore assumed that it is a local development like that seen in Nidderdale.

The northern outcrop of the Grit is obscured by drift N. of the Fowl Lay overflow channel, but a tongue shaped outcrop of sandstone has been mapped in the channel itself where there are some exposures. The Grit is exposed at several points on the edge of the fells facing out on to Wensleydale, which appears to be drift-free for the most part. Whilst the full thickness is perhaps 45', exposures are incomplete. The section in How Gill Plantation shows an intermittent section in 28' of massive medium to coarse grained sandstone which is also seen in several quarries in the vicinity.

The feature on the Grit becomes less persistent as it is traced on to lower ground owing to increasing boulder clay cover, but good exposures are seen in quarries at Quarry Hill (173841) where 28' of massive current bedded medium to coarse grained feldspathic sandstone are seen and in Ellington Firth where the thickest single exposure shows 30' of medium grained feldspathic sandstone. It is probable that the full thickness of this horizon is here about 45', since it has been quarried intermittently through approximately this thickness.

PLATE 34

Comparative sections in the Lower Follifoot Grit , with a map to show thickness and facies variations at this horizon.


1 Great Whernside
2 Carle Fell
3 Woo Gill
4 Beldin Gill
5 Scrafton Moor
6 Grimes Gill
7 Thrope Edge
8 Spruce Gill
9 Leighton Dam Trench
10 Roundhill Dam Trench
R. Cover
R. Ure
WITTON FELL
WITTON MOOR
R. Burn
LITTLE WHERNSIDE
KEY TO SECTIONS
Medium or coarse grained sandstone
Fine grained sandstone
Shale
Gap in section-probable rocks indicated
40 Feet
20
0
KEY TO MAP
Slump structures in upper leaf of Grit
Upper leaf of Grit present with limits as shown
45 Thickness of Grit inclusive of shale partings
Lower leaf of Grit present
0 1 2 MILES

CHAPTER 16

THE BEDS BETWEEN THE LOWER FOLLIFOOT GRIT AND FIRST BRIMHAM GRIT

The earliest record of strata belonging to the group considered in this Chapter is of the Cayton Gill Beds, by Tute (1868), who named them after Cayton Gill near Ripon. This term was subsequently used by Fox-Strangways (1874) in his memoir on 1" O.S. 93 N.W. who also termed these beds the 'Shell Bed' on the Geological Survey map. The first work on the strata between the Lower Follifoot and First Brimham Grit actually carried out in the present area was the survey of 1" Geological Survey Sheet 97 S.E. (New. Ser. 51) by Dakyns and others. This mapping involved the recognition of a 'Shell Bed', which is the Cayton Gill Shell Bed of the present account and in addition, several other horizons between the First Brimham Grit and the Lower Follifoot Grit. Dakyns (1891) recorded the occurrence of the Shell Bed in the present area and noted that it was a useful horizon for correlation purposes. The mapping carried out by Dakyns and his colleagues is partially correct, but important errors have been incorporated in the published maps in the area where the Limley Fault crosses Low Ash Head Moor. The chief mistake is the mapping of the outcrop of a fine grained sandstone, here referred to as the Libishaw sandstone, into the outcrop of a coarse pebbly sandstone which is the First Brimham Grit. This threw out the correlation of the uppermost three divisions of the succession dealt with in

this chapter. This error has never been rectified in print, though Bisat (personal communication) had early recognised it.

Bisat (1914) furnished the only original account of the beds considered in this chapter. This contribution is especially useful on account of the long faunal lists determined by Hind, which included large faunas from the Cayton Gill Shell Bed and the Libishaw sandstone. Bisat called all beds the Lower Follifoot Grit of the present work and a horizon 55' below that here termed the First Brimham Grit, the 'Cayton Gill Beds'. This term is restricted in the present account to the Shell Bed, in view of the fact that the various authors who have worked on this horizon since Bisat have given this term a much more restricted connotation. In the present work this is restricted yet further, to a single bed of sandstone, in order to avoid confusion in correlation with other areas.

Bisat considered that the lowest beds, clay shales with Lingula, rested on the underlying Grit with an erosive base (this is the contact of the Lower Follifoot Grit and the Ganister Beds of the present work). He also noted the occurrence of ganisteroid sandstones in the vicinity of Great Haw, which is confirmed in the present work. Bisat records two Shell Beds, the lower of which he regarded as the more persistent (these are the Cayton Gill Shell Bed and Libishaw Sandstone of the present study). The vertical section appended to this paper is based largely on the records of the reservoir trenches and the Roundhill borehole. The record of this borehole is regarded

as being inconsistent with the observed geology, and indeed it is impossible by examining the section given of Table 1 by Bisat to determine which bed is his Upper Shell Bed (the Libishaw Sandstone of the present treatment). This is because the Roundhill borehole log records no thick sandstone, but chiefly shale, at the horizon where on all reasonable supposition a sandstone about 40' thick (the Libishaw Sandstone) occurs.

Tonks (1925) added little to the previous knowledge of the beds discussed in this chapter, but he incidentally confused the connotation of the term 'Cayton Gill Beds' (Fig. 8). Whereas Bisat (1914) used the term 'Cayton Gill Beds' to embrace strata between the top of the Lower Follifoot Grit of the present account and the base of the Capelshaw Shales of the present account, Tonks used this term differently to exclude the Ganister Beds at the base of the sequence and appears to have included the Capelshaw shales which were specifically excluded from the Cayton Gill Beds by Bisat (1914). In addition to this confusion, the Upper Follifoot Grit of areas to the south is shown in the present work to be a time equivalent of part of the Ganister Beds, which were strata included in the Cayton Gill Beds by Bisat. Moreover, the Libishaw sandstones of the present account, considered to be part of the Cayton Gill Beds by Bisat, and it appears, by Tonks, are shown to be correlates of the Libishaw sandstone of ground to the south, this being a horizon which has never

been referred to the Cayton Gill Beds elsewhere (vide Hudson, 1939, Jones, 1943, Dunham and Stubblefield, 1945).

It is owing to these nomenclatorial troubles that the term Cayton Gill Beds has been discarded save in reference to the lower shell bed of Bisat which is here referred to as the 'Cayton Gill Shell Bed', or more simply as the 'Shell Bed'. The Upper Shell Bed of Bisat is now called the Libishaw sandstone. The clay shales which made up the lowest part of Bisat's Cayton Gill Beds' are here referred to as the Ganister Beds, and their partial time equivalence with the Upper Follifoot Grit of country further South is recognised for the first time, on the basis of the discovery of Homoceras beyrichianum in these beds. This affords a correlation with a band with the same goniatite in the shales between the Upper and Lower Follifoot Grits of areas further south (Hudson, 1939, Hudson et al., 1938, Jones, 1943, Stephens et al., 1953).

Whilst the terms 'Libishaw Sandstone' and 'Shell Bed' are attributed to the Geological Survey, the terms Libishaw Shales and Capelshaw Shales originated with Hudson (1939). These terms are employed in the present account on the basis of fairly certain correlations put forward on lithological and faunal grounds and since confirmed by the work of A.T. Thompson in the ground immediately to the south of the present area (personal communication). In addition to terms already in the literature, the name 'Ganister Beds' was coined for strata which are correlated with the Follifoot shales and Upper Follifoot Grit of

areas further south. This is in view of the fact that the Upper Follifoot Grit is virtually defunct in the present area, and the beds which represent this and the Follifoot Shale are mappable, single lithological unit. The name 'Agill Sandstone' is also new. It appears that the Geological Survey mapped this horizon in conjunction with the Cayton Gill Shell Bed which is here regarded as a distinct, mappable lithological unit separated from the Agill sandstone by a shale which quite often forms a feature.

Stratigraphy

These beds comprise approximately 205' of strata which appear to thin to about 30' to the north. As a whole, measured sections are rare since they tend to form extensive plateaus and unexposed slopes below the outcrops in the Brimham Grits. The several units which make up the sequence have been dealt with together because they show, broadly speaking, a general lithological similarity in that they include repetitions at various levels of soapy shales, shells, fine grained sandstones, fine grained unfossiliferous sandstones and ganisters. A sequence of beds can be recognised over much of the area, where the drift cover is absent, but subdivision is impossible in Lower Colsterdale and in the vicinity of Ellington and Ellingstring owing to drift cover with consequent lack of exposures. The available evidence appears to suggest strongly that the beds between the Lower Follifoot and First Brimham Grit have thinned most markedly to the north, though it is

unfortunate that exposures are so limited as to make the manner of this thinning a matter for conjecture. The sequence of strata which has been recognised in the district around Masham Moor is:

FIRST BRIMHAM GRIT
Capelshaw Shales
Libishaw Sandstone
Libishaw Shales
Agill Sandstone, resting on shales
Cayton Gill Shell Bed, resting on shales
Ganister Beds
LOWER FOLLIFOOT GRIT

The area of Masham Moor where this sequence is most readily established shows an intricate pattern of dipslope outcrops, whilst further evidence for determining the stratigraphic succession comes from Agill Beck and Arnagill, in the Pott Beck drainage.

The Ganister Beds are so named in the present Thesis owing to the fact that this series of beds includes frequent beds of ganister. This division is in part a time equivalent of the Upper Follifoot Grit of the area to the south, as is shown by the occurrence of the Homoceras beyrichianum fauna near the base of the group.

The group varies from 17' to about 70' in thickness and consists of soapy shales with chalybite nodules together with ganisters and compact, fine grained sandstones. These ganisters are typically compact, blocky, irregularly weathering fine grained quartz sandstones with Stigmaria sp. abundantly developed. Locally the group appears to thicken and fine grained micro-current bedded sandstones are developed which

are possibly the approximate equivalents of the Upper Follifoot Grits of the ground to the south of the present area.

The Cayton Gill Shell Bed appears to overlie shales always, and consists of about 8' of fine grained, compact quartz sandstone with, quite frequently, a basal stratum of worm chewed siltstone carrying glauconite. A prolific and distinctive fauna is obtained from weathered material on the outcrop of the Shell Bed. Brachiopods and pelecypods make up the bulk of the genera, but gastropods are locally abundant.

The Agill Sandstone is so named after its outcrop in Agill, which is one of the very few exposures at this horizon. It is distinguished from the Cayton Gill Shell Bed by a coarser grain size and general absence of a fauna. This sandstone is usually separated from the Shell Bed by a shale parting which is seen in very occasional exposures and also locally forms a feature. This stratigraphic name is new to the literature. The Agill sandstone appears to rest usually on about 10' of shale, but locally it appears that it can lie immediately on the Cayton Gill Shell Bed. The sandstone is fine grained, but is distinctly coarser than the Shell Bed and is only locally fossiliferous. The preservation is inferior to that seen in the Shell Bed and the fauna apparently is more restricted, consisting chiefly of pelecypods. Blocks from this horizon have yielded what appears to be the only known British Upper Carboniferous ophiuroid.

The Libishaw Shales are seldom exposed, but very often make

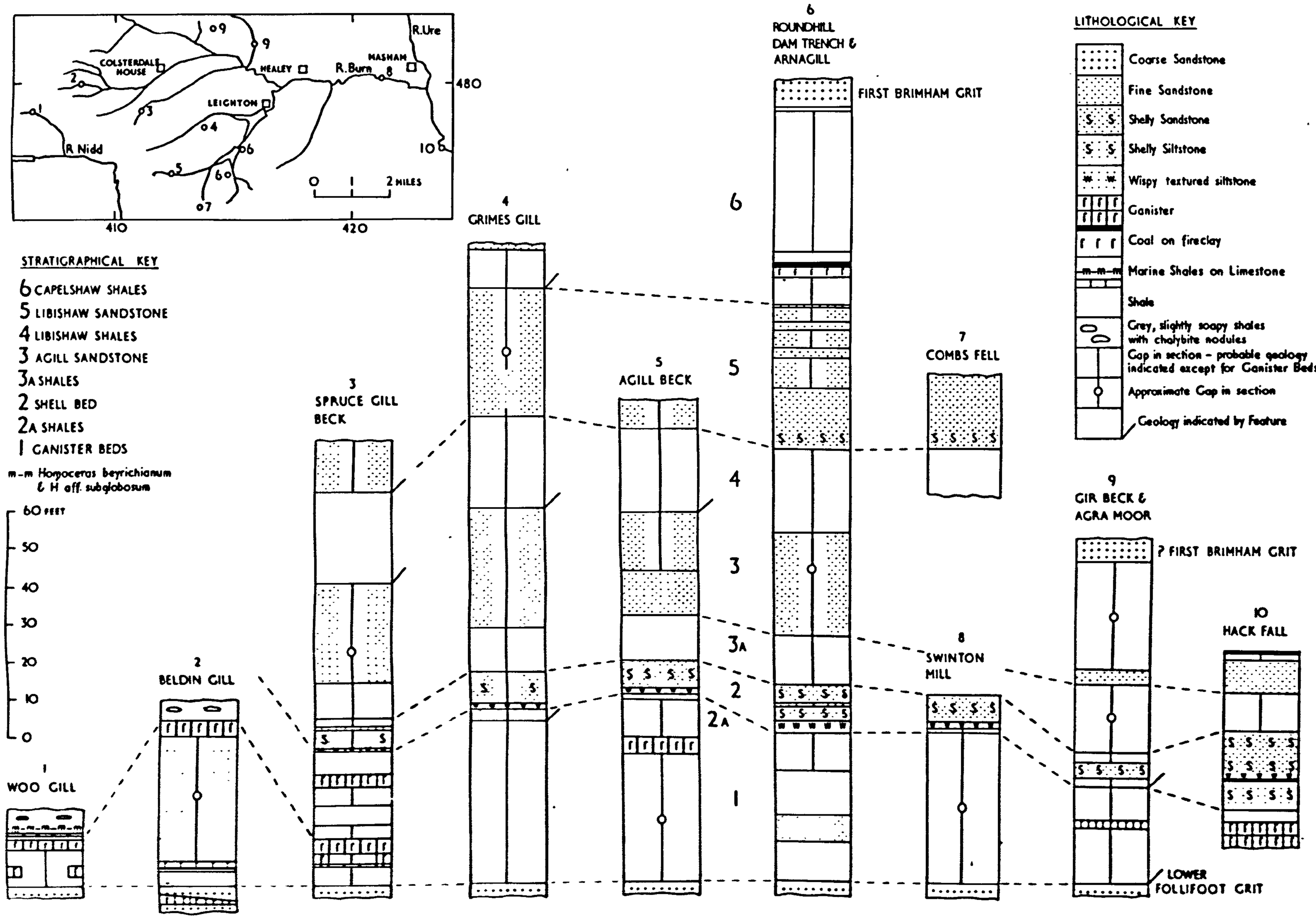
a distinct feature. They appear to be unfossiliferous where seen and consist of greenish non-soapy shales and locally soapy shales, but without any trace of a fauna. A thickness of 25' is a good average for this horizon, but locally these beds appear to be somewhat thicker.

The Libishaw Sandstone tends to form characteristic plateaux and is usually a fine grained, feldspathic rock without fossils. Whilst it is difficult to get an accurate estimate of its thickness, it appears to be about 40' thick to the south of the R. Burn; to the N. of this river it is possible that this horizon is thin or absent. In the S.E. of the area the lower beds tend to be darker in colour and more compact; these beds yield a characteristic fauna of brachiopods with some pelecypods.

The Capelshaw Shales are inadequately exposed and in Arnagill form a sequence which is about 52' thick. The few small exposures in these beds show they include shales of soapy type with associated coals, siltstones and a possible fossiliferous sandstone horizon. The mapping of the strata between the Lower Follifoot and First Brimham Grits has involved special techniques owing to lack of exposure. Weak features, together with copious use of blocks of rock in the soil and in stream courses without exposure enabled mapping of the lowest three divisions to be effected, using the vital evidence furnished by a small number of stream sections showing exposures in these beds. The Libishaw Sandstone and Shale, in contrast with the beds

PLATE 35

Comparative sections in the beds between the Lower Follifoot and First Brimham Grits.


COLSTERDALE HOUSE
HEALEY
R.Burn
MASHAM
R.Ure
LEICHTON
R Nidd
480
410
420
0 1 2 MILES
STRATIGRAPHICAL KEY
6 CAPELSHAW SHALES
5 LIBISHAW SANDSTONE
4 LIBISHAW SHALES
3 AGILL SANDSTONE
3A SHALES
2 SHELL BED
2A SHALES
1 GANISTER BEDS
m-m Homoceras beyrichianum & H aff. subglobosum
60 FEET
50
40
30
20
10
0
1 WOO GILL
2 BELDIN GILL
3 SPRUCE GILL BECK
4 GRIMES GILL
5 AGILL BECK
6 ROUNDHILL DAM TRENCH & ARNAGILL
FIRST BRIMHAM GRIT
7 COMBS FELL
8 SWINTON MILL
9 GIR BECK & AGRA MOOR
? FIRST BRIMHAM GRIT
10 HACK FALL
LOWER FOLLIFOOT GRIT
LITHOLOGICAL KEY
Coarse Sandstone
Fine Sandstone
Shelly Sandstone
Shelly Siltstone
Wispy textured siltstone
Ganister
Coal on fireclay
Marine Shales on Limestone
Shale
Grey, slightly soapy shales with chalybite nodules
Gap in section - probable geology indicated except for Ganister Beds
Approximate Gap in section
Geology indicated by Feature

beneath them, are associated with well defined features whenever these rocks occur on the plateau, The sandstone shows a strong tendency to form cake-like hills with well defined bounding features at the base of the shales. In contrast, when these rocks form part of a continuous hill slope they usually show no mappable feature. The Capelshaw Shales normally occur on unexposed slopes below the outcrops in the First Brimham Grit; they also form three outliers bounded by mappable features in the Pott moor area, which do not however show good exposures.

The Ganister Beds

The name 'Ganister Beds' has been selected to include strata between the Lower Follifoot Grit and the shales immediately underlying the Cayton Gill Shell Bed. The series is not very clearly defined at the base owing to lack of exposure, but appears to be a readily recognisable horizon everywhere excepting the S.E. fringe of the present area where a sandstone occurs a very short distance above the Lower Follifoot Grit. To the north, however this Grit is only very sporadically developed and cannot be recognised as a mappable horizon. Thus it has been convenient to include beds of certain H zone age with strata which may possibly include the lowest part of the R_1 subzone to provide one mapping unit of consistent facies, namely a series of shales with thin impersistent ganisters and fine grained quartz sandstone.

Only two sections give a measurable sequence through the whole of this group; these are given first, before the systematic description of this horizon. The section in Spruce Gill (112787) (Plate 35) is a dip stream section and thus the overall measurements are somewhat unreliable, though an approximate thickness of 29' is here assigned to this series:

-	shales below the Cayton Gill Shell Bed
3'	ganisteroid sandstone containing <u>Stigmaria</u> sp. in the top stratum
5'	approx. gap
5'	rotten, green mudstone, apparently without fossils
3'	approx. gap
-	decayed blue shale (this is at the approximate horizon of a band containing <u>Homoceras beyrichianum</u> in Woogill, Nidderdale)
1'6"	blocky, massive compact ganister with plant remains
2'6"	well jointed, pale ganisteroid medium grained, compact quartz sandstone with small voids which may have carried organic remains
3'	gap, includes large slabs of ganisteroid sandstone, which probably occurs here with perhaps a thin shale
6"	dark blue, somewhat ganisteroid sandstone
5'	approx. gap
-	Follifoot Grit

The section in the Roundhill Dam Trench (152774) (from ms. plan kindly loaned by Mr. W.S. Bisat) shows the following section:

10'	gap to shell bed, of which about 4' may be referable to the Ganister Beds
12'	shale
7'	yellow sandstone (very broken)
10-14'	shale with signs of an erosion channel at the base
-	Lower Follifoot Grit

The total thickness given by this section is thus comparable with that measured at Spruce Gill (Plate 35).

The remaining exposures in the Ganister Beds in the present area provide partial sections of the group and are here described systematically from the various parts of the complex outcrop which they make.

Great Whernside - A small outlier occurs on beds above the Lower Follifoot Grit on the summit plateau of Great Whenside, south of the fault which crosses the summit of the mountain (around the point 740004). The Ganister Beds appear to consist chiefly of shales making a plateau-top veneer of probably less than 10' of beds. A section at 005740 shows:

-	blocks of thin bedded ganister
5'	clay with mudstone fragments (presumably a decayed mudstone)
6"	ganister
6"	mudstone
-	Follifoot Grit, showing a slump structure on its upper surface which was not eroded prior to the deposition of the superincumbent beds.

The adjacent plateau carries ganister blocks and clay ironstone fragments. The southen part of the platform around 004738 appears to be in 2' orange fireclay which probably occurs immediately above the Lower Follifoot Grit, and may be at the horizon of the clay with mudstone fragments cited above. The highest beds of Great Whernside appear to be at almost the identical stratigraphic level as the band which yielded H. beyrichianum in Woogill, Nidderdale.

Clay and ganister fragments occur over an area which is 150 yd. S.E. of the mapped southern limit of the Cayton Gill Beds. It is possible that these beds are in a depression in the top of the

Lower Follifoot Grit, but the relations are not clear and these traces are treated as redistributed debris from the area to the N.W. where beds of this facies are known to occur in situ.

Area round Woo Gill, Nidderdale - the area south of Great Haw is poorly exposed and the top of the Ganister group is not here mappable. The best sections occur in Woo Gill, but a major gap occurs in the exposures. The Ganister Group is apparently well over 40' thick, which is substantially in excess of the thickness observed at Spruce Gill and in the Roundhill Trench. The lowest beds of the series provide the following measured section (066788) (Plate 35):

-	gap in section
5'	soapy, fissile ferruginous shale without fossils, but with a few unfossiliferous chalybite nodules 3' above the base
2"	black shale with lenticular fragments of hard, brittle shale, splitting with difficulty, containing Homoceras beyrichianum (Haug) and which also yielded a single gingerbready weathered limestone nodule with H. cf. subglobosum Bisat
6"	orange mud - almost certainly derived from an original limestone
6"	grey calcite mudstone, weathering as a jointed pavement in the stream. It has weathered to a red mud on the surface and shows rounded edges. Grains of quartz of diameter about 10 microns occur scattered throughout the rock, together with disseminated limonite. Fossils are seen, but do not weather out, occurring as cross sections indicative of crinoid ossicles, gastropods, pelecypods and possible brachiopods
1'	approx. gap
3'	tough, greenish fine grained, pale grey ganisteroid quartz sandstone with scattered mica plates, showing bedding planes with plant remains
10'	approx. gap with ganister blocks
-	Lower Follifoot Grit.

Upstream from the top of the beds seen in the present section a large gap occurs in the exposures, but numerous blocks of fine

grained sandstone occur under the peat. Though there is no evidence to show that they are a thick formation, it is convenient to regard these beds as the approximate equivalent of the Upper Follifoot Grit which overlies strata with Homoceras beyrichianum elsewhere (Hudson, 1939 Jones, 1943). The highest horizons seen in the Ganister Beds are 3' green mudstone underlain by 6" fire-clay and overlain by 2' slightly soapy, blue mudstone; this exposure is in the headwaters of Woo Gill at 062788.

Carle Fell - On Carle Fell, which is the most westerly part of the main outcrop on the beds above the Lower Follifoot Grit, it has not been possible to map separately the Cayton Gill Shell Bed and the Ganister Beds. Blocks of rock typical of both of these divisions occur on the summit of the fell.

Loose blocks of a conglomerate are seen at the head of Tops Gill (057780) under peat. These occur together under blocks of ganister and appear to form the lower part of the Ganister Beds. The conglomerate contains quartz pebbles upto 1 mm. in diameter in a fine grained matrix of detrital quartz, and carries carbonised plant remains. It is possible that this rock is indicative of the presence of the depositional break noted by Bisat at the base of the Ganister Beds in the Roundhill Dam Trench, though the apparent absence of erosion at this level at one locality on Great Whernside has already been noted.

The most northerly tributary of Arkleside Gill (054787) shows a section in 9' greenish silty mudstone with a fauna of brachiopods and crinoid columnals. Inclusive of what are apparently rotten

silty mudstones, these beds appear to be 14' thick here and appear to be faulted against a small exposure of 1' greenish sandstone resting on 6" mudstone. On the mapping evidence these rocks are interpreted as belonging to the Ganister Beds, let down between two parallel faults of small throw, though it must be stressed that no comparable fossiliferous mudstones have been seen elsewhere at this stratigraphic level.

The drainage ditch on the summit of Carle Fell shows a mixture of ganister blocks and fragments characteristic of the Cayton Gill Shell Bed containing Schizophoria hudsoni. This confusing combination of blocks characteristic of the Shell Bed and the Ganister Beds is repeated on the edge of Carle Fell overlooking Coverdale (057795). Due to this mixture of fragments derived from two lithological divisions elewhere separately mappable, they have not been divided by a geological line, to the west of Great Haw and Little Haw.

The tributaries of Lead Up Gill show blocks of ganister and compact flaggy sandstone. The presence of the peat ponded lakes of Woogill Tarn and Coverdale Tarn suggest that they are floored ultimately by shaly beds which probably belong, at least in part, to the Ganister Beds.

Plateau around Little Haw - North of Little Haw the Ganister Beds occur over an area of plateau. Blocks of ganister and fine grained sandstone are seen in the upper part of Barnley Beck, in and near Backstone Gill and in a protruberance of the outcrop on Colsterdale Moor. The lithological types seen are

ganisteroid sandstones with micro-current bedding often shown, together with typical ganisters which have yielded specimens of Stigmaria sp. The tributaries of Long Gill yield blocks of ganisteroid sandstone and compact, fine grained, flaggy sandstone. It is thought that a considerable part of the succession is here, as elsewhere, shale.

Beldin Gill and Steel House Gill - The lowest beds of the Ganister Beds are clearly exposed in Beldin Gill (093799) (Plate 35) where the following section is seen:

2'	soapy shale chips
1'	gap
5"	dirty coal
6"	ganisteroid sandstone
4'	grey fireclay
5'	ganisteroid sandstone and rotten sandstone (Lower Follifoot Grit)

These beds are closely followed upstream by 1' greenish ganisteroid sandstone with Stigmaria sp. Further upstream, blocks of ganisteroid sandstone with rootlets are abundant; these beds appear to belong to a local thick development of sandstone within the Ganister Beds and blocks from this horizon are abundant immediately to the north of Beldin Gill, on Bracken Hill.

The highest beds seen in Beldin Gill occur in a measurable section:

3'	soapy, fissile blue shale
2"	layer of chalybite nodules
3'6"	soapy, fissile blue shale
4'	massive, blocky, irregularly weathering ganister with Stigmaria sp. which in hand specimen is a compact fine grained, golden coloured quartz sandstone with pockets of limonite.

Yet further upstream blocks in the bed of the watercourse are ganisteroid sandstones and compact flaggy sandstones which are no doubt derived from the highest part of the Ganister Beds. On the interfluve between Beldin and Steel House Gills micro-current bedded sandstones with occasional rootlets occur in abundance and appear to belong to the same horizon responsible for the numerous blocks on Bracken Hill, to the north.

The exposure in Steel House Gill is incomplete. The lowest beds appear to be 1'6" of ganister resting immediately on the Lower Follifoot Grit whilst further upstream at different levels there are seen 10' blue, soapy shale with chalybite nodules and 5' grey, slightly soapy shale (the latter is at a slightly higher stratigraphic level). At a possibly still higher level a little more soapy shale with chalybite nodules occurs. The total thickness of the Ganister Beds is here probably about 70', a thickness greatly in excess of that observed in Spruce Gill to the E., whilst soapy shales are much thicker than at this latter exposure. The upper beds are not well exposed in Steel House Gill, but quantities of compact flaggy sandstone and ganister blocks occur, the latter being massive and irregular weathering with Stigmaria sp.

Thorny Grane Gill to Towler Hill - An isolated exposure in Thorny Grane Gill (099788) in 4' medium grained, massive sandstone appears on mapping evidence to belong to the Ganister Beds, but is not lithologically like most horizons seen in this group. On Gollinglith Fleet, compact flaggy sandstone and ganister blocks occur in channels cutting through the peat cover; a single

exposure shows 1' massive, blocky ganister with Stigmaria sp. (108787).

The section in Spruce Gill has already been considered on account of the completeness of its exposure.

Between Spruce Gill and Towler Hill the outcrop is poorly exposed but ganister blocks occur sporadically along the strip of outcrop on the S.E. side of Spruce Gill. 1' massive, irregular weathering ganister with large plant remains is seen at 118787, whilst blocks of ganister and ganisteroid sandstone occur on Hambleton Litch. W.N.W. of Towler Hill (at 141799) a compact ganisteroid fine grained quartz sandstone with rootlets forms an exposure in a pasture.

Grimes Gill and the Pott Beck drainage - Strata referred to the Ganister Beds are seen adjacent to the line of a small fault which crosses Grimes Gill (125776). 2' pinkish very fine grained sandstone with a little mica and containing ossicles are here exposed in such a position as to make it extremely unlikely that these rocks should belong to the Shell Bed. To the N.E. of this point the outcrop on the Ganister Beds shows abundant blocks of ganisteroid sandstone. To the E. of Grimes Gill these beds form a marked feature with some boulders of massive, medium grained sandstone which are not usually found in this division, but may be taken to be possibly the local equivalent of the Upper Follifoot Grit.

Traces of the Ganister Beds are rare at the end of the spur near Pott Hall, but are more numerous on the outcrop near Roundhill

Reservoir. At 145768 2' compact, flaggy sandstone are exposed in the stream draining from Summer Side. Ganister blocks persist along the hillside round the N. and S. side of Agill Beck. On the right bank of Agill Beck (128762) 5' thin bedded yellow flaggy sandstone with plant remains outcrops. At a higher stratigraphic level chips of black, brittle fine grained shale occur with traces of organisms. Still higher in the succession soapy grey shale chips are seen and above these are the highest beds which directly underlie the shales below the Shell Bed; these are 4' pale ganisteroid very fine grained sandstone with traces of carbonised plants overlain by 1' yellow sandstone.

At Roundhill (149767) 3' of blocky siliceous sandstone occur just above reservoir level. These beds appear to be here at least 8' thick, judging by the appearance of the debris on the hillside. This horizon is probably at the same level as the highest strata of the Ganister Beds seen in Agill Beck.

The section in the Roundhill dam trench has already been detailed at the beginning of the present section. Apart from fragments of ganister and mudstone at one locality on the E. side of Leighton Reservoir, indications of the Ganister Beds are lacking in the lower part of the valley of Pott Beck.

Exposures in the N. of the valley of the R. Burn - 4' of cream sandstone outcrop in the R. Burn downstream from Swinton Mill (211802) which are stratigraphically below the Shell Bed and are assumed to belong to a portion of the Ganister Beds.

On the N. side of the valley of the R. Burn, no undoubted strata belonging to these beds are seen except in Ger Beck (159819)

where the following section occurs:

-	probable shales below the Shell Bed
1'6"	yellow, somewhat ganisteroid sandstone
6"	greenish siltstone
15'	unexposed
-	Lower Follifoot Grit

The total thickness of the Ganister Beds does not appear to exceed 17' at this point, which is a substantially smaller thickness than is seen in the ground to the S. 450 yds. further upstream a section in the same beds shows 2' ganister with carbonaceous fragments overlying a 1'6" ganisteroid sandstone with a gap of 4' between these beds.

The plateau of Agra Moor shows blocks of ganisteroid sandstone with some Stigmaria casts scattered along the outcrops in the Ganister Beds. The slopes of Tranmire Hill show blocks of compact, flaggy sandstone and of ganister which are, no doubt, derived from the outcrop of the Ganister Beds, here obscured by a light cover of drift.

An exposure in Healey Corn Mill Quarry (179806) is probably at this horizon; the beds exposed are:

11'	flaggy ganisteroid, fine grained quartz sandstone with some plant remains
1'	grey mudstone
3'	ganisteroid sandstone

It is conceivable that beds at this exposure belong, in part to the Shell Bed, but in the absence of any fauna, this seems unlikely.

South of the Limley Fault - The Ganister Beds are poorly exposed on the moors E. of Lofthouse, but appear to include more arenaceous horizons than in the outcrops to the north. West of

Lofthouse Level (108751) ganisteroid sandstones are seen shortly above the Lower Follifoot Grit. They appear to rest immediately on the L. Follifoot Grit 160 yd. S. of Thrope Edge shooting box, but further south their immediate contact with the grit cannot be proved. The thickest exposure in this ganisteroid sandstone is in a quarry W. of Lofthouse Level (107748). Indications of clay ironstone chips occur further up hill; chalybite nodules are typically associated with soapy shales immediately above the H. beyrichianum band and it is thus possible that the ganisteroid sandstones which appear to underlie them on the hill-side are here equivalent to the lowest ganisters of the section in Woogill, under the goniatite horizon. The highest beds seen at Lofthouse level appear to be massive medium grained sandstones which occur as huge boulders on the moor top (108747). Though it is possible that they were transported into place by high level ice, it is more probable that they are a local development of the Upper Follifoot Grit.

The hill side E. of Backstone Gill shows a persistent feature formed by a compact, fine grained ganisteroid sandstone, present either as numerous blocks or in a small cliff. This horizon is apparently at the level of the lower part of the Ganister Beds and is assumed to be equivalent to similar strata seen above the Lower Follifoot Grit at Lofthouse Level. Though the exact horizon of these beds is uncertain they appear to be at too low a level for the Upper Follifoot Grit.

Hack Fall - The section in the Hackfall Gorge is outside

the bounds of the present area, but was examined for the purpose of obtaining additional information about the Shell Bed. The Ganister sandstone are seen which appear to be overlain by the shales which underlie the Cayton Gill Shell Bed.

Cayton Gill Shell Bed and underlying shales

The Cayton Gill Shell Bed appears to persist throughout the area. It is seldom exposed, but a few good sections occur. The section in Agill Beck (123762) (Plate 35) is the most complete and is quoted first as a characteristic section:

-	soapy, grey shale
1'	ochreous, rotten weathering fine grained sandstone, compact when fresh and yielding an abundance of <u>Schizophoria hudsoni</u> George, preserved as internal casts
6'6"	yellow, well jointed flagstone with no fossils visible, probably due to the fresh state of the rock - Cayton Gill Shell Bed
1'3"	thinly and irregularly bedded silty flagstones
10"	fine grained, streaky sandstone, apparently partly chewed by annelids and carrying grains of glauconite. Limonitised voids representing organic fragments occur.
10'	gap - probably shale
-	Ganister Beds

The tripartite division into shelly sandstone, basal worm chewed beds and shale appears to be characteristic of the strata at this level throughout the present area.

<u>Carle Fell and the moor around Little Haw</u> - The Shell Bed is not mappable as distinct from the Ganister Beds W. of Great Haw, but indications of its presence exist on the summit of Carle Fell.

At 062789, in Woogill, large slabs of sandstone 6" thick occur with some shelly remains. These presumably belong to the

Shell Bed. The ditch on the boundary fence on Carle Fell (058788) shows blocks of ganister apparently belonging to the Ganister Beds and also blocks with abundant Schizophoria. Blocks under peat on the W. edge of Carle Fell at 057796 include pieces of sandstone with Schizophoria hudsoni, preserved as internal casts in a matrix of fine grained quartz sandstone. The presence of these blocks at the plateau edge shortly above the Lower Follifoot Grit raises difficulties, since the upper reaches of the western tributaries of Lead Up Gill show only compact flaggy sandstone and ganister fragments, but none of the Shell Bed. It is assumed therefore that the distinction between Shell Bed and Ganister Beds is here difficult to make for unknown reasons.

On the moor N.W. of Little Haw the Shell Bed forms a slight feature which is apparently displaced by the Scrafton Moor fault, and carries on it blocks of worm chewed sandstone and fine grained flaggy sandstone with Derbyia gigantea. The outcrop can be traced south by means of blocks in channels cutting through the peat and pieces of shelly sandstone occur in the headwaters of Beldin Gill and Steel House Gill. At 088791 blocks showing wispy bedding occur, and these like the worm chewed blocks noted N.W. of Little Haw no doubt belong to the basal worm chewed portion of the Shell Bed seen in situ in Agill Beck. No trace of the shales below the Shell Bed was seen in the area round Little Haw nor was the Shell Bed seen in situ.

Thorny Grane Gill to Grimes Gill. The headwaters of Thorny Grane Gill (094786) show numerous blocks with Derbyia gigantea

preserved in a fine grained sandstone, characteristic of the Cayton Gill Shell Bed.

Spruce Gill (109784) (Plate 35) shows the following section:

1'	pale, flaggy fine grained quartz sandstone with *Derbyia gigantea*
5'	approx gap, presumably Shell Bed
1'	greenish, worm chewed fine grained sandstone with a few glauconite grains
5'	rotten shale
1'	approx gap
-	Ganister Beds

A comparison of this section with that of Agill Beck (see ante) shows great similarities - the threefold division of Shell Bed, worm chewed beds and underlying shales again occurs, and the shales are accessible for examination here (they were inferred at Agill Beck) . They are seen to be non-soapy shales of a grey-blue colour, becoming more blue downwards and apparently without a fauna, though it is interesting to note that Hudson (1939) records a lowest R_1 assemblage from this approximate horizon in the Simonseat area, south of the Rigid Block. This has not been met with during the present investigation and is here thought to be absent.

East of Spruce Gill shelly sandstone blocks occur commonly. Together with features whose base is on the top of the Ganister Beds they have been used as a basis for mapping the Shell Bed on the intricate dip slope outcrops between Sourmire Moor and Towler Hill. Actual exposures do not exist however, but blocks are so numerous at surface that quite extensive fossil collections

have been made from loose material on the outcrop of the Shell Bed.

Rubble in Grimes Gill (125776) has yielded shelly sandstone and worm chewed sandstone blocks representative of the Shell Bed and its basal worm chewed member. Near Grimes Gill (at 139783) the Shell Bed and its underlying shales form a distinct feature - this shows 1' of worm chewed silty flagstone in situ at 137781 which is presumably the lowest 1' of the Shell Bed, blocks of which occur on the feature at points immediately above the worm chewed bed.

Valley of Pott Beck - Continuing round the spur from Pott Hall, the next exposure seen is at 144769 where 6' yellow, flaggy, shelly sandstone are seen. Nearby, streams show debris in rock of the same lithology. Shelly sandstone debris occur intermittently around the sides of the valley of Agill Beck where the exposure described at the beginning of this section occurs.

The Shell Bed outcrops at the head of Roundhill Reservoir where the following section occurs (151764) (Plate 35):

6"	blocks of yellow, fine grained soft sandstone with *Schizophoria hudsoni*
2'6"	yellow, compact fine grained sandstone, weathering ochre and showing shelly remains only in the deeply weathered fallen blocks
2'	pale yellow, fine grained sandstone
1'	gap
1'6"	pale ganisteroid sandstone with undulating bedding planes
2'	compact, fine grained sandstone with some glauconite grains and with organic traces in pockets infilled with kaolinite
3'	siliceous, platy, banded siltstone, weathering blocky with shelly remains and wispy structures attributed to annelids

Though the shales below the Shell Bed are not here seen, they must practically underlie the lowest beds in this section, which show very clearly the worm chewed lower part of the Cayton Gill Shell Bed.

The Shell Bed was encountered in the Roundhill Dam trench where 4' of beds appear to be assigned to this horizon by W.S. Bisat. Fox Strangways records this as 5'9" and shows it overlying 16' of shales, a portion of which probably belong to the shales which normally come between the Ganister Beds and Shell Bed. Occasional fragments of the Shell Bed occur in the outcrops N.E. of Roundhill on the E. side of the valley of Pott Beck. Blocks of Shell Bed occur W. of Broadmires farm, where this horizon forms a localised feature.

Beds which are probably the Shell Bed, but are too fresh to yield a fauna, are exposed in Linders Gill (181799) where 5' of blocky, compact sandstone are seen and also 2' of compact flaggy sandstone with plant remains and some wispy bedding.

An exposure near Swinton Mill (212802) (Plate 35) shows the following beds:

7'	fine grained sandstone with a pelcypod fauna; fossils are hard to extract because the rock is fresh (no top seen)
1'6"	sandstone digested by annelids
2'	worm chewed platy siltstone (no base seen)

<u>Outcrops North of the River Burn</u> - The Shell Bed forms a ring shaped outcrop on Agra Moor, with blocks occurring in quantity at several points. North of Agra Moor Top fragments

of fine grained quartz sandstone with numerous shell casts are abundant. These include pieces of a layer which is made up only of internal casts of Schizophoria hudsoni. In Ger Beck the Shell Bed forms a feature (821159) where 4' of shelly, yellow limonitic sandstone are seen. 8' of unexposed beds between the feature with the Shell Bed and the highest exposed Ganister Beds may represent the thickness of the shales which normally occur at this horizon below the Shell Bed.

Other isolated occurrences are seen N. of the R. Burn. The E. slopes of Tranmire hill are thinly mantled in drift and show blocks of the Shell Bed which are no doubt obtained from a nearby exposure. An exposure in Ellington Village (195834) shows a portion of the Shell Bed involved in faulting. Here 3" of pinkish sandstone with ochreous shell casts, comprising a brachiopod fauna, are exposed. The rocks splits up into 3" slabs which are characteristic of the several localities in the present area where loose blocks of the Shell Bed can be collected. However, where the Shell Bed occurs in situ it usually presents a massive appearance unless deeply weathered. An exposure 30 yd. from the one above shows 1'3" of compact grey siltstone which contains shelly debris in a wispy matrix. It is possible that these beds belong to the basal siltstones which underlie the Shell Bed elsewhere, but at this locality exposures are fragmentary and involved in faulting.

Exposures involved in faulting in Swinney Beck are unfortunately too scattered to show their interrelations. Strata which

resemble the Shell Bed are exposed in Dawsons Lane Plantation (205817) where the following section is seen (the beds include a limestone, the only record in proximity to the Shell Bed in the present ground, but with parallels at Sawley and Turwath Bridge (Jones, 1943)).

3'	of slopes with limestone blocks probably almost in situ. The limestone is a grey crystalline rock with traces of brachiopods
2'	shelly, fine grained, compact sandstone, resembling the Cayton Gill Shell Bed
6"	blue siltstone with a high proportion of glauconite
1'	shelly fine grained sandstone (base not seen)

75 yd. upstream from this point 2' of pale, much jointed fine grained sandstone are seen close to a fault. Beds 60 yd. further upstream adjacent to this fault and on the opposite (west) side of it are 5' of pale blue silty shales carrying a brachiopod-pelecypod fauna with lingulids. It is to be regretted that the position of this exposure relative to the horizon of the Shell Bed is unknown, though there is a little mapping evidence to suggest that these rocks are low in the sequence. The fauna of an exposure on Carle Fell (see ante, under 'Ganister Beds') is more restricted, but the lithology is fairly similar; namely a rather pale, silty shale. The exposure on Carle Fell is somewhat puzzling as well, since the occurrence of a fossiliferous horizon at the level of the Ganister Beds was not parallelled with certainty elsewhere, except for some sponge spicules and crinoid ossicles in blocks from the Masham Moors. Thus it is possible that either or both of these exposures are more properly

associated with the Shell Bed rather than the Ganister Beds and find their parallels beneath the Main Shell Bed at Greenhow and Simonseat where similar shelly siltstones occur.

South of the Limley Fault - At Birky Bank on High Ash Head Moor (137751) 8' of the Shell Bed are exposed. Here it is a blocky, soft, yellow sandstone forming a localised feature overlooking the Low Ash Head Moor landslip.

On the E. side of Cockle Hill on the slopes of Nidderdale the Shell Bed forms a mappable feature on which are fossiliferous sandstone fragments at one point below the peat. Exposures are rare however on the outcrop overlooking Nidderdale except in Sypeland Gill where the section at Red Scar (127736) shows 1' shelly sandstone overlying 2'6" shelly sandstone with a gap of 2' between the exposures.

Hack Fall - The section in the gorge of the Ure at Hackfall (236773) was examined to provide additional data about the Shell Bed, though it is outside the limit of the present area and is the furthest east of all the outcrops examined. The beds seen here are:

9' fine grained yellow weathering sandstone
2' very fine grained sandstone, abundantly worm chewed, with carbonaceous wisps and with occasional grains of glauconite
8' compact, dark blue platy calcareous siltstone with a restricted fauna of brachiopods which can be extracted from the fresh material. The fossils are partially preserved in calcite which is unusual in the Shell Bed. The siltstone is calcareous enough to effervesce mildly with dilute HCl
3' shale chips
- Ganister Beds apparently underlying these beds in a normal fashion, though there is some slight doubt about the possible effects of faulting in this section.

Washouts in the Shell Bed - At two points on the Masham Moors at the horizon of the Shell Bed there are developed lenticular, current bedded, medium grained sandstones. The chief development is at Haugh Crags (073789) where 10' of current bedded sandstone forms a strong feature with a line of prominent scars. It appears that this feature can be mapped into that which flanks Coverdale Tarn and dies out northwards, as also does the Haugh Crags featurein an easterly direction. The sandstone appears to map as a lense and is developed at the horizon of the Shell Bed.

S milar beds occur at Autherlands (124779) where, though exposures are absent, medium grained sandstone boulders and blocks are quite abundant. The area of hillside on which these blocks occur appears to form a lense which transgresses the outcrop lines of the Shell Bed.

The horizon of both these washouts does not appear to interfere with the outcrops of the Agill sandstone and it is possible that these lenticular sandstones are distributary bar fingers of a deltaic system. The lowest members of the Agill sandstone were perhaps the inter-distributary trough deposits laid down whilst the channels were functioning. No deduction can be made from these lenses about the courses of the original channels, if in fact they existed.

Agill Sandstone and underlying shales

The section in Agill Beck (124762) is first quoted since it gives clearly the relation of these beds to the Shell Bed.

It is one of the few sections in the Agill sandstone which are seen in the present area, though the horizon is widely known from the blocks along the outcrop. The beds exposed here are:

12'	approx. brown, fine grained flaggy sandstone with a few kaolinised feldspar grains. Carbonised plant remains occur in small quantities
4'6"	gap - almost certainly shale
7'	shale (not exposed in its entirety) - greenish and dark blue unfossiliferous soapy shales
-	Shell Bed

The 11'6" of shales appear to be cut out laterally in an upstream direction to nil in 120 yds. and the Agill Sandstone thus rests locally on the Shell Bed.

In the area round Little Haw and Great Haw the Agill Sandstone is least typically developed and is least easy to separate from the Shell Bed. Blocks of flaggy sandstone, coarser than the Shell Bed, occur together with some ganister under peat near the base of Little Haw.

A channel in the peat at the head of Beldin Gill (076798) shows pieces of sandstone coarser than the Shell Bed with shell casts. The blocks are of a fine grained quartz sandstone frequently showing micro-current bedding and with a fauna somewhat different from that of the Shell Bed. Pelecypods and gastropods are the chief forms.

Following the outcrop of the Agill Sandstone towards South Haw, blocks are seen in many peat channels of flaggy fine grained sandstone with is always noticeably coarser than the Shell Bed (this is due to the difference of nearly 100 microns

in the grain size). These contain shell casts and occasional rootlets, whilst some ganisteroid sandstone fragments are also seen.

The headwaters of Thorny Grane Gill (around 093786) show blocks of sandstone and of compact flaggy sandstone at this horizon, but no fossils were seen. Blocks occur sporadically under the peat along the outcrop in the direction of Sourmire Moor where numerous fragments are seen on the surface, but they appear to yield no fossils.

Three separate outliers of the Agill Sandstone occur between Baldcar Head and Ox Close Plantation on the spur between Grimes Gill and Spruce Gill Beck. Mapping is here based on weak features on the shales which underlie the Agill Sandstone and on blocks of the sandstone in the soil. The blocks are of a brown, or greenish flaggy fine grained, sometimes ganisteroid sandstone with scattered kaolinised felspar grains. Blocks on the Baldcar Head outlier yielded numerous shelly casts preserved rather crudely, which appear to be pelecypods and gastropods. This is a similar faunal assemblage to that obtained from fragments in Beldin Gill. It appears therefore that the Agill sandstone may be locally fossiliferous, but the preservation tends to be poor due to the coarseness of the grain (good fossils are seldom preserved in a sandstone of over 125 microns grain size, whilst the Agill Sandstone is usually about 200 microns grain size).

Deep Gill shows one of the rare exposures in the Agill Sandstone 12' of which are here exposed; it is here a blocky, fine grained pale brown sandstone apparently without any fossils, Between this point and Grimes Gill blocks of ganisteroid sandstone dot the outcrop at intervals, whilst to the E.N.E. of Grimes Gill this horizon forms a feature. Little trace of these beds is seen

on the outcrop round the Pott Ridge spur, until Agill Beck is reached where the exposure detailed at the beginning of this section is seen. Exposures are not seen at Arnagill or on the E. side of Pott Beck, though it is probable that this horizon is still present near Broadmires farm (173796) where blocks of fossiliferous sandstone, coarser in grain than the normal shell Bed are seen in a field.

North of the R. Burn the capping of Agra Moor is in a sandstone without fossils. This bed forms a slight feature at the W. end of a plateau on which blocks of this same sandstone are seen. Elsewhere N. of the R. Burn, whilst it is quite possible that this horizon occurs, there is little proof of its existence and indeed it will probably be thin in the extreme N. of the area owing to the apparent general thinning of the beds between the Lower Follifoot and Brimham Grits.

The section in the Hack Fall Gorge is interesting since beds above the Cayton Gill Shell Bed here appear to contain a limestone. The sequence which occurs appears to be as follows:

6"	blue impure muddy limestone with organic traces
2'	approx. gap
6"	ganister
8'	flaggy, limonite spotted fine grained sandstone
10'	approx. unexposed
-	Cayton Gill Shell Bed.

Libishaw Sandstone and Shale

The outcrops of the Libishaw Sandstone and Libishaw Shale are here described from west to east, concluding with S.E. corner of the area.

Little Haw, Great Haw and South Haw.- Three prominent outliers dominate the featureless moors at the head of Colsterdale (Plate 43b). They all show a common set of topographic features, namely steep sides on the Libishaw Shale and flat tops on the Libishaw Sandstone. Little Haw (078803) has blocks of sandstone on its summit as also does Great Haw (074793). No in situ Libishaw Shale is seen on Little Haw, but its thickness was estimated at about 25' by measuring the available features. The Libishaw Shale is seen in place on the E. side of Great Haw along the line of York Dike (077793). These beds are seen to be flaggy mudstones and shales, apparently without any fossils in the small portion which is exposed. Blocks of Libishaw Sandstone occur on top of the hill and shelly fragments were noted in sandstone at 074792 on its S. side. This fossiliferous development is either analogous with that seen 5 miles E.S.E. of this point, or alternatively the few pieces seen with fossils were derived from the Shell Bed and transported into place by high level ice.

South Haw was levelled at the W. end of the hill and the Libishaw Shale appears to be about 45' thick here, which is considerably thicker than elsewhere. 10' of greenish shales without fossils are seen in place at 091788. An old stone pit below the summit of the hill shows sandstone in place whilst blocks occur below the thin peat on its summit plateau. This isthe most conspicuous of the three relict hills on the Masham Moors (Plate 27B).

Brown Ridge - The Libishaw Sandstone forms an extensive outcrop on Brown Ridge which is bounded by sharp features on the

Libishaw Shale. The sandstone has been worked in several old stone pits along the length of the south facing edge of Brown Ridge and along Dale Edge and one of these excavations shows 10' of soft, yellow sandstone in place, (106775). The Libishaw Shale is seldom seen, but 7' of unfossiliferous mudstone is exposed at 101782. The outcrop of the sandstone forms a ring round Throstle Hill, an outlier of the Capelshaw Shales which overlies the Libishaw Sandstone, and a good feature on the Libishaw Shale (constant in thickness) faces out on to Sourmire Moor, to the north of the outcrop. A spring line is seen at the base of the sandstone. Levelling between the feature at the base of the shale and one such spring gave a thickness of 24' for the Libishaw Shale at 116783. Grey, unfossiliferous shale is here seen shortly below the sandstone.

A small faulted inlier in shale, which is probably Libishaw Shale, is seen at 116772 where a section shows 6" of layered, micro-current bedded sandstone overlying 1' silty mudstone. This contact is probably the base of the Libishaw Sandstone. An exposure 20 yds. further up the same stream channel show 3' of micaceous, pale green shale, assumed to be Libishaw Shale, adjacent to a fault which has considerably contorted it, bringing it up in the middle of a tract of Libishaw Sandstone. Blocks of Libishaw Sandstone are common on the moor E. of Throstle Hill and small thicknesses occur in situ, whilst quantities of debris from this bed occur along the sides of Deep Gill. The thickness of the Libishaw sandstone around Throstle Hill is hard to estimate, but is about 40' or 50'. The

blocks which occur commonly on the outcrop of this sandstone maintain a constant character, with a grain size bordering on the limit between fine and very fine sandstone, and a brown colour with a speckled appearance due to scattered flecks of limonite and kaolinised feldspar grains.

Pott Moor - The Libishaw Sandstone forms the capping of the spur between Grimes Gill and Agill Beck, with the exception of two small outliers on the Capelshaw shales, which overlie the sandstone. The edge of Pott Ridge shows a feature which is especially well marked on the N.W. side of this spur. The Libishaw Shale is almost never seen. Its thickness is estimated by levelling as 24', 200 yd. S.W. of Grimes Gill Farm, whilst the sandstone is about 34' thick in the same vicinity (the results of these measurements are set out in Section 4, Plate 35, but they are only to be regarded as approximations which show an undue dependence upon anticipated average dips used as correctives during the levelling operation, this being especially true of the sandstone which here forms a fairly broad outcrop).

Weathered Libishaw Shale is seen at 144772 where the streams below Summer Side are entrenched in gulleys which appear to have been eroded in shale, though no fresh rock is seen.

The Libishaw sandstone occurs as scattered blocks over much of the spur of Pott Ridge and has also been worked in a number of old stone pits. Those at East Summer Side and Stott Fold have been worked for tilestone. The exposure at Stott Fold shows 4' of well bedded micro-current bedded micaceous sandstone. At 137772 the section seen is 3' flaggy, speckled sandstone resting on 3' massive speckled sandstone. 2' more

of the flaggy beds are seen below the beds detailed above, beneath a 2' gap in the succession.

A quarry at 135772, which is perhaps on slightly higher beds than the section detailed above shows 7' flaggy brown speckled sandstone with micro-current bedding, which is a feature developed at several other outcrops in the Libishaw Sandstone. Other exposures on Pott Ridge show massive outcrops in the Libishaw Sandstone. Other exposures on Pott Ridge show massive or flaggy variants of the Libishaw Sandstone.

At 130768 massive sandstone boulders occur almost in place with well developed slump structures picked out by fluted weathering along the layers of rock. This is the only occurrence of penecontemporaneously disturbed strata at this level in the present area.

Agill Beck - The headwaters of Agill Beck show small exposures in the Libishaw Sandstone illustrating its characteristic lithological features. The base of the sandstone is apparently seen, resting on 6" flaggy mudstone. The Libishaw Shale is exposed at 120765, where 3' of greenish brown shale are visible. Another exposure shows pale blue soapy shale chips. Blocks of the Libishaw Sandstone occur on the hillside S. of Agill Beck, but apart from a probable feature on this horizon on the down thrown side of the Limley Fault, indications of this horizon are lacking between Bank Top and Arnagill.

Arnagill - At 149763 a shelly development of the Libishaw Sandstone is seen. The strata consist of 9' of sandstone with scattered shell casts and a horizon with Chonetes hardrensis

6' above the base of the section. The rocks seen are wispy bedded sandstones with a bluish tinge when fresh and with a somewhat poorly preserved fauna of brachiopods. Though the base of the Libishaw sandstone is not seen at this exposure, it is probably almost immediately below the beds observed in this section.

A large portion of the Libishaw sandstone is seen in the scar of the Arnagill landslip (149762) where this horizon is intermittently seen through 33' and is a fine to very fine grained sandstone with a speckled appearance due to carbonaceous flecks and numerous kaolinised feldspar grains. The lowest 6' of the present exposure yield Chonetes hardrensis and is thus correlated with a similar horizon in the exposure 90 yd. to the N.N.W. cited above. The total thickness assigned to the Libishaw Sandstone in this area is thus over 39', which is gained by adding the 6' of sandstone below the horizon with C. hardrensis to the figure obtained by measuring the Arnagill landslip exposures (see also Plate 35).

The Libishaw sandstone has not been positively recognised on the E. side of the valley of Pott Beck, but it almost certainly occurs below Arnagill Crags in view of the fact that it makes a constant and extensive outcrop on Pott Ridge to the W. The borehole record cited by Fox Strangways (1908) appears to be misleading. Although the bore appears to have been sunk through the Libishaw Sandstone, this horizon cannot be recognised in the log which appears to give shales at the anticipated horizon of the sandstone. This record is accordingly disregarded since

it is incompatible with the field evidence which indicates that the Libishaw Sandstone is a constant mapping horizon, not likely to die out so close to extensive good outcrops.

South of the Limley Fault - A plateau on the Libishaw Sandstone bounded on the west by a clear feature on the Libishaw shales occurs around Ouster Bank (121751). As elsewhere, the Libishaw Sandstone has been worked in stone pits at a horizon a few feet above the top of the Libishaw Shale. The lithology is very similar at all outcrops and is here a fine grained sandstone with kaolinised feldspars, a few scattered mica plates and also flecks of carbon. Traces of the Libishaw Shale occur adjacent to the track between Lofthouse and Ilton (119748) where a gulley occurs in a badly weathered shale. The recognisable fragments are a brittle, dark green unfossiliferous shale. A clay ironstone nodule about 1' long was found in the debris in the gulley, in addition. The Libishaw Sandstone was estimated to be at least 45' thick.

In an old stone pit E. of Black Gutter (126741) there is exposed 9' of thin bedded fine to very fine grained sandstone, micaceous on the bedding planes, showing micro-current bedding and a flaggy parting. 50 yd. N.W. of this point is a 15' scree in soapy shale debris belonging to the Libishaw Shale - all the recognisable chips are of a blue, soapy unfossiliferous shale, which is here deeply weathered.

The scar of the Low Ash Head Moor landslip provides an important section on Combs Fell. (Plate 35). The following beds are seen:

18' fine grained brown sandstone - the lower portion carries

a somewhat scattered brachiopod-pelecypod fauna, portions of which are in an excellent state of preservation in a bluish very fine grained silty sandstone

3' flaggy sandstone

3' shale without fossils.

At 139757 on Low Ash Head Moor a stream which has cut into slipped beds in the Low Ash Head landslip reveals a section including 15' of soft, fine grained brown sandstone. They yield a somewhat sparse brachiopod-pelecypod fauna which is seen to be quite rich in species when the outcrop is subjected to prlonged collecting.

Adjacent to the sandstone exposure are greenish-black rather soapy shales which were carefully examined for a fauna without success. These shales, which are somewhat contorted owing to slippage, are almost certainly Libishaw Shales, in view of their close proximity to the Libishaw Sandstone in the slip.

Capelshaw Shales

The Capelshaw shales are infrequently exposed and outcrop below the Brimham Grit on the E. side of Pott Beck, but no exposures are seen. The chief indications of the rocks which make up these beds are found on three outliers on Pott Moor, and in Arnagill.

Throstle Hill - (111776) Low features face out on to the platform of Libishaw sandstone on the N. and S. of Throstle Hill. These aid in delimiting a ganister, showing irregular weathering which locally appears to immediately overlie the Libishaw sandstone. A second feature forms an arcuate line

N. of Throstle Hill and is no doubt on a shale parting above this ganister, which is probably in turn capped by a hard bed. This feature is not present on the S. side of Throstle Hill and it is assumed that the shale has died out. The hill itself is a prominent conical outlier bounded by good features. Levelling up its side was attempted, but the results were rather divergent giving about 30' of beds actually in the conical part. A small exposure on the S.W. side of the hill (110775) shows 9" of shaly coal overlain by a bed resembling a wathered fireclay. A little further uphill more beds resembling weathered fireclay occur, though these may possibly be badly decomposed fine grained shales. There is no evidence for a cap rock on Throstle Hill which is apparently formed of soft beds. The presence of two massive sandstone boulders to the E. of the hill at 115773 which do not fit into their stratigraphic surroundings may be explained by their once having formed a capping to this hill in the First Brimham Grit. These may have been shifted off to the east by an early glaciation affecting high country.

Sievey Hill - The ganisters immediately above the Libishaw Sandstone are weakly represented on the plateau W. of Sievey Hill, but they are not here mappable as a distinct horizon from the Libishaw Sandstone. Sievey Hill is a tabular outlier of ovoid shape almost certainly owing its existence to a cap rock overlying a small thickness of shale. The type of rock found on the summit varies, but at the W. end of the hill (120768) debris of greenish flaggy sandstone and shelly sandstone are seen which may belong to the cap rock. The shelly block

is a loosely cemented, fine grained sandstone with scattered muscovite plates. Voids representing crinoid ossicles are scattered through the specimen, which presents a different kind of fossiliferous rock to that normally seen in the Cayton Gill Shell Bed or the Libishaw Sandstone. It is therefore thought probable that the Capelshaw Shales contain a fossiliferous horizon at Sievey Hill, but this contention is difficult to prove in the absence of in situ exposure.

Pott Ridge - A well defined feature crosses the Pott Moor High Road at 142778. This bounds an outlier of beds resting on the Libishaw sandstone which appear to be at the same stratigraphic level as those beds seen at Sievey Hill. Soapy black shale chips were seen in the side of the feature at one point and blocks on the summit indicate that the cap rock may be a greenish sandstone. This agrees well with blocks seen on Sievey Hill, but no fossils were seen on the outlier on the Pott Moor High Road.

Arnagill - The scar on the edge of Arnagill landslip (150761) shows a partial exposure of the Capelshaw Shales and provides the only good overall estimate of the thickness of these beds in the present area. The section here seen is:

-	First Brimham Grit
6"	black, soapy shale
12'	gap (probably chiefly shale)
-	unfossiliferous shale chips
26'	gap (probably chiefly shale)
3'	soapy grey shale, apparently unfossiliferous
1'	impure coal, possibly the equivalent of the coal on Throstle Hill
3'	grey fireclay
5'	gap
6"	silty shale
4'	gap

2'	flaggy sandstone (possibly top of Libishaw sandstone).
5'	gap with traces of mudstone chips
-	sandstone (Libishaw Sandstone)

The Capelshaw Shales of Arnagill are thus 57', or possibly 64' thick and, in view of the fact that slipping has taken place on these beds, it is assumed that they are chiefly shales. It is unfortunate that the debris of the landslip are not dissected, since data on the Capelshaw Shales is unfortunately very fragmentary in the present area, and the presence of a fossiliferous horizon is suspected, but not certainly established.

The beds immediately below the First Brimham Grit are exposed on the E. side of Arnagill (152758) where they are seen to a thickness of 1'. They are soapy shales with interleaved siltstones, but apparently without any fossils.

Palaeontology

Ganister Beds - A horizon with *Homoceras beyrichianum* (Haug) which was found in the lower part of the Ganister Beds during the present work, has also been recorded from ground to the S. of the Askrigg Block by Hudson (1934), Hudson et al. (1938), Hudson (1939), Jones (1943), Stephens et al. (1953) and Moseley (1954). Further to the S., *H. beyrichianum* has been found in Edale, where Hudson and Cotton (1939) show that it occurs in the lower part of the H zone. This conclusion is supported by the work of Hodson (1954) who describes a very full H zone succession from County Clare, Eire in which five faunal bands occur. The two forms from Woo Gill, in the present area are *H. beyrichianum* and *H. aff. subglobosum* which are also characteristic of Band A of

Hodson, which is the lowest band of the H zone. The above records cover a wide area and suggest the fairly continuous occurrence of a band characterised by H. beyrichianum south of the Craven Faults. The present work provides the first record of this band, or indeed of an H zone fauna, on the Rigid Block.

The fauna found in conjunction with H. beyrichianum is a sparse one of thin shelled pelecypods. The single specimen of H. aff. subglobosum is uncrushed and preserved as a void in a calcareous nodule. The specimens of H. beyrichianum, are preserved as crushed specimens in very compact, black shale. These fossils, though resembling H. henkei superficially, when compared with the material at the Geological Survey, London, are seen to be conspecific with H. beyrichianum. This latter form is characteristically coarser ribbed than H. henkei, whilst the raised, beaded rim round the margin of the umbilicus is coarser and more prominent (all fossils from this level are in the Geological Survey Collection, London. Identifications were made initially by Dr. Ramsbottom and Dr. Hodson). Immediately below the H. beyrichianum band a limestone with a fauna preserved only as cross-sections is seen. The assemblage appears to be of nuculids and gastropods and is perhaps similar to that developed in the nuculid-gastropod beds at the base of the Colsterdale Marine Series of Colsterdale and in the Mirk Fell Ironstones of Mirk Fell Gill (Hudson, 1941).

At two widely separated localities, shales have yielded a fauna preserved as partly crushed impressions in a pale, rather silty shale. In both instances the exact horizon is in doubt,

but it is assumed to be at the approximate level of the Cayton Gill Shell Bed. Both shales are pale in colour and contain some fossils preserved in a mineral of the kaolinite group, which is also a feature of the preservation of crinoid ossicles in the Libishaw sandstone. The fauna from the locality in Swinney Beck is the richer in individuals, but both records include Productus carbonarius and crinoid ossicles. The remaining fauna at Swinney Beck is somewhat similar to that at other horizons in the R_1 shell beds of the present area.

Cayton Gill Shell Bed - The previous work on the palaeontology of the Cayton Gill Shell Bed and the Libishaw Sandstone in the present area was carried out chiefly by Hind, working on material collected by Bisat. This work followed the earlier study of Tute (1868, 1887) and Hind (1907) who did not collect from the present area, however, though their records, which are from areas to the south of the present ground, are closely comparable with those from Colsterdale. Hind furnished a large list of fossils which were published with all previous lists and these were incorporated in Table 111 in Bisat, 1914. The localities which were collected from by Bisat, are not now in every case accessible; the Leighton Valve Shaft, the well at High Ellington and the occurrence at Pott Hall all appear to be inaccessible. The remaining in situ exposures collected from by Bisat, were also visited for this purpose during the present work with the exception of that on High Ash Head Moor (Birky Bank). In addition, during the present work several outcrops littered with blocks of the Shell Bed were systematically examined on the Masham Moors and on Agra Moor. These are all new

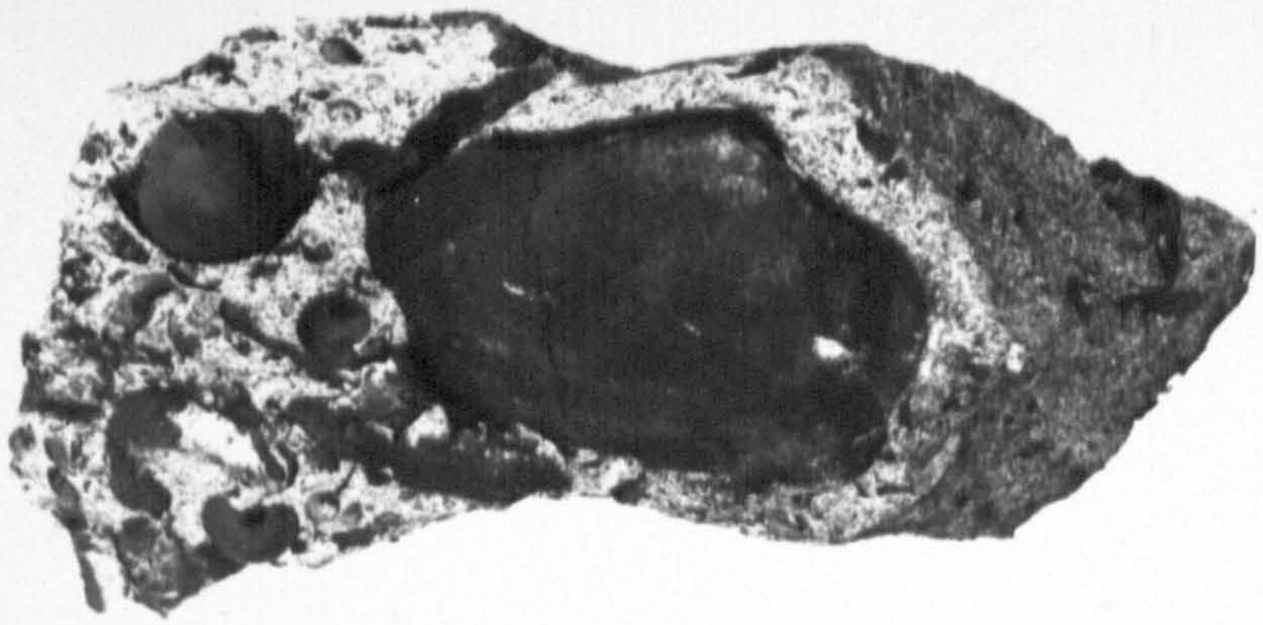


PLATE 36 A

Cayton Gill Shell Bed, Sourmire Moor, Colsterdale, with an internal cast of a pelecypod with a trepostome of circular shape replacing the interior of the ventro-anterior part of the shell. Other forms include a bellerophontid, top left and Euphemites urei , centrel left; many other shelly fragments are preserved in a matrix of very fine grained sandstone. Natural size.

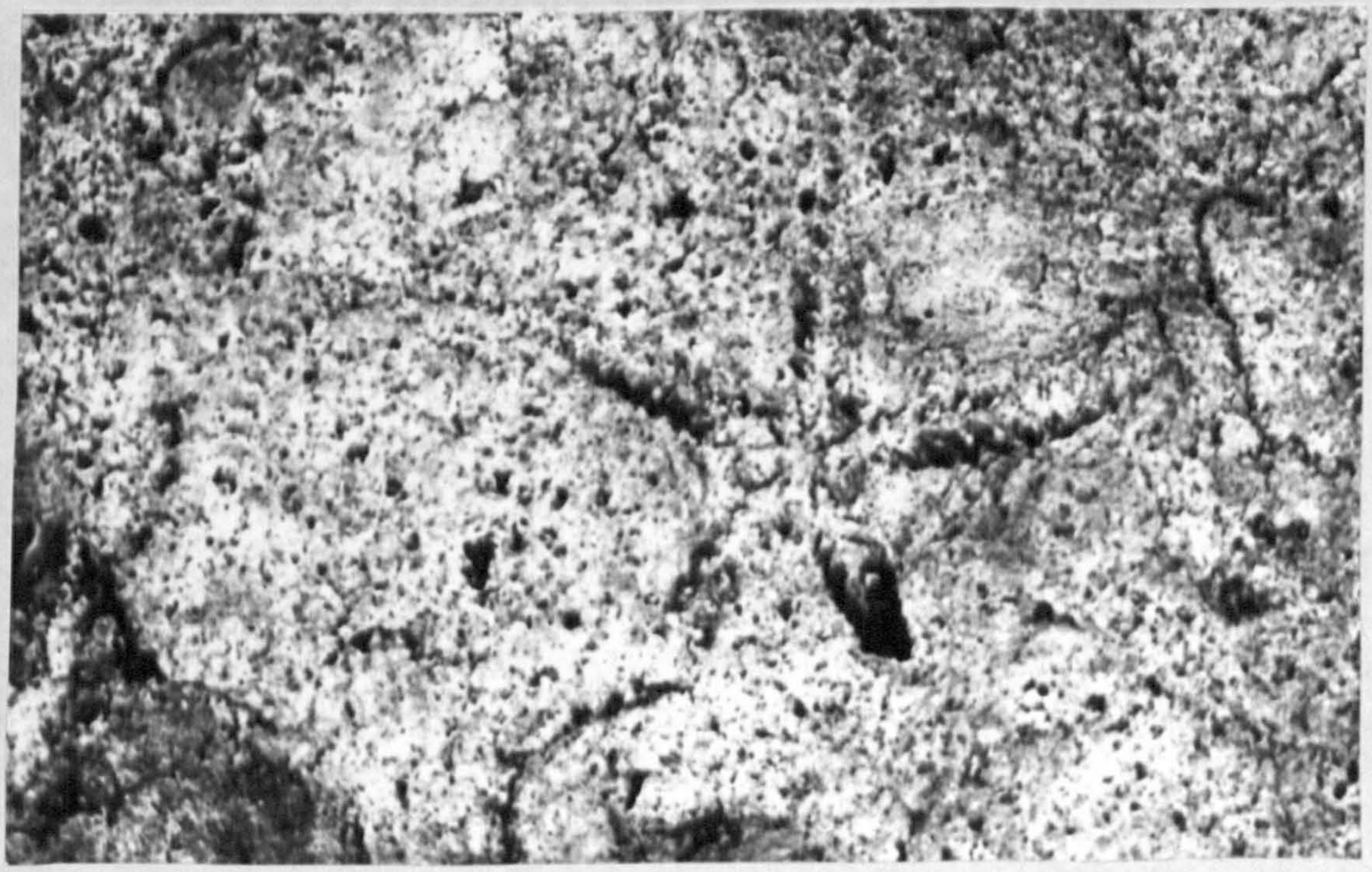


PLATE 36 B

Protaster sp. aff.piltonensis Spencer
Agill Sandstone, Beldin Gill, Colsterdale. Magnified 5.5 times.
One arm of the animal is complete and is seen centre, left.

localities to the literature and have yielded a large suite of specimens.

George (1932) has more recently described several new forms from the Cayton Gill Shell Bed which were not met with during the present work, with the exception of Schizophoria hudsoni, which is found in abundance at most localities in a band full of internal casts of this fossil.

The fauna of the Shell Bed is preserved as casts (Plate 36A). Fossils are rarely apparent except on weathered bedding planes on which numerous specimens are often seen. This peculiarity renders in situ exposures poor sources for collecting large faunas. The most successful collecting in the present area was carried out on outcrops of the Shell Bed, by examination of large numbers of blocks lying on the surface.

The fauna is a prolific one and includes a well balanced assemblage of most of the invertebrate phyla, with the absence of crustacea and eleutherozoa, whilst pelmatozoans, in this case crinoids, are only very rare. Bryozoa are very rare, but include a species of Fenestella with an unusual, broadly corrugated zoarium. The brachiopod fauna is characterised by a moderate profusion of individuals, but with a restricted number of genera represented. Locally, pieces of the Shell Bed are full of internal casts of Schizophoria hudsoni George. This band is only seen in situ twice, and is then in the top layer of the Shell Bed. Blocks occur at most of the places where faunas were collected and there is no known limit to the occurrence of this bed in the present area (it is, of course, possible that this rock full of Schizophoria may occur locally at more than

one horizon). Productus carbonarius and Derbyia gigantea occur in large numbers. Derbyia gigantea is preserved as both internal and external impressions. A transverse variety of this species, which appears to be a new variant, is only recorded from two localities on the spur between Spruce Gill and Grimes Gill. Dictyoclostus hindi occurs only in small numbers; the specimens include an excellent internal mould of the brachial valve which shows the muscle scars and brachidial bases preserved in relief.

A varied pelecypod fauna characterises the Shell Bed, and this is apparent by examination of either the present lists or those in Bisat (1914). Whilst the brachiopod fauna of the Shell Bed is reminiscent of a fauna in shales of Yoredale facies, the very extensive development of pelecypods and gastropods is not parallelled at other horizons. The pelecypods of the Shell Bed, unlike the brachiopods, are rich in species, but not individuals. This is made apparent by examination of the appended lists in which several of the brachiopods are recorded from the bulk of all localities, whilst most of the pelecypods are recorded from one or two localities. The most characteristic pelecypods are members of the genus Edmondia, which appears to have been the most gregarious form, since several specimens may be found on a single slab of rock. Aviculopecten is also well represented. The remainder are chiefly rare records of forms which are largely of elongate, rather than of pectiniform shape.

An examination of the list of gastropods shows that though there is a variety of these forms unparallelled at any other

horizon in the present area, the bulk of the records are from a locality on Sourmire Moor. At most other places gastropods are not common and it appears that conditions were especially favourable for them in the Sourmire Moor area (possibly an abundance of plant food, since most gastropods are herbivores). The most common gastropods numerically are the bellerophontids; the bulk of the remaining records are of rare individuals, or small groups of specimens. The identification of these fossils is often from voids which show the shape and less clearly the ornamentation of the conch. This poor preservation of many of the specimens is the cause of the several queried identifications which appear in the appended lists. Nautiloids are never abundant and are rare, single records; fish remains are extremely rare and poorly preserved.

The 'worm chewed' siltstones which appear to be a persistent horizon at the base of the Shell Bed are considered to mark a period of intense activity by annelids, which burrowed in the silt, and perhaps partially digested it. The resulting rock is intensely disturbed, with irregular, roughly tube shaped markings which have been described and figured by Jones (1943) from a horizon at Beamsley which appears to be equivalent to the Shell Bed of the present area. (see also Plate 52B). The association of worm burrows with glauconite is seen at several widely scattered localities at the level of the siltstones below the Shell Bed. It is probable that this period of re-working of the sediment by worms was carried out at a time of minima

sedimentation, since glauconite is elsewhere found to be characteristic of diastems (e.g. the occurrence of glauconite in the basal beds of the Grassington Grit above the intra-E_1 unconformity N. of Lofthouse, Nidderdale).

Agill Sandstone - In the ground where this bed is readily distinguished from the Cayton Gill Shell Bed, fossils are sporadic and badly preserved in a sandstone of grain size 200 microns (too coarse for good preservation). A specimen from near Towler Hill showed numerous shelly casts with pelecypods, possible bellerophontids and a conceivable productid. Blocks of this lithology are seen in Beldin Gill, which yield the most abundant fauna from this horizon. The chief pelcypods are Myalina and Leiopteria; both are genera not characteristic of the Cayton Gill Shell Bed and are preserved in a matrix considerably coarser than that of the Shell Bed. The records of Edmondia maccoyi and Euphemites urei are characteristic of the Shell Bed proper and it is possible that the specimens collected include some material from the Shell Bed. The record of Protaster is of some interest however, since this is the only Upper Carboniferous ophiuroid extant in Great Britain, in the knowledge of the present author (Plate 36B). The fact of the preservation of an asteroid in a sandstone of grain size about 150 microns (coarser than the Shell Bed) is a remarkable feature, since the described species, which are at nearly all stratigraphic levels excessively rare records, are almost invariably preserved in a clay matrix.

Libishaw Sandstone - Records of fossils from the Libishaw Sandstone date from the work of Bisat (1914) who recorded

a brachiopod fauna from this level. The present collection has yielded more extensive lists and a pelecypod assemblage in addition to the brachiopods. Collection was carried out at all of Bisat's localities and also in the debris of the Low Ash Head Moor Landslip. The inclusion of the records from Hack Fall by Bisat with the records from the Libishaw Sandstone (referred to by him as the upper Shell Bed) is here considered to be in error since the fauna and lithology of the beds at Hackfall is thought to be more closely comparable with that of the Shell Bed. Schizophoria hudsoni which is recorded from Hack Fall has not been found in the Libishaw Sandstone of the present area, whilst the beds immediately above the fossiliferous siltstones in the Hack Fall section are lithologically similar to the Shell Bed and not to the Libishaw Sandstone.

The brachiopod fauna of the Libishaw Sandstone is rich in a few recurring species, Chonetes hardrensis, Dictyoclostus hindi, Buxtonia scrabiculus, and Crurithyris sp. In addition other brachiopods occur more rarely, and together these records make a considerable contrast with those from the Shell Bed which has not yielded Pustula or Buxtonia, whilst Chonetes and Crurithyris are much rarer in the Shell Bed. In contrast, orthotetids are rare in the Libishaw Sandstone records, whilst they are prominent specimens in the Shell Bed. The presence of Hyalostelia and 'cauda galli', albeit rare records, is reminiscent of the Richmond Chert Series, which some of the more compact sandstones of the Libishaw Sandstone vaguely resemble owing to their dark colour and streaky texture.

The pelecypod fauna is, as in the Shell Bed, richer in species

than in individual specimens; most of the specimens are rare, single records. Mytilimorpha and Solenomya were not recorded from the Shell Bed, but otherwise the faunas are fairly similar. The sum total of pelecypods is however much smaller than in the Shell Bed and the brachiopod fauna is proportionately more varied.

Capelshaw Shales - no in situ record of fossils was made in the present area. It is felt that this is probably due only to bad exposure since a block found on the Sievey Hill outlier in Colsterdale was probably derived from a crinoidal sandstone in these beds. On the assumption that the correlation of the Libishaw Sandstone of the present area with the Addlethorpe Grit of the Bradford and Skipton area is correct, it seems likely that any shell bed at the level of the Capelshaw Shales would be approximately equivalent to the Otley Shell Bed, a highly fossiliferous development described from Otley Chevin by Stephens et al. (1953) which contains a fauna rich in pelecypods, gastropods and brachiopods preserved in a siltstone, giving a faunal assemblage which strongly resembles that of the R_1 shell bed exposed in the present area. The Scotgate Ash Marine Band of Walker (1952) also appears to lie at this level.

Faunal Lists

Beds between the Lower Follifoot and First Brimham Grits.

H. beyrichianum band in the Ganister Beds. ('s' denotes preservation in shale, 'L' in limestone).

Plants, s

?Sponge spicules, L

Crinoid ossicles, L

Brachiopod fragments, L

?Nuculid cross-sections, L
?Posidonia corrugata (R.Etheridge jun.), s
Posidoniella minor (Brown), s

Gastropods, possibly Glabrocingulum sp., L

Homoceras beyrichianum (Haug), s
---------- aff. subglobosum Bisat, s

Locality

Woo Gill, Nidderdale 066788

Ganister beds above the H. beyrichianum band.

Stigmaria ficoides Brongniart, 1,2,3,4,5

Sponge spicules, 6

Crinoid ossicles, 7

Lingula sp., 8

Index of localities for the above

1.	Agra Moor, Colsterdale	139822
2.	Colsterdale Moor	101808
3.	Black Gutters, Spruce Gill, Colsterdale	110785
4.	Beldin Gill, Colsterdale	088800
5.	Hambleton Lith, Colsterdale	141799
6.	Tributary of Steel House Gill, Colsterdale	088795
7.	Deep Gill, tributary to Grimes Gill, Colsterdale	125777
8.	Beldin Gill, Colsterdale	092800

Unplaced fossiliferous shales at approximate horizon of Cayton Gill Shell Bed:

Crinoid ossicles, 1,2

Chonetes sp., 1
?Cleiothyridina sp., 2
Lingula mytiloides J. Sowerby, 1
Productus (Productus) carbonarius de Koninck, 1,2

Aviculopecten clathratus (McCoy), 1

Sanguinolites tricostatus (Portlock),1

Straparolus sp., 1

?Coleolus sp., 1

Index of localities for the above.

1.	Swinney Beck, Colsterdale	203816
2.	Headwaters of Arkleside Gill, Coverdale	053787

Cayton Gill Shell Bed

Fossil Wood, 8, 10

Sponge spicules, 9

Crinoid ossicles, 1,8

Fenestella sp., 1,6,8
Rhombopora sp., ?3,?8,9
Trepostome (encursting type), 1,2,?4,?9

Annelid castings, 9

Chonetes sp., 9,10
Cleiothyridina roysii (Leveille), 10
Crurithyris sp., 10
Derbyia gigantea Thomas, 2,4,8,9
-------- gigantea Thomas laterally elongate variety, 2,4
-------- hindi Thomas, 8
Lingula mytiloides J. Sowerby, 10
Orbiculoidea nitida (Phillips), 5,10
Productus (Dictyoclostus) hindi Muir Wood, 2,8,8,10,11
---------- (Productus)carbonarius de Koninck, 1,2,3,4,6,8,9,10
Schizophoria hudsoni George, 1,3,6,7,8,9,10,11
Tylothyris laminosa (McCoy), 9

Aviculopecten clathratus (McCoy), ?1, 8,9
---------- intermedius (McCoy), 2
---------- cf. intermedius (McCoy), 2
---------- aff. interstitialis (Phillips), 1
---------- planoclathratus (McCoy), 2
---------- sp., 2,4
Cardiomorpha sp., ?5
Chaenocardiola sp., ?4
Edmondia accipiens (Sowerby),?2, 8
--------- cf. expansa Hind, 8,9
----------maccoyi Hind, 1,8,9
--------- rudis McCoy, 5
--------- cf. rudis McCoy, 9
--------- transversa Hind, 8
--------- sp. 2,10
Grammatodon cancellatus (Martin), 8, ?9

Leda attenuata (Fleming), ?1,?2,4,8
Leiopteria laminosa (Phillips), 8
---------- sp., 9
Limatulina sp., 9
Limipecten dissimilis (Fleming), 2,?8
Modiola patula (McCoy), 9
Myalina peralata de Koninck, 1, ?2
-------- sp., ?9
Pinna mutica McCoy, 8
Protoschizodus axiniformis (Portlock), 2
---------- sp., ?9
Sanguinolites tricostatus (Portlock), 8
---------- sp., 2
Scaldia benedeniana de Ryckholt, 1,2
------- fragilis de Koninck, 2
Schizodus antiquus Hind, 1
---------- sp., 4,8
Spathella cylindrica (McCoy), 4
?--------- sp., 1

Aclisina sp.,2
?Anomphalus sp., 2,3,
Bellerophon sp., 1,2?
Bulimorpha sp., 2
Euphemites urei (Fleming) 1,2,3
---------- sp., indet., 5,9
?Flemingella sp. 2,4
Glabrocingulum aff. interstrialis (Phillips), 2
---------- sp. indet., 1,4,6,8
Loxonema sp., 2
Macrocheilina sp., 1,2,
?Murchisonia sp., 2
?Naticopsis sp., 2
?Pithodea sp., 2
?Turbonellina lepida (de Koninck), 2
---------- sp. indet.
Yunnania cf. subsinuata (Meek and Worthen), 1,2
Zygopleura cf. robroystonensis Longstaff, 2,8
---------- sp. indet., 9

Dolorthoceras attenuatum (Fleming), 5
Ephippioceras sp., 8
Orthocone indet. 2,?4,8
?Stroboceras sp., 8
Nautiloid indet., 10

Fish scale, 3
Fish tooth, 8

Index of localities for the above.

1. Loose blocks in old stone pits W.of Broadmires Farm, Colsterdale 175798
2. Loose blocks on outcrop, Sourmire Moor, Colsterdale 119786
3. Outcrop in High Ellington Village 195834

4.	Loose blocks on outcrop, S. of Baldcar Head, Colsterdale	129789
5.	Outcrop S.S.E. of Swinton Mill, Colsterdale	211801
6.	Outcrop S.S.E. of Roundhill Farm, Colsterdale	150764
7.	Loose blocks on summit of Carle Fell.	058795
8.	Loose blocks cleared from field on outcrop W. of Towler Hill, Colsterdale	142797
9.	Loose blocks on outcrop, Agra Moor, Colsterdale	141829
10.	Gorge of R. Ure at Hack Fall	246772
11.	Agill Beck, Colsterdale	124763

In addition to the above, the following records were made during the process of survey:
Derbyia gigantea Thomas from Black Gutters, Spruce Gill, (109784), Thorny Grane Gill (094786), Ger Beck, Colsterdale (158823) and Leda attenuata (Fleming) from the stream draining from Summer side, Colsterdale, (144769)

Agill Sandstone

Protaster sp. aff. piltonensis Spencer

Crinoid ossicles

Annelid borings

Aviculopecten clathratus (McCoy)
Edmondia maccoyi Hind
Leda attenuata (Fleming)
Leiopteria grandis Hind
---------- laminosa (Phillips)
Myalina peralata de Koninck
Schizodus sp.

Euphemites urei (Fleming)
Turriculate gastropod indet.

Orthocone nautiloid indet.

All the above specimens are from headwaters of Beldin Gill.

Colsterdale, (078799)

Libishaw Sandstone

'Cauda galli' (problematic markings), 3

Hyalostelia parallella (McCoy), 2

Crinoid ossicles, 1,2

Branched cryptostone ?, 1
?Rhombopora sp., 1
Rod cryptostone, 2

Chonetes (Chonetes) Hardrensis Phillips, 1,2,3,4
Chonetes sp., 1
Crurithyris urei (Fleming), 1,2,3

Derbyia gigantea Thomas, 2
Productus (Buxtonia) scrabiculus (Martin), 1,2,3
---------- (Dictyoclostus) hindi Muir Wood, 1,2
---------- (Productus) carbonarius de Koninck, 1,2
---------- (Pustula) rugata (Phillips), 1
Rhipidomella michelini (Léveillé), 3
Spirifer trigonalis Martin, 3
Tylothyris laminosa (McCoy), 1,3,

Aviculopecten gentilis J. de C. Sowerby, 1
Leiopteria ?thompsoni (Portlock), 1
---------- sp indet., 2
Limipecten dissimilis (Fleming), 1
---------- cf. dissimilis (Fleming), 2,3
Mytilimorpha angulata Hind, 2
Mytilimorpha sp., 2
Scaldia sp., 2
Schizodus sp., 2
Solenomya aff. primaeva (Phillips), 1

Ephippioceras sp., 1
?Stroboceras sp., 1,2

Index of localities for the above:

1.	Landslip scar, High Ash Head Moor, Colsterdale	140749
2.	Landslip debris, Low Ash Head Moor, Colsterdale	139753
3.	Scar, 90 yd. N.W. of Arnagill landslip scar, Colsterdale	149762
4.	Scar of Arnagill landslip, Colsterdale	149762

Capelshaw Shales

crinoid ossicles

The above record is from a loose block, probably derived from the outcrop, on Sievey Hill, Colsterdale, (120769)

CHAPTER 17

THE BRIMHAM GRIT GROUP

The Brimham Grits of Geological Survey 1" sheet 97 S.E. (New Ser. 51), covering the present area includes the first arenaceous horizon mapped above the Shell Bed, namely the Libishaw Sandstone. This is consistent with the usage of the Geological Survey when mapping the sheet immediately south of the present one (92 N.E. New Ser. 61) in which this same horizon was taken as the lowest arenaceous member of the Brimham Grits. This apparent consistency is felt to be at least a partial coincidence, however, because the Libishaw Sandstone and First Brimham Grit (as defined by the present author), though lithologically dissimilar, appear to have been mapped as the same horizon on High Ash Head Moor and in the Pott Beck valley. In the key of the map only two Brimham Grits are listed, but they appear to comprise three horizons, the First and Second Grits of the Pott Beck valley and the Libishaw Sandstone which was erroneously correlated with the First Brimham Grit during the mapping.

The present author prefers to amend the nomenclature of the Brimham Grits which was followed in the mapping of Sheet 92, south of the present one, in which the Libishaw Sandstone was included with the Brimham Grits. This amendment is due to the lithological contrast between the Libishaw Sandstone and the sandstones which are here termed the First and Second Brimham Grits. In addition a shelly fauna occurs locally in

the Libishaw Sandstone and probably in the Capleshaw Shales of the present area and its probable equivalents at Pateley Bridge and in the Otley area. This factor links the Libishaw Sandstone and Capelshaw Shales faunally with the other R_1 shell beds, namely the Cayton Gill Shell Bed and the local fossiliferous sandstones which underlie it. It is preferred therefore to associate the term Brimham Grit Group with the massive, feldspathic sandstones and to exclude the Libishaw Sandstone.

Stratigraphy

The lower part of the Brimham Grit Group was examined, since it forms an outcrop in the east of the area. It consists of two very massive medium and coarse grained feldspathic sandstones here called the First and Second Brimham Grits. The lower Grit varies from 36' to nothing in thickness and the upper leaf from 22' to over 52'. The measures between them are 70' of shales at Arnagill. A ganister band 32' below the base of the Second Brimham Grit in the section in Rowten Sike, Arnagill is overlain by dark grey shales with Lingula and rhizodont scales. Elsewhere the horizon at which this band occurs is unexposed.

The First Grit appears to die out N. of Clints Quarry near Leighton and is not seen elsewhere on the S. and E. sides of the Pott Beck valley nor on the south side of the R. Burn. At Quarry Gill, Swinton, 108' of shales and silty sandstones appear to represent both the First and Second Grits. To the N.

of the R. Burn and on the Ure near Clifton Castle the First Brimham Grit seems to appear again. An exposure on the E. side of Ger Beck (161818) is in coarse sandstone which is only 50' above the Cayton Gill Shell Bed. The two horizons seem to be also in close juxtaposition at High Ellington, but this is at least partly the result of faulting. The mapping indicates that the fault is of small throw however. It therefore seems likely that at Ellingstring and High Ellington the First Brimham Grit is only about 30' above the Shell Bed. It is possible that this is due to transgression at the base of the First Brimham Grit similar to that described by Walker (1952) from Pateley Bridge. He maintained that the Grit equated with the First Brimham of Colsterdale transgressed 300' of sediments to the south so that it came to rest on the horizon correlated with the Cayton Gill Shell Bed of the present work.

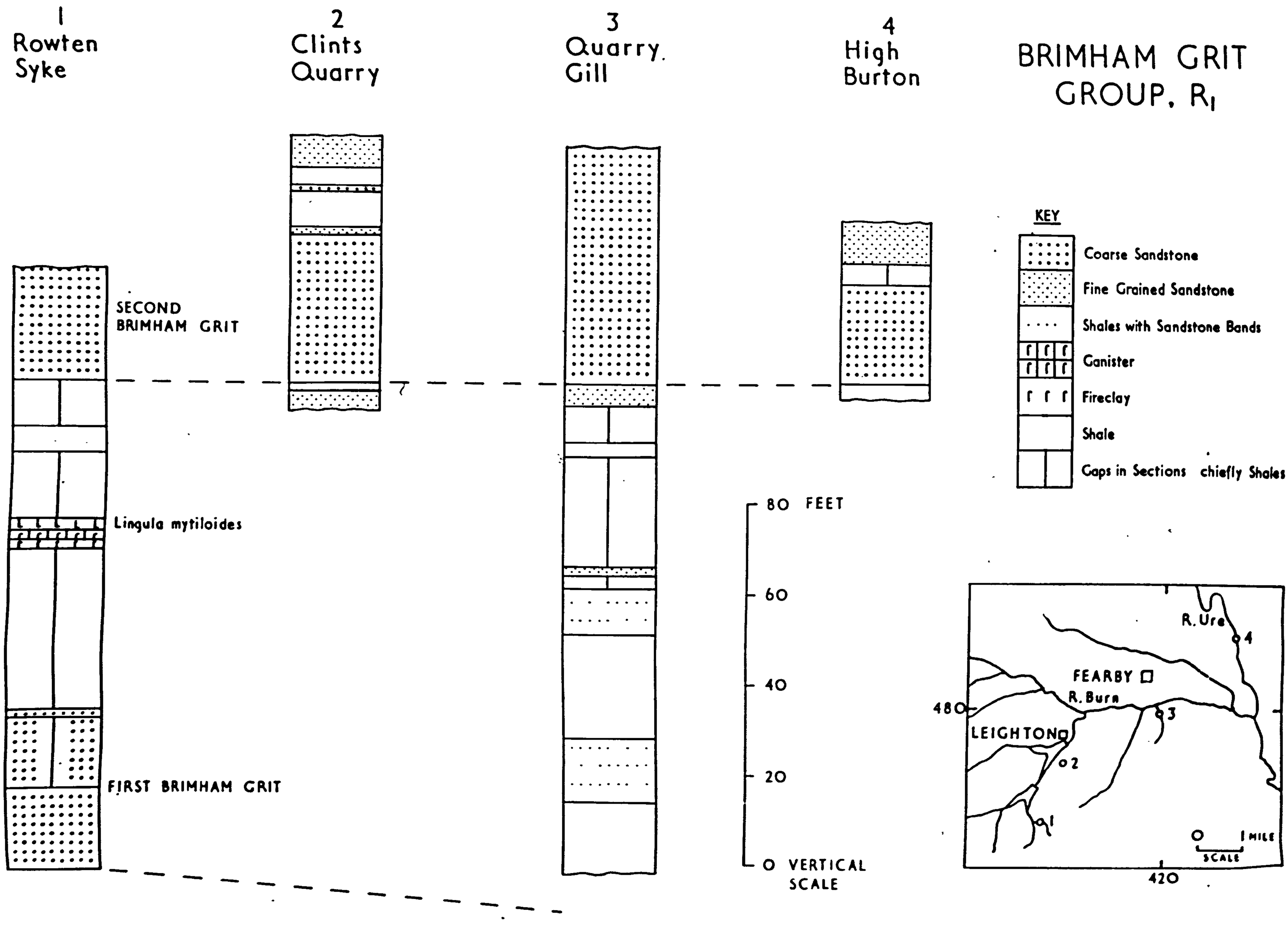
It should be emphasised that the correlations of beds at Quarry Gill and near High Burton with the section in Arnagill are not quite definite. In the first case this is due to faulting and in the second to the distance of the exposures from the main outcrop. It is not inconceivable that extension of the mapped area to the E. and S. might lead to modifications.

No attempt was made to map the upper beds of the Brimham Grit Group. The sandstone at White Lodge Crags and Clints Crags is also very massive and may belong to this division. Above the base of the Second Brimham Grit, the highest horizon here mapped, over 150' of sediments outcrop to the summit of

PLATE 37

Comparative sections in the Brimham Grits and intervening beds.

BRIMHAM GRIT GROUP, R_1



Shortlick Hill. This eminence is bounded by a feature on its W. and N. sides. This appears to be capped by an arenaceous horizon, the exact zonal position of which is in doubt.

The Brimham Grits form excellent boulder strewn features in drift-free country in the south east of the area. The picturesque cliffs of Arnagill and of Arnagill Crags are so prominent as to make mapping easy. The measures between the two Grits are, in contrast, poorly exposed. The ill-exposed, largely drift mantled tract round Fearby and Swinton has lead to some difficulties of interpretation which are dealt with in the pages which follow. The highest geological horizon mapped during the present survey was the base of the Second Brimham Grit.

Details

The southern outcrops from Sypeland Crags to Swinton

The section in Rowten Syke, Arnagill (152757) (Plate 37) is first detailed, because it shows clearly the relation of the First and Second Brimham Grits:

25'	very massive, feldspathic, coarse grained sandstone - Second Brimham Grit (top not seen)
10'	unexposed (flaggy mudstone is seen at this horizon in the head of Arnagill)
6"	flaggy siltstone
5'	dark blue, finely micaceous shale
14'	gap
6"	grey shale
1'	blue shale
1'	dark blue shale with *Lingula sp.*
2'	pale ganister with rootlets
2'	cream fireclay
35'	approx. unexposed
2'	coarse sandstone, apparently in situ

PLATE 38 A

Nidderdale from Thrope Edge, looking N.N.W. (looking up valley from 105747) 1. Skyline- Left, outlier of South Haw; Centre, Brown Ridge, both outcrops of Libishaw Sandstone with steep slopes and feature on Libishaw Shale. 2. Left of centre- the right angled bend of the Nidd is seen and the large railway cutting and tunnel entrance where the Middle Limestone is exposed, north of Limley Farm (in valley bottom) 3. Right of centre- Thrope Edge landslip scar with cliffs visible in Nidderdale Shales. The feature uphill from the scar is an impersistent Grit high in the Nar Hill Beds, which has died out at the point where the photograph was taken .

PLATE 38 B

Scar House Reservoir and Little Whernside (viewed from 068767) Little Whernside (centre) and Great Whernside (left) are capped with Lower Follifoot Grit. The bench formed by the Red Scar Grit on the S. slopes of Little Whernside is clearly seen. Gulleys in the Nidderdale Shales are visible at two points in the middle distance (left and right, showing up pale) . The Three Yard Limestone is exposed in Trows Beck (right of centre , with trees).

8'	gap, assumed coarse sandstone
25'	extremely coarse, massive feldspathic sandstone, the lowest 9'6" of which forms a single stratum.- First Brimham Grit
-	Capelshaw Shales

The remainder of the exposures in the Brimham Grit Group are described systematically from S.W. to N.E.

Sypeland Crags are a conspicuous line of scars in the Nidd drainage (133737). 20' of extremely massive, coarse sandstone, often current bedded and weathering into fluted pillars is here seen. Grit relicts stand on the plateau above Sype Land, one of which is in 14' of coarse sandstone at a higher stratigraphic level than the rocks in the main line of Sypeland Crags. The most conspicuous residual belongs to the lower outcrop, in line with Sypeland Crags, and is called "Jenny Twigg and her daughter Tib" (130742). These are pillars in 18' of massive, current bedded, coarse sandstone with the bedding fluted by the wind along lines of varying resistance to denudation (see Plate 40A). Certain other relicts are mushroom forms reminiscent of the 'pilzfelsen' of an arid erosion cycle.

Lulbeck Crags (138758) shows 15' of massive, coarse grained sandstone, whilst blocks and outcrops over a tract of ground north of this point. It is possible that beds higher than the First Brimham Grit come in with a feature near Lulbeck Head (the lines of the geological map appended to this work were constructed on this assumption).

Outcrops on the First and Second Brimham Grits, occurring on two well marked features continue from the line of the Limley fault on Low Ash Head Moor to ground east of the Roundhill dam. The First Grit forms Nappa Stones (141756), where 12' of current bedded, coarse sandstone is visible, though it is possible that the full thickness may be nearly 50'. This Grit can be traced into the lower line of cliffs in Arnagill where up to 25' coarse sandstone is seen on the west side of the valley. This is an extremely massive, coarse grained feldspathic sandstone, huge boulders of which are numerous in the valley, the largest ones having a volume similar to that of a single deck omnibus.

The Second Brimham Grit forms Combs Crags (143753) (Plate 40B) in 30' massive, pebbly, coarse current bedded sandstone with slump structures in the lower beds. A feature with blocks of coarse sandstone runs into Arnagill where the Second Grit forms cliffs in very massive, coarse grained feldspathic sandstones (Plate 39A). A double line of scars with numerous boulders of coarse sandstone (the First and Second Brimham Grits), runs along the hillside to Clints Quarry (Plates 39B, 49). N.E. of Clints Moor, however, the First Brimham Grit appears to die out, since the feature on this horizon together with its attendant boulders is absent. This is consistent with the evidence of sections at Swinton Park which show a large thickness of unfossiliferous sediments below the Second Brimham Grit, but without any development of the First Grit.

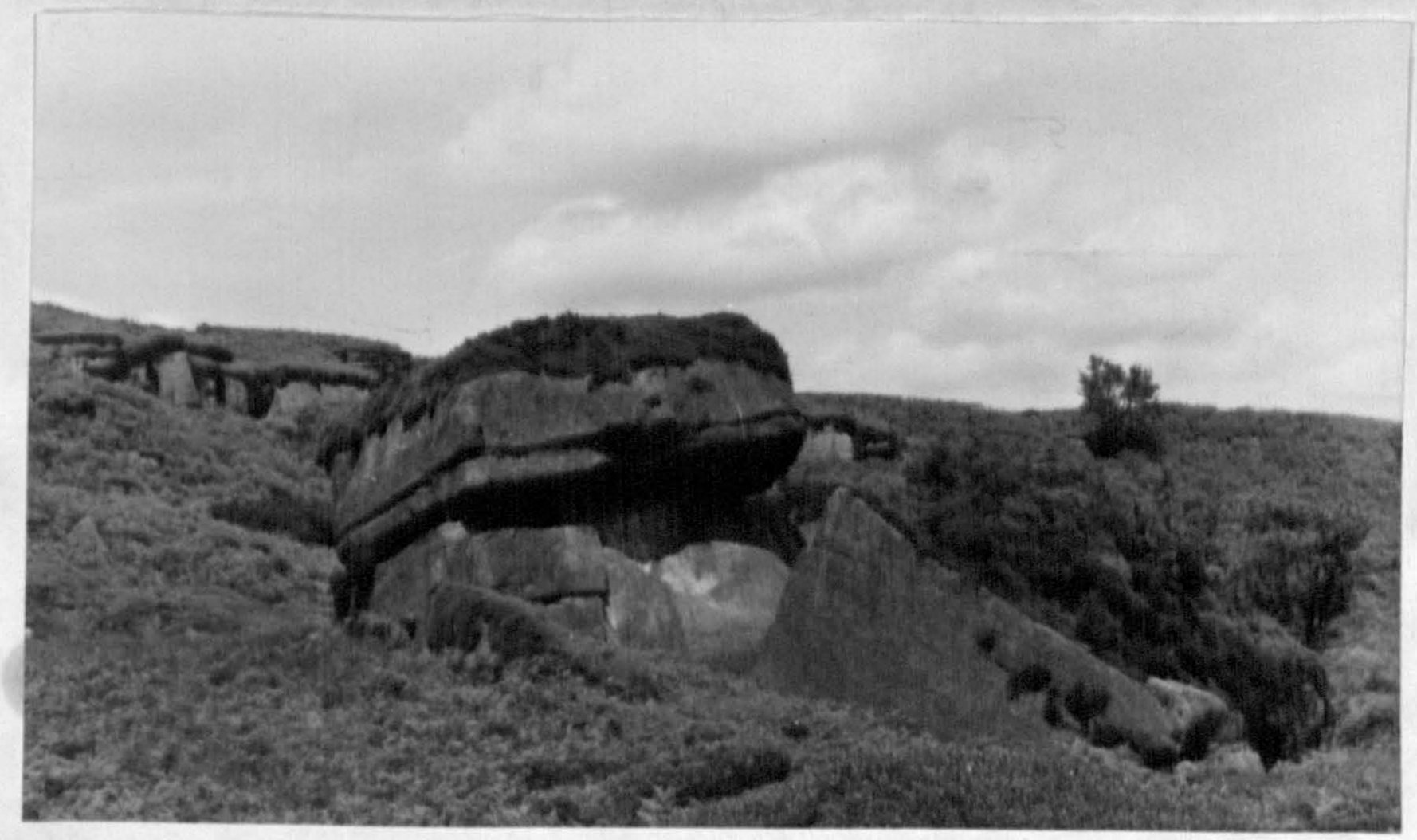


PLATE 39 A

The Second Brimham Grit, Arnagill valley, Colsterdale. The scar in the background shows the rock in place. The boulders in the foreground which are derived from the outcrop, show the very massive nature of the sandstone, which is intersected by strong joints, spaced widely apart.

PLATE 39 B

Arnagill Crags viewed from Arnagill valley. The prominent double feature in the First and Second Brimham Grits with their huge sandstone boulders is clearly seen. The dislocation of features by a fault running up the stream in the middle-ground , throwing beds down to the south is also evident. Leighton Reservoir and Bales Plantation, N. of the R. Burn appear top left. The prominent tower is the sighting tower for the Harrogate Corporation water tunnel.

The Second Brimham Grit is well exposed in Clints Quarry (164780) (Plate 37) where 32' of extremely massive, coarse grained feldspathic sandstone make its full thickness. The beds above the Grit in the quarry are shales with a coal smut and fine grained sandstones. The strata beneath it are 2' mudstone overlying a 4' soft, micaceous very fine grained quartz sandstone, with plates of muscovite.

The Second Brimham Grit forms a distinct feature north of the quarry. This can be traced to Knowle Plantation (175793) east of which it becomes indistinct, but has been mapped as being the horizon of a feature north of Lobley Plantation (188794) which shows two coarse sandstone boulders possibly belonging to this horizon. The outcrop is inferred to be displaced by a fault running up Sole Beck Gill and the Grit appears again in quarries in this gill (192797). They show 18' very massive medium to coarse grained sandstone with only one bedding plane and with slump hitches in the base of the section, these being comparable to similar, minor, slump structures at Combs Crags, adjacent to the Limley Fault. A quarry at a slightly higher level uphill is in 8' of massive sandstone.

The beds exposed in Sole Beck Gill (191798) below the Second Brimham Grit appear to comprise over 100' of strata. The lowest beds are flaggy sandstones with some silty partings, overlain by silty mudstones followed by alternating flagstones and siltstones. The beds below the Second Brimham Grit are not exposed for some tens of feet and thus it is possible that the

Lingula horizon of Arnagill is present, but not exposed.

The section at Quarry Gill, Swinton is a similar one to that seen in Sole Beck Gill. 52' of Second Brimham Grit are exposed below Fiddle Neck Pond (196480) in an old quarry in massive, medium grained, feldspathic sandstone. Large numbers of blocks of massive sandstone line the banks of the ornamental lakes of Swinton Park between Lake Superior and Storth Pond. According to Fowler's History of Masham and Mashamshire (1865) these boulders were brought in at great expense from the surrounding country to add scenic effect to the ponds and they do not provide evidence for the occurrence of an extremely thick Second Brimham Grit as one might suppose.

The section between 16' and 40' below the Grit in Quarry Gill is obscured, and it is possible that the Lingula band of Arnagill occurs here, but is not seen. The beds seen below the Second Brimham Grit are chiefly silty mudstones with thin flagstones and flaggy mudstones. They form a steep cliff, overlooking the R. Burn downstream from the mouth of Quarry Gill, in silty mudstones with a 6' band of flaggy sandstone. The lowest beds in this section show no sign of a fauna or a soapy shale facies and are accordingly assigned to the Brimham Grit Group. In all about 100' of strata occur below the Second Brimham Grit. These are assumed to be lateral equivalents of the First Brimham Grit and the beds above it.

Outcrops N. of Colsterdale and on the banks of the R.Ure above Masham -

The Brimham Grit Group forms an outlier on the north side of

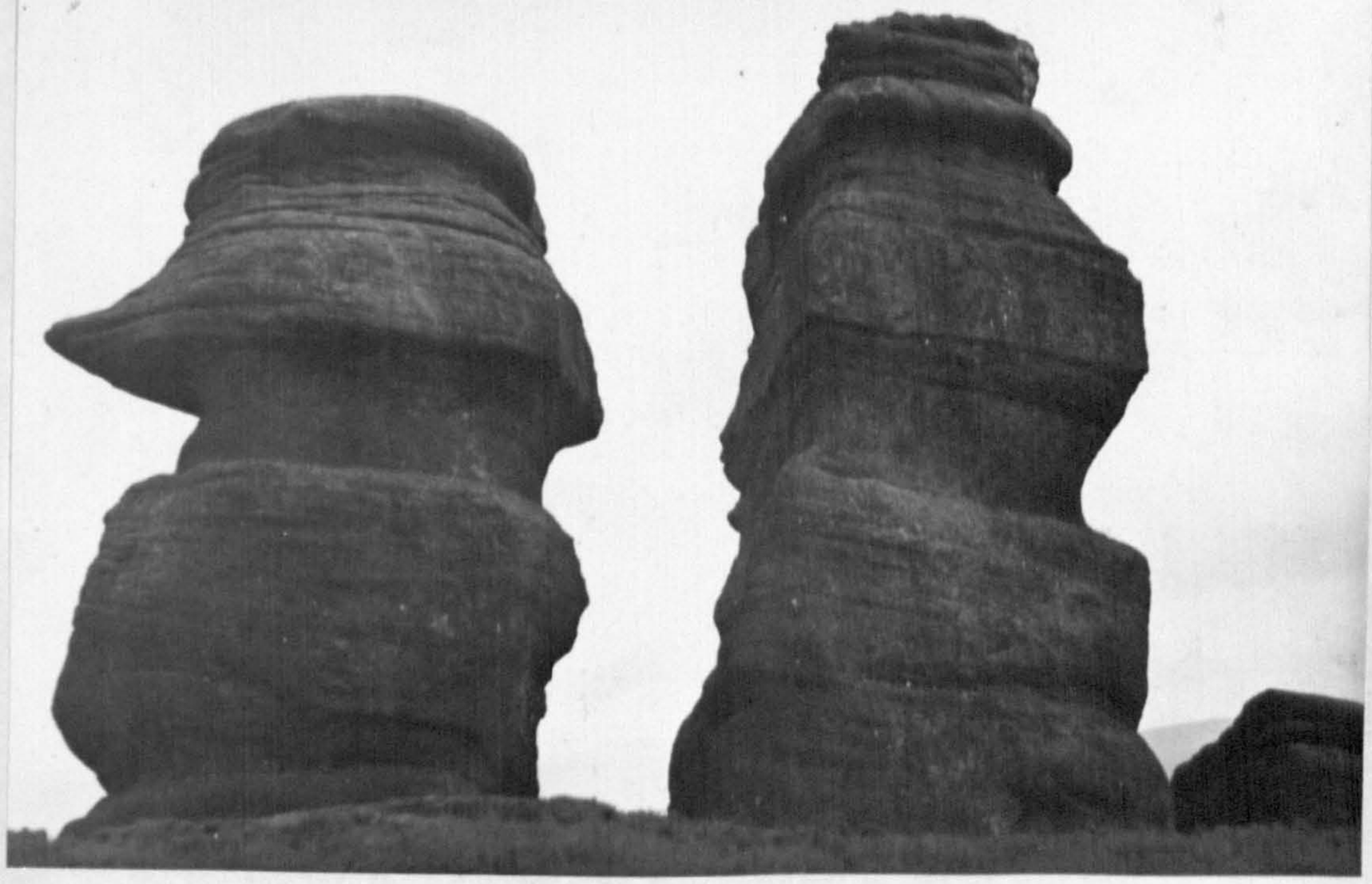


PLATE 40 A

First Brimham Grit in 'Jenny Twigg and her daughter Tib', Sype Land, Nidderdale (130741). These curious relicts are Grit pillars in situ, isolated from the main outcrop by denudation. The highest pillar is 18' tall. The coarse and massive nature of this sandstone, with occasional current bedding is clearly seen.

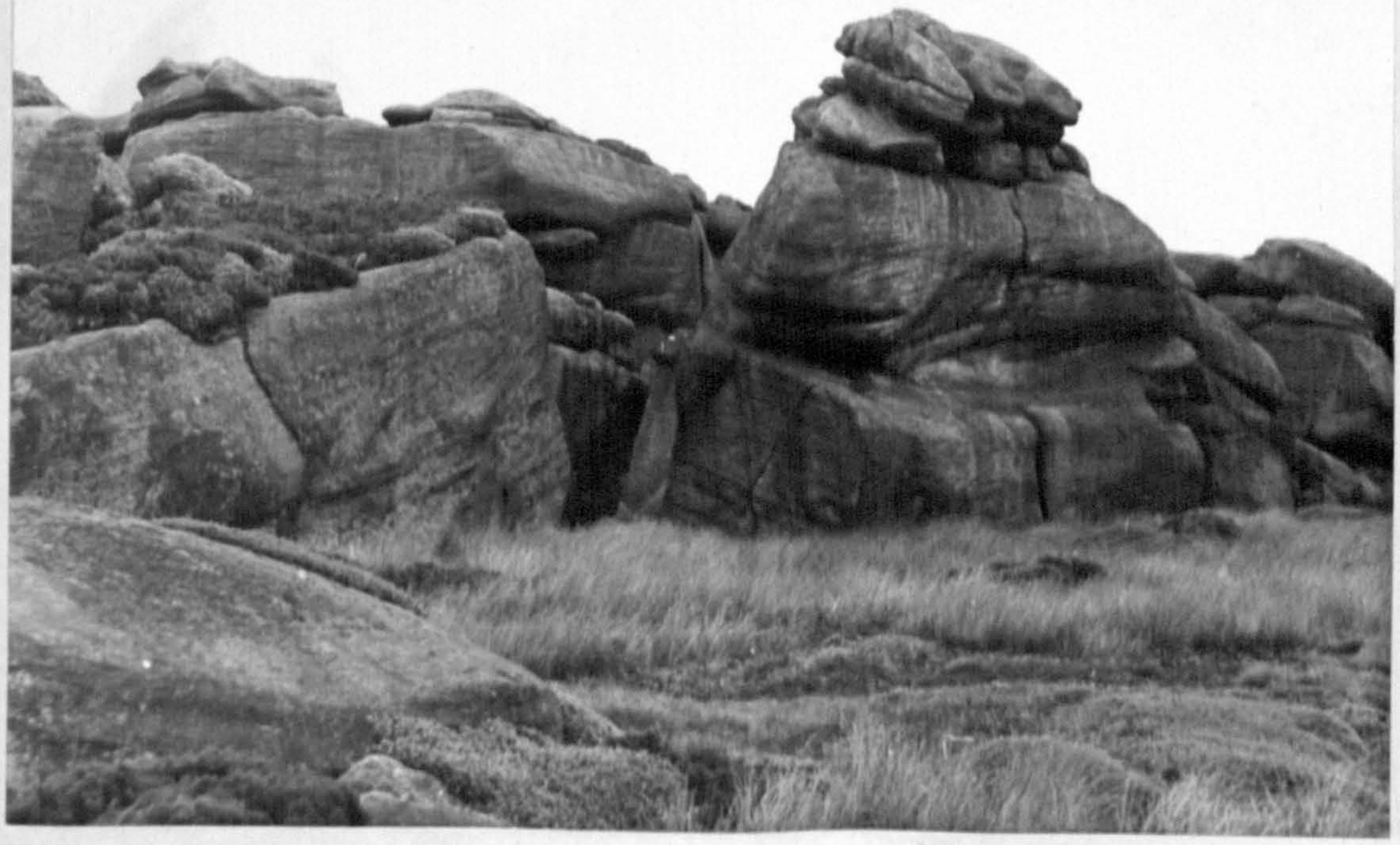


PLATE 40 B

Second Brimham Grit in Combs Crags, Low Ash Head Moor, Colsterdale (143753). These crags mark the outcrop edge of the Grit and show effectively the exceedingly massive nature of the sandstone. Current bedding is excellently developed. The pinnacle on the right side of the centre of the photograph is over 20' high.

Colsterdale, largely obscured by drift. No complete succession can be made out, but it appears that beds between the Cayton Gill Shell Bed and the First Brimham Grit thin out to the the north so that the outcrops of the Follifoot and Brimham Grits are sometimes so close together that, in drift covered country, they cannot be readily distinguished.

On the east side of Ger Beck (161818) 4' coarse grained arkosic sandstone with grains up to 1 mm. in size are seen 50' above the Cayton Gill Shell Bed. This means that, if this is the First Brimham Grit, there has been a large diminution of thickness of beds between these horizons, which in Arnagill are approximately 150' apart. The naming of this exposure as the First Brimham Grit is a purely lithological one, since no coarse sandstones are known from the horizon of the Libishaw Sandstone which is approximately 50' above the Shell Bed further south. Abundant blocks of coarse sandstone, assumed to be at the same stratigraphic level occur between this exposure and Bales House and also near Tranmire Stone (160826).

Massive sandstone boulders on the summit of Tranmire Hill (147833) are interpreted as belonging to a capping of First Brimham Grit. Since the Quaternary ice sheet has ridden against the sides of the hill, no great reliance can be placed on this interpretation. A feature on the north side of the summit lends some support to the view that a cap of hard rock exists.

An exposure of 10' of current bedded medium grained sand-

stone near Millstone Bank (166837) is interpreted as belonging to the Brimham Grits. This suggestion involves considerable northerly thinning of the beds between the Follifoot and Brimham Grits which are here apparently little in excess of 30' thick, compared with 200' at Arnagill and a probable 85' at Ger Beck. Owing to lack of definite evidence regarding the horizon of the above exposure, however, this correlation must be regarded as tentative. It seems possible that the northerly thinning of beds below the First Brimham Grit may be due to erosion at the base of the First Brimham Grit, analagous to that described from Pateley Bridge by Walker (1952) which involved transgression on to the Cayton Gill Shell Bed.

At the west end of the overflow channel south of Ellingstring village (173836) blocks of very massive coarse grained sandstone are considered to belong to the First Brimham Grit. In this district there appear to be about 40' of beds between this horizon and the Follifoot Grit. A feature running between Ellingstring and High Ellington is also interpreted as being in the First Brimham Grit.

At Brewers Spout, near High Ellington (198832) 5' of massive, medium grained sandstone occur. This rock is not a typical Brimham Grit however, but is a poorly sorted quartz sandstone with a grain size varying from 100 to 1000 microns, and hence similar to the Brimham Grits in coarseness rather than composition (the Brimham Grits are usually feldspathic). The feature the First Brimham Grit makes south east of Ellington appears to

be displaced by a fault which is mapped as continuous with the one seen to the east in the banks of the Ure near Low Mains. The displaced feature runs through Ellington Hall Covert and above Sutton Pen towards Spelder Banks; no exposures are seen, but angular blocks of sandstone occur in the covert (200828).

The Lower Brimham Grit is not mapped in the Fearby district and, in order to be more consistent with the interpretation of the Quarry Gill section, is assumed to be absent between Healey and Fearby, as it appears to be at Quarry Gill. The only exposure seen in the group is near Healey (at 184809) where old stone pits have been worked in a fine grained, compact, massive quartz sandstone which is not again typical of the coarse, massive sandstone making up the main Grits of the group. The stratigraphic level at which this exposure appears to occur makes it likely that it belongs to the Brimham Grit Group, of which it is probably one of the minor sandstones.

The beds above the First Brimham Grit are not exposed in the outlier north of the River Burn, but at Froggersgill Wood (186830) blocks of flaggy, fine to very fine grained quartz sandstone occur. These are thought to belong to a horizon between the First and Second Brimham Grits. There is no evidence for the presence of the Second Brimham Grit in the outlier north of the river Burn, though it is possible that it may occur under drift on the higher ground of the district.

A number of outcrops occur in the vicinity of the River

Ure north of Masham which are here tentatively correlated with beds of the main outcrop, but not without some hesitation. Along South Spring Bank (225825) a sandstone occurs, the outcrop being represented by numerous blocks which have permitted measurement of this horizon in conjunction with a small outcrop. (Plate 37). The beds under the sandstone, which is considered to be the Second Brimham Grit, are soapy shales and siltstones. No fossils were extracted, but the lithology suggests that the shale may have been deposited in a marine environment. The Grit is exposed in a cliff N.W. of High Burton (225828) where 15' of massive, coarse sandstone are seen with some small shale pebbles in the lower beds. A section further north on the east bank of the Ure shows beds below the Second Brimham Grit (224830) which are silty shales and soft, flaggy sandstones, of which 17' are seen.

Beds which appear to be at a still lower stratigraphic level are seen in the west bank of the Ure (222831) where 25' of fine grained arkosic sandstones are exposed. They are bedded regularly in 3" posts and carry numerous flecks of carbon, derived from plants. The apparent order of succession of the beds detailed above is only correct if there are no faults and for this reason these records have not been appended to the figured measured section of South Spring Bank.

The lowest horizon seen in this neighbourhood is apparently the First Brimham Grit, exposed in the River Ure below the grounds of Clifton Castle (219839). This is considered to underlie flaggy sandstone interbedded with silty mudstones

which are faulted against the 25' of arkosic sandstones described at 222831.

If the above interpretation of the sections, which are unfortunately somewhat scattered is correct, both of the Brimham Grits occur, whilst the sediments between them are lithologically closely comparable with those seen below the Second Brimham Grit of Quarry Gill and Sole Beck Gill.

Palaeontology

A dark grey, compact shale 30' below the Second Brimham Grit in Rowten Sike, Arnagill, yielded a restricted fauna consisting chiefly of plant remains, Lingula and minute gastropods. The fauna is reminiscent of that obtained 50' below the Addingham Edge Grit in the Keighley Co-operative Laundry borehole (Stephens et al., 1953) since both show records of Lingula and rhizodont scales. A further possibility is that this band is at the horizon of the Eccup Marine Band with Reticuloceras reticulatum type form recorded from the Leeds area by Edwards et al., 1950. This latter possibility is quite plausible since it is well known that many of the marine goniatite bands die out on to the Rigid Block, and this band may be a quasi-marine equivalent of the goniatite band since it contains Lingula and dwarf gastropods.

Faunal Lists

Lingula band between First and Second Brimham Grits

Carbonised plants

Discina sp.
Lingula mytiloides J. Sowerby

Actinopteria sp.

?Aclisinia sp.

Orthocone nautiloid

Rhizodont scale

All specimens are from the same locality: Rowten Sike, Arnagill (152757).

CHAPTER 18

CORRELATION

Tonks (1925) and Chubb and Hudson (1925) have drawn up successions within the present area in which the naming of the beds has been dependent on correlations with adjoining ground. The nomenclature of strata adopted by Tonks has been continued by several subsequent authors who have quoted his section of Upper Nidderdale in effecting correlation with the present area. The validity of these correlations is discussed in the ensuing pages.

Beds of Yoredale facies - Correlation by lithological and palaeontological methods has met with some success during this study, though the chief errors in the past have been due to over-reliance on the palaeontological aspect. Tonks (1925) correctly correlated the Middle Limestone of Nidderdale with that of the type locality in Wensleydale, on the basis of the occurrence of *Gigantoproductus*, *Palaeosmilia regia* and *Orionastraea* in the Nidderdale outcrops. However, in the Angram area three distinct limestones occur above the Middle Limestone. The highest two of these Tonks refers to the Five Yard Limestone on the basis of the occurrence of a zaphrentid fauna beneath the second limestone, which is termed the lower leaf of the Five Yard Limestone on the strength of there being a similar zaprentid fauna below this limestone in Wensleydale. The present work, using the findings of Moore (1955), shows

that in reality the Five Yard, Three Yard and quite probably the Underset Limestone are represented at Angram, whilst at Lofthouse the two lowest of these beds still occur. The arguments used are partly lithological and partly faunal. These are summarised here and a fuller treatment is to be found in chapters 4 and 5. Moore shows that the Five Yard Limestone consists of three leaves, the lowest of which carries a Gigantoproductus-coral assemblage. The shales and sandstones of the Middle cyclothem which underlie the Five Yard Limestone thin drastically to the S.E. until, in the S.E. of Moore's ground, the shales which comprise all the beds between the Middle and Five Yard Limestones are very thin. In upper Bishopdale these shales are 5'-8'9" thick, whilst in the W. of the present area shales varying from 4' to 9'6" in thickness separate the Middle Limestone from a higher limestone with a Gigantoproductus-coral faunal assemblage in its lower part. This latter horizon is correlated with the similar Five Yard Limestone in Bishopdale, 2½ miles W. of the present area. Whilst the Five Yard Limestone of Nidderdale does not contain a distinctive fauna it is separated from the underlying Middle Limestone by a small thickness of shales, as in Coverdale. It is overlain by shale with Weberides sp. and a normal shale fauna. This is similar in thickness, biofacies and lithofacies to the shale above the Five Yard Limestone in Coverdale. By these means the correlation of the Five Yard Limestone in Nidderdale is effected and the over-lying limestones are

therefore the Three Yard and probably the Underset Limestones (the latter has only a limited occurrence at the head of the dale).

The earlier correlations of Tonks (1925) in Nidderdale have been quoted by many authors, among them Dunham and Stubblefield (1945). The present revision of nomenclature in Nidderdale, in the opinion of the present writer, may affect the naming of the highest beds at Greenhow. The upper limestone at Greenhow is the Toft Gate Limestone. In the available exposures and underground workings it is separated from the lower beds of the sequence by a gap which is probably of small size. Orionastraea was found in the shales between the Upper and Lower Toft Gate Limestones and on this account it was suggested by Dunham and Stubblefield that the Lower Toft Gate is probably the Simonstone Limestone and the Upper Toft Gate the Middle Limestone. This is because Orionastraea is known from the top and bottom respectively of these two limestones and its occurrence in the shales between is therefore looked upon as not improbable (in fact Moore, 1955, records Orionastraea from a thin limestone in the Simonstone cyclothem, between the Simonstone and Middle Limestone). Thus, whilst it seems probable that the Upper Toft Gate is the Middle Limestone, a further, thin limestone occurs above it which appears to be in the position of the Five Yard Limestone of upper Nidderdale. This possibility has thus far been overlooked,

probably because it has not hitherto been realised that the Five Yard Limestone lies only about 8' above the main mass of the Middle Limestone in Nidderdale.

Chubb and Hudson (1925) correlated the limestone at Coverhead with the Underset Limestone, though this was later altered to the Main Limestone by Hudson (1933) without stating any reasons. The mapping evidence in Coverdale is in the opinion of the present author conclusive that this horizon is in fact the Main Limestone. The point at which the Main Limestone was shown to thin to nil to the E. in the map on p. 282 in Chubb and Hudson was expressly examined to see if there was any sign of a limestone being cut out by the Grassington Grit Group. Mapping here showed that the Main Limestone extends unbroken round the spur at Stony Gate and all the evidence thus validates the emended correlation of Hudson and that here put forward.

Though Phillips (1836) and Dakyns (1891, 1892) had both mentioned the occurrence of the Little Limestone in the present area there does not appear to have been a clear notion of the exact horizon of that bed. The key of the Geological Survey 1" map refers to these beds simply as the 'Cherty Beds' without specifying their horizon. Since the work of Rowell (1953), Wells (1955a) and Scanlon (1955) it has been shown that the Little Limestone of the northern half of the Askrigg Block carries in it a bed of vertical cherty tubes, possibly made by annelids. Whilst Wells (1955 a, b) measured two sections in the present

area, he did not visit any localities showing the Little Limestone Pipe Bed and it remained for the present author to verify that the horizon at the base of the chert series in Howden Beck and Thupton Gill is in fact the Little Limestone. During the present work the Pipe Bed has been found at six localities at the base of the chert series which is named the Richmond Chert Series, following Wells (1955a). The presence of the Little Limestone south of the River Ure is established as a virtual certainty since there is no other extensive horizon of cherty pipes known which could be confused with the present horizon. The effect of the present discovery is to confirm the belief of Wells that the Little Limestone descends on to progressively lower horizons to the south so that finally it rests on the Main Limestone.

The Crow Limestone has not been previously recorded from the area here described and is not mentioned in the key to 1" sheet 97 S.E. (New. Ser . 51). In the vicinity of East Witton and on the north side of the Ure at Leyburn a limestone was mapped by the Geological Survey which was called the Crow Limestone in the Leyburn district. No name was given to the Limestone south of the Ure and its relations with the underlying beds are obscurely shown due to the non-recognition of the fault in Red Beck Gill which displaces the outcrop of this horizon. Owing to the fact that it is separated from the Richmond Chert Series by a shale and sandstone it appears to be a virtual

certainty that this is the Crow Limestone overlying the Ten Fathom Grit.

South of the Craven Faults the rocks of Yoredale lithology are represented by the Bowland Shales, which are shown to be their equivalents by the rare records of goniatites from the Askrigg Block. The Bowland Shales are appreciably thinner than their equivalents on the Block and do not contain thick limestones.

Beds of Millstone Grit facies - Strata of this facies up to the top of the Red Scar Grit were originally correlated with the Kinderscout Grits of south Yorkshire (key of 1" sheet 97 S.E. - New Ser. 51). Since the advent of goniatite zoning (Bisat, 1924) it has been shown that in reality it is the higher beds of the sequence, the Brimham Grits, which should be thus correlated. Correlations with adjoining areas given by many authors have involved inaccuracies. These are very largely due to the erroneous nomenclature of beds in upper Nidderdale dating from the work of Tonks (1925) whose section is often quoted with slight modifications.

At the level of the Grassington Grit Group it had been realised by Dakyns (1891, 1892) that a facies change from predominant sandstones to predominant shales took place in a northwards direction. He also suggested that one of the sandstones in the degenerate shaly facies of the Grassington Grit Group might be the Ten Fathom Grit of the country north of the ground here described. The present author recognises

the Ten Fathom Grit and Crow Limestone in the N. of the area in such a position that their southwards dying out due to intra-E_1 erosion seems most likely, for these beds thin out with some suddenness which is consistent with the view that they have been eroded away in the south. The misinterpretation of part of the Grassington Grit Group as the Ten Fathom Grit was unwittingly perpetuated by Wells (1955b, Plate 19) who named a sandstone in the Grassington Grit Group of Thupton Gill the Ten Fathom Grit. The most detailed comment on northwards changes at the level of the Grassington Grit Group is that of Chubb and Hudson (1925, figure on p. 268) who suggested that the Grassington Grit Group was overlapped southwards and that the Pinlow Pike Sandstones were the equivalent of the Howgate Edge Grits of Shunner Fell. Hudson (1941) himself provided the first piece of evidence for the correction of this view by the discovery of Cravenoceras cowlingense in the Mirk Fell Beds. C. cowlingense has since been found a short distance above the top of the Grassington Grits by Dunham and Stubblefield (1945) and subsequently by the present author. Since this goniatite appears to have a widespread distribution in a single band the correlation of the Cockhill Limestone with the Mirk Fell Beds is here followed, in common with several other authors, including Rowell (1953) and Scanlon (1955). Further, Scanlon (1955) has demonstrated on mapping evidence that the arenaceous horizon below the level of C. cowlingense, namely the Mirk Fell Ganister (which underlies the Mirk Fell Beds) maps into

the Lower Howgate Edge Grit. This gives a southerly thickening of the arenaceous beds below the C. cowlingense horizon from 4' to about 60'. In the present area the Grassington Grit group is 200' thick in the south and thins in a northerly direction to 150' and probably to little more than 100'. It appears that there is progressive northerly thinning of the Grassington Grit Group which is continued further to the N.W. in the Shunner Fell area (the full evidence is set out in Chapter 9). Whilst the Grassington Grit Group is about 190' thick at Greenhow, a figure corresponding closely with that in the south of the present area, a vast thickening of the sandstones and shales below the C. cowlingense horizon and its equivalents is seen S. of the Craven Faults so that ultimately there are 2900' of beds in the Skipton Moor Grit Group in the Rombalds Moor Area (Stephens et al., 1953). Owing to the absence of goniatites in these beds and in their equivalents on the Askrigg Block it is not possible to verify if the Grassington Grit Group of the present area was deposited synchronously with the whole of the Skipton Moor Grits, or just with the upper part. The latter suggestion seems less likely since it involves a Yoredale type sedimentation on the Block forming the Stonesdales Limestones and a Millstone Grit facies south of the Craven Faults; this seems an unlikely concurrence, but cannot be ruled out, because cases are known of the two facies being deposited within fairly small distance of each other (limestones occur in the Arnsbergian of Scotland). It seems more logical to regard

the Upper Bowland Shales of low E_1 age as the probable equivalents in toto of these Yoredale facies beds. South of the northern part of the Central Basin where sedimentation was everywhere thick (Skipton Moor Grit Group, Pendle Top Grit, Bowland Grit Group) the beds are again thin when exposed in Edale, where the whole of E_1 is only 406' thick (Hudson and Cotton, 1945).

The next important horizon for correlation is the marine band with Cravenoceratoides nitidus. This goniatite was first recorded from the present area by Tonks (1925) and has subsequently been often found to the south of the present ground, but never to the north, with the exception of the record of a poorly preserved Ct. cf. nitidus in the Castlecary (Levenseat) Limestone (in Currie, 1954) which suggests the presence of Ct. nitidus subzone in the Upper Limestone Group of Scotland. This goniatite has been found over a wide area to the south of that here described and a correlation was proposed by Hudson (1939) of the Colsterdale Limestone with Ct. nitidus, and a similar limestone in the Birk Gill Shales of the Simonstone area. Ct. nitidus has also been found in the Greenhow area (Dunham and Stubblefield, 1945) and in the Lancaster Fells (Slinger, 1936, Mosely, 1954). In each case it occurs in a limestone which was probably deposited simultaneously over a large area, since it is nearly constant in fauna, thickness and lithology. Records from the Bradford and Skipton area (Stephens et al., 1953), the Leeds area (Edwards et al., 1950)

and the Beamsley anticline (Jones, 1943) do not include Ct. nitidus. Instead there are recorded Cravenoceras subplicatum, which occurs in the Alport borehole (Hudson and Cotton, 1943) below Ct. nitidus, and Ct. stellarum (in the first two areas cited above) which occurs above Ct. nitidus in the same borehole. It follows therefore that the Colsterdale Marine Series with Ct. nitidus are the equivalents of part of the Marchup Marine Beds with the above named fossils (this opinion has already been expressed in Durham and Stubblefield, 1945).

The Colsterdale Marine Series have been broadly correlated with the Shunner Fell Marine Beds (Hudson, 1939, Scanlon, 1955,). These have been in turn correlated with the High Seat Marine Beds (Rowell, 1953) and the Botany Limestone (Reading, 1954). The evidence for the first correlation is faunal and is discussed in detail in Chapter 13. Since the correlation at this level is well established at least as far as Shunner Fell, and the Mirk Fell Beds are the equivalents of the Cockhill Marine Band, it appears that the lower part of Arnsbergian thickens greatly to the north west from the present area towards Shunner Fell (Plate 41) and includes a marine horizon, the Hearne Beck Limestone, which is not represented in the present ground, except possibly by one of the thin, impersistent limestones in the Nidderdale Shales. It must be stated however that the evidence from Coverdale points to a northerly thinning of the Nidderdale Shales from 270' in the Great Whernside area to 200' or less on Penhill.

In view of the fact that the beds are thinning and not thickening towards Shunner Fell, a large and somewhat sudden thickening of the equivalents of the Nidderdale Shales is necessary to the N.W. of Penhill.

It is interesting to note that the lithological characters of the sandstone which occurs over a wide area below the beds with Ct. nitidus are similar in several respects with those of the Red Scar Grit of the present ground. In both the Bowland Fells and at Simonseat the sandstone below the beds with Ct. nitidus and other goniatites shows a coal developed with coarse sandstones below it and fine grained sandstone above. This compares closely with the coarse and fine grained Lower and Upper Red Scar Grits, with the intervening Woogill Coal, found in the present ground. It further seems possible that the fossiliferous development in the Upper Red Scar Grit of the present area is equivalent to a fossiliferous sandstone found below the shales with ironstone nodules described by Rowell (1953) from the High Seat Marine Beds, north of Swaledale. The shales with ironstone nodules compare well lithologically with shales developed in Colsterdale in the lower part of the Colsterdale Marine Series, which are here regarded as the probable equivalents of the High Seat Marine Beds.

The discovery of Homoceras beyrichianum and H. aff. subglobosum above the 'Upper Follifoot Grit' of Tonks (1925) has led to a revision of the nomenclature of beds at that level since H. beyrichianum is widely known S. of the Craven Faults between the

Upper and Lower Follifoot Grits and their equivalents. The 'Upper Follifoot Grit' of Tonks is accordingly renamed the Lower Follifoot Grit. The rare upper Follifoot Grit is only represented by local fine grained sandstones in the Ganister Beds. The beds formerly referred to the Lower Follifoot Grit are now termed the Nar Hill Beds since they are broadly equivalent to similar beds with fine sandstones in the ground to the south. The strata equivalent to the Nar Hill Beds over a wide area south of the Craven fault are lithologically similar to those of the present ground since they consist of shales with highly variable fine grained sandstones. The Cravenoceratoides stellarum and Nuculoceras nuculum faunas (high E_2) have been extensively recorded south of the Craven Faults at this stratigraphic level, but neither of these appear to persist on to the Block, where the Nar Hill Beds are without marine fossils.

It appears that the Homoceras zone is thin in the present area. The whole of the Ganister Beds probably lie within this zone since the H. beyrichianum assemblage found at the base of the Ganister Beds is a low H zone fauna (Hudson, 1954). The zonal position of the Lower Follifoot Grit is debatable. About 50' under its equivalents south of the Askrigg Block the Nuculoceras nuculum (highest E_2) fauna occurs whilst above it a lowest H zone fauna (with H. beyrichianum) occurs (Stephens et al., 1953). Moseley (1954) prefers to refer the Grit to the upper part of the H zone, and possibly this is the most likely

interpretation.

At the level of the beds of R_1 age confusion in correlation has arisen in the past. Bisat (1914) recognised two shell beds in Colsterdale. The measured section quoted by authors in effecting correlation with the present area has invariably been that of Tonks (1925) which shows two shelly sandstones; these have been assumed to be the two shell beds of Bisat. During the mapping of Geological Survey 1" sheet 92 N.E. (New. Ser. 61) the Libishaw Sandstone was recognised as the lower member of the Brimham Grits. This is a fine grained sandstone, separated from a coarse one, the Comb Hill Grit, by the Capelshaw Shales of Hudson (1939). In view of the fact that a coarse sandstone occurs in a similar relationship to a fine one in the present ground, a lithological correlation is made with areas to the south. The Comb Hill Grit is equated with the First Brimham Grit of the present work, since both are coarse, pebbly sandstones. The Libishaw Sandstone is correlated with the sandstone of the same name in the present area since both are fine grained sandstones, with a local shelly development in Colsterdale. If these correlations are correct the Libishaw Sandstone of Greenhow and elsewhere is the Upper Shell Bed of Bisat (1914) and therefore higher than the 'Hard Bed' of Simonseat with which it had earlier been correlated by Hudson (1939).

An examination of the fauna of the Hard Bed and its equivalent at Simonseat, Beamsley and Greenhow shows that it

contains the same brachiopod as the Cayton Gill Shell Bed (so called by the present author) of Colsterdale. Productus carbonarius, Derbyia gigantea and Schizophoria hudsoni are records held in common. Comparison of the faunas of the Hard Bed and those from the shelly development of the Libishaw Sandstone in Colsterdale shows that there is very little similarity. Whilst D. gigantea is a rare record, the other two species named above do not occur in the Libishaw Sandstone. Lithologically the Hard Bed is like the Cayton Gill Shell Bed of Colsterdale and shows similar worm chewed beds. In thickness there is a s trong correspondence which is not seen when the Hard Bed of Simonseat is compared with the sandstone here called the Libishaw in Colsterdale.

The shelly sandstones and siltstones found below the Hard Bed and its equivalents at Simonseat and Greenhow appear to be thin or absent in the present area, but shelly siltstones seen at Carle Fell and Swinney Beck may lie at this level. The Agill Sandstone of Colsterdale does not appear to be present at Simonseat and Greenhow and seems to be a horizon peculiar to Colsterdale and upper Nidderdale. Due to the absence of this sandstone to the south the Hard Bed (equivalent to the Cayton Gill Shell Bed of the present ground) and the Libishaw Sandstone are closer together at Greenhow and Simonseat than in Colsterdale.

Walker (1952) stated that the Libishaw Sandstone south of the area here described is coarse grained, saying that "it is obvious however that Jones (1943) and Dunham and Stubblefield

(1945) considered the Libishaw Grit to include the fine and coarse sandstones". The present author is unable to verify these suggestions from an examination of the relevant papers, since neither of them mention the word "coarse". Dunham and Stubblefield explicitly state that the Libishaw Sandstone is medium grained (and this, when employing a dual sandstone-grit scale of coarseness values which cannot be directly compared with the Wentworth scale used by Walker and the present author, but probably implies 'fine grained' - Wentworth). Walker claimed that field examination of a section in the Simonseat area had showed that the Libishaw Grit was of coarse pebbly type. The present author would prefer to rely on the evidence of Hudson who has mapped this complex area in detail and who stated that this horizon was a "coarse feldspathic sandstone" (on a dual sandstone-grit grain size classification) as distinct from the Comb Hill Grit which was a "coarse pebbly feldspathic grit". It seems therefore that in the view of Hudson the grain size of these beds would be at most medium grained on the Wentworth scale and certainly not coarse and pebbly. On grounds of lithological similarity the Audlethorpe Grits of the Bradford and Skipton area are correlated with the Libishaw Sandstone. It appears that if this is correct the Otley Shell Bed which lies between this horizon and a coarse, pebbly grit (the Plumpton Grit) is the equivalent of part of the Capelshaw Shales of the present area. The Scotgate Ash Marine Band of Walker (1953) is probably an

approximate equivalent of the Otley Shell Bed, since it underlies the first pebbly sandstone in the R_1 sequence near Pateley Bridge (a view previously expressed by Walker).

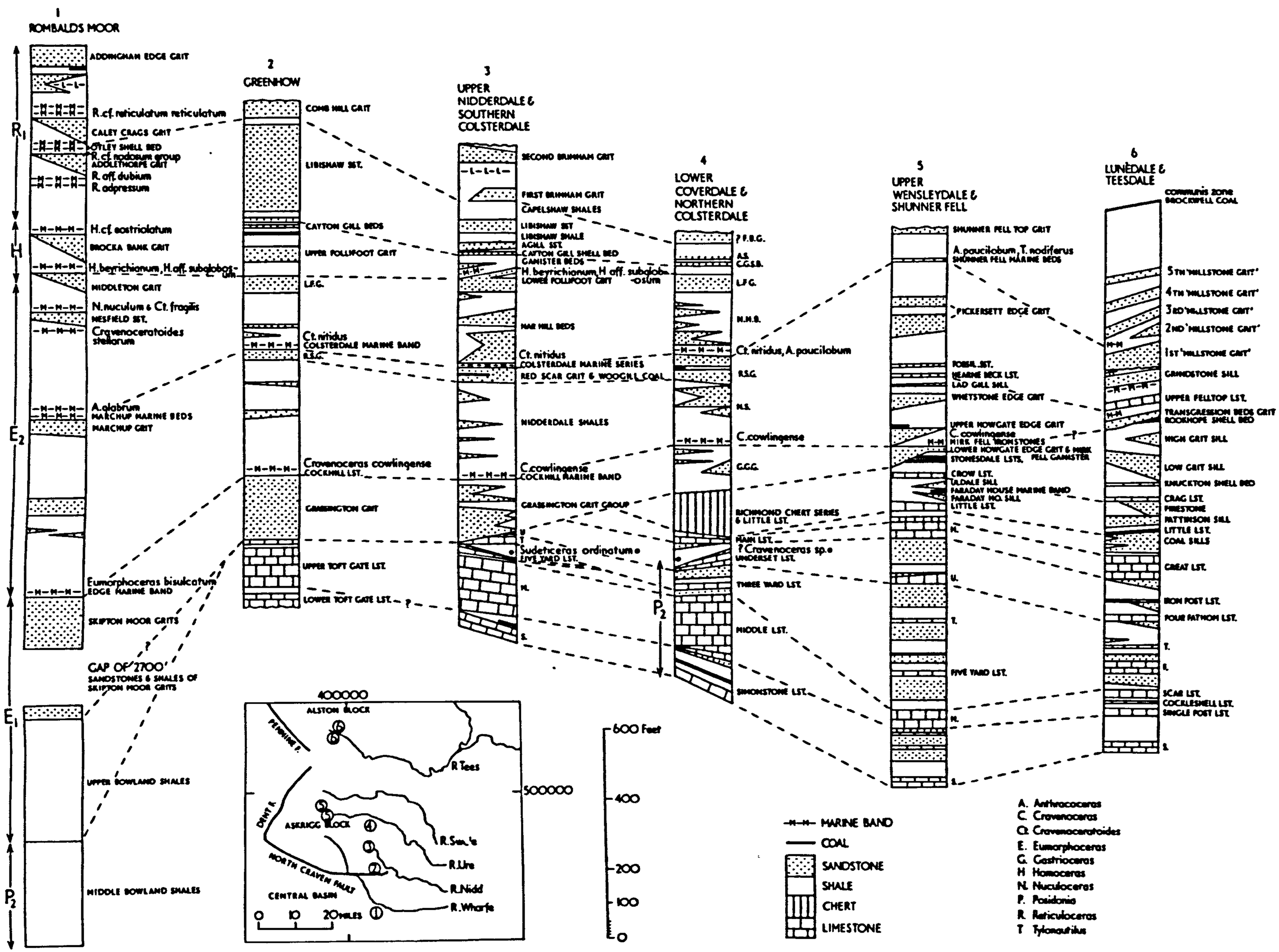
In the R_1 shell beds of the present area no trace of a goniatite fauna was seen and it appears that several of the marine bands which occur in R_1 beds south of the Craven Faults die out on to the Askrigg Block. The evidence from the Rombalds Moor area (Stephens et al., 1953) and from Simonseat (Hudson, 1939) suggests that R_1 commences below the base of the Cayton Gill Shell Bed. The inconstans subzone closes above the Libishaw Sandstone, the eoreticulatum subzone comprises the lower part of the Capelshaw Shales, whilst the reticulatum subzone includes all the overlying beds here surveyed. It is possible that the Lingula Band found in Colsterdale 30' below the base of the Second Brimham Grit is equivalent to a band with Lingula recorded 50' below the base of the Addingham Edge Grit in the Keighley Co-operative Laundry borehole (Stephens et al. 1943).

PLATE 41

Correlation Diagram.

Information is derived from the following sources:

1. Stephens et al., 1953.
2. Dunham and Stubblefield, 1945.
3. Based entirely on the present work.
4. ditto
5. Hudson, 1924 up to the Little Lst. Scanlon,1955 above Little Lst.
6. Jones (Durham Thesis in preparation).


1
ROMBALDS MOOR
ADDINGHAM EDGE GRIT
R.cf. reticulatum reticulatum
CALEY CRAGS GRIT
OTLEY SHELL BED
R.cf. nodosum group
ADDLETHORPE GRIT
R. off. dubium
R. adpressum
H.cf. eostriolatum
BROCKA BANK GRIT
H. beyrichianum, H. off. subglobosum
MIDDLETON GRIT
N. nuculum & Ct. fragilis
NESFIELD SST.
Cravenoceratoides stellarum
A. glabrum
MARCHUP MARINE BEDS
MARCHUP GRIT
Eumorphoceras bisulcatum
EDGE MARINE BAND
SKIPTON MOOR GRITS
GAP OF '2700'
SANDSTONES & SHALES OF SKIPTON MOOR GRITS
UPPER BOWLAND SHALES
MIDDLE BOWLAND SHALES
R1
H
E2
E1
P2
2
GREENHOW
COMB HILL GRIT
LIBISHAW SST.
CAYTON GILL BEDS
UPPER POLLIFOOT GRIT
L.F.G.
Ct. nitidus
COLSTERDALE MARINE BAND
R.S.G.
Cravenoceras cowlingense
COCKHILL LST.
GRASSINGTON GRIT
UPPER TOFT GATE LST.
LOWER TOFT GATE LST.
3
UPPER NIDDERDALE & SOUTHERN COLSTERDALE
SECOND BRIMHAM GRIT
FIRST BRIMHAM GRIT
CAPELSHAW SHALES
LIBISHAW SST
LIBISHAW SHALE
AGILL SST.
CAYTON GILL SHELL BED
GANISTER BEDS
H. beyrichianum, H. off. subglobosum
LOWER POLLIFOOT GRIT
HAR HILL BEDS
Ct. nitidus
COLSTERDALE MARINE SERIES
RED SCAR GRIT & WOOGILL COAL
NIDDERDALE SHALES
C. cowlingense
COCKHILL MARINE BAND
GRASSINGTON GRIT GROUP
Sudeticeras ordinatum
LIVE YARD LST.
4
LOWER COVERDALE & NORTHERN COLSTERDALE
? F.B.G.
A.S.
C.G.S.B.
L.F.G.
N.H.B.
Ct. nitidus, A. paucilobum
R.S.G.
H.S.
C. cowlingense
G.G.G.
RICHMOND CHERT SERIES & LITTLE LST.
MAIN LST.
? Cravenoceras sp.
UNDERSET LST.
THREE YARD LST.
MIDDLE LST.
SIMONSTONE LST.
5
UPPER WENSLEYDALE & SHUNNER FELL
SHUNNER FELL TOP GRIT
A. paucilobum, T. nodiferus
SHUNNER FELL MARINE BEDS
PICKERSETT EDGE GRIT
FOSSIL SST.
NEARNE BECK LST.
LAD GILL SILL
WHETSTONE EDGE GRIT
UPPER HOWGATE EDGE GRIT
C. cowlingense
MIRK FELL IRONSTONES
LOWER HOWGATE EDGE GRIT & MIRK FELL GANISTER
STONESDALE LSTS.
CROW LST.
ULDALE SILL
FARADAY HOUSE MARINE BAND
FARADAY NO. SILL
LITTLE LST.
FIVE YARD LST.
6
LUNEDALE & TEESDALE
COMMUNIS ZONE
BROCKWELL COAL
5TH 'MILLSTONE GRIT'
4TH 'MILLSTONE GRIT'
3RD 'MILLSTONE GRIT'
2ND 'MILLSTONE GRIT'
1ST 'MILLSTONE GRIT'
GRINDSTONE SILL
UPPER FELLTOP LST.
TRANSGRESSION BEDS GRIT
ROOKHOPE SHELL BED
HIGH GRIT SILL
LOW GRIT SILL
KNUCKTON SHELL BED
CRAG LST.
FIRESTONE
PATTINSON SILL
LITTLE LST.
COAL SILLS
GREAT LST.
IRON POST LST.
FOUR FATHOM LST.
SCAR LST.
COCKLESHELL LST.
SINGLE POST LST.
400000
500000
ALSTON BLOCK
PENNINE F.
R. Tees
DENT F.
ASKRIGG BLOCK
R. Swale
R. Ure
R. Nidd
R. Wharfe
NORTH CRAVEN FAULT
CENTRAL BASIN
0 10 20 MILES
600 Feet
400
200
100
0
MARINE BAND
COAL
SANDSTONE
SHALE
CHERT
LIMESTONE
A. Anthracoceras
C. Cravenoceras
Ct. Cravenoceratoides
E. Eumorphoceras
G. Gastrioceras
H. Homoceras
N. Nuculoceras
P. Posidonia
R. Reticuloceras
T. Tylonautilus

CHAPTER 19

STRUCTURE

Since the work of Marr (1921) the country between the Craven Faults and the R. Tyne has been regarded as a rigid block, little affected by large scale folding and faulting and consisting of sediments with a relatively low dip. The southern half of this block was termed the Askrigg Block by Hudson (1938). This structural unit is bounded on the south side by the Craven Faults, on the west side by the Dent Fault and on the north side by the syncline of Stainmore; the eastern limit is hidden under the younger sediments of the Vale of York.

The structure of the present area, situated in the south east of the Askrigg Block, has not been studied in detail, though the maps of the Geological Survey indicate clearly that the rocks have an easterly dip. Over the entire ground here considered the rocks dip in an easterly direction at a little over 1 degree to $2^2/3$ degrees and this tilt is never reversed or much altered in direction except in the immediate vicinity of some of the faults. The gentlest dips are in the west of the area, and it is known from the Geological Survey maps and from the work of Moore (1955) that the beds in the centre of the Askrigg block are only very gently inclined to the east. Further east the dip accelerates and in mid Colsterdale approaches 3 degrees, but this appears to decrease again near Masham. In the north the beds dip in the direction 110 to 130 degrees (nearly E.S.E.), but in Nidderdale in the south of the ground dip in the direction 90 degrees (due

east). This swing in the direction of dip is readily seen in the structure contour map, Plate 42.

Faults

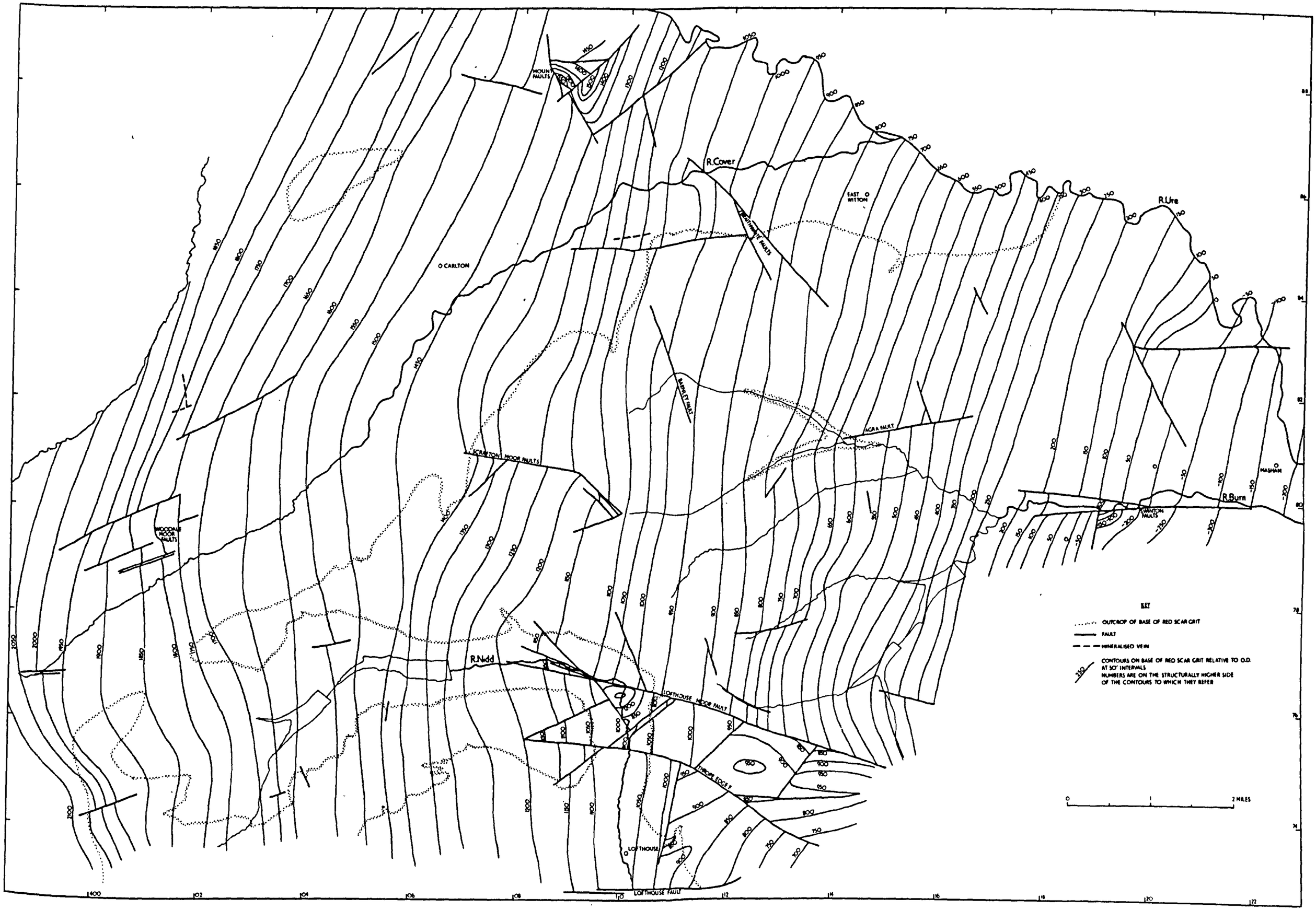
The fault pattern is simple and localised in extent; no comprehensive mesh of faults crosses the area. They are here treated consecutively from Nidderdale, Coverdale and Colsterdale.

Nidderdale - the largest plexus of faults is centred on Limley in Nidderdale, the biggest of which is here named the Lofthouse Moor Fault. This trends at 100 degrees and has a throw of about 125' to the north. It dies out to the west in a plexus of small faults of which two appear to throw north and two to the south with the net effect that the throws cancel out rapidly in an up-dale direction. In an easterly direction the fault crosses Lofthouse Moor and runs past the south end of Combs Crags and Knappa Stones in the Brimham Grits. This extension of the Lofthouse Moor Fault had been recognised by Bisat (personal communication), but escaped the notice of the primary surveyors who had however mapped it in Nidderdale. The regional dip of the beds on the north side of the fault in the Combs Crags area is unusually steep, is divergent from the regional dip and has apparently been affected by the fault. On the south side of the fault in the High Ash Head Moor area the exposures are very poor, but it seems that the sediments dip into the fault quite steeply as indicated in the structure contour map. Associated with this fault in Nidderdale is a small anticline seen in the railway cutting N.N.W. of Limley and in the Nidd below this exposure; the

PLATE 42

Structure contour map of the country between Masham and Great Whernside.

The persistent regional dip and the lack of a comprehensive fault pattern are noteworthy features.



MOUNT FAULTS
R.Cover
EAST WITTON
R.Ure
CARLTON
BRAITHWAITE FAULTS
BARNLEY FAULT
AGRA FAULT
SCRAFTON MOOR FAULTS
WOODALE MOOR FAULTS
MASHAM
R.Burn
WANTON FAULTS
R.Nidd
LOFTHOUSE MOOR FAULT
THROPE EDGE F
LOFTHOUSE
LOFTHOUSE FAULT
KEY
OUTCROP OF BASE OF RED SCAR GRIT
FAULT
MINERALISED VEIN
CONTOURS ON BASE OF RED SCAR GRIT RELATIVE TO O.D. AT 50' INTERVALS
NUMBERS ARE ON THE STRUCTURALLY HIGHER SIDE OF THE CONTOURS TO WHICH THEY REFER
0
1
2 MILES

dips associated with this structure are in the vicinity of 10 degrees.

Associated with the Lofthouse Moor Fault is a plexus of smaller dislocations, some of which branch off from the main fault whilst others run parallel to it. Two of the faults which branch off from the Lofthouse Moor Fault are well exposed in the scar of the Thrope Edge landslip. Faults parallel to these displace the outcrops on Rainstang to the west, and these appear to be associated with a cross fault truncating the Middle limestone of the inlier N.N.W. of Limley on its west side. The Thrope Edge Fault is one of the fractures trending parallel to the Lofthouse Moor Fault; its course is clearly marked on the east side of Nidderdale by the displacement of the outcrops of the Lower Follifoot Grit. A prolongation of this fault appears to cross Ouster Bank into Sypeland Crags whilst an offshoot travels over Lulbeck Head. Other dislocations running sub-parallel to the Lofthouse Moor Fault are the Lofthouse Fault which is well exposed in Blayshaw Gill and small fractures in Colsterdale in the valleys of Grimes Gill, Agill Beck and Arnagill. In upper Nidderdale scattered small faults are seen, but none persist for more than a mile.

Coverdale - A series of faults en echelon occurs in the upper part of the valley, none of which shows a throw of over 25'. In the lower dale a few small faults are seen; the largest are the Braithwaite Moor Faults, one of which has a throw of over 50'. The Middleham Low Moor Faults are a small local plexus of dislocations which die out rapidly, but show considerable local throws. The chief structure is a fault-bounded canted slab of

lower Middle Limestone resting on sandstone which lies parallel to the hillside round The Mount. The faults on the western and eastern sides both appear to be scissors faults with a complete reversal of throw in the centres of their courses. This fact is apparent on examination of the geological map by noting the displacement of the base of the Middle Limestone.

Colsterdale - The Steel House faults are part of a small plexus probably continuous with the faults on West Scarfton Moor which displace the outcrops of the Lower Follifoot Grit. The throws of these dislocations are all under 50', but they include some material in Long Gill which appears to have travelled about 60' down the plane of a fault. Debris characteristic of the Ganister Beds seem to be wedged in between the walls of the fault which are in Nar Hill beds on the upthrow and downthrow sides.

Several fractures were mapped in lower Colsterdale, but their courses are in many cases inferential owing to drift cover. The chief faults are those in the vicinity of Swinton Castle which throw beds belonging to the Brimham Grits and their intervening shales against the Lower Follifoot Grit, giving a dislocation of perhaps over 100' throw.

Directions of Faults - All fault directions have been analysed in proportion to the total length of fault in any one class of direction. The resulting diagram (Plate 44B) shows that there are no conspicuous directions of maximum intensity of faulting, but the lack of fractures trending north-south is noteworthy. The same fact is apparent on examination of similar

data given by Reading (1954) and Wells (1955b). From work on the joint system it appears that the compressive stresses which gave rise to the joints and also presumably to the faults, came from northerly and southerly directions. It is by no means clear to the present author why normal faults, which are presumed to be tension features, should attain their minimum intensity in the direction parallel to line of application of maximum compression, and their greatest intensity at right angles thereto, i.e. in the direction that features resulting by compression would be formed (e.g. the east-west Bewcastle folds of Trotter and Hollingworth, 1928, which were adjudged to be the result of Hercynian compressive forces directed from the south and north). It is possible that compression was later followed by tension in the same direction, forming first the fold and then the faults; or alternatively the sequence may have taken place in the reverse order.

Joints

The present work has involved the measurement of the directions of 88 pairs of joints in beds of both Yoredale and Millstone Grit lithology. Joints taken in beds of both lithologies were initially plotted in different colours to see if there was any appreciable difference in direction between the two. Those in beds of Millstone Grit lithology showed a slightly greater tendency to 'box the compass', but faithfully followed the maxima and minima of the joints measured in rocks of Yoredale lithology, though without a perceptible double

PLATE 43 A Horizontal section from Penhill to Pott Beck.
The colouring is identical with that used for the map,
Vertical exaggeration 4.6 approx.

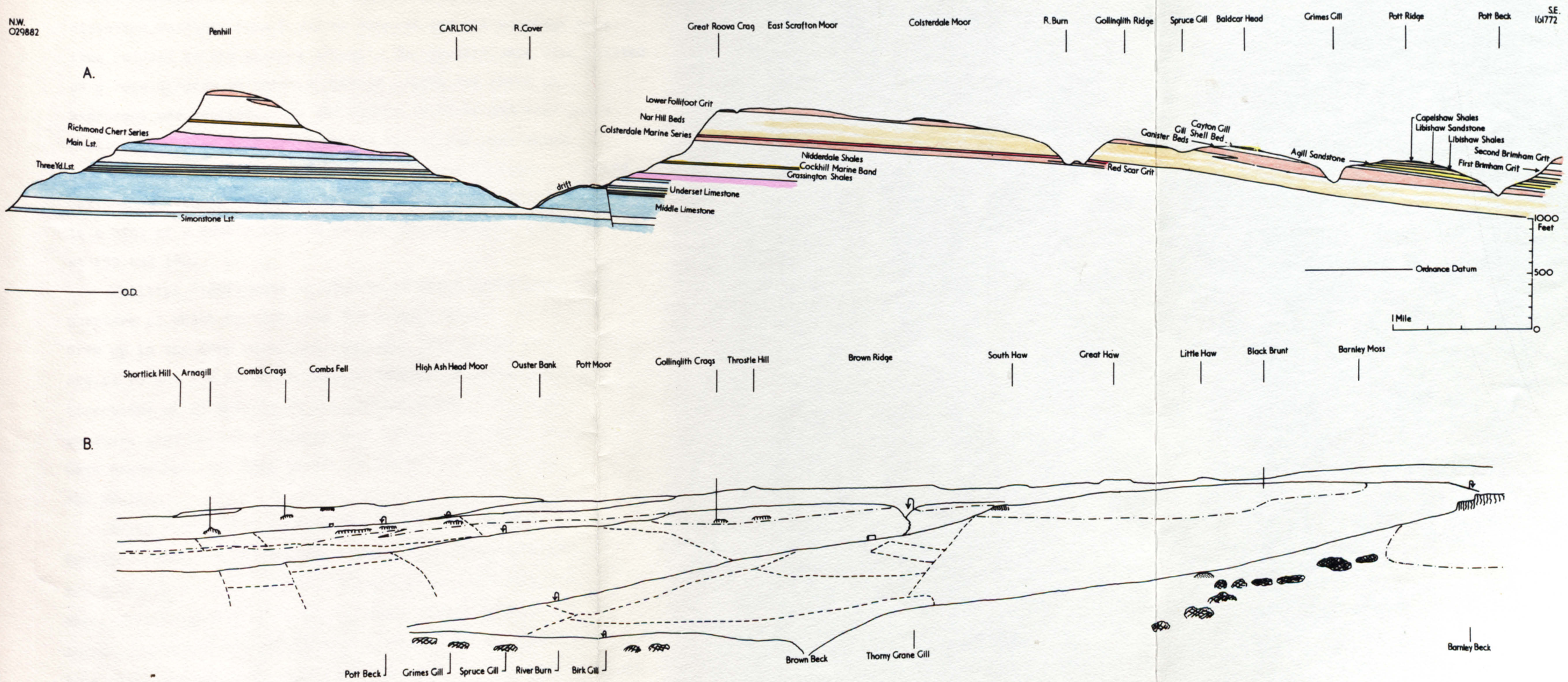
PLATE 43 B Panorama from Slipstone Crags, Colsterdale (138882).
The view covers 115 degrees of arc and centres on the direction 215 degrees geographic from the observer. The succession of dip-slopes forming the spurs between the several tributary valleys of the dale is clearly seen. The dot-dash line indicates the base of the Lower Follifoot Grit from the outcrop of which the sketch was made. Fallen boulders of the grit are seen in the foreground. The gradual easterly fall of the Grit is apparent. In the upper dale (right of picture) the L. Follifoot Grit forms the hill tops and spur tops, whilst to the left it has sunk gradually to a position on the side of the spur, so that on the spur between Pott Beck and Spruce Gill, it is overlain by Ganister Beds and Shell Bed, whilst on the distant hillside the highest horizons in the present area are seen (refer also to Plate 43 A).

Also note the occurence of cliffs in the Follifoot and Brimham Grits. The main outcrop of the Libishaw Sandstone forms the spur of Pott Moor and also makes features with the steep slopes on the Libishaw Shales at the W. and E. ends of Brown Ridge. The three Haws are outliers on the Libishaw Sandstone and show steep bounding features on shales.

An area of Libishaw Sandstone up-faulted by the Limley Fault forms Combs Fell and High Ash Head Moor in the extreme distance.

The heap ornamented with a stipple in the right foreground is a tip on the site of a shaft working in the Woogill Coal.

The panorama was taken from a field sketch made on squared paper.


N.W.
029882
Penhill
CARLTON
R.Cover
Great Roova Crag
East Scrafton Moor
Colsterdale Moor
R. Burn
Gollinglith Ridge
Spruce Gill
Baldcar Head
Grimes Gill
Pott Ridge
Pott Beck
S.E.
161772
A.
Richmond Chert Series
Main Lst.
Three Yd. Lst.
Simonstone Lst.
O.D.
drift
Lower Follifoot Grit
Nar Hill Beds
Colsterdale Marine Series
Nidderdale Shales
Cockhill Marine Band
Grassington Shales
Underset Limestone
Middle Limestone
Red Scar Grit
Ganister Beds
Gill Shell Bed
Cayton Gill
Agill Sandstone
Capelshaw Shales
Libishaw Sandstone
Libishaw Shales
Second Brimham Grit
First Brimham Grit
1000 Feet
500
0
Ordnance Datum
1 Mile
Shortlick Hill
Arnagill
Combs Crags
Combs Fell
High Ash Head Moor
Ouster Bank
Pott Moor
Gollinglith Crags
Throstle Hill
Brown Ridge
South Haw
Great Haw
Little Haw
Black Brunt
Barnley Moss
B.
Pott Beck
Grimes Gill
Spruce Gill
River Burn
Birk Gill
Brown Beck
Thorny Grane Gill
Barnley Beck

maximum in the south east quadrant of the rose diagram. The method followed in plotting the results involved grouping direction readings into 5 degree classes and all readings were thus reduced to the nearest class. The results were then plotted on a rose diagram in which a unit of length was taken to represent one reading. In the figure on Plate 55A each joint reading is marked by a notch on the ray of the rose which corresponds to class of direction to which it belongs. A clear maximum is seen in two directions, at 75 and 155 degrees. There is a hint of a double maximum in the 155 direction with a peak at 150 and 160.

Phillips (1836) made an analysis of joint directions, three quarters of which he took from the Askrigg Block; these he drew up in the form of a rose diagram. The maxima of Phillips are at 79 and 158 which correspond remarkably closely with the directions of 75 and 155 in the present work. The joint readings used for this diagram were partly obtained from the area here described, but they do not constitute a large portion of the whole.

Wager (1931) made a detailed study of the joints on the southern fringe of the Askrigg Block. The directions diagram for Littondale, near Arncliffe, in ground close to the present area, yielded maxima at 75 (as in the present instance) and a double maximum at 155 and 170 which corresponds broadly with the less well defined double maximum obtained during the present work.

Dunham (1933) published results of a study of joint directions on the Alston Block, the bulk of the readings being

obtained in the quarries in the Great Limestone of Weardale. He obtained maxima at 60-70 and 155-160 degrees; the first maximum corresponds only partially with the one obtained in this direction in the present work, but the second maximum is very close to the figure here given, though there is no good evidence for a double maximum here.

Reading (1954) made similar determinations in the area of the Stainmore syncline with less success, for the average of his results showed a tendency to 'box the compass'. A very broad maximum is discernible in his figure of analysed joint directions around 45 degrees and a slight double maximum is seen at 130-135 and 160-165 degrees. These can only be compared with the present results in a most general way.

Wells (1955b), working on the Gilling Dome some ten miles north of the present area obtained maxima at 55-60 degrees and a double maximum at 130-135 and 160-165. The directions of Wells do not agree closely with the present results since they show a pronounced northerly swing in the case of the joints in the N.E. quadrant of the rose diagram as compared with the present directions. The peak at 130-135 is not matched in the present work, though a poorly defined double maximum does in fact occur (Plate 44A).

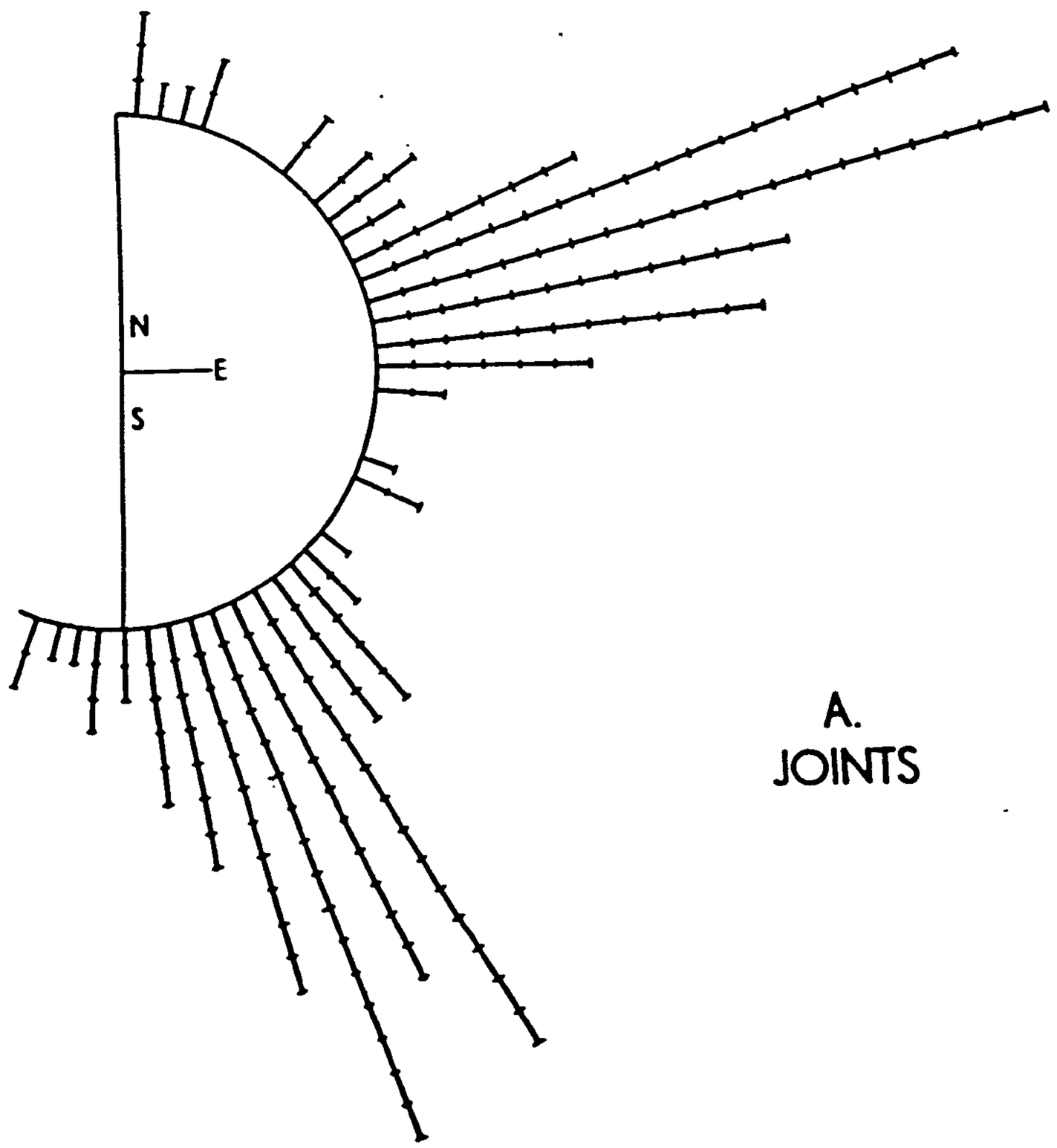
The mode of formation of the joint system has led to some divergence of opinion, though all authorities working on the Askrigg Block postulate a north-south rather than an east-west direction of compression. Dunham followed Wager in interpreting the joint system as shear fractures symetrically disposed about the

PLATE 44

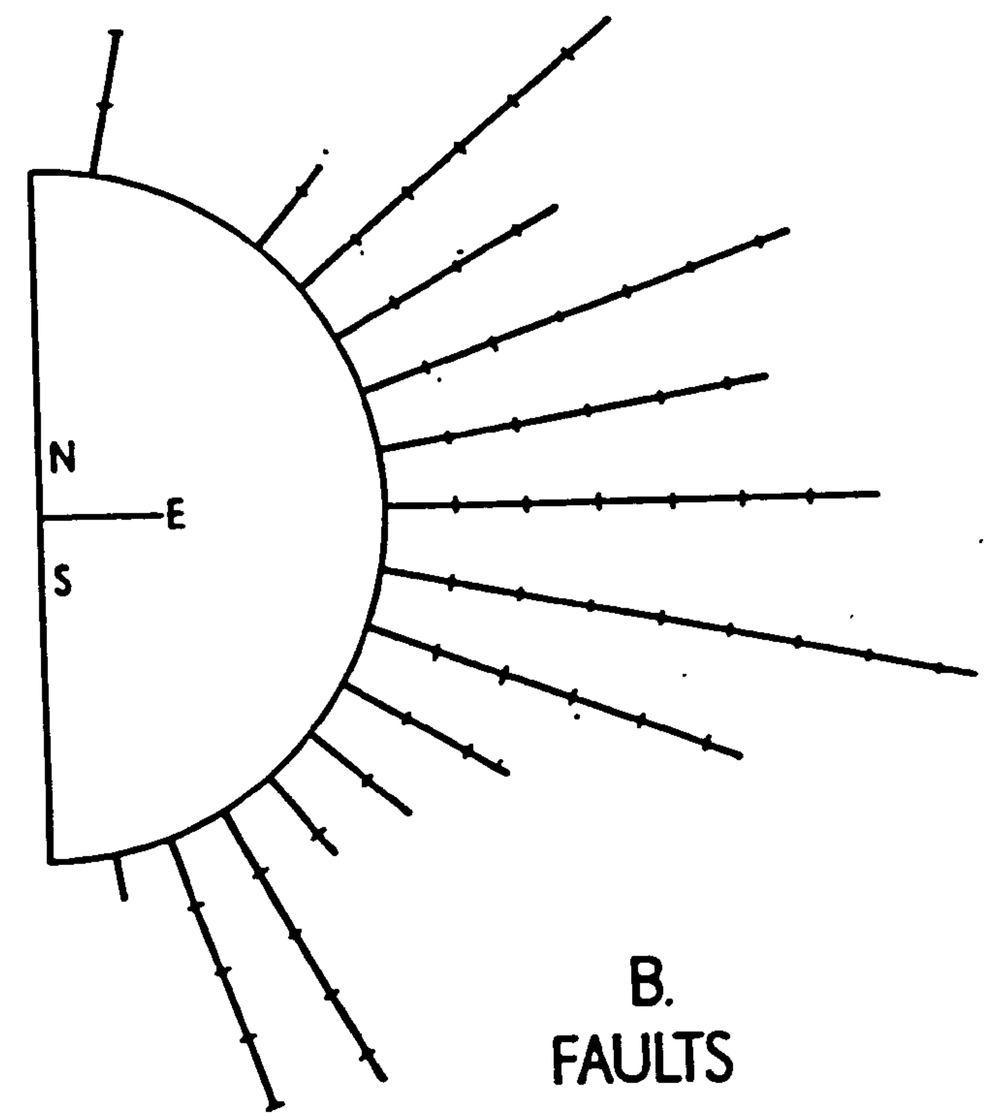
Statistical analysis of structural trends

A. Joints- each division represents one joint reading. Joints were measured in pairs.

B. Faults- each division represents a mile length of fault.



A.
JOINTS



B.
FAULTS

direction of maximum compression. Trotter and Hollingworth (1928) had postulated a north-south compression in Hercynian times to cause the east-west Bewcastle folds and it was on these grounds that Dunham took the compressive stresses as originating in a N.N.E.-S.S.W. direction, in the direction of the bisectrix of his major joint directions. This direction differed radically from the direction postulated by Wager on the same premises (i.e., in the direction of the bisectrix of the major joint directions) since he postulated a N.W.-S.E. compression. Wells (1955) cited the work of Parker (1942) who gave experimental evidence to show that a set of joints with a double maximum resulted from compression, whilst a set with a single maximum resulted from tension. Since Wells showed results with a double maximum in the S.E. quadrant of the rose diagram he concluded that the compression took place in a N.W.-S.E. direction and the tension at right angles to this. If the views of Wells, following Parker, apply here, the compression in the present area would be in the direction N.N.W.-S.S.E. Alternatively if the hypothesis of Wager (1931) is right the compression probably came from the S.S.W. The available results from other areas in the rigid block do not show in even half the cases an undoubted double maximum in the S.E. quadrant of the rose diagram and it is for this reason that the views of Parker, as interpreted by Wells, are possibly not applicable for more than the N.E. corner of the Block.

Chapter 20

GLACIAL AND POST-GLACIAL DEPOSITS; GEOMORPHOLOGY

Glaciology

The glaciology of the present area has been fairly fully studied by previous workers, the first of whom was Carvill Lewis (1894) who paid a brief visit to the area round Masham and recognised morainic material in a belt between Jervaulx and Fearby. Kendall and Wroot (1924) gave details of a series of periglacial spillways north and south of Colsterdale. The main details of Lake Colsterdale were described and the presence of lake muds, which gravely impeded the engineers during the construction of the Leighton Dam, was recognised. An early glaciation was noted and it was supposed to be synchronous with the Basement and possibly the Purple Clays of the Yorkshire coast, whilst the main glaciation which affected the Yorkshire Dales is correlated with the Hessle Clay of the Yorkshire coast.

Raistrick (1926) recognised the former presence of ice-dammed lakes in Coverdale and Sowden Beck, in addition to Colsterdale. He provided a map showing the chief overflow channels which are grouped by the use of lines to show how they operated successively during the retreat of the ice. In this paper he agreed with Kendall and Wroot on the suggested chronology of the glaciations in the Yorkshire Dales.

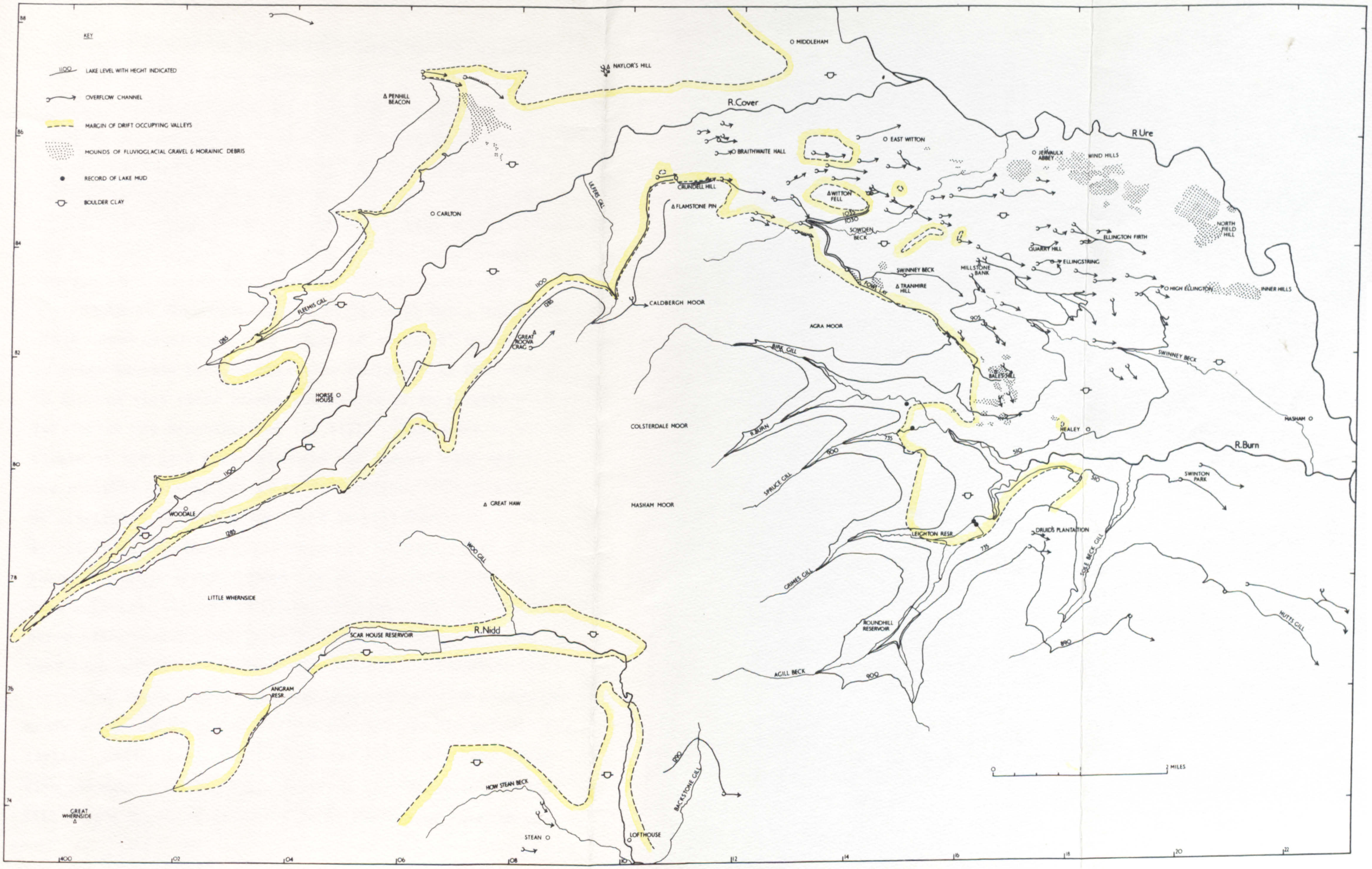
In a later paper Raistrick (1934) altered the dating he proposed in 1926 and said that the Lower Purple Clay was equivalent to the early Maximum Dales Glaciation and the Upper

Purple Clay and Hessle Clay to the Main Dales Glaciation. He held that Hessle Clay marked a local re-advance of the Vale of York ice which formed the Escrick and York moraines, and it was in this period that the glaciers in the dales were shrinking. Thus he correlated two of his later retreat stages, D and E, with the Escrick and York moraines respectively. In this paper Raistrick provided a map showing the supposed correlation of the series of overflow channels and associated moraines southward from the moors N. of Colsterdale towards Ripon. He gave the index letters B, C, D, E, F to the stages of retreat.

The glacial geology of Nidderdale has been described by Tillotson (1934) and several of his observations refer to the present area. He claimed that between 'Scar' (presumably Scar House) and Lofthouse four lateral moraines could be followed from gill to gill and could be checked by the percentage composition of erratics in the several stream sections. The present work has yielded no evidence to support these contentions and it is held that hill creep on the steep sides of the dale would have long since obliterated any features suggestive of lateral moraines. Further, much of this ground has been under the plough and this too would tend to even out, or alter the shape of any supposed minor topographic irregularities. The valley heads of Nidd Head and How Stean are called a 'corrie' conjointly. In concept this is correct insofar as ice patently must have formed in these depressions, but these valley heads, treated jointly or separately bear little resemblance to true corries and show no signs of over-deepening or of morainic development (this last feature is characteristic of the only

PLATE 45

Glacial and periglacial phenomena associated with the Main Dales Glaciation of the country between Masham and Great Whernside. The most notable features are the localisation of thick drifts in the valleys and on the margins of the Vale of York and the development of an extensive series of periglacial spillways and associated glacier-dammed lakes.


KEY
LAKE LEVEL WITH HEIGHT INDICATED
OVERFLOW CHANNEL
MARGIN OF DRIFT OCCUPYING VALLEYS
MOUNDS OF FLUVIOGLACIAL GRAVEL & MORAINIC DEBRIS
RECORD OF LAKE MUD
BOULDER CLAY
MIDDLEHAM
NAYLOR'S HILL
PENHILL BEACON
R.Cover
EAST WITTON
BRAITHWAITE HALL
R Ure
JERVAULX ABBEY
WIND HILLS
CRUNDELL HILL
WITTON FELL
FLAMSTONE PIN
LEFRE GILL
CARLTON
SOWDEN BECK
NORTH FIELD HILL
ELLINGTON FIRTH
QUARRY HILL
ELLINGSTRING
SWINNEY BECK
MILLSTONE BANK
TRANMIRE HILL
HIGH ELLINGTON
INNER HILLS
CALDBERGH MOOR
AGRA MOOR
FLEMIS GILL
GREAT NOOVA CRAG
BIRK GILL
BAILEY HILL
SWINNEY BECK
HORSE HOUSE
COLSTERDALE MOOR
R.BURN
HEALEY
MASHAM
R.Burn
SPRUCE GILL
SWINTON PARK
WOODALE
GREAT HAW
MASHAM MOOR
LEIGHTON RESR.
DRUIDS PLANTATION
WOO GILL
GRIMES GILL
FOLE BECK GILL
LITTLE WHERNSIDE
ROUNDHILL RESERVOIR
MUTTS GILL
SCAR HOUSE RESERVOIR
R.Nidd
AGILL BECK
ANGRAM RESR.
HOW STEAN BECK
BACKSTONE GILL
GREAT WHERNSIDE
STEAN
LOFTHOUSE
0
1 MILES
2

undisputed corries in the Askrigg Block, in the upper Eden valley Rowell and Turner, 1952).

The Maximum Dales Glaciation - In many parts of the north of England there is evidence of an early glaciation which is correlated with the Lower Purple Clay episode of the glaciation of the Yorkshire coast by Raistrick (1934). The boulder clay of this episode is usually described as being highly weathered and dissected. In the present area there is some evidence, but not much, of the deposits of this early glaciation.

South of Flamstone Pin, at about 1325' O.D., limestone chips occur under peat at a height of over 400' above the nearest outcrops in this rock. Whilst no boulder clay is now seen, it is assumed that these blocks are relics of an earlier glaciation, left after the weathering of the till. Elsewhere on the dip slopes at the head of Colsterdale the blocks under the peat are somewhat varied, but it is difficult to tell if this should be attributed to soil creep prior to peat formation or to the effect of an earlier glaciation. The various kinds of block found on Sievey Hill (120769) are of greater interest because this cake-like outlier is raised 20' above the level of the surrounding plateau and it is not possible that blocks could have been carried on to it by solifluction. Nevertheless the variety of rocks seen on the summit covers a large number of grain sizes and it seems likely that they are the relics of an earlier drift, the clayey elements of which have long since disappeared. On the whole, however, the debris on the high hill slopes do not show such a large mixture of rock types

and the highest summits, Great Whernside, Little Whernside Brown Haw, Penhill and Great Haw are characterised by blocks of the rocks which form them. It appears that these hills acted as centres of ice dispersal rather than as eminences which were overridden by an early ice sheet. High up Lead Up Gill, Coverdale (065796), a local patch of boulder clay occurs with fragments of Cayton Gill Shell Bed which were probably derived from the plateau above. This occurrence may be related to an early glaciation, but this is difficult to prove.

Whilst it is not possible to offer proof, it seems very likely that periglacial phenomena associated with the Maximum Dales Glaciation are preserved in the present area. It is not possible to show that any of the spillways are second cycle channels which were merely overdeepened during the later Main Dales Glaciation, but there is undeniable evidence from records of reservoir excavations and trials in Colsterdale that large thicknesses of boulder clay overlie lake deposits. At two points in Colsterdale this is seen to occur. Since it is axiomatic that the formation of periglacial lakes with a descending sequence of overflow channels is a retreat phenomenon, it follows that the boulder clay of the most recent glaciation (which is elsewhere considered to be the Main Dales Glaciation) overlies the lake deposits of the retreat stages of a previous glaciation (which is presumably the Maximum Dales Glaciation).

The log of trial borehole 'C' sunk by Leeds Corporation in the valley bottom near Gollinglith Foot, Colsterdale, shows the following superficial deposits:

3'6"	yellow clay
51'	boulder clay

PLATE 46 A

Boulder clay in Lead Up Gill, Coverdale, above West Scrafton. The view is from 074836 , looking upstream. The stream bed is in the uppermost of the Middle Limestone. The steep banks are in boulder clay into which the stream is excavated.

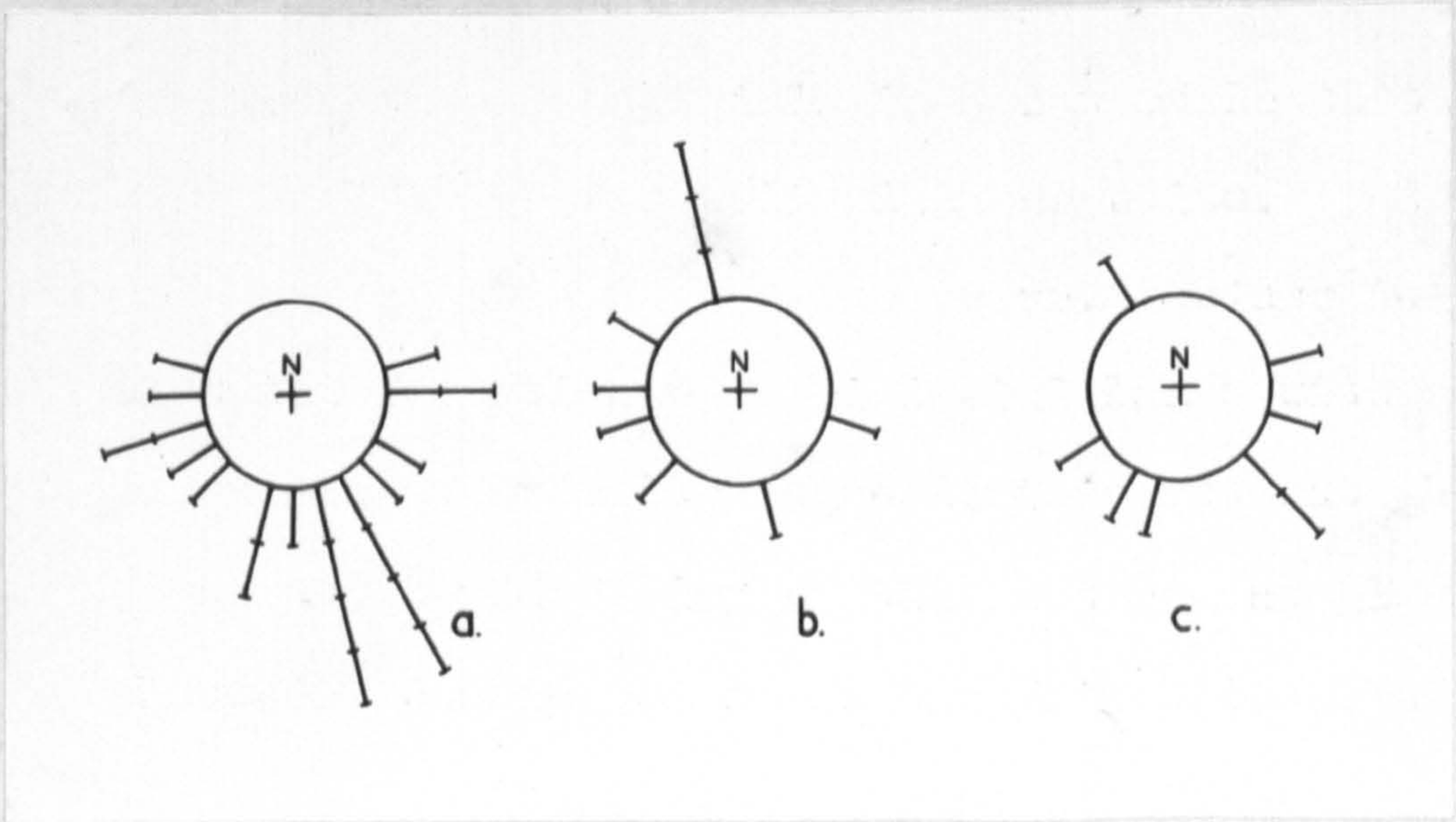


PLATE 46 B

Rose diagrams of current bedding directions. Class interval of 15 degrees. a. Grassington Grit of Coverdale and Nidderdale b. Red Scar Grit c. Follifoot Grit

13'4"	'bible clay' (i.e. laminated lake clays)
11'	gravel, getting sandier downwards
-	solid geology

The maximum thickness of laminated clay found in these boreholes which were sunk in series across and along the valley bottom was about 25', implying that the lake in which the clays were formed was of long duration. The boreholes sunk higher up the valley sides showed no records of laminated clays. Since solifluction would easily affect such mobile laminated deposits, too much reliance must not be placed on these findings. It seems likely however that the lake in which the clays were formed did not stand higher than the known highest level of lake Colsterdale during the closing stages of the Main Dales Glaciation. In the Leighton Reservoir trench up to 80' of boulder clay occur above the laminated clays forming a continuous layer on the valley bottom on the north side of the valley where they are about 4' thick and pesistent where protected by the drift. On the south side of the valley the laminated lake muds are entirely absent, however, as is also the protecting layer of boulder clay.

If the sediments described above are lake muds belonging to an earlier stage of glacial retreat there is still the necessity of finding deposits in these diggings and borings which were laid down during the period when a lake was known to occupy the area at the close of the Main Dales Glaciation. No undoubted lake deposits overlie the boulder clay however, but there are clays which are not apparently markedly laminated and these are tentatively referred in part to the sediments of the later lake, the overflow system associated with which is so well marked.

The Main Dales Glaciation - The Main Dales Glaciation, correlated with the Upper Purple and Hessle Clay stages of the Yorkshire coast, achieved its maximum in Upper Purple Clay times (Raistrick, 1934). It is characterised by a less great advance of ice conditions than in the earlier Maximum Dales Glaciation, but its relics are much fresher. The evidence for this last glaciation is based on the widespread occurrence of boulder clay, which is located chiefly in the valleys and on the low hills on the eastern fringe of the area close to the Vale of York, and on the occurrence of various periglacial phenomena, both glaciofluviatile and glaciolacustrine.

The Phase of Maximal advance (Stage A of Raistrick, 1934) - The margins of the ice at this stage lay approximately along the boundaries of the boulder clay shown on the map (Plate 45). A large glacier occupied Wensleydale, with a tributary glacier in Coverdale and a small one in Waldendale, whilst another occupied upper Nidderdale. The ground between Waldendale and Coverdale and the high dip slopes north and south of the R. Nidd were large ice-free areas. The low country near Masham was thickly overwhelmed by ice occuping Colsterdale as far up as Leighton and fed by the ice fields at the heads of the Colsterdale valleys. The immediate effect of the formation of land ice was to mantle the valley sides in boulder clay which was the ground moraine of the valley glaciers. Whilst the Ure Glacier is known to be large, the south side of Wensleydale below Penhill is drift-free for reasons not readily apparent. The ice sheet near Masham heavily mantled the area in drift so that there is little solid geology to be seen in this area. This

drift is also local in origin and was probably derived from ice which had spread out at the foot of the main stream issuing from Wensleydale. This mingled a little further east with the ice in the Vale of York. It seems also that the valleys in lower Colsterdale also had their own small glaciers as is shown by the thickness of the boulder clay at Leighton and Gollingliph Foot (this reaches over 50' at its maximum).

All the boulder clay in the area is indigenous to the Askrigg Block and was transported by the Ure glacier, its tributaries and the Nidderdale glacier. It is only to the east of the present area where the ice streams of the Vale of York were effective that erratics derived from distant sources are encountered. The boulder clay in the present ground includes the common lithological types of the Carboniferous sequence i.e. medium and fine grained sandstone, limestones (showing all variants from crinoidal limestone to calcite mudstone) and cherts and cherty limestones. The clay matrix is markedly coarser and less unctuous than that of the lowland boulder clays such as are seen on the Yorkshire coast. Occasionally blocks of recognisable horizon occur. For instance, pieces of Cayton Gill Shell Bed and of Colsterdale Limestone were found. The latter specimen yielded the characteristic goniatite, Cravenoceratoides nitidus together with numerous palaeoniscid scales. Large erratics are not common and when they occur are associated with the Wensleydale ice which was more powerful than the tributary ice streams or the Nidderdale ice. A large limestone boulder, probably an erratic, stands on the village green in East Witton. Blocks cleared from the fields near Healey

are often over a foot in diameter and these were no doubt transported by the Wensleydale ice which flowed over the low hills W.N.W. of Masham. The boulder clay appears to be rarely over 100' thick and is often much thinner. The only reliable records of thick boulder clay are from Colsterdale where the trial holes at Gollinglith Foot encountered 51' in the valley bottom, and in the bed of the valley at Leighton along the line of the dam trench which showed 60' of boulder clay dying out laterally to nil on the south side of the valley. In Coverdale the drift is often thick and obscures all solid features. Locally it is deeply dissected by streams (Plate 33B, 46A).

The retreat of the ice (stages B to F of Raistrick) - A trough shaped depression with its intake at 1500' O.D. is seen E. of Great Roova Crag, Coverdale. It closely resembles an overflow channel in shape since it has a typical U shaped profile. It is possible that this spillway which drains over a low col into the head of Ulfers Gill was formed during the first amelioration of climate in the course of the Main Dales Glaciation. The ice field in upper Coverdale appears to have melted sufficiently to form a small marginal lake which was ponded against the protruberance in the valley side marked by Great Roova Crag, against which the Coverdale ice was pressed. The next spillway to form was that draining over the col between Coverdale and Birk Gill, Colsterdale (099831). The intake is at 1275' O.D. (see Plate 45 for the location of the channel and lake margin) and it seems likely that when this channel was operating the ice in Coverdale had melted to a considerable extent and was at least

partly covered by a lake ponded by the still active Wensleydale glacier which was being fed by the ice fields near the head of that dale. At this time the main body of the Wensleydale ice must have stood high against the side of Flamstone Pin holding back the waters of Lake Coverdale which was forced to drain over the low col into Colsterdale. This latter dale was itself becoming a lake owing to the melting of the Masham Moor snowfields, the waters from which were impounded by the ice overflowing across the low hills W.N.W. of Masham from the Wensleydale glacier.

At a slightly later stage the level of the ice in Wensleydale dropped slightly and the lake in Coverdale (where the local glacier was presumably fast melting owing to lack of supply) drained across the north face of Flamstone Pin and thence into small channels on Braithwaite Moor with intakes at 122846, 122845 and 129483. This melt-water is presumed to have found its way into Colsterdale through the Fowl Lay channel (139836) which appears to have been initiated at this time whilst the ice front stood on Tranmire Hill.

Slightly later the waters of Lake Coverdale drained across the hillside above the present site of Crundell Hill and began to excavate a channel. From thence the meltwaters drained round the north face of Braithwaite Moor and then across Witton Fell. In the first instance they crossed the fell from 125849 where a small moraine is seen near the end of the overflow channel. A small recession of the ice front caused the waters to enter at a slightly lower level at 129849, but both channels join up and drain into Sowden Beck. The characteristic U shaped profile

of this latter channel is maintained to 1035' O.D. which is the level of a small lake in the Sowden Beck valley, drained by the already operative Fowl Lay overflow into Lake Colsterdale. The formation of a lake in Sowden Beck was initiated after the retreat of the ice. This had filled the valley at an immediately previous stage when a small spillway with flanking moraine had been formed (129843). The Fowl Lay channel which drained the lake is one of the largest ones in the present area. It shows a very broad boggy bottom at its intake end and becomes narrower downhill as the gradient increases. The point at which it looses the U shaped profile of the typical spillway is the exact height of the highest known level of Lake Colsterdale which then stood at 900' O.D. The channel draining Lake Colsterdale at this level is south of Druid's Plantation (173785). It shows the characteristic profile of the spillway and has at its outfall end a well defined deltaic flat laid down at water level in the lake and standing at the same height as the overflow draining Lake Sole Beck into the Wreaks Beck valley. At this stage the ice-front must have extended across Colsterdale to Bales Hill and Tranmire Hill and thence across the face of Braithwaite Moor and Flamstone Pin and ultimately to Penhill, forming a barrier to the waters of Lake Coverdale.

A minor recession was marked by a further overflow at Druid's Plantation with an intake at 890' O.D. It was probably during this slight retreat that the N. slopes of Tranmire Hill became free of ice. The Fowl Lay exit of Lake Sowden Beck was also abandoned and a new spillway, that of Swinney Beck, was initiated which drained into a small lake at Tranmire Bog. This

in turn drained via a small overflow past Bales House (163826) and no doubt the waters eventually found their way into Lake Colsterdale. The present work presents certain correlations of overflow stages which differ from those put forward by Raistrick (1934). The difficulties are largely connected with the stage C, D and E channels in the vicinity of Braithwaite Moor. It seems unlikely that the Bales House overflow (stage C according to Raistrick) antedates the Swinney Beck overflow (stage D according to Raistrick) since the intake end of the Bales House channel corresponds so nearly with the level at which the outfall of the Swinney Beck looses its characteristic profile. It therefore is most probable that a lake of small size occupied the site of Tranmire bog and that the two spillways operated synchronously. A spillway on Braithwaite Banks given by Raistrick as Stage C has its outfall end only 5' approximately above the intake level of the Swinney Beck channel (stage D according to Raistrick). As it is well known that the general fall in level of successive spillways to the east is considerable it is most likely that the Braithwaite Moor channel which is nearly 2 miles W.N.W. of Swinney Beck actually postdates it (not antedates, as Raistrick maintained). A fall in level of the rapidly moving meltwaters of only 5' in nearly two miles is virtually inconcievable and this would occur if the two channels operated together. A fall of 100' is nearer the order of the actual fall which is observed to occur in the majority of spillways in a distance of two miles. On this account it is held that the Swinney Beck channel operated before that at Braithwaite Moor.

A further slight recession of the Wensleydale ice allowed the meltwaters which were coursing above the site of Crundell Hill to excavate a well defined channel on the south side of this hill. This spillway is about 30' deep and shows bifurcation with re-joining of channels; the outlets are also multiple and one of them appears to have had a waterfall in the lower Red Scar Grit at its lowest end (113853). The outfall end of the Crundell Hill channel shows a steep gradient and it is evident that a lobe of ice must have been pressing against the W. end of the hill whilst at the E. end the waters fell considerably in level before continuing on their course along shelf overflows on Braithwaite Banks. The waters at this stage found their way into Sowden Beck via the north face of Witton Fell since the summit overflows from Braithwaite Moor across Witton Fell were no longer operative. It seems likely that the meltwaters accumulated in the Sowden Beck lake, then standing at a much lower level than previously and possibly then drained off via the spillways on Millstone Bank. The principal one of these is the Sail Hill channel which splits up into a number of distributary branches at The Warren (180830). The characteristic profile of overflow channels is lost at about 735' O.D. which is the approximate level of Lake Colsterdale when draining out at the Hutts Gill spillway, standing E. of the surveyed area. This channel is larger than most seen in the present ground and appears to have marked a long period of still-stand of the ice front, at which stage Lakes Colsterdale and Sole Beck were merged, since the ice had retreated from the spur below Druid's Temple. Raistrick refers the Hutts Gill spillway to stage D,

which is synchronous with the Swinney Beck channel and not with the Millstone Bank overflows as is here maintained. Whilst it is not possible to offer final proof of the differing correlation here put forward, the criterion of using the point at which a spillway looses its characteristic profile at its outfall end has in several instances yielded consistent results.

At the approximate time that the Crundell Hill spillway was in operation, further channels were developed on the N.W. slopes of Penhill. It appears that meltwaters were travelling east across the face of this hill, possibly from a lake in Waldendale or Bishopdale. Over most of East Witton Moor, spillways are not in evidence however and it must be supposed that the platform on the Richmond Chert Series, which is here very wide, had streams of meltwater coursing across it without actually forming channels. An extensive gravelly deposit around Ellersley Hills (071860) has a fluvioglacial appearance and is possibly the product of one of a series of englacial streams which left a moundy deposit similar to a kame. It is difficult to envisage that all this material was transported by the few, small spillways in the area which in any case do not drain in the exact direction of these hillocks.

The progressive fall of Lake Coverdale is marked by the formation of a channel at Castle Steads below Crundell Hill (103853), the waters from which drained across Braithwaite Banks and below Witton Fell. A discontinuous series of spillways is seen below Witton Fell, showing a progressive and rapid fall in level down the geological features. It is not possible to fit the formation of these successive channels into a system since they are

all short and are largely controlled by the geological features which they often emphasise.

During these stages some meltwater was no doubt travelling eastwards into Lake Coverdale via a plexus of spillways which are seen in the vicinity of Ellingstring and High Ellington. This lake was gradually falling in level since progressive recession of the ice margin had lead to the abandonment of the Hutts Gill channel in favour of the spillways which were formed at successive stages of still-stand of the ice at Danby's Nursery, and Oak Bank (212779, 226778).

During these later stages some meltwater found its way into Lake Coverdale along the N. face of Penhill and formed a double notch on Naylor's Hill (094873). It is presumed that at this stage the Wensleydale ice was still on Middleham Low Moor, but at a later stage this too, was clear of ice, leaving the remaining stagnant masses of ice standing in the valley bottoms. At this stage numerous small spillways marginal to the ice were formed in the East Witton area together with mounds of gravel which are probably kames. The best developed of these are in Jervaulx Park where quarries show them to be made up of cobbles and pebbles in a gravel matrix. The mound shows a lens of sand which affords proof of its origin as an aqueous deposit.

These last phenomena are referred to stage F of Raistrick, at which time the Ure ice had shrunk away from that in the Vale of York. It lay in a stagnant condition in the valley bottom, deprived of its supplies due to the melting of the snowfields which had once fed it. At this date the amelioration of the

climate had no doubt lead to heavy rains which fell in Wensleydale and drained eastwards out of the valley. The plug of ice in the valley bottom hindered this drainage which was therefore still perglacial to a considerable degree, though the gravels of Jervaulx probably point to englacial streams in addition. One of the final relics of this periglacial drainage is the impressive spillway of Ellington Firth (184841) which was operative at several successive stages of ice retreat since it has several inlets and one outlet. It is probable that, judging from its size, much of the water normally draining down the R. Ure was diverted through this gap which was gradually enlarged to its present impressive proportions.

In addition to the mounds at Jervaulx, formed during stage F of glacial retreat, a series of hillocks are seen at Wind Hills (205833), North Field Hill (204843) and Inner Hills (212831) in the ground between Jervaulx and Low Ellington. Sections in these mounds are rare, but cobbles of sandstone and limestone are very abundant in the soil in their sides. These hillocks have previously been called end moraines (Kendall and Wroot, 1924), but it seems more likely that they are at least in part kame-like deposits, the mound forms of which often show elongation along the length of the Ure valley. Similar deposits are seen where mounds are not developed in a gravel pit north of Masham (221819) where the material consists of cobbles and pebbles of rocks, indigenous to Wensleydale, in a matrix of sand. A section in a cliff on the right bank of the R. Ure near High Mains (216836) shows the following section:

25' subrounded cobbles of limestone, sandstone and chert in a gravel matrix- a presumed fluvioglacial deposit
15' poorly cemented gravel - a presumed fluvioglacial deposit
- smear of sticky clay, which may be a boulder clay.

The presence of deposits which are almost certainly fluvioglacial in the Ure valley, but are not markedly moundy, suggests that much of the valley bottom may be coated in deposits of this nature. A lens of sand in a mound shaped deposit at Jervaulx is strong evidence that some or all of the low hills between Jervaulx and Low Ellington are fluvioglacial.

The morphology of periglacial spillways In the present area spillways are morphologically of two types. Some channels are fully excavated and occur as a deep notch in the side of a major valley, or trenching a col between two adjacent valleys. This kind of channel is the most common one and varies in depth from about 10' to 75'. In the general the deepest channels are developed furthest east, where the gradual accretion of eastwards travelling melt waters had provided the outflow from Lake Colsterdale, with the considerable volume of water responsible for the deep overflow of Hutts Gill. Still further to the S.E. outside the bounds of the area examined in detail the channels are yet bigger, due to the larger available volume of water.

Many of the spillways on the south side of Wensleydale, above East Witton, are not developed as troughs, but are merely due to the passage of melt water for prolonged periods at the base of a geological feature with the result that it is very sharp, undulates slightly and may show incipient troughing which may have locally been developed into a well defined channel.

The shape of fully formed overflow channels is characteristic.

Invariably they consist of a steep sided trough with a more or less flat bottom. At the outfall end of the channel the gradient steepens and the U shaped profile becomes less pronounced, presumably due to the enhanced cutting power of the waters with the increase of gradient. A gradient of over 100' per mile is usual in most spillways and it must be presumed that the waters were rapid moving. They no doubt carried a quantity of debris in suspension together with a number of flows which periodically became detached from the front of the ice lying against the intake end of many of the channels.

Delta cones - at the outfall ends of spillways deltaic deposits are occasionally recognisable. The chief places where these appear to occur are at the outfall end of the upper channel at Druid's Plantation, Colsterdale and at the lower end of the Sail Hill channel, Colsterdale which splits up into several branches over what is possibly an inclined cone of deltaic debris.

The bifurcation of spillways is a little understood phenomenon but is probably due to rapid overdeepening of a braided stream with the result that this pattern is preserved. Branching with re-joining is seen in the channels at Crundell Hill and at St. Martin's church, East Witton (148856).

Intakes at differing levels - a few spillways appear to have had a long history and received meltwaters during successive phases of retreat. An overflow draining across Witton Fell into Lake Sowden Beck and the Ellington Firth channel are cases in point.

Spillways with closed intake ends - a channel on Braithwaite Moor (122845) and another at Quarry Hill (172841) show a closed

upper end into which it is assumed that the meltwaters running along the ice-front cascaded, wearing out a sort of plunge-bowl at the head of the channel. In the case of the Quarry Hill spillway there appear to be two slight troughs feeding the closed end which is over 20' deep.

Subglacial drainage - many of the short spillways on the south side of the Ure valley near East Witton show a rapid fall at their lower ends. It is possible that this is solely due to heavy rainfall sweeping out of the already formed channel and prolonging its lower end downhill. However it is also a possibility that the steep lower end marks in many cases the point where periglacial drainage found a point of entry under the ice and became subglacial. A spillway at Low Newstead (164853) ~~end~~ may be of this kind since its chief component appears to be in a downhill direction.

Post glacial deposits

Peat - No special study has been made of the peat deposits which cover extensive areas of high plateau and dip slope terrain on Penhill, Masham Moor and Kay Head Allotment and the shelving slopes round Coverhead. The maximum thickness of about 10' is seen occasionally where the slope of accumulation is small, but 6' is a more common record. Normally the peat rests on a clayey substratum which contains blocks of sandstone. These are often of varied lithology indicating solifluction prior to peat formation. Over some tens of square miles of the present area geological survey procedure has been govered by the presence of a peat cover. Most of the available evidence for mapping is then derived from the channels intersecting the peat and from

area where it has been denuded. Wasteage has not been great however and it is this lack of eroding peat and channels which has contributed to the success of Masham Moor as a grouse moor.

Alluvium - The chief rivers, the Ure, Cover, Burn and Nidd, all show alluvial plains with some development of river terraces, all of which are shown on the appended geological map. The alluvium is usually of silt or of fine sand grade, but exposures in a terrace of the R. Ure near Broughs Farm shows cobbles in sand (141874 and 138871). Since it is most unusual for such coarse sediment to be associated with flood-plain alluvium and there is no doubt about the terrace form of the ground in which they occur, it appears that these deposits must be redistributed fluvioglacial debris brought down by the river in times of flood.

The highest river terrace developed is on the R. Ure at Masham where it stands about 30' above present river level. Terraces occur in the valleys of the R. Burn and the R. Cover, but they are never more than 20' above river level. The best are seen near Gollinglith Foot in the valley of the R. Burn and it is probable that these were formed at the same time as one of those at Masham. In Coverdale terraces are not as well developed as in the valley of the R. Burn, but several are seen below Caldbergh and farther up the valley.

Old river courses are occasionally seen. The most important is a former course of the R. Ure which bypassed the present one round the Clifton Castle meander by going south pas High Mains Farm. This course is defined by several ponds occupying a well defined depression. The point at which the channel joins the

present course of the Ure at its lower end is not clearly defined. A former course of the R. Cover, seen along Turnbeck Lane (057831), is marked by a depression above the present level of the waters of the Cover which are now entrenched in their new course, much as the Ure is at High Mains (the Ure at High Mains is over 40' below the apparent level of the top end of the old channel).

Landslips - Slipped masses of rock are common in all the major valleys in the present area except Colsterdale. All the landslips appear to have taken place in postglacial times and possibly at the time when the permafrost below the cover of snow and ice at the close of the Quarternary ice age was melting. At this time there would be much interstitial water in the rock which might aid lubrication and consequent collapse. The landslips are developed in most cases in predominantly shaly beds, the chief of which are the Nidderdale shales and the strata of the Underset cyclothem below the Main Limestone, also a thick series of shales. The large landslips at Black Scar, Penhill Crags (both of them on Penhill), Blackfell Scar and Woodale Scar (both in Nidderdale) are in the Nidderdale Shales. Big slips at Crag Brea, Waldendale and above Horsehouse in Coverdale are in shales below the Main Limestone. Undoubtedly the most spectacular ones are below Penhill in which an immense volume of debris with an irregular surface and strong bounding features lies beneath the two major scars. The Penhill Crags landslip has involved the collapse of a thick sandstone in the Nidderdale Shales which probably rests on a thickness of shales, slipped out from underneath it. The landslip rests below the scar shown in Plate 32B. Between the observer and the cliff is an enormous volume of rock debris which include many boulders

PLATE 47

Great Whernside and Nidderdale from Kettlewell. Taken in the direction N.60 E. In the far distance is Coverdale (1), eroded in sediments of Yoredale facies and flanked on the S.E. side by the escarpment of the main outcrop of Millstone Grit beds on the Askrigg Block (centre and right of the background). The base of the L.Follifoot Grit is shown by dashes. Beds at this and higher levels form the extensive plateaus at the head of Colsterdale (3). On it are three cake-like outliers (4,5,6). The R. Nidd rises on Gt.Whernside, flows E. and then S. It is joined by Howstean Beck at Lofthouse, where there is an inlier on Yoredale facies sediments. The Thrope Edge Landslip is visible and the extensive dipslopes of Kay Head Allotment, chiefly in the Red Scar Grit (8,10). 11 is a quarry in Nar Hill Beds for the Scar House Dam (12). Round Angram Reservoir (13) there is a further inlier on Yoredale rocks. Little Whernside (15), Great Whernside (14) and the northern spur of this mountain (16) have a capping of L. Follifoot Grit. On the W. flank of Gt. Whernside the Red Scar Grit forms a feature (17) with landslips (hatched). The base of the Main Lst. is shown by a fine dotted line and forms a wide outcrop on Coverhead. The limestone dies out to the S. at the point indicated. The base of the Middle Limestone is shown (18). Also seen are Kettlewell (20), scars in the Great Scar Lst. (21), R.Wharfe (22), Park Gill Beck (23). The whole of the foreground is in beds of Yoredale lithology and the Great Scar Limestone

The boundary of the mapped ground is approximately shown by the thick, broken line. Everything except the extreme distance was surveyed, in Coverdale, Nidderdale and Colsterdale.

Air Photo: C.H. Wood Ltd.

Plate 47

of sandstone derived from the scar. Extensive slips also occur below Great Whernside on its west side. These are seen in the air view on Plate 47 and in common with all other landslips are also marked on the geological map. Other landslips appear on photographs as Plate 25A and 33B.

Geomorphology

King (1935) studied certain aspects of the geomorphology when dealing with the Wensleydale river system. Arguing by analogy with similar drift-mantled spurs higher up Wensleydale, he suggested that a pre-glacial exit of the R. Cover lay under the distal end of the spur S.E. of Middleham which is thickly plastered by drift. The fact that the lower part of the R. Cover showed a steeper thalweg than its upper reaches he ascribed to adjustment to a pre-glacial nick-point; in the nature of the case this can only be regarded as a tentative suggestion.

Hughes, when working on Ingleborough (1901) recognised the presence of a peneplane extending over the Askrigg Block to the Howgill Fells and Lake District. Trotter subsequently (1929) described a peneplane on the Alston Block which he considered to have been tilted in late Tertiary times. Hudson (1938) on the basis of long profiles of spurs and summits in the Askrigg Block deduced the presence of a peneplane, which, as in the case of that described from the Alston Block, showed a pronounced tilt to the east, attaining its maximum on the eastern border of the block. He gave a late Tertiary age to this surface and also to the movements which tilted it. Certain summits, including Great Whernside, were considered to be monadnocks on the peneplane.

Whilst the present author agrees with Hudson regarding the fact that a peneplaned surface is likely on the crown of the Askrigg Block, he would question the evidence for its being warped. Whilst there is a gradual falling off of summit levels to the vale of York this fall decreases again in the low hills standing at about 500' O.D. near Masham. On the opposite side of the Vale of York the escarpment of the Hambleton Hills is not clear. Any suggestion that it is due to complex warping of a Tertiary surface would seem most implausible. Whilst Hudson mentions the pre-Permian surface, he does not appear to go so far as to explicitly link the supposed tilted peneplane west of Masham with it. The summits of the spurs west of Masham are in a horizon approximating to the Second Brimham Grit near Healey, but to the west are in the Follifoot Grits and ultimately in Penhill in the Red Scar Grit. This involves the crossing of over 300' of strata by the 'surface'. Whilst it is undeniable that the pre-Permian erosion surface locally cuts across Carboniferous sediments, there does not appear to be any good evidence that it stepped down on to lower levels across the Askrigg Block. For this reason the linking of the peneplane constructed on the spur profiles on the eastern margin of the Askrigg Block with the pre-Permian surface is thought unwise. If both the Tertiary and ressurected pre-Permian explanations are not likely ones, there appears to be little remaining reason for supposing that a surface exists except on the crown of the Block where the summit levels are concordant. The gradual fall in spur levels to the Vale of York is best explained as due to the Tertiary tilt of the rocks.

Since the spurs are dip slopes for many miles this explanation seems to be the valid one.

The influence of geology on scenery - The rocks of the present area consist of an alternating succession of hard and soft beds which tend to weather into features. The easterly dip of the strata has lead to a gradual fall in features to the east, together with the formation of plateau dip slopes and tilted relict hills.

The scenery developed on the Yoredale facies beds differs from that of the Millstone Grit country in general, but a cover of drift minimises these differences.

The Yoredale facies strata consist of an alternation of beds which tend to make excellent features. In Coverdale and Waldendale the features are not always well developed, this being partly due to a cover of drift, but on the northern slopes of Penhill an exceedingly well defined step topography occurs. The hard limestones form the crest of well defined features, whilst the underlying sandstones and shales form their steep faces (Plate 17A). Middleham Low Moor and Middleham High Moor are a very long dip slopes on the Richmond Chert Series (Plate 1 and geological map).

The massive nature of the bulk of the Middle Limestone has lead to the formation of gorges at several points where it is cut into by major streams. The most notable are Caygill Scar, near West Scrafton (074840) and the How Stean Gorge near Lofthouse (092735). Solution phenomena have lead to the formation of cave systems and pot holes in the thicker limestones. All the caves seen are in the Middle Limestone, the chief of which

are the cellar holes of Manchester Holes and Goydin Pot. In dry weather these take all the waters of the Nidd and discharge the bulk of it from two vauclusian springs near Lofthouse. In Coverdale similar springs occur, chiefly in the Middle Limestone. Sink holes often develop in drift-free ground at the top of a limestone. Such lines of sinks, especially in the top of the Middle and Main Limestones of Waldendale and Coverdale have aided mapping, since they help to mark the upper contact of the limestones which they drain into. Perhaps the largest collection of sinkholes is in the top of the Middle and Main Limestones of Waldendale where the sinks are of large size and receive a fair portion of the drainage.

The presence of the Main Limestone and Richmond Chert Series in a thick series in lower Coverdale has helped to give the lower dale its characteristic open profile. This was commented on by King (1935) who also suggested that rejuvenation may have had an effect of giving a steep valley slope near the river Cover which gently shelving valley sides above this level (Plate 43A shows the step on the N.W. side of Coverdale). The last suggestion is hard to prove. The geological cause is quite sufficient since a platform on the Richmond Chert Series is also developed on the north face of Penhill.

The sediments other than limestones do not usually form striking landforms, except locally in Coverdale where an extensive series of gulleys on the shales below the Underset Limestone is seen on the N.W. of Great Whernside.

In beds of Millstone Grit lithology the contrast between hard and soft rocks is not always so well marked as in strata

PLATE 48

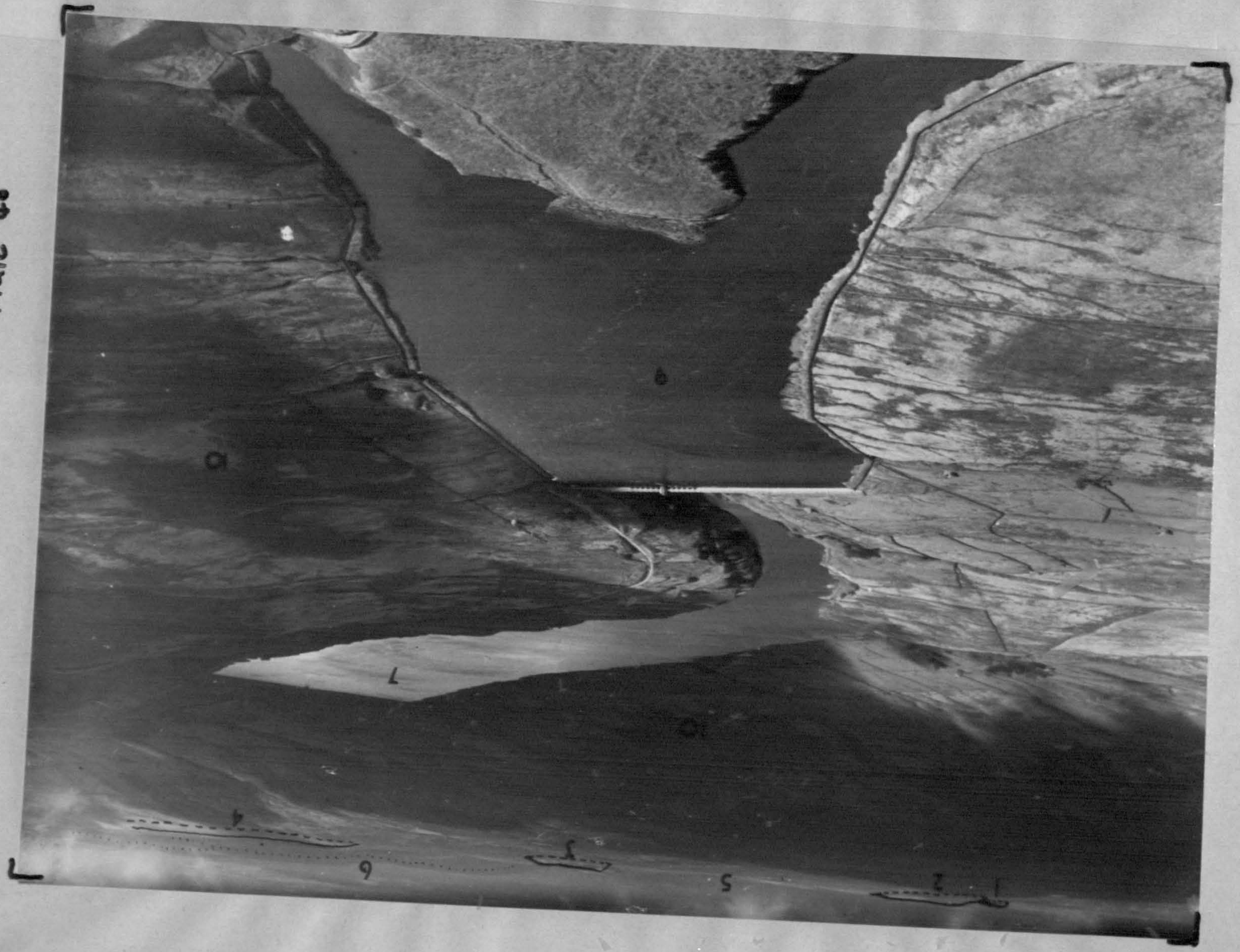
Nidderdale from above Low Pasture, Angram, taken in the direction N.60 E.

The distant hills are 1. Little Haw, 2. Great Haw, 3. South Haw, all outliers capped by Libishaw Sandstone, with steep bounding slopes in the Libishaw Shales. Brown Ridge (4) is the main outcrop on these beds. The Ganister Beds, Shell Bed and Agill Sandstone form extensive dipslopes (5) round the head of Colsterdale. The distant spurs (6,dotted) are those between the southerly tributary valleys of Colsterdale.

The Scar House Reservoir (7) has a cliff at its upper end with good sections in the uppermost beds of Yoredale lithology in Nidderdale (8). The Angram Reservoir (9) and the lower dam are flanked by steep valley slopes in beds of Millstone Grit facies. The Red Scar Grit forms the plateau on the right. Higher beds, up to the Libishaw Sandstone outcrop on the N. side of the valley (left, centre background).

Air Photo: C.H. Wood Ltd.

Plate 48



of Yoredale facies and thus features are less distinct in many cases. The Grits tend to form plateaus as in Penhill, Great Whernside, Little Whernside and round the head of Colsterdale (Plates 1, 27B, 33A, 43, 47). The Red Scar Grit, Lower Follifoot Grit and Ganister Beds form the bulk of the extensive plateaus in the area. Lines of scars are a common feature and are developed especially on the Red Scar, Lower Follifoot and Brimham Grits (Plates 25B, 27A, 39, 40). The crags fringing the north side of Colsterdale and the strong boulder covered features of the Brimham Grits at Leighton are the most persistent and well defined.

The Libishaw Sandstone has weathered into hills of distinctive shape with flat tops and steep sides. The three conspicuous relict hills (Great, Little and South Haws) situated on the plateau at the head of Colsterdale are capped by this sandstone, with their steep bounding slopes in the Libishaw Shales (Plates 1, 27B, 38A, 43B, 48), as also are plateaus of similar shape situated on the interfluve between Nidderdale and Colsterdale.

The effects of glaciation on the topography and the development of landslips on the thick shales of the area are discussed earlier in this chapter.

An examination of the present drainage pattern gives no undoubted evidence of the former courses of rivers, but it is noteworthy how many streams flow from S.W. to N.E. The Nidd is the most peculiar in this respect, because initially it flows roughly N.E. and finally in a southerly direction owing to a sudden right angled bed in the course of the river north of Manchester Holes (this is well shown in the air photo, Plate 47).

It seems possible that the place where the change of direction occurs was once the site of the capture of a river flowing to the N.E. by a vigorous south flowing stream which is now the portion of the R. Nidd above Lofthouse.

CHAPTER 21.

ECONOMIC GEOLOGY

The economic geology of the area is basically a history of past exploitation of resources, chiefly coal and building stone, with some lead ore. The records of the construction of the several reservoirs is also interesting, not only because they furnished valuable sections of strata, but also because problems of a geological nature were encountered in the building of one of the dams, necessitating a large outlay of money over a period of years.

Water Supply

The considerable relief of the ground, combined with high rainfall and proximity to the industrial West Riding, has lead certain undertakings to site their reservoirs in Nidderdale and in the valley of Pott Beck, a tributary of the River Burn.

Four dams have been constructed within the last fifty years, two by Bradford Corporation in Nidderdale and two in the valley of Pott Beck, one by Leeds Corporation, the other by Harrogate Corporation. The two Bradford reservoirs supply over half the requirements of the Bradford Corporation Waterworks Department. The remaining two supply significant amounts of the water used by Leeds and Harrogate.

Angram and Scar House Dams. (Bradford Corporation) - The two Nidderdale dams are both large concrete ones with masonry faces, constructed along the line of trenches, well set back into the valley sides. Owing to the dip being gentle and almost downdale they have been free from subsidence and leaks, and are

generally considered to be model examples of construction.

The trenches were excavated in the Grassington Grit Group and sediments of Yoredale facies, providing Tonks (1925, Plate XVII) and the present author with useful sections.

Two tunnels were constructed under Rainstang, one to take water from Rainstang into the reservoir (the Rainstang Tunnel) and one to take water towards Bradford from the reservoir (the Scar House Tunnel). This last conduit continues south of Rainstang as a pipe in a covered trench and crosses the Stean valley and other streams by aqueduct. It is proposed further to increase the Nidderdale catchment by taking water from How Stean Beck by conduit.

Leighton Reservoir (Leeds Corporation).- Leeds Corporation became interested in Colsterdale as the site of a reservoir at the beginning of the Century. In 1904 trial bore holes were sunk near Gollinglith Foot, in two directions, across the valley and parallel to the length of the valley, close to the River Burn. Results were disappointing, as the drift proved unexpectedly thick. The projected reservoir was abandoned and an alternative site was chosen at Leighton, in the valley of Pott Beck.

The waters were impounded by a puddle dam of unusual length and bulk. It was early discovered that it leaked and expensive steps were taken to rectify the trouble. The chief measures initially involved gauging springs on the tributaries of the Burn, farther downstream, to find out to where the water was escaping. This proved unsuccessful.

PLATE 49

Pott Beck and Colsterdale from above Combs Crags, taken in the direction N.15 E.

In the distance (1) is the Ure Valley. The plateau (2) on the N. side of the R.Burn (3) is in the Lower Follifoot Grit (the pecked line indicates the base of the Grit, or where that is not possible, the plateau edge which it makes) and higher beds. The base of the Grit falls down-valley and makes an inlier (3) in the Nar Hill Beds and lowerestrata, with an offshoot into Grimes Gill (5). The Towler Hill spur is capped by strata of low R_1 age (4). Progressively newer beds come in south of Grimes Gill, on Pott Ridge (6), with a capping of Libishaw Sandstone. This is due to the easterly dip, which is illustrated by the gradual falling of the dipslopes to the right of the view. The highest strata appear S. of Agill Beck (7) where the First Brimham Grit makes an outcrop at Knappa Stones which continues round into Arnagill (bottom,right) The Grit appears to die out below Clints quarries, right of the lower reservoir. The base of the Brimham Grit Group, irrespective of whether the First Brimham Grit is present of not, is shown by a dot-dash line. An outlier occurs on these beds to the N. of the R.Burn. The reservoirs are Roundhill (9) and Leighton (10). 11 denotes the source of the boulder clay for the lower dam. Healey village (12) and the Vale of Mowbray (13) are seen in the distance. 'M' denotes fluvioglacial or morainic mounds near Healey Pasture Cottage, Colsterdale, marking the point of maximum ice-advance during the Main Dales Galciation. Several large spillways trench the moor behind these mounds. Faults are indicated by solid lines with downthrow as indicated.

Air Photo: C.H. Wood Ltd.

Plate 49

Cementation Ltd., were given the contract to sink a row of closely spaced, oblique boreholes on the eastern bank on the reservoir, which were filled with liquid cement. In all, 10,000 tons of cement were used in 160 holes sunk just above reservoir level a few yards from water's edge. The operations were covered by two drilling programmes, the bores extending two thirds of a Mile along the north eastern edge of the reservoir.

The boreholes encountered a shattered horizon, apparently the Follifoot Grit, which was the cause of the excessive leakage. At Leighton there is a strong dip component into the hillside and there is a tendency for water to drain down bedding planes out of the reservoir along the shattered strata. The point of emergence of this water was never solved, in spite of the use of fluorescein during the drilling programme. There was also some leakage round the east end of the dam trench which was rectified by cementation of boreholes immediately east of the line of the dam. It appears that the original trench was not long enough to prevent this defect which, like all other sources of leakage, has been greatly slowed down by the expensive remedial measures outlined.

The dam trench showed sections in the Nar Hill Sandstone and Shales and Follifoot Grits, providing valuable additional data for the study of these rock units. The dam constructed along the line of the trench has shown signs of subsidence, which is assumed to have occurred due to the compaction of the boulder clay of which it was made. The subsidence is virtually at a sand-still now, but the effect is quite noticeable.

The water intake of the reservoir is supplemented by a conduit

with intakes in Birk Gill and Spruce Gill.

Roundhill Dam (Harrogate Corporation).- This dam, unlike that at Leighton, was constructed at a narrow point in the valley and is of masonry. The trench was excavated in almost the identical beds in which the Leighton trench was dug. The dam is free from major leaks. The water is taken away by pipeline in a tunnel under Arnagill Sighting Tower.

Reservoir silting.- A problem which has beset all the reservoirs of the area, but most notably the Angram Reservoir, is rapid silting. This is well illustrated by the fact that small dams constructed as sediment traps at the head of the main reservoir are both virtually full with many hundreds of tons of debris, deposited in the last 40 years. This unfortunate state of affairs, which must eventually impair the capacity of the actual reservoir unless costly preventitive measures are taken, is largely due to the numerous gulleys in the soft Nidderdale Shales, from which debris are rapidly removed, lining the sides of the streams draining into the reservoir. These gulleys are more numerous in the Stone Beck drainage than in the River Nidd proper and it is significant that the Stone Beck sediment trap is brim full, while that on the Nidd is still filling up.

Local water supply.- Local water is from springs which are fairly numerous throughout the area. These are usually impounded and lead off by pipes at the source.

Coal

Coal has been of some importance in historic times and records of workings date back to 1334 A.D., after which date the monks of

Jervaulx had control over them. At the Dissolution, authority passed into the hands of the Danby family of Swinton, who had a coal mine in active operation in 1768. However, by 1860 only the oldest inhabitants had memories of what was then a defunct industry, indicating that the Industrial Revolution and the opening of the major coalfields had provided cheaper fuel elsewhere in the early Nineteenth Century. Added to this fact is the probability that the Woogill Coal of Colsterdale was virtually exhausted, and was becoming uneconomical to work. The workings in the area were by shafts and levels at the horizon of the Woogill Coal (E_2) and the Grassington Grits (E_1).

Coal in the Grassington Grits.- Coal has been worked at three horizons and since the seams appear to be very restricted in distribution, so also are the workings.

The lowest seam has been worked by shallow shafts at Great Hunters Sleets (981760) and is locally over 18 inches thick. It is also worked in the vicinity of Coverhead shooting box; it is probable that this coal was less than 10 feet from the base of the Grassington Grit Group. In the vicinity of Fall Gill, occasional adits were driven at this same stratigraphic level. Further workings occur at Fleensop Colleiry (022816) where by several adits and numerous shafts two separate coals, low in the Grassington Grit Group, were exploited.

Near Hodge Holes, Penhill (056861), several adits and bell pits are seen about 100 feet above the base of the Grassington Grit Group. This horizon is somewhat similar to one worked on Whernside Pasture (991740) by a series of levels and again by a single level at

Ruscoe Beck, in Nidderdale (082745). Lines of levels on the south side of Angram Reservoir and on Witton Banks were for working coals in the Grassington Grit Group, but they were relatively unimportant.

The Woogill Coal.- The Woogill Coal occurs in a parting in the Red Scar Grits, usually in conjunction with fireclay and shale. This seam is of greater importance than those previously described, for Fleensop Colliery is the only working on a commercial scale in the Grassington Grits. Some of the shaft workings were of large size, as shown by the impressive dimensions of their tips.

Coverdale.- The coal appears to be impersistent and is worked in local concentrations of levels along the outcrop. The chief lines of levels are in Ulfers Gill (095828), on the slopes of Scrafton Moor (076819) (See Plate 29, which shows clearly that the levels have here penetrated deeply into the hillside as is shown by the size of the tip heaps), on Hindlethwaite Moor at two points and at the head of Arkleside Gill (046786). West Scrafton Colliery is the chief shaft working and has been open within living memory. It is also probably the largest single coal mine within the area.

Nidderdale.- Adit workings occur in Woogill (after which place the coal is named, the contraction to 'Woogill' being due to Dakyns, who originated this stratigraphic term) and shafts on the moor to the north east. Further adit workings are seen on the north and east sides of Rainstang and at Bleasfield. (005762).

Colsterdale.- Unlike the Nidderdale and Coverdale workings

which occur in scattered groups, the lines of adits in Colsterdale are more continuous and indicate that the coal was less apt to die out frequently in this area. Long Lines of closely spaced drifts are a feature of Birk Gill and the Burn valley in the area round Colsterdale hamlet. (The worked outcrops are shown on the geological map by means of solid black lines). Several shafts occur high up Colsterdale where the coal is below valley level (as at High Engine Pit (096798) and on the surrounding moors. The most important one is Brown Beck Colliery (133827), with its exit on the moor top.

Braithwaite Moor.- The Woogill Coal is worked by numerous shafts and in a few levels and appears to be fairly continuous in this area, North of Colsterdale.

Extraction of the Coal.- The workings in the Woogill Coal, as in the case of the coals in the Grassington Grits, have involved the extraction of much incombustible rock, chiefly fireclay, which bulks largely in the tips from this seam throughout the area. Since the Woogill Coal was not recorded as exceeding 2 feet in thickness, it is probable that 2 feet, or more, of unprofitable rock was shifted during mining.

The Woogill coal, like those in the Grassington Grits, appears to be fairly pure, but under present circumstances all these seams would be unprofitable to work due to prhibitive mining and transport costs. However it appears that the available coal has been largely worked out, except possibly under remote moorland tracts such as those around Great Haw, which would in any case necessitate the sinking of deep shafts for purposes of mining.

Lead Ore

Veins have been worked for lead in Coverdale, Waldendale, on the North slopes of Penhill, on the slopes above Kettlewell and in Nidderdale. In no case is there evidence of rich oreshoots. Galena in the spoil is always a rarity and it appears that much money was spent for a very small return. Extraction was by shallow shafts and bell pits which usually followed the lines of rakes, though there are numerous scattered trials.

The chief oreshoots were in the Main Limestone and Richmond Chert Series, whilst above Kettlewell and near Lofthouse the Grassington of Bearing Grit (as it was called by the miners, in recognition of the good veins which occur on Grassington Moor at this horizon) is the ore bearing horizon. The vein material belongs to a mesothermal paragenesis and the only metalliferous ore seen was galena, with a gangue of calcite and more occasional barite.

Petticoats Rake (016818) Trends N.65-72 E., N.12 W.

The bulk of the mineralisation is in the Richmond Chert Series which has been worked chiefly by three lines of shallow shafts and bell pits. The tips are practically barren of ores and it seems remarkable that such unproductive veins were exploited to the degree to which they patently were. Around the centre of the Rake there is a large concentration of shallow workings and it seems probable that there are numerous small veins developed at this point. The vein directions correspond with the predominant joint directions for the area.

In central Coverdale occasional scattered lead workings occur, but none appear to have worked rich veins and they were, no doubt,

rarely, if ever, profitable.

Flamstone Pin. (002852) Trends N.80 E.

Shallow shafts mark the direction of a vein on Caldbergh Pasture. It does not appear to have been a rich oreshoot and is developed in the Richmond Chert Series and shales of the Grassington Grit Group.

Braithwaite Hall. (118860) - Mineralisation is developed in the Richmond Chert Series and the tips of shaft workings yield barite. One of the oreshoots appears to be on the line of a fault, but the exact direction of the veins is difficult to decide from surface evidence.

Dovescar Plain, Penhill.- Scattered trial shafts and one row of shallow shafts were sunk in the Richmond Chert Series. An old shaft at 035869 shows galena traces in the spoil, but as a whole the tips are deficient in vein material.

Chance Hill Lead Mine, Harland Hill (023847) - Shafts and diggings occur in a poor vein.

Limley, Nidderdale. Trends N.100.E (002753) - A series of shafts were sunk along the line of the Thrope Scar Fault. They do not appear to have encountered any rich deposit.

The Lofthouse Moor fault zone in the River Nidd near New Houses (093768) and the Lofthouse Fault in Blayshaw Gill show barite veinlets. The mineralisation on the Lofthouse Fault has been worked by a level in Blayshaw Gill and in shafts on Stean Pasture (092748). The Grassington Grit is the vein bearing horizon.

Great Whernside (West Slopes) - Veins have been worked at Caseker Gill Beck (743985) and at the Providence Lead Mine (992728) which is on the fringe of the area; this latter working was not examined, but

appears to have been more successful than any within the present area.

Steel House Gill, Colsterdale. (near 096798) - In 1709, when miners were following workings in the Woogill Coal, they encountered lead ore in several veins. This was eventually abandoned as unprofitable after several years of working. These oreshoots were no doubt on the line of the faults in Steel House Gill.

Ironstone

Whilst there appear to be no good deposits of chalybite ironstones within the area, records exist of ironstone mines in Colsterdale prior to the earliest records of coal mining. As early as 1250 ironstones were mined there. Since the only possible horizon appears to be the chalybite nodules in the lower beds of the Colsterdale Marine Series, it must be assumed that they were worked in diggings. It is quite impossible to verify this assumption in the field however as the outcrops at this level appear to have been undisturbed.

Building Stone

The limestones and sandstones of the Yoredale cyclothems have been quarried at numerous points on a small scale. All major limestones, with the exception of the Five Yard Limestone, have been quarried for wall stone and sometimes for lime burning. There are however no quarries worked at present, one of the larger, disused ones being at Limekiln Hill (081873) in the Main Limestone.

The sandstones have seldom been worked in spite of the fact that they appear to be often good building stones. The sandstones of

the Three Yard cyclothem was worked in the Hudson Quarry, on the north west slopes of Penhill. In the vicinity of Tunstall Scar, Coverdale, (063834) levels have been driven into the sandstone of the Simonstone cyclothem, underlying the Middle Limestone. The workings were for roofing stone and appear to have been extensive, judging by the extensive tips in the reject rock, which are a feature of this highly selective industry. Levels driven into a sandstone in the middle of the Underset Cyclothem on the north slopes of Penhill appear to have been also for roofing tiles.

The chief sandstones of Millstone Grit facies have also been quarried locally at many points, but the chief exploitation has been for dam construction. The large quarries in Nidderdale at Carle Fell Side (075764) and Rainstang (062775) yielded rock for the Angram and Scar House dams from the sandstones in the Nar Hill Beds, which attain their maximum development in this part of the dale. The quarried rock is often very massive and is a good freestone. The Second Brimham Grit was used for the same purpose at Clints Quarry, near Leighton (163780) and was used for the Harrogate and to a lesser extent the Leeds dams. The rock is coarse and exceedingly massive and appears to be of immense durability. The mock ruins and grottoes built by the Lords of Swinton in Colsterdale are all made of boulders of Brimham Grit. The Second Brimham Grit was worked in Quarry Gill. Swinton Park (198799) and was no doubt used for constructing the Gothic style Quarry Gill Bridge and Swinton Castle.

The sandstones in the Grassington Grit Group have been little

worked in the area, except for a horizon on the north slopes of Penhill which has been wrought in quarries and levels for roofing stones. The rock is a thinly bedded, strong flagstone and is ideal for this purpose. This industry was once of some importance and appears to have died out about fifty years ago. (See Plate 25A).

The Lower Follifoot Grit has been worked on a moderate scale at Healey Pasture Quarry (160809) (the source of the stone in Masham Parish Church) and at Ellington Firth (184842). The most widely worked horizon is the Libishaw Sandstone, whose outcrop edge on the tabular plateaus which it forms on Masham Moors were commonly worked in small quarries, some of which may have been for roofing stone.

At Stott Fold, in Colsterdale, (145776) this is undoubtedly true since the tips from the old quarry are here extensive and the rock is bedded in layers about half an inch thick, which is ideal for this purpose.

Fluvioglacial and glacial Deposits

A large 'puddle field' for the Leighton dam was worked on the north west side of the reservoir, in the drift which here mantles the Follifoot Grit, which was laid bare during the workings. The dam was constructed chiefly of this boulder clay and is of unusual size and bulk.

Fluvioglacial gravels containing many blocks of cobble size have been worked North of Masham, adjacent to the Isolation Hospital (221819) and at Wind Hills on the North Side of Jervaulx Park (181856). Stones similar to those in the Wind Hills gravels

form the cores of the walls of Jervaulx Abbey.

Peat

A peat cover occurs on the moorland plateaus and is sometimes 10 feet thick. It has been worked in the past in quite extensive diggings on Penhill and near Scrafton Colliery. It is still being dug on Scar House Moss where it is dried prior to burning. The reserves of this fuel are enormous and thick accumulations are located on the high plateaus of Penhill, Masham Moor and Kay Head Allotment, and also on the more gently shelving slopes around Coverhead.

CHAPTER 22

PALAEONTOLOGY

The literature relating to the zonal division of the Carboniferous is large and is not here considered in detail (but also see Johnson, 1953, Rayner, 1953, Short, 1954). The rocks of Yoredale facies were divided up on a faunal basis by Smith (1911 who split up the D zone of Northumberland into four divisions, the upper two of which included the strata of Yoredale facies in the present study. D2-3 included strata to the base of the Great Limestone and D_y comprised strata above this horizon to the level of the Fell Top Limestone. These two divisions were subsequently named the Middle and Upper Limestone Groups by the Geological Survey (Fowler, 1926). The divisions of Smith were carried out on a coral-brachiopod scheme as also were those of Garwood who worked on ground closer to the present area. The subdivisions of the D zone proposed by Garwood were such that all the strata of Yoredale facies in the present area belong to the upper part of his D zone which he characterised by Dibunophyllum muirheadi, a division which extends from the base of the Hardraw Limestone to above the Botany Limestone which is correlated with the Colsterdale Marine Series of E_2 age (following Reading, 1954 and Scanlon, 1955). The chief elaboration of this scheme was proposed by Hill 1938) who suggested a subdivision based on coral faunas. Whilst this scheme is more detailed than that of Garwood at the stratigraphic level of the present study, it is based on large assemblages of corals and depends much on relative numbers of forms. Certain aspects of the scheme appear to be readily

workable; for instance Orionastraea is not recorded from above the Middle Limestone. On the other hand the large number of long ranged forms cited do not appear to make this an easily workable scheme. Johnson (1953) divided up the rocks of Yoredale facies in the valley of the South Tyne by means of several types of fossils including algae and showed that a faunal change occurred between the horizons of the Five Yard and Four Fathom (Underset) Limestones. Some of the important fossils mentioned by Johnson are further discussed in the text.

The zonal schemes using goniatites, have been shown to have limitations since the goniatites were, like the corals limited to certain biofacies and lithofacies. Generally speaking however, goniatites have been of much greater use since they have a rapid rate of evolution so that quite often a particular species is only characteristic of a particular band and is never seen again elsewhere. A detailed zonal scheme has been built up in Britain by the efforts of many workers and in particular Bisat, Hudson and Moore. The chief limitation of this scheme is the rarity of goniatites in rocks of Yoredale facies and also their relative scarcity in rocks of Millstone Grit facies on the Rigid Block. The equivalents of the rocks of Yoredale facies south of the Rigid Block are rich in goniatites and thus a detailed scheme has been built up for the P zone and correlation at this level carried north across the Craven Faults on to the block have depended on rare records from rocks of the Yoredale facies (the available evidence was summarised by Rayner, 1953; subsequent work by Moore, 1955, Joysey, 1955, Hopkins, 1956 and the present

author has allowed of some addition to these records). For beds of Millstone Grit facies the goniatite faunal scheme pioneered by Bisat has proved most useful. Its applicability is decreased by the dying out of many of the bands northwards on to the Askrigg Block, but the present work has shown that more horizons than had hitherto been realised do in fact persist on to the Block, and these act as valuable aids to correlation.

The process of naming the fossils listed in this thesis has involved the use of a large literature, reference to which is made in the bibliography.

Palaeontological details - a) Plant remains

Algae - this group has been little studied during the present work and the reader is referred to Johnson (1953) and Moore (1955) for a more detailed consideration of these forms. In thin section small calcareous algae have been recorded from the chief limestones, the most common form being Girvanella. One specimen of "Organism α" Johnson ms. has been found in the Main Limestone to which this form is virtually restricted (Organism α is figured and described by Johnson, 1953 and Short, 1954 and is also recorded by Wells, 1955; the present record is the furthest south that it has so far been found). Whilst the affinities of "Organism α" are not known it has been tentatively referred to the algae. by Johnson. Macroscopic algal nodules occur in the Three Yard Limestone in upper Coverdale in a well defined band; a single record of a band in the Simonstone limestone in Waldendale has also been made and this may correspond with a horizon frequently recorded by Moore from Upper Wensleydale at this level.

The problem of the origin of 'cauda-galli' markings (olim Spirophyton cauda-galli Hall) has involved the suggestion that they were caused by algal agency, though this was only one of several tentative suggestions put forward by Wells, 1955b. Wells asserted, but could not show in any specimen which he actually possessed that a casual relationship existed between bands of arcuate markings preserved in vertical sections of chert and their supposed external manifestation, broadly concentric corrugations of somewhat irregular shape covering areas several centimetres in width. It is significant that the author has in his possession a platy chert with both markings visible, though the two cannot be positively related and has in addition seen the two sets of markings within the compass of a small exposure of calcite mudstone in Westmoreland (in the Cockleshell limestone of Trout Beck near Great Dun Fell). It seems therefore that the relation suggested by Wells may easily be the correct one. A specimen of chert from Thorow Gill, Coverdale shows cuspidal markings which appear to be arranged in a concentric shape which suggests an algal origin. (Plate 18B).

Plant remains other than algae are not common except in the Ganister Beds where Stigmaria is a common record from the massive ganisters. No other identifiable remains were collected, though fragments of plants sometimes occur in rocks of Millstone Grit lithology.

b. Protozoans

Foraminifera - work on the foraminifera of the beds of Yoredale facies on, or adjacent to the Rigid Block has been carried out by several workers, the chief of whom is Short (1954). In

addition Johnson (1953), Moore (1955) and Wells (1955) provide valuable lists which show many of the salient points regarding the forms found which were chiefly detailed by Short. From the present work, as from the the previous work it has been shown that the common Yoredale forms belonging to the genera Archaediscus, Ammodiscus, Endothyra, Orobias, Tetratataxis and Textularia persist throughout the sequence which is covered in this Thesis up to the level of the Richmond Chert Series above which level records of foraminifera appear to be unavailable. All these forms seem to show no systematic variation with the exception of Archaediscus which Short (1954) splits up into a characteristic from and two varieties. Var. β, a small ovate as distinct from a large subcircular from (var α) tends to predominate and eventually replace var. α upwards in the succession. The present, small number of specimens examined of this genus lends some support to this scheme. The most variable of the genera, Endothyra, unfortunately shows little systematic variation. The most important form is Howchinia bradyana (Howchin) which is of distinctive shape and was recorded by Short as dying out at the level of the Three Yard Limestone above which it was not seen. Wells (1955) records this form as high as the Underset Limestone, which is the only record from this horizon. During the present work Howchinia was only seen in the Middle Limestone. In addition to Howchinia Short records Stacheia and Valvulinella as forms which do not persist above the Three Yard Limestone; neither Moore, Johnson, Wells or the present author have recorded these forms and it must be assumed that they are rare (in fact Short also comments on their presence only in

small numbers).

Short mentions his lack of success in separating faunas of foraminifera of worthwhile proportions from his fossiliferous shales. The disaggregating agent he used for the separations was detergent. During the present work only two separations were attempted on Yoredale Shales with a normal shale fauna; these were from the Simonstone and Five Yard cyclothems. Both separations yielded foraminifera in moderate abundance with the use of 10% H_2O_2 solution with ebullition, followed by sieving under water. These forms were not damaged in any way and were readily determinable. It is noteworthy that the specimens were of the genera Ammodiscus, Endothyra, Orobias and Tetrataxis; these are the same genera which existed under the clear water conditions giving rise to the limestones in which the bulk of the foraminifera are found.

As in the case of the other workers in this field, the majority of identifications were carried out in thin sections cut somewhat thicker than the average petrographic slice. No foraminifera were seen in thin sections of limestone from rocks of Millstone Grit facies such as the Cockhill Limestone, Colsterdale Limestone or the limestone below the Homoceras beyrichianum horizon of H zone age.

The debt to the numerous photographs of Short (1954) is here acknowledged, since they have been a valuable aid in identification. Some of the nomenclatorial innovations of Short have not been followed here and in this respect the present nomenclature is almost uniform with that of all authors, excepting Short. All forms referred to as tetrataxiids in the faunal lists

are apparently synonymous with Cribrostomum bradyi Moller as interpreted by Short and with Tetrataxis gibbosa Fleming as understood by Wells (personal communication).

c. Porifera

Sponges - these are found chiefly in the cherty beds of Yoredale facies sediments where they are represented by tri and tetra- radiate spicules and also probable mooring ropes referred to Hyalostelia spp. Spicules have also been found in the Ganister Beds and Cayton Gill Shell Bed in rocks of Millstone Grit facies. Hyalostelia is also not restricted to cherts and occurs in shales of the Underset cyclothem, the nuculid-gastropod beds of the Colsterdale Marine Series and from the Libishaw Sandstone. The association of sponge remains and cherts suggests that the spicules and Hyalostelia may all have belonged to siliceous organisms which flourished under unusually favourable conditions with much silica gel on the sea bottom which was available to supplement the silica supply of these sponges. Hyalostelia is supposed to have been a siliceous sponge and it also is evident that the spicules in the cherts are at least now silicified, even if in fact they were not originally siliceous.

d. Coelenterates

Corals - these are numerous in beds of Yoredale facies and are virtually restricted to limestones and shales; their greatest development is found in the limestones. With the exception of two specimens from the Cockhill Limestone they are absent from beds of Millstone Grit facies. This lack of corals is a little surprising in view of the fauna of the shell beds of R_1 age which yield many pelecypods, brachiopods and gastropods which

occur commonly in beds of Yoredale facies. Since it is difficult to conceive that the faunas of these shell beds consist entirely of derived forms it is possible that a sandy sea bed did not favour the growth of corals, or otherwise depth or other unknown conditions may have been unfavourable. The corals from beds of Yoredale facies tend to group themselves into distinct faunules which have been commented on in detail by Hill (1938) and also by Moore (1955). The present results may be arrived at independently, though in concept they are based partly on that of previous authors. The following faunules are recognised:

1. Clisiophyllid faunule - the association of Clisiophyllum and Aulophyllum in limestones of pale grey type appears to be well established and occurs in the Three Yard and Underset Limestones in the N.W. of the area. The dominant forms are Dibunophyllum bipartitum vars. (olim D. muirheadi which was the diagnostic fossil of the upper part of the D zone of Garwood, 1913) and Aulophyllum fungites with rarer Koninkophyllum. The corals are normally lying on their side and are not preserved in their original, somewhat insecure growth position.

2. Lithostrotionoid faunule - these forms occur exlusively in limestones which are usually of blue rather than grey colour. They are often accompanied by rare specimens of the clisiophyllid faunule as in the Gigantoproductus Beds and the Five Yard Limestone. Locally colonies of Lithostrotion several feet or even yards in length occur forming miniature reefs which are associated with numerous gigantoproducti in the Gigantoproductus Beds; these huge colonies are evidently still in the position of growth. Basaltiform

Lithostrotion is rare except in the Five Yard Limestone of upper Coverdale and upper Waldendale. The genera Lithostrotion and Diphyphyllum make up the members of this faunule which normally occurs in conjunction with a moderately prolific brachiopod fauna.

3. Aulophyllum faunule - whilst clisiophyllids were not found in shales during the present work, Aulophyllum, preserved as flattened calcitised calices on bedding planes was found in large numbers in the shales of the Simonstone cyclothem at one locality in Coverdale. A single specimen was also recorded from shales underlying the main part of the Underset Limestone in Fleemis Gill, Coverdale.

4. Zaprentid faunule - normal shale faunas commonly carry small zaprentid corals which are only very rare records from the limestones. In the bulk of instance the calyx is crushed and a full determination is not possible.

5. Orionastraea faunule - in the present ground this coral appears to occur almost alone and is found at a single stratigraphic level with the individual colonies several yards apart. It seems that for a while the sea bed was dotted with colonies of this coral which appear to be still in their living positions.

The clisiophyllids and Aulophyllum are long ranged forms. Neither Orionastraea nor Lithostrotion junceum were recorded above the Middle Limestone (these findings correspond closely with those of Johnson, 1953).

d. Echinodermata

Asterozoa - A single specimen of an ophiuroid was obtained from the Agill Sandstone (R_1). The specimen (Plate 36B) shows

portions of all five arms, one of which is seen to completeness (13 mm. in length). The ambulacrals are clearly seen and also the ambulacral grooves which run between the ambulacral plates. The central system of five plates is the mouth-angle plates which are interambulacral in position. The disc is only very imperfectly seen; it is suggested by a slight elevation of the matrix of the rock which is apparent in the two areas between the arms on the right of the illustration. There is no trace of the component plates of this disc. The angles of the mouth frame do not appear to extend to the third ambulacral plate as in Protaster piltonensis Spencer; also the present specimen is considerably smaller than P. piltonensis. Otherwise the relative proportions of the animal are broadly similar and the present specimen is referred tentatively to Protaster sp. aff. piltonensis Spencer.

Echinoids - these forms are a rare element of the normal shale fauna of beds of Yoredale facies. Spines of Archaeocidaris occur in numerous thin sections of limestone, but never in large quantities; they are readily identifiable by their radiate-cellular internal structure which distinguishes them from crinoid ossicles, showing a rectangular-cellular structure. A horizon about 24' above the top of the Underset Limestone has yielded fragmentary ?Palaechinus sp. at two widely scattered localities; the record from East Stone Gill is of an assemblage of ambulacrals and interambulacral plates together with spines. Plates of Echinocrinus and Platycrinites occur as rare records in the normal shale faunas.

Crinoids - from the point of view of sheer bulk the crinoid remains in the Yoredale facies limestones must far outnumber the

other forms represented. In the Middle Limestone mounds formed exclusively of unusually large stems of crinoids occur which may have been built up by masses of such stems, or alternatively they may have been swept together by currents. Elsewhere in the sequence large stems are also seen, chiefly in the Richmond Chert Series, where they are especially abundant at the horizon of the Marske Chert Bed and were also found in shales of R_1 age on Carle Fell and in Swinney Beck, Colsterdale. Normally however the stems are only a few millimetres in width and make up varying proportions of the Yoredale limestones and also occur in lesser abundance in the shales. Usually the crinoid ossicles have been separated and it is only in limestones of biostromal aspect where the stems are still in a state of articulation. Occasionally the ossicles preserved in shales include in addition to rounded forms bizarre laterally spinose forms and also polygonal ones. Crinoid calyces were never found during the present work but have been found in the Richmond area by Wells (1955a) and others.

The absence of crinoid ossicles except as very rare records from the Cayton Gill Shell Bed is noteworthy and it must be supposed that the conditions which prohibited the development of corals at that time may have also inhibited the growth of crinoids. It is possible that the sandy nature of the sea bottom provided no safe anchorage for the stems of the crinoids which also appear to have abhorred the environment in which the goniatite flourished (ossicles are recorded from shales in the C. cowlingense band, but rarely from the same level as the goniatites).

Holothuroids - remains referred to holothuroids have been recorded only from shales with a normal shale fauna where they are

locally quite abundant. Whilst identifications may be made on hand specimens with the binocular microscope, undoubtedly the best method is to separate out the fossils with H_2O_2. The chief form are preserved in calcite and are plates and wheels of various kinds. Ancistrum is a characteristic perforated plate which appears to be more abundant than the more symmetrical Protocaudina traquairii, which is a wheel. Petaloid plates with a pair of depressions which do not appear to perforate the plate are also quite common at some horizons. Rods and books occur only rarely. No definite holothurian remains were recorded from a limestone matrix.

e. Bryozoa

Bryozoa - the bryozoa from the present area have not been exhaustively studied, but more attention has been paid to them than is usual to this neglected group. The bulk of the bryozoa are cryptostomes which are more readily identifiable in hand specimens than the trepostomes which are the less abundant forms. They are found in the bulk of the fossiliferous shales of Yoredale facies and also in the nuculid-gastropod beds of the Colsterdale Marine Series and the Cayton Gill Shell Bed. Few species of Fenestella can be readily recognised if the zooecial apertures are not apparent in the fossil, since the chief diagnostic characters are the size of the fenestrules and dissepiments together with a measure of the number of zooecia per fenestrule. The material preserved in the platy beds below the Underset Limestone is unusual in that it often shows the zooecia and includes very large specimens of Fenestella plebeia McCoy in excellent preservation. The distinctive and beautiful circular networks of Fenestella haemispherica McCoy are also a feature of this

horizon. Some fenestellids from the shales of the Simonstone cyclothem were separated from the matrix by coating the reverse side of the zoarium (which is almost invariably uppermost when the rock is split, because the side with the zooecial apertures sticks more readily to the matrix) with 'Durofix' adhesive. The matrix is then removed with 10% H_2O_2 solution, with gentle ebullition, giving a very clean zooecial surface whilst the reverse of the zoarium is still visible through the transparent 'Durofix'.

The remaining cryptostomes can be often identified generically in hand specimen with the binocular microscope, but are readily studied in separations made by boiling with H_2O_2 followed by sieving. Most of the specimens cannot be subdivided beyond genera without cross-sectioning and this procedure was not carried out. The most abundant forms are the stick-like genera Rhabdomeson and Rhombopora. The first of these two genera is characterised by a median rod which is excellently seen in specimens from Morpeth Scar Penhill, preserved in calcite mudstone of the Gigantoproductus Beds, which split axially to reveal this structure. Branched forms referred to Penniretepora with rarer Rhombocladia and Streblotrypa also occur at intervals in shales with a normal shale fauna.

Thus far no attempt has been made to zone the sequence of beds of Yoredale facies by means of bryozoa, but this is in actual fact probably one of the most promising groups for this purpose, its only drawback being that for detailed studies thin sections involving a fine technique are essential. It is thought that variation in the rod and strip shaped forms may possibly be systematic enough

to act as an index of horizon. The fenestellids include long ranged forms such as F. plebeia, but it is interesting to note that dorsally nodulose forms have thus far only been recorded from the shales of the Simonstone cyclothem whilst hemispherical forms have only been recorded from below the Underset Limestone.

At only two horizons in the present area do bryozoa bulk large in the fauna though they are fairly abundant in some of the shales with a normal shale fauna. The platy beds below the Underset Limestone in cross-section are seen to include lamina after lamina of crushed bryozoa, mainly fenestellids, preserved in calcite, together with a distinctive fauna of small brachiopods. An exposure of the upper Middle Limestone at Long IngWood, Waldendale shows several feet of a grey limestone with a profusion of tubular cryptostomes and fenestellids in a matrix of calcite mud; it appears that this horizon constitutes a local bryozoan biostrome.

f. vermes

Annelids - markings attributed to annelids are found at several levels and especially in well laminated, fine grained flaggy sandstones where Crossopodia is abundant locally. The sandstones of the Three Yard cyclothem contain abundant specimens at some localities and they have also been recorded locally from the Nar Hill Beds. Occasionally, pyritised markings occur in shales with a normal shale fauna which may owe their origin to annelids. Vertical burrows comparable with Arenicolites have been recorded from three horizons in sandstones. It is also possible that the Pipe Bed of the Little Limestone was caused by annelids, since the tubes are about 1' long and under 1" wide; no satisfactory U-shaped tubes have been found at this level.

g. Brachiopoda

The brachiopods are a persistent and frequently dominant element in faunas from beds of Yoredale facies and occur preserved in limestone, shale and sandstone in conjunction with members of several other phyla. The most characteristic and abundant forms are the productids, extinct protrematous forms showing large variation in shape, size and spinosity. They occur preserved in limestone, shale and sandstone, but attain their maximum development in some of the limestones.

Productids- these are here considered under the subgenera into which they are now divided.

Cancrinella is represented by a single species, C. undatus which appears to be limited to the lower beds of the present area and is only found in conjunction with a normal shale fauna. The highest record is in the shales of the Five Yard cyclothem.

Dictyoclostus is represented by eight species, which tend to occur in fairly small numbers in limestone and shale. The present records suggest that several species die out at the Underset Limestone or thereabouts and neither D. pugilis, D. antiquatus, D. multispiniferus or D. pinguis have been recorded higher than the Three Yard Limestone. Only D. hindi persists into the R_1 shell beds where it is a firly common record. A specimen from the Cayton Gill Shell Bed showed the musculature of the brachial valve in excellent detail, in relief.

Eomarginifera is represented by six species of which E. setosus and E. tissingtonensis occur in the lowest beds of the sequence only and have not been recorded from above the Five Yard Limestone, which is a conclusion similar to that of Johnson (1953). E. longispinus on the other hand was not recorded from below the shales of the Middle cyclothem, nor was E. lobatus.

Gigantoproductus is numerically well represented since it appears to have had the facility of promoting its kind in a colonial fashion over a large area for long periods. It is on this account that G. giganteus is so common in the Gigantoproductus Beds and also occurs locally in numbers near the top of the Middle Limestone. Large gigantoproducti occur in moderate profusion at may localities in the Five Yard Limestone of upper Coverdale and Upper Waldendale, and also occur locally in numbers in the lower leaf of the Three Yard Limestone of Downs Gill, near Hunter's Hsll, Coverdale. Moore (1955) also records large gigantoproducti in numbers from some localities in the Main Limestone of upper Wensleydale. As a general rule the large gigantoproducti are fossilised with their brachial valve uppermost; it is probable that this is their living position since the brachial valve is much lighter valve and would be kept uppermost so that the valves could be allowed to gape in order to collect food.

Latissimoid productids are also locally present in large numbers and appear to have had some of the gregarious habits of their larger relations; it is significant that the only occurrence of G. latissimus in the shales of the Five Yard cyclothem is at a locality where they are present in large numbers, whilst at many others localities at this horizon they are entirely absent

Productus sensu stricto is represented by three species of which P. carbonarius appears to be the dominant form in beds of Millstone Grit facies, whilst P. productus and P. concinnus are the common records from beds of Yoredale facies. The bulk of the recorded specimens are from shale, but Pproductus s.s. is also

recorded from limestone and sandstone.

Spinose productids- forms referred to the genera Buxtonia, Echinoconchus, Krotovia and Pustula are a recurring element in faunas of Yoredale type and are also found in the R_1 shell beds in rocks of Millstone Grit facies. Echinoconchus punctatus, E. elegans and Buxtonia scrabiculus are persistent forms which are recorded from many horizons up to the Main Limestone, whilst the last named species is one of the characterisitic brachiopods of the fossiliferous phase of the Libishaw Sandstone of R_1 age. It seems probable that this species was specially tolerant of a sandy environment since it is recorded in a shelly sandstone of the Underset cyclothem of Rampshaw Bank, Coverdale in a faunal association similar to that seen in the R_1 shell beds.

Spiriferids- forms with a spirally arranged brachidium are a constant element in faunas of Yoredale facies and attain their maximum development in shales.

The true Spirifer and forms which closely resemble it such as Tylothyris show considerable variation in dimentions and ornamentation. The bulk of the forms belong to S. bisulcatus and S. triangularis, both of them species groups covering a wide range of variation, but three other species which were recorded from beds of the Simonstone cyclothem were not found at higher levels in the succession. Smooth spiriferids referred to Brachythyris and Martinia are found chiefly in shales with a normal shale fauna.

Genera allied to Athyris, namely Actinoconchus, Cleiothyridina and Phricodothyris are a persistent element in the normal shale fauna and are rare in the limestones. It is likely that these forms exerted a preference for the shallower waters in which shales were forming rather than the deeper environment of limestone deposition. It has not been possible to determine any sequence of forms, though Phricodothyris appears promising owing to its variability.

Rhynchonellid and Terebratulid forms - these are chiefly Camaratoechia and Dielasma which occur in small numbers in beds of Yoredale facies, but do not figure in the lists from the R_1 shell beds which contain many other forms of Yoredale aspect.

Orthids - forms referred to Rhipidomella and Schizophoria are persistent records from beds of Yoredale facies and appear to occur chiefly in shales. S. hudsoni forms a layer in the Cayton Gill Shell Bed which is made up of internal casts of this form in a matrix of fine sand.

Orthotetids - several genera occur, differentiated on their internal characters, which are in many cases not fully seen, rendering identifications tentative. They form a persistent small element in the normal shale fauna and occur sometimes in limestone. The most abundant records are in the Cayton Gill Shell Bed where D. gigantea Thomas occurs in large numbers and includes an undescribed broad variant. A giant orthotetid from the shales of the Middle Limestone of Slape Gill, Coverdale is also an undescribed form.

Lingula and Discina - Lingula is recorded rarely from shales with a normal shale fauna and attains its maximum development in

shales with a restricted fauna consisting of Lingula with fish remains, with in some cases Discina. Such shales are usually dark, compact shales the best example of which is from the Underset cyclothem of Hindlethwaite Gill, Coverdale where a local band carries giant L. squamiformis and palaeoniscid scales. The only records of marine fossils from the Grassington Grits and Shales are of Lingula sp.. Since these sediments are of deltaic origin it seems likely that these shales in which Lingula occurs were not laid down in a fully marine environment, but perhaps a brackish water one.

h. Mollusca

Pelecypods - the pelecypod fauna is a large one which occurs in two distinct assemblages. The pelecypods of the normal shale assemblage in beds of Yoredale facies and those from the R_1 shell beds are characterised by their variety, whilst the records from shales with goniatites in beds of Millstone Grit facies show an abundance of individuals of a small number of thin shelled genera.

The assemblage in the normal shale fauna consists of species of Aviculopecten with a marked radial ornament, pectiniform genera with a concentric ornament, or occasionally chevron markings or no ornament at all (Amusium, Pseudamusium and Streblopteria), nuculids and less commonly elongate forms such as Grammatodon and Edmondia. The most persistent species of pectiniform shape is Limipecten dissimilis which was recorded at five horizons, including the R_1 shell beds. Aviculopecten clathratus, A. interstitialis and A. intermedius are common to the shales of the Simonstone cyclothem and the Cayton Gill Shell Bed and hence are long ranged forms. Whilst Aviculopecten is strongly represented in the Cayton Gill Shell Bed the genera such

as Amusium are unaccountably absent. Nuculids, referred to Nucula, Nuculopsis and Leda include the long ranged L. attenuata, which is found at several successive horizons; the bulk of the remaining species are rare records. Edmondia is a rare record from the shales with a normal shale fauna and attains its maximum development in the Cayton Gill Shell Bed where it is the dominant pelecypod. In addition to the above named genera there are a number of forms which occur in the R_1 shell beds some of which are rare records from the normal shale faunas of the beds of Yoredale facies. These includ Leiopteria, Schizodus, Spathella, Myalina and Schlenomya.

The pelecypod fauna of the goniatite shales in beds of Millstone Grit lithology contrasts strongly with that associated with the normal shale assemblage of shales of Yoredale facies. The forms represented are chiefly Posidonia and Posidoniella, thin shelled pelecypods preserved as impressions or as thin calcite films. In the absence of any of these forms being attached to fossil wood, it is assumed that they were benthonic, and may have lived in large numbers since they sometimes crowd the bedding planes, this being especially a characteristic of Posidoniella laevis. Though no apparent preference was exerted in favour of a limestone or shale environment of deposition it is interesting to note that the forms in the Colsterdale Limestone are of small size, in contrast to those in the shales which are larger and more markedly ornamented with sulcations and radiating markings. These last forms are named as Posidonia corrugata, P. sulcata, and P. trapezoedra, though it appears likely that they belong to overlapping species groups which show variation in shape, intensity of sulcate ornament, in a complex manner which defies the simple scheme of

of speciation here followed.

Gastropods - Gastropods form a persistent element in the normal shale fauna in beds of Yoredale facies, but appear to be rare in the limestones (this tendency to avoid the limestone environment is shared with the pelecypods which are rare records in limestones; these beds are supposed to have been laid down in too deep water for the littoral pelecypods and gastropods to flourish). The chief gastropods are of turriculate and bellerophontid type and are perhaps found in their greatest profusion in the Cayton Gill Shell Bed where they appear to occur only locally in large numbers. The most persistent gastropod is Euphemites urei, which is recorded throughout the sequence, in matrices of shale, sandstone and chalybite. Taken as a whole the gastropods are difficult to determine at the specific level since the aperture, which usually figures in the diagnosis, is rarely preserved. It is for this reason that few species are given, whilst the poor preservation of external form and ornament in the Cayton Gill Shell Bed has lead to many queried identifications.

Cephalopods - Nautiloids are recorded from shales with a normal shale fauna and from the goniatite bearing shales in rocks of the Millstone Grit facies. They are almost always rare records and this supports the view of Craig (1954) that they were not usually gregarious forms, but lived dispersed over a large area. Both orthocone and curved forms are represented and belong to the genera Dolorthoceras, Ephippioceras, Epistroboceras and Liroceras.

Goniatites, unlike the nautiloids, were apparently gregarious forms since they usually occur in quantities. They were however intolerant of the environment which gave rise to the normal shale

fauna since they are only very rare records in beds of Yoredale facies. Dark, carbonaceous shales with an accompanying fauna of thin shelled pelecypods are their characteristic lithic environment. Rapid morphological changes coupled with a wide distribution in space have made these forms good zonal fossils. The chief correlations with surrounding areas here made on palaeontological grounds are by means of these fossils. Reference is made in the text to the seven genera which are represented.

h. Arthropoda

Ostracods - these forms are common in normal shale faunas and are occasionally seen in thin sections of limestones. They have also been recorded in conjunction with a *Lingula*- palaeoniscid assemblage in strata of the Underset cyclothem and from chalybite nodules in the nuculid-gastropod beds of the Colsterdale Marine Series of Colsterdale. The chief forms represented are the long ranged genera, *Bairdia*, *Kirkbyia* and *Paraparchites* which are preserved as calcite films; these are best studied in separations. Two such separations were submitted to Dr. F.W. Anderson for examination. In view of the fact that some of the forms were unusual his report is here quoted in toto.

Separation from fossiliferous shales of the Simonstone cyclothem with a normal shale assemblage, left bank of R. Cover, $\frac{1}{4}$ mile N. of Bradley, Coverdale. Dr. Anderson makes the following comments.

"This is an unremarkable and normal ostracod fauna. The species most abundantly represented is *Bairdia hisingeri* (Münster) which is common in the D_1 and D_2 limestones of both England and Scotland, though it is by no means confined to these zones. Also

represented is a form resembling the common and long-range form Waylandella cuneola (Jones and Kirkby) and the much rarer 'Cytherella' scrobiculata of Jones, Kirkby and Brady, here tentatively assigned to the genus Cardiniferella. Another species present in this fauna is Paraparchites scotoburdigalensis (Hibbert) which is known to range throughout the Lower Carboniferous, with also Kirkbyia permiana Jones, another ubiquitous species."

Separation from fossiliferous shales of the Five Yard cyclothem with a normal shale assemblage, R. Cover, below Hunterstone Bank, Coverdale.

Dr. Anderson: "This fauna includes much the same species as that from the exposure near Bradley, with in addition the not uncommon Healdia cornigera (Jones and Kirkby). It is characterised however, by the presence of a number of exotic forms. Some of these, though not before recorded, are not entirely unknown in Britain, but are better known from the Lower Carboniferous rocks of the United States. These are species of Roundyella very like the American species R. simplicissima (Knight), a species of Coryellites, two species of Cribroconcha, one of which closely resembles C. costata of Cooper, and a species of Knightia which appears to be undescribed.

Two other forms present have a distinct Pre-Carboniferous aspect, one of which is superficially like a species of the genus Acronotella is probably an entirely new genus. The other belongs to the genus Ctenobolbina and most closely resembles the Middle Devonian species C. armata Ulrich. The one Carboniferous species of this genus, C. loculata Ulrich, described from the Mississippian of the U.S.A. is found rarely in the Lower Limestone group (D_2)

of Scotland and is quite unlike this form from Hunterstone bank."

Trilobites - forms referred to Weberides occur at six stratigraphic levels and fall into two distinct types, the mucronate and the non-mucronate species. An attempt was made on the basis of specimens collected in Northumberland by Johnson (1953) to divide the sequence into two divisions - a series of beds below the Four Fathom (Underset) Limestone without mucronate forms and a series above this limestone with chiefly mucronate forms. Whilst the present work is based on a study of fewer horizons with less numerous trilobite records (this excepting the shales of the Five Yard cyclothem in which trilobites are quite abundant) it is apparent that some modification can be made to the original scheme of Johnson, because Weberides mucronatus is now recorded in the shales of the Five Yard and Three Yard cyclothems It is thus apparent that the mucronate forms (which in the Five Yard cyclothem occur at the same horizon as dominantly non-mucronate forms) evolved earlier than had been anticipated, in fact at the beginning and not at the end of the faunal break which recognised as occurring between the Five Yard and Underset Limestones.

A form described by Woodward (1906) from Angram, Nidderdale, within the present area was made the type specimens of Weberides barkei (Woodward) which several of the non-mucronate specimens at this level resemble. Largely, the trilobite remains are too fragmentary to determine their species; pygidia are much more common than cephala, which are often without free checks. The records from shales of the Five Yard cyclothem Hunterstone Bank include several complete specimens of W. mucronatus which occurs in greater profusion than the non-mucronate forms at this locality. The

specimens which include a hypostome are housed in the Geological Survey Collections (G.S.M. No. Zi 7317-7326).

The rarity of trilobite records in limestones may be due to the fact that the waters in which these rocks were deposited were too deep. ?

CHAPTER 23

SEDIMENTOLOGY AND PETROGRAPHY

Yoredale sedimentology

The sedimentation pattern associated with Yoredale facies beds and its probable origins have been discussed by many authors (for instance see Dunham, 1950, Johnson, 1953, and Moore, 1955, for discussions of this topic with extensive bibliographies). The present work has involved the study of eight rhythmic units or cyclothems (repetitions broadly speaking of limestone, shale and sandstone in that upwards sequence). Within the area here described it is apparent that they are seldom perfect, but certain of the rhythmic units and especially the Underset cyclothem correspond well with the ideal scheme as outlined by Dunham. The variation in the Middle, Five Yard and Three Yard cyclothems and their departure from the scheme is so large however that the evidence appears to favour the views of Moore, who stresses the variability of these sediments, nearly as much as the more orthodox views on cyclicism as expounded by Dunham, who would stress the cyclic aspect of the sedimentation pattern rather than the variability. Moore explains the repetitions of beds in the Yoredale type of sequence by shifts of the course of a major river with a consequent change in the type of sedimentation taking place. Taking evidence from the whole of the Rigid Block however it is apparent that many of the thicker limestones are very persistent and point to extensive inundations which must rest in deeper causes than the change in direction of a major river, namely that of wholesale subsidence of a large area

in the manner envisaged by Dunham and others. It seems probable that much of the thickness variation and the absence of portions of cyclothems in the present area is due to unwarping of the S.E. corner of the Askrigg Block which has caused a large south easterly thinning of the shales and sandstones of several cyclothems.

Yoredale petrography

Past work on the petrography of Yoredale facies sediments excepting work on the heavy minerals has centered on the study of the fabric of the limestones. Johnson (1953) and Moore (1955) have given special attention to this aspect.

Limestones - The present work confirms many of the conclusions of Johnson and Moore. Basically there are two chief types of limestone, holo-crinoidal limestone composed entirely of ossicles, and calcite mudstone composed of finely comminuted organic remains plus mud which may be an inorganic or organic precipitate (compare Place 50 A, B). All variations from 100% crinoids to 100% calcite mud occur and by far the commonest rock types are the intermediate ones. In addition to crinoids other organic remains are frequent; these include algae, foraminifera, corals, echinoid remains, bryozoa, brachiopods and ostracods. The proportion of terrigenous material is usually low; normally the basal few feet of a limestone is blue and it may be supposed that this colour is due to impurities such as mud and organic carbon, though the work of Moore (1955) appears to indicate that the reverse is true i.e. organic carbon is more abundant in grey than in blue limestones. Many limestones have suffered change by recrystallisation which

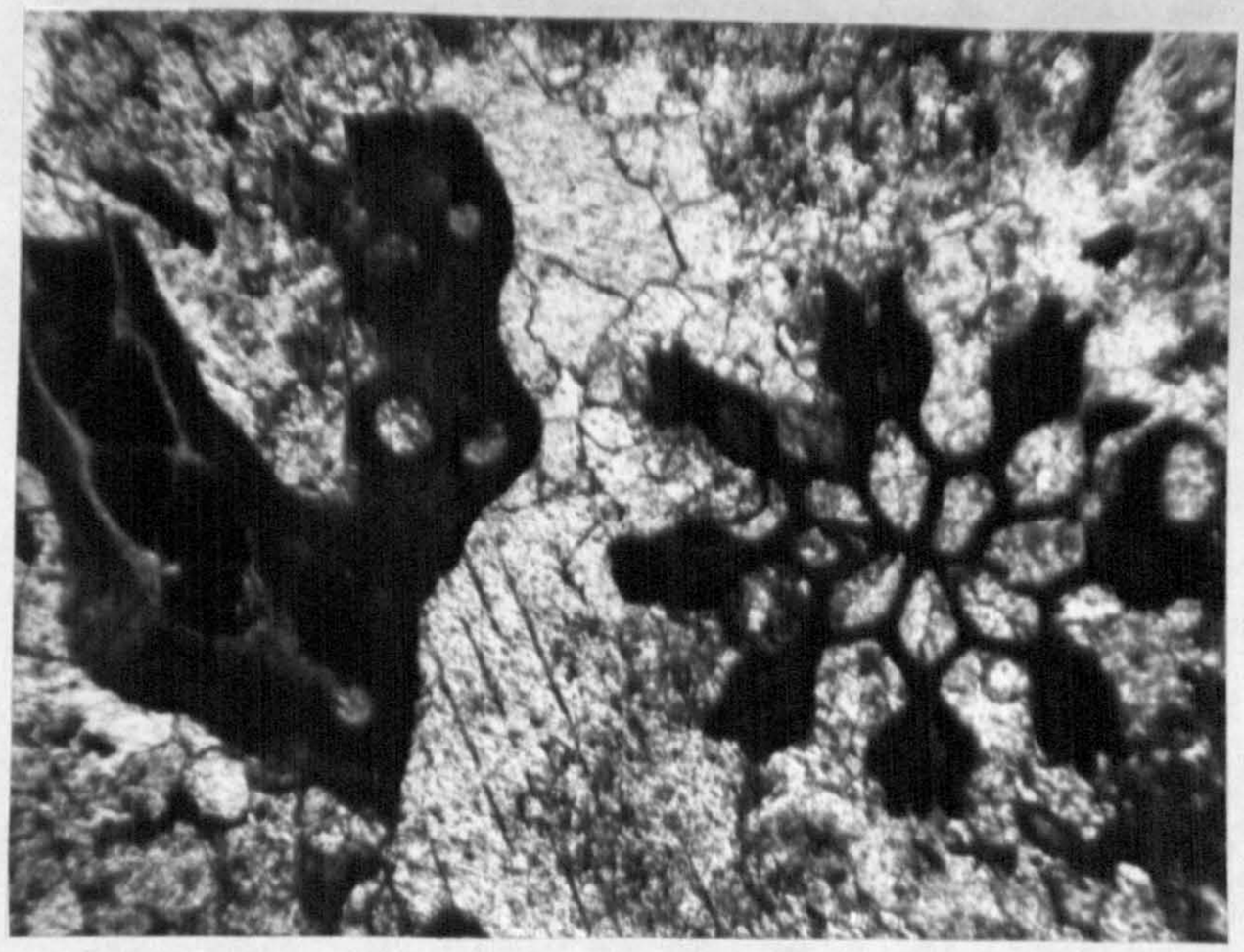


Plate 50 A

Middle Limestone, railway cutting N.N.W. of Limley, Nidderdale.
The matrix is calcite mud in varying degrees of recrystallisation enclosing bryozoan fragments which include Rhombopora sp.(right).
Normal light. Field 1.8 mm.

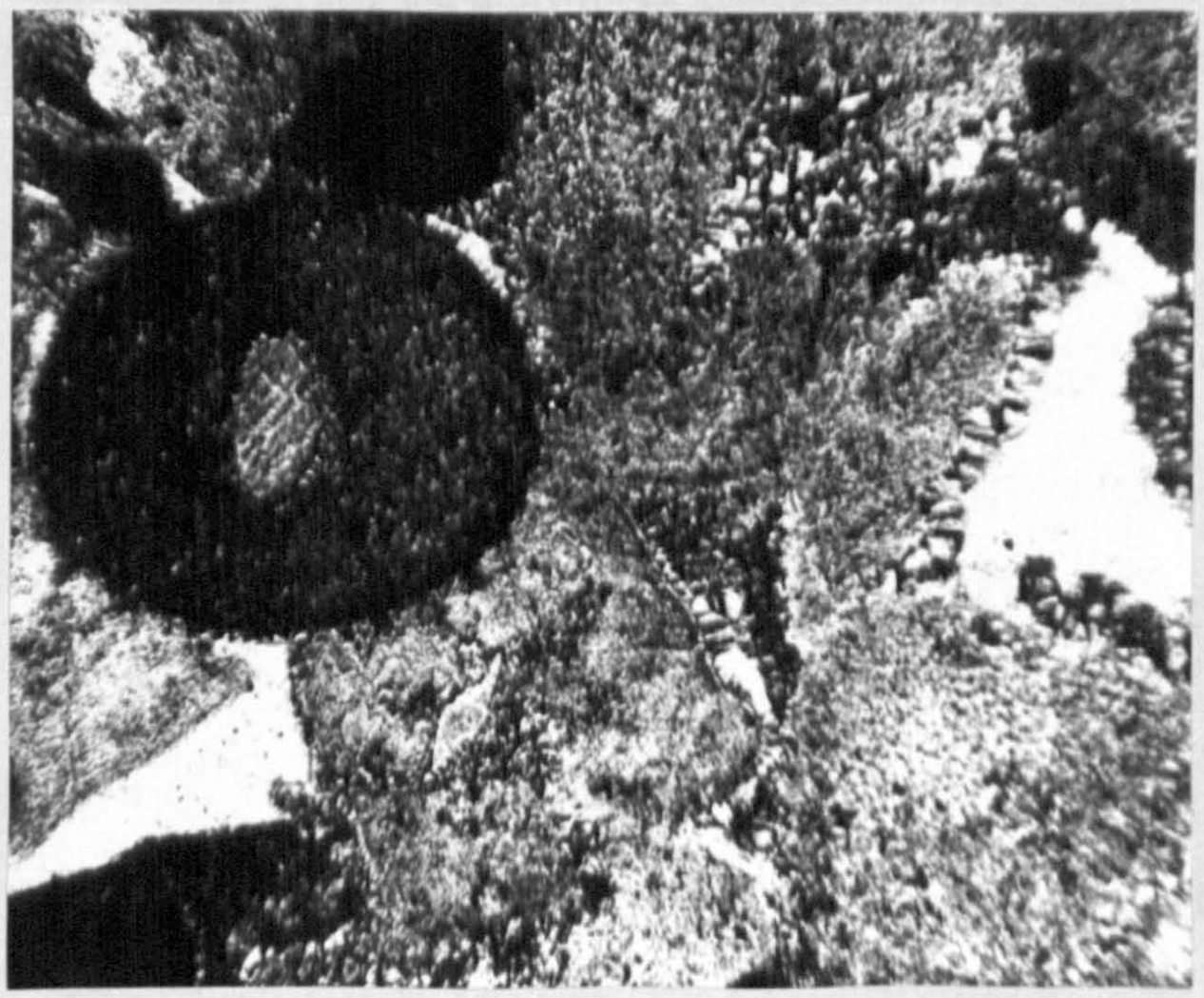


Plate 50 B

Chertified beds in the Richmond Chert Series, W. side of Harland Hill, Waldendale (debris from old lead workings)
The rock consists of crinoid ossicles, some of which are abraded.
Radiating aggregates of chalcedony (showing as rapidly alternating black and white bands in the photograph) have replaced the margins of ossicles on the right side of the photograph, but the ossicles on the left side are quite unaltered.
Cross nicols. Field 2.2 mm.

may obscure the structures of the original crinoid ossicles which can be preserved as 'ghosts'. The specimen figured in Plate 50A shows the effect of partial recrystallisation of a rock composed largely of calcite mud. Chertification is in some instances undoubtedly diagenetic; this is probably the case in nodules and irregular bands of chert in limestone which show a replacive relation to the country rock in both field relationships and in thin section (for instance see Plate 50B in which silica is replacing the calcite mud of a crinoidal limestone and is also affecting the ossicles themselves marginally).

Sandstones - all the arenaceous horizons in beds of Yoredale facies in the present area resemble each other in being well sorted, fine or very fine grained quartz sandstones with a little white mica (Plate 51A). A point counter analysis of the sandstone of the Three Yard cyclothem below Low Dove Scar, Penhill showed the following proportions: quartz 98.9%, orthoclase 0.7%, plagioclase 0.2% and white mica 0.2%.

The quartz grains are usually sutured one against the other due to secondary growth of silica in optical continuity with the grains. This often makes it difficult to determine the original shapes which seem to have been subangular. Strain shadows in grains of quartz are often seen and it may be presumed that the rock was derived from a metamorphic terrain, possibly largely of psammitic gneiss. The uniformly small grain size and dearth of feldspar is indicative of prolonged sorting and progressive attrition of the bulk of the feldspar of the parent rocks. Several specimens carry some calcite as a cement, though this does not

always preclude many of the grains being in sutured contact with each other. In hand specimen mottling by limonite is a common feature and in thin section it is often apparent in strings and patches.

Millstone Grit sedimentology

Sorby (1859) made a study of beds of Millstone Grit facies and concluded on the basis of a study of direction of current bedding that the area of origin of these rocks lay to the N.E. towards Scandinavia and the North Sea where a landmass was then supposed to have been situated. This work was later amplified by Gilligan (1920) who gave a detailed description of the petrography of the arenaceous horizons in beds of Millstone Grit facies with special reference to the light which these details cast on the point of origin of the sediments. The conclusion as to the source area was similar to that of Sorby, and Norway and Scotland were mentioned as possible areas from which sediments were transported to form the delta of a great river in which the Millstone Grit facies sediments were deposited.

Walker (1952) considered rocks of R_1 age from the general district of the Aire valley in some detail from the sedimentological standpoint. He attempted a classification of lithic types and a fundamental distinction was made between coarse sandstones which were deemed to be persistent and fine sandstones and their accompanying siltstones and shales which are supposed to be impersistent. Walker believed that the first type was the product of fan-spread conditions such as gave rise to the gravels of the Citronelle formation or the Colorado cones described from the

United States, whilst the second type was said to be the product of channel, levee and interdistributary through conditions such as are described from the Mississippi delta. Though the present author appreciates the value of this suggestion he would question the wisdom of making this fundamental distinction owing to the fact that the present study (albeit concentrating chiefly on sediments of sub-R_1 age) shows that grain sizes of arenites varying from 100 to over 1000 microns are encountered and there does not appear to be any clear division between fine and coarse sandstones; many of the rocks investigated are of medium grain. It merely happens that Walker was working on a part of the sequence where the contrast between fine and coarse sediments was especially notable, but this does not apply for much of the succession. With regard to the supposed persistence of coarse sandstones as compared with the finer deposits the evidence of field mapping during the present work does not bear out Walker's view wholly, though it does appear that the coarser horizons tend to be the more persistent. For instance the Libishaw Sandstone is fine grained and is persistent and almost constant in thickness for several square miles at the head of Colsterdale. It is also represented south of the present ground over a large area by similar beds which are however somewhat thicker. In contrast the Nar Hill Beds include fine grained sandstones all of which vary in thickness in a most extreme manner and none of which are persistent throughout the area. Whilst the coarse or medium grained Second Brimham Grit appears to occur throughout the present ground and over wide tracts to the south, the coarse sandstones of the Grassington Grit

Group die out abruptly and over much of the area their time equivalents appear to be shales with sandstones which are chiefly fine grained. In the Red Scar Grit the lower leaf is medium or coarse grained and the upper leaf is more usually fine grained. Locally at the same exposure both coarse and fine grades occur at slightly different levels in the upper leaf of the Grit. This evidence lends little support to any fundamental distinction between coarse and fine sandstones from the genetic viewpoint at the stratigraphic level here investigated.

It seems possible that the apparent localisation of thick sandstones in the Nar Hill Beds in a central strip in the present area is due to the fact that they were deposited as part of the bar finger of a bird-foot delta of the type described by Fisk et al. (1954). If this is the case the predominantly shaley beds on the S.E. margin of Coverdale belong to the interdistributary trough facies, characterised by silts and clays in the Mississippi delta. This expantion helps to explain why sandstones were deposited in the centre of the area over a long period whilst further west the beds were principally shales, since Fisk et al. showed that the passes (channels) of the bird-foot delta of the Mississippi have flowed over the same course for centuries. Thus the bar deposits which they have bult up form a wedge many tens of feet in thickness, whilst the interdistributary troughs show a comparable thickness of sediment on each side of the bar finger of lower grain size than that constituting the bar.

Whilst the Grassington Grits of the present area are coarser than recent bar sediments described from the Mississippi delta, it

is somewhat remarkable that the arenaceous facies at this level is localised in extent through a large thickness of strata as in the case of a bar finger. Elsewhere the equivalents of these arenaceous beds are largely muddy and silty with coal seams and therefore analagous with the interdistributary trough deposits. If the present local development of thick sandstones at the level of the Grassington Grit Group can be interpreted on the lines of a bar finger, this marks a divergence from the views of Walker who considers that coarse sandstones are the product of a fan spread environment, a hypothesis which does not appear to fit the present facts so well owing to the lateral facies changes taking place in the same area at successive stratigraphic levels. This phenomenon is characteristic of bars and their environs, rather than the margins of fan deposits which would tend to show a gradual thinning where thick coalesced fans die out laterally.

Current bedding foresets are developed principally in arenaceous beds of Millstone Grit facies. They are best seen in medium and coarse grained sandstones such as the Lower Follifoot and Grassington Grits. Fine grained sandstones also show current bedding, as in certain horizons in the Nidderdale Shales; micro-current bedding is a variant which occurs in rocks of this grain size.

A small study was carried out of current bedding directions. The results from the coarse sandstones in the Grassington Grit Group present the most unified picture and indicate a maximum flow of water from the N.N.W. (Plate 46B). This direction agrees well with that of the edge of the sandy facies of the Grassington

Grit Group which may take the form of a bar finger (compare with Fisk et al., 1954).

Current bedding in the Upper Red Scar Grit is developed on an unusually large scale. The plot for the Red Scar Grit (Plate 46B) is largely made up of readings at this horizon which show a wide divergence of direction, though it is apparent that there is a tendency for the sediments to be derived from all directions other than the S.W. A wide spread of directions occurs in a restricted area in Colsterdale in spite of the fact that the foresets are all of large size and involve much of the upper Red Scar Grit (Plate 26).

The few readings taken on the Lower Follifoot Grit show a similar wide range of variation with a suggestion that the currents were coming from a northerly direction, as in other instances, agreeing broadly with the conclusions of Gilligan (1920).

Millstone Grit petrography

The petrography of the rocks here studied agrees in main details with that given by Gilligan (1920). It will be noted in due course that systematic variation occurs at some horizons, but a description of the general characters of sediments of Millstone Grit facies is first given.

<u>Sandstones</u> - The sandstones studied range in grain size from under 100 to over 1000 microns and in composition from quartz sandstones (the orthoquartzite of Krynine) to feldspathic sandstones (a full arkose was never seen, but is sometimes approached). Some types approach subgreywacke owing to a markedly bimodal grain size, with feldspars quite strongly developed. A maximum of 20% feldspar

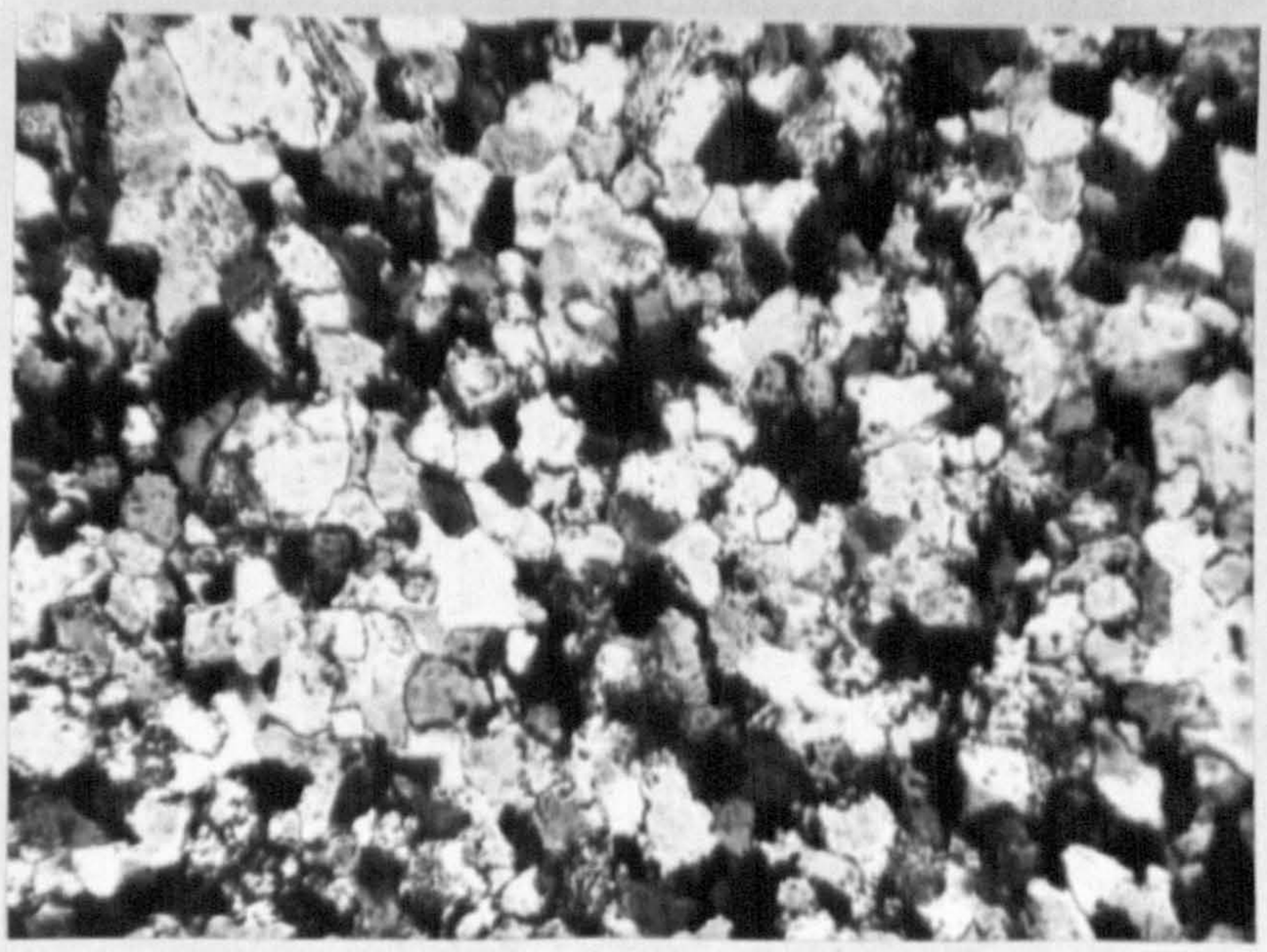


Plate 51 A

Sandstone below the Three Yard Limestone, quarry below Low Dovescar, Penhill. Very fine to fine grained sandstone composed almost entirely of quartz grains in welded relationship to each other. A single flake of muscovite is seen, top left.
Field 1.8 mm. Crossed nicols.

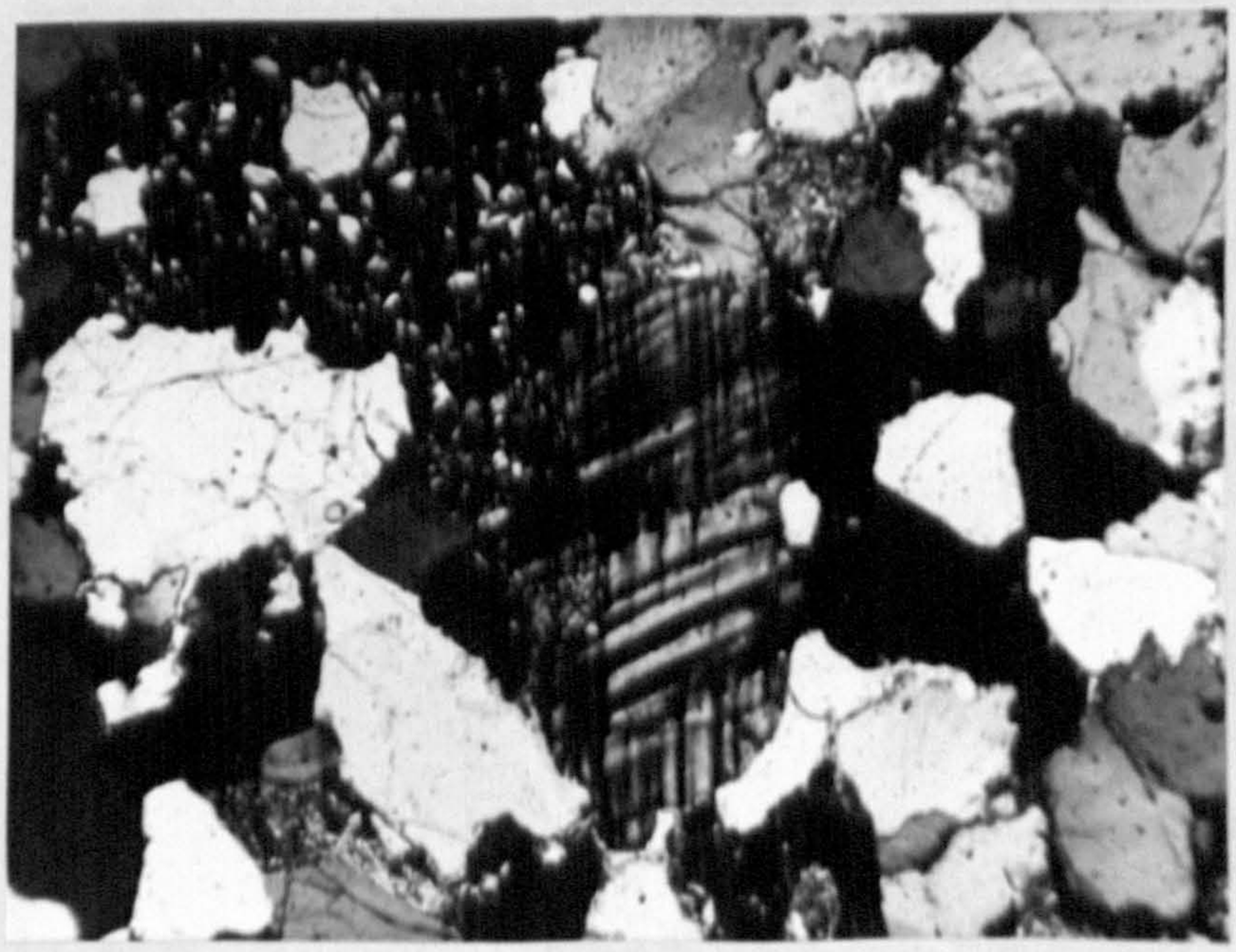


Plate 51 B

Lower Follifoot Grit, Great Roova Crag, Coverdale.
A medium grained feldspathic sandstone with microcline, a grain of which is in the centre of the field (a point counter analysis showed 1.5% microcline throughout the rock) Strain shadows are seen in several quartz grains. The majority of grains are sutured due to secondary growth and the original grain boundaries are difficult to discern. A pocket of silt is seen top left.
Field 1.9 mm. Crossed nicols.

was seen; the most common type is orthoclase, with plagioclase, microcline, microcline microperthite and perthite. All feldspars are more or less kaolinised, but the orthoclase markedly more so than the remainder. Mica is usually present, but in quantities normally under 1% and is of two kinds, muscovite and a dark brown or green mica with flexuous laminae, tentatively referred to hydrobiotite. Some interstitial kaolinite may occur which is possibly derived from feldspar grains that have been crushed. Interstitial silt may be so abundant as to give a distinctly bimodal grain size to the rock causing it to resemble subgreywacke in this respect, but not in the detail of high percentage feldspar and rock fragments. All pebbles noted were of vein quartz, or possibly in some cases quartzite (none were sectioned). Grains of quartzite are especially common in the Lower Red Scar Grit (up to 3% is recorded). Schistose fragments occur rarely.

The quartz grains which constitute the bulk of the rock are often enlarged by deposition of silica in optical continuity, with the development of sutured contacts. Strain shadows are often seen, but appear to become rarer as grain size diminishes, this in reality being due only to the fact that the phenomenon becomes increasingly difficult to observe with decreasing grain size. Inclusions are common and include zircon, sphene, rutile, tourmaline, and apatite, all of which may develop euhedral shape. Acicular crystals are frequently seen which are here tentatively referred to rutile, following Gilligan (1920). Gas bubbles and trains of fine dusty cavities are also often developed.

The possible source rocks of the sandstone of Millstone Grit lithology were studied by Gilligan and subsequent work has brought few modifications. The abundance of strained grains of quartz suggests an origin in a deformed rock such as a psammitic gneiss which may have provided some of the feldspars of the sandstones since these occasionally show strain structures. Microcline and microperthite are common feldspars of simple pegmatites and it is possible that they may have intersected a gneissose source area and provided some of the debris now in the sandstones. Fragments of quartzite and schist in thin sections point to other lithological types which were present in the source area of the sandstones. It seems probable that the relative freshness of many of the feldspars is due to transport over a somewhat arid terrain.

Shales and siltstones - no full study has been made of these sediments owing to the special techniques which are required. Rocks of this type vary widely in grain size, texture, colour, fissility and presence or absence of layers of contrasting degrees of coarseness. It is a abundantly evident that shales which are certainly marine (Colsterdale Marine Series, Cockhill Marine Band) and shales associated with marine sediments (shales in the Ganister Beds and those below the Cayton Gill Shell Bed and the Agill Sandstone) are usually fine in grain, dark in colour and frequently soapy. In contrast the shales and siltstones which are non-marine (as evidenced by their lack of marine fossils, lenticular nature and presence of plant remains and worm trails) are fairly light in colour, show development of silty layers in the shales and are markedly less fissile than many of

the marine shales. This is because marine muds were deposited more slowly with more numerous and smaller pulses of sediment, giving finer lamination than in the case of their non-marine counterparts. This distinction between non-marine and marine shales is also found in rocks of Yoredale lithology.

Petrography of individual arenaceous horizons - The detailed petrography shows some systematic variation with horizon which is here considered.

Grassington Grit Group - In the Great Whernside area much of the strata at this level consist of current bedded coarse, feldspathic sandstones with layers of quartz pebbles frequently developed. A bed of coarse sandstone in Wench Gill, Nidderdale showed the following composition by a point counter modal analysis; quartz 79.9%, orthoclase 13.5%, microcline 6.6%, giving a total of 20.1% feldspar. The high proportion of feldspar gives a composition approaching an arkose; the percentage microcline is higher than in any thin sections examined from other horizons. In the areas where the Grassington Grit Group is predominantly shaly the sandstone bands are usually fine grained feldspathic or quartz sandstones.

Red Scar Grits - when the Red Scar Grit occurs in two leaves there is a persistent lithological difference between the upper and the lower leaves. The lower Red Scar Grit is usually a medium grained feldspathic sandstone, whilst the upper leaf is a fine to medium grained quartz sandstones. The lower Grit occasionally shows the development of quartz pebbles which may attain 1 cm. in length. In thin section quartzite fragments

occur in small quantities in all but one of the eight slides examined. The feldspars which make up less than ten per cent of the rock in all the sections seen include sodic plagioclase, orthoclase, perthite, microcline and microcline microperthite. In no section are all these five types seen and there does not appear to be any distinct assemblage of types of feldspar. Muscovite and hydrobiotite occur in some of the slides. Point counter modal analyses of two specimens of the feldspathic development of the Red Scar Grit gave the following results: Deep Gill Beck, near East Witton: quartz 78.2%, oligoclase 2.5%, microcline 1.0%, orthoclase 0.8%, mica 0.9%, silt 16.6%. Crundell Hill: quartz 92.7%, oligoclase 0.5%, microcline 0.2%, orthoclase 1.4%, silt 5.2%, quartzite 0.2%.

The Upper Red Scar Grit in all four sections examined is a feldspar-free quartz sandstone of fine to medium grain. Muscovite is a common record. Locally crinoid ossicles are abundant. A point counter analysis of a sandstone from the tip of a shaft on Braithwaite Moor from this horizon showed: quartz 69%, calcite 31%.

Nar Hill Beds - the sandstones at this level are usually fine grained and feldspathic and where they are thickly developed are very constant in their blocky nature, fine grain size and brown colour. Two thin sections from the Carle Fell quarries were of well sorted feldspathic sandstones with interstitial limonite which is the cause of the brown colour of the rock. A point counter modal analysis of a specimen from the quarries showed: quartz 86.8%, orthoclase 9.5%, plagioclase 0.7%, mica 3.0%

Lower Follifoot Grit - this is characteristically a fine to coarse

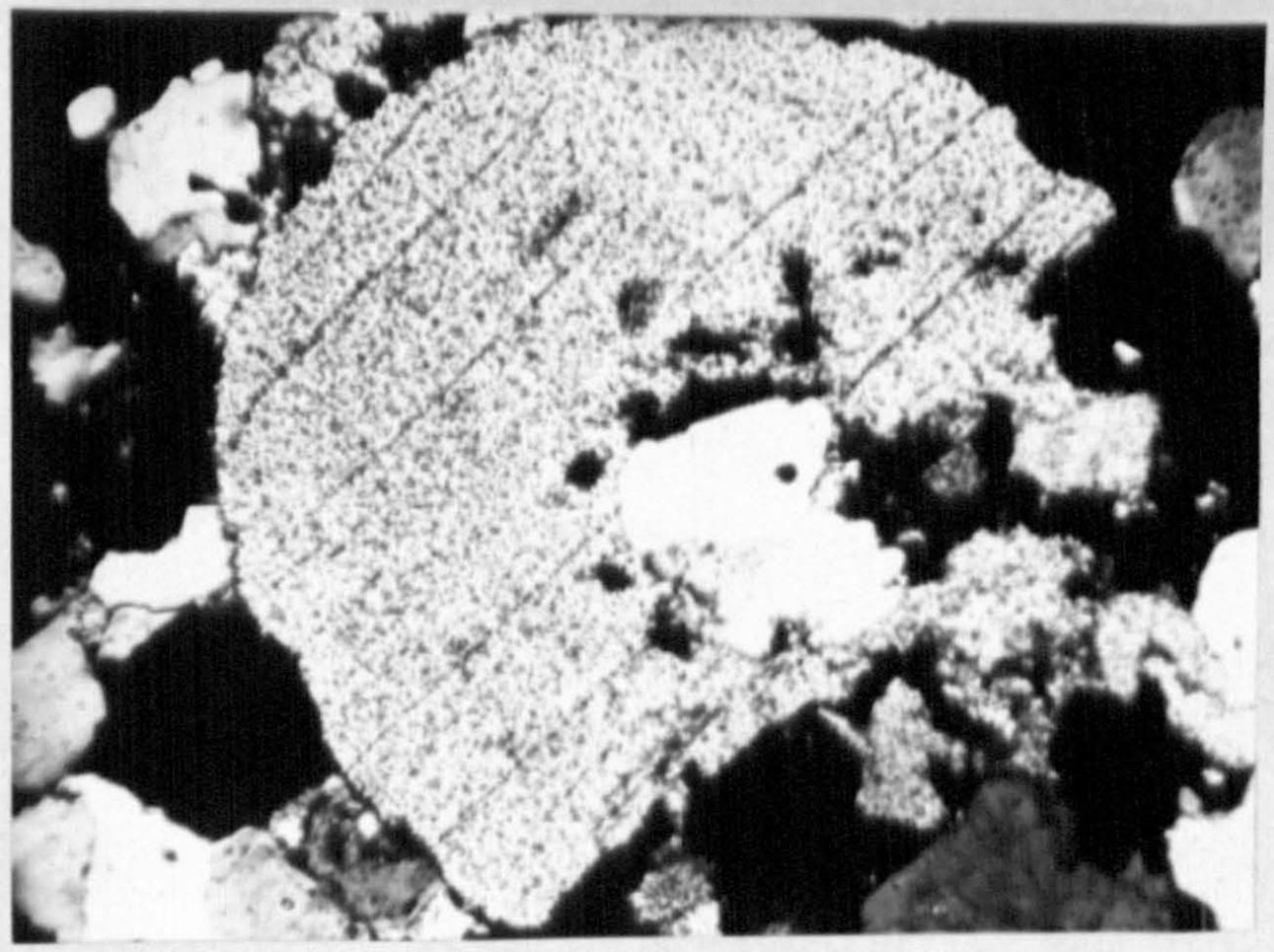


Plate 52 A

Upper Red Scar Grit in tip of old coal pit, Braithwaite Moor, Wensleydale. Crinoid ossicles set in a matrix of coarse grained quartz sandstone make up 31% of the rock by volume.
Field 1.8 mm. Crossed nicols.

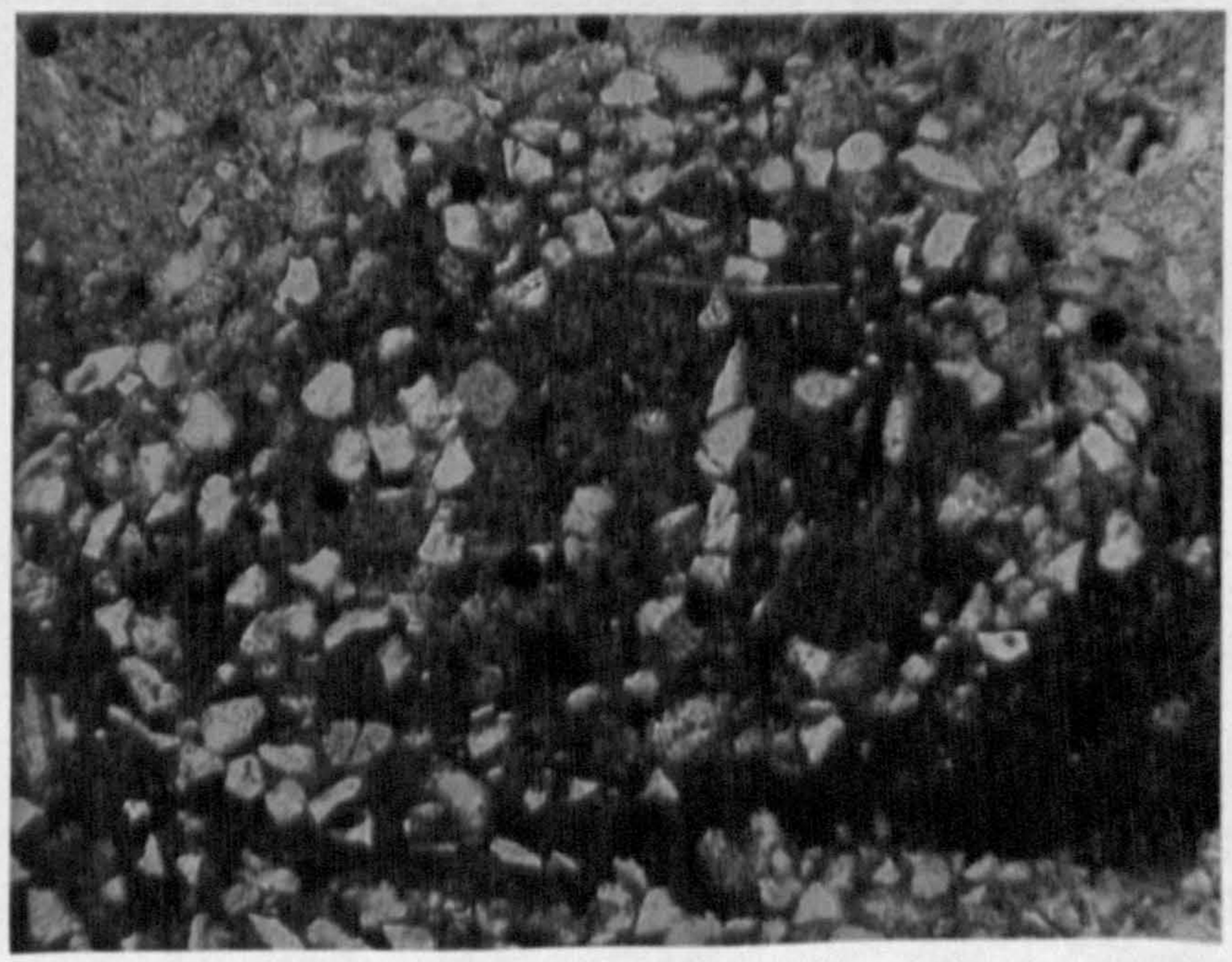


Plate 52 B

Worm chewed lower part of Cayton Gill Shell Bed, Grimes Gill, Colsterdale. Fine sand in a matrix of clay minerals. The rotated appearance of the sand grains is well shown; this is presumed to be caused by annelids. Occasional laths of muscovite occur (top centre).
Field 2 mm. Normal light.

grained feldspathic sandstone with a somewhat different average composition to the feldspathic sandstones in the Red Scar Grits. In thin sections of the Lower Follifoot Grit soda plagioclase, microcline, and white mica occur commonly, whilst quartzite is only a rare record. In contrast, in the Lower Red Scar Grit there is little soda feldspar, rather little microcline, nearly always a little quartzite and only sometimes mica. Inclusions in the quartz grains of the Lower Follifoot Grit are of apatite, tourmaline, rutile and zircon, a similar assemblage to that seen in the Lower Red Scar Grit. Sorting is usually moderate and a mesostasis of silt and fine quartz fragments was seen in most of the sections, with occasional limonite staining. A point counter analysis of a specimen from Great Roova Crag, Coverdale gave: quartz 81.5%, oligoclase 1.4%, microcline 1.5%, orthoclase 3.3%, muscovite, 0.2%, silt and clay 12.1%.

Beds between the Lower Follifoot and First Brimham Grits - some of the details about these horizons have been already considered (chapter 16). The sandstones at the level of the Ganister Beds, Cayton Gill Shell Bed and Agill Sandstone are consistently fine grained and are almost invariably quartz sandstones without feldspars. These form a contrast with the feldspathic Libishaw Sandstone which is consistently fine grained and feldspathic. A point counter modal analysis of a specimen from this horizon gave: quartz 71.9%, orthoclase 17.6%, plagioclase 4.2%, hydrobiotite 2.8%, muscovite 3.5%. This indicates a composition approaching an arkose.

Brimham Grits - These are massive medium or coarse grained

feldspathic sandstones with several types of feldspar represented, namely sodic plagioclase, orthoclase, microcline and perthite. Rock fragments include quartzite and slate. A thin section from Brewers Spout, High Ellington is a medium grained quartz sandstone which is very badly sorted and varies in grain size from 10 to 1000 microns. Detrital minerals are unusually abundant and include zircon, rutile and tourmaline. A point counter modal analysis of the Second Brimham Grit at Clints Quarry, Leighton showed: quartz 82.5%, orthoclase 7.3%, oligoclase 1.2%, mica 0.5%, silt and clay minerals 8.5%.

LIST OF WORKS TO WHICH REFERENCE IS MADE

ANDERSON, F.W. 1928. The Lower Carboniferous of the Skyreholme Anticline, Yorkshire. Geol. Mag. 65, 518-27.

BISAT, W.S. 1914. The Millstone Grit sequence between Masham and Great Whernside. Proc. Yorks. Geol. Soc. 19, 20-24.

_____. 1932. On Some Lower Sabdenian Goniatites. Trans. Leeds. Geol. Assoc. 5, 27-36.

BLACK, W.W. 1950. The Carboniferous Geology of the Grassington Area. Proc. Yorks. Geol. Soc. 28, 29-42.

BLACK, W.W. and G. BOND. 1952. The Yoredales succession on the flanks of the Skyreholme anticline, Yorkshire. Proc. Yorks. Geol. Soc. 28, 180-7.

CHUBB, L.J. and R.G.S. HUDSON. 1925. The nature of the Junction between the Lower Carboniferous and Millstone Grit of North-west Yorkshire. Proc. Yorks. Geol. Soc. 20, 257-92.

CRAIG, G.Y. 1954. The palaeoecology of the Top Hosie Shale (Lower Carboniferous) at a locality near Kilsyth. Q.J.G.S. 110, 103-19.

CURRIE, E.D. 1954. Scottish Carboniferous Goniatites. Trans. Roy. Soc. Edinburgh. 62, 527-602.

DAKYNS, J.R. 1891. On the changes of the Lower Carboniferous Rocks in Yorkshire from North to South. Proc. Yorks. Geol. Soc. 11, 353-62.

DAKYNS, J.R. 1892. The Geology of the Country between Grassington and Wensleydale. Proc. Yorks. Geol. Soc. 12, 133-144.

DAKYNS, J.R. and OTHERS. 1891. The Geology of the Country around Mallerstang with parts of Wensleydale, Swaledale and Arkendale. Mem. Geol. Surv.

DUNHAM, K.C. 1933. Structural features of the Alston Block. Geol. Mag. 70, 241-54.

_____. 1948. The Geology of the Northern Pennine Orefield. 1. Tyne to Stainmore. Mem. Geol. Surv.

_____. 1950. Lower Carboniferous sedimentation in the Northern Pennines (England). Intern. Geol. Congr. XVIII, G.B. part IV, 46-63.

_____. and C.J. STUBBLEFIELD. 1945. The stratigraphy, structure and mineralisation of the Greenhow mining area, Yorkshire. Q.J.G.S. 50, 209-68.

EDWARDS, W. and OTHERS. 1950. Geology of the District North and East of Leeds. Mem. Geol. Surv.

FISK, H.N. and OTHERS. 1954. Sedimentary framework of the modern Mississippi delta. J. Sediment. Petrol. 24, 76-99.

FOWLER, A. 1926. The geology of Berwick-on-Tweed, Norham and Scremerston. Mem. Geol. Surv.

FOX-STRANGWAYS, C.E. 1874. The geology of the country north and east of Harrogate. Mem. Geol. Surv. (1st edn.).

GARWOOD, E.J. 1913. The Lower Carboniferous succession in the North West of England. Q.J.G.S. 68, 449-586.

_____. and E. GOODYEAR. 1924. The lower Carboniferous succession in the Settle District and along the line of the Craven Faults. Q.J.G.S. 80, 184-273.

GEORGE, T.N. 1932. Brachiopods from the Cayton Gill Beds. Trans. Leeds. Geol. Assoc. 5, 37-48.

GILLIGAN, A. 1920. The petrography of the Millstone Grit of Yorkshire. Q.J.G.S. 75, 251-94.

HEY, R.W. 1956. Cherts and limestones from the Crow Series near Richmond, Yorkshire. Proc. Yorks. Geol. Soc. 30, 289-99.

HILL, D. 1938-41. The Carboniferous Rugose Corals of Scotland. Pal. Soc. Monograph.

HIND, W. 1907. Life zones in the British Carboniferous rocks. Pt. II. The fossils of the Millstone Grit and Pendleside Series. Naturalist 17-23, 90-6.

HODSON, F. 1954. Beds above the Carboniferous Limestone in north-west county Clare, Eire. Q.J.G.S. 109, 259-83

HOPKINS, W. 1956. Neoglyphioceras cf. spirale (Phillips) from Ingleborough. Geol. Mag. 93, 173-4.

HUDSON, R.G.S. 1924. On the Rhythmic succession of the Yoredale Series in Wensleydale. Proc. Yorks. Geol. Soc. 20, 125-35.

HUDSON, R.G.S. 1925. Faunal horizons in the Lower Carboniferous of North-West Yorkshire. Geol. Mag. 62, 181-86.

_____. 1929a. On the Lower Carboniferous Coral Orionastraea and its distribution in the North of England. Proc. Leeds phil. lit. Soc. 1, 440-57.

_____. 1929b. A Carboniferous Lagoon deposit with sponges. Proc. Yorks. Geol. Soc. 21, 181-96.

_____. 1930. The Carboniferous of the Craven Reef Belt: the Namurian Unconformity at Scaleber near Settle. Proc. Geol. Assoc. 41, 290-322.

_____. 1933. The scenery and geology of north-west Yorkshire. Proc. Geol. Assoc. 44, 228-55.

_____. 1934. The Millstone Grit Succession south of Harrogate. Trans. Leeds Geol. Assoc. 5, 118-24.

_____. 1938. The Carboniferous rocks in Geology of the Country around Harrogate. Proc. Geol. Assoc. 49, 295-330.

_____. 1939. The Millstone Grit Succession of the Simonseat Anticline. Proc. Yorks. Geol. Soc. 43, 319-49.

_____. 1941. The Mirk Fell Beds (Namurian, E_2) of Tan Hill, Yorkshire. Proc. Yorks. Geol. Soc. 24, 259-89.

_____. and G. COTTON. 1943. The Namurian of

Alport Dale, Derbyshire. Proc. Yorks. Geol. Soc. 25, 142-73.

_____. and G. COTTON. 1945. The Carboniferous Rocks of the Edale Anticline, Derbyshire. Q.J.G.S. 101, 1-36.

_____. and OTHERS. 1938. Report of the Summer Field Meeting 1938: The Harrogate District. Proc. Geol. Assoc. 49, 353-72.

HUGHES, T. McK. 1901. Ingleborough. Part 1 Physical Geography. Proc. Yorks. Geol. Soc. 14, 125-50.

JOHNSON, G.A.L. 1953. The biostratigraphy of the Carboniferous Middle Limestone Group succession between Tipalt Burn and the River North Tyne in South West Northumberland. Ph.D. Thesis, Durham University (King's College).

JONES, T.W. 1943. The Geology of the Beamsley Anticline. Proc. Leeds Phil. Lit. Soc. (Sci. Section) 4, 146-66.

JOYSEY, K.A. 1955. On the geological distribution of Carboniferous blastoids in the Craven area, based on a study of their occurrence in the Yoredale Series of Grassington, Yorkshire. Q.J.G.S. 101, 209-24.

KENDALL, P.F. and H.E. WROOT. 1924. Geology of Yorkshire. Privately printed in Vienna.

KING, W.B.R. 1914. A new trilobite from the Millstone Grit of North Yorkshire. Geol. Mag. 1, 390-4.

KING, W.B.R. 1935. The upper Wensleydale river system. Proc. Yorks. Geol. Soc. 23, 10-24.

LEWIS, H.C. 1894. The glacial geology of Great Britain and Ireland. London.

MARR, J.E. 1921. The rigidity of North-West Yorkshire. Naturalist, 1921, 63-72.

MILLER, A.A. and J.S. TURNER. 1931. The lower Carboniferous succession along the Dent Fault and the Yoredale beds of the Shap district. Proc. Geol. Assoc. 42, 1-28.

MOORE, D. 1955. The sedimentology and fauna of the Yoredale Series of upper Wensleydale and adjacent areas. Ph.D. Thesis. Leeds University.

MOSELEY, F. 1954. The Namurian of the Lancaster Fells. Q.J.G.S. 109, 423-54.

PARKER, J.M. 1942. Regional systematic jointing in slightly deformed sedimentary rocks. Bull. Geol. Soc. Am. 53, 381-408.

PHILLIPS, J. 1836. Illustrations of the Geology of Yorkshire. Part II. The Mountain Limestone district, London.

RAISTRICK, A. 1934. The correlation of glacial retreat stages across the Pennines. Proc. Yorks. Geol. Soc. 22, 199-214.

RAYNER, D.H. 1953. The lower Carboniferous rocks in the N. of England: a review. Proc. Yorks. Geol. Soc. 18, 231-315.

READING, H. 1954. The stratigraphy and structure of the Cotherstone (Stainmore) Syncline. Ph.D. Thesis, Durham University (Durham Division).

ROWELL, A.J. 1953. The Upper Limestone Group and Millstone Grit of the Stainmore Outlier and the Askrigg Block from Tan Hill to Swarth Fell. Ph.D. Thesis Leeds University.

_____. and J.S. TURNER. 1952. Corrie glaciation in the Upper Eden Valley, Westmoreland. Liverpool and Manchester Geol. Journ. 1, 200-7.

SARGENT, H.C. 1929. Further Studies in Chert I. Geol. Mag. 66, 399-413.

SCANLON, J.E. 1955. The Upper Limestone Group and Millstone Grit of the Askrigg Block from Swarth Fell to Rogan's Seat and Summer Lodge Moor. Ph.D. Thesis, Leeds University.

SCHMIDT, H. 1934. Cephalopoden faunen des alteren Namur aus der Umgegend von Arnsberg in Westfalen. Jb. Preuss. geol. Landesanst. 54, 440-61.

SHORT, K.C. 1954. The Geology of the Pennine Escarpment from Croglinwater to Ardale. Ph.D. Thesis, Nottingham University.

SLINGER, F.C. 1936. Millstone Grit and glacial geology of Caton Moor, near Lancaster (abstract) Rept. Brit. Assoc. 345.

SMITH, S. 1911. The faunal succession of the Upper Bernician. Trans. Nat. Hist. Soc. Northumb. 3, 591-645.

SORBY, H.C. 1859. On the Structure and Origin of the Millstone-Grit in South Yorkshire. Proc. Yorks. Geol. and Poly. Soc. 3, 669-75.

STEPHENS, J.V. and OTHERS. 1953. The Geology of the Country between Bradford and Skipton. Mem. Geol. Surv.

TILLOTSON, E. 1934. The glacial geology of Nidderdale. Proc. Yorks. Geol. Soc. 22, 215-28.

TONKS, L.H. 1925. The Millstone Grit and Yoredale rocks of Nidderdale. Proc. Yorks. Geol. Soc. 20, 226-56.

TROTTER, F.M. and S.E. HOLLINGWORTH. 1932. The geology of the Brampton District. Mem. Geol. Surv.

TURNER, J.S. 1927. The Lower Carboniferous succession in the Westmoreland Pennines and the relation of the Pennine and Dent faults. Proc. Geol. Assoc. 38, 339-74.

TUTE, J.S. 1887. The Cayton Gill Beds. Proc. Yorks. Geol. Soc. 9, 265-7.

_____. 1887. Note on the occurrence of Lingula in the Millstone Grit Series, West of Ripon. Proc. Yorks. Geol. Soc. 9, 425.

WAGER, L.R. 1931. Jointing in the Great Scar Limestone of Craven and its relation to the tectonics of the area. Quart. Journ. Geol. Soc. 87, 392-424.

WALKER, C.T. 1952. Stratigraphical directional studies in the Kinderscout Grits of Wharfedale and adjacent areas. Ph.D. Thesis, Leeds University.

WELLS, A.J. 1955a. The stratigraphy and structure of the Middleton Tyas-Sleightholme anticline and the development of chert between the Underset and Crow Limestones in north Yorkshire. Ph.D. Thesis. Durham University (Durham Division).

_____. 1955b. The development of chert between the Main and Crow Limestones in north Yorkshire. Proc. Yorks. Geol. Soc. 30, 177-96.

WOODWARD, H. 1906. On a Carboniferous trilobite from Angram in Nidderdale. Proc. Yorks. Geol. Soc. 16, 84-6.

LIST OF PALAEONTOLOGICAL WORKS TO WHICH REFERENCE WAS MADE IN THE PROCESS OF IDENTIFICATION OF FOSSILS

BASSLER, R.S. and B. KELLETT. 1934. Bibliographic index of Palaeozoic ostracoda. Geol. Soc. America Special Paper No. 1.

BISAT, W.S. 1934. Anthracoceras from the E_2 zone of the Namurian. Trans. Leeds Geol. Assoc. 5, 112-7.

BRADY, H.B. 1876. The Carboniferous and Permian Foraminifera. Pal. Soc. Monograph.

DAVIDSON, T. British Fossil Brachiopoda. Vol. II. Part V. Pal. Soc. Monograph.

DEMANET, F. 1938. La faune des Couches de passage du Dinantien au Namurien dans le synclinorium de Dinant. Mem. Mus. Roy. d'Hist. Nat. de Belgique No. 84.

_____. 1941. Faune et stratigraphie de Belgique No. 97.

DUNBAR, C.O. and G.E. CONDRA. 1932. Brachiopods of the Pensylvanian System in Nebraska. Nebraska Geol. Surv. Bull. 5.

GEORGE, T.N. 1927. Studies in Avonian Brachiopoda: I. The Genera Brachythyris and Martinia. Geol. Mag. 64, 106-19.

_____. 1931. Ambocoelia Hall and certain similar British Spiriferidae. Q.J.G.S. 87, 30-61.

GEORGE, T.N. 1932. The British Carboniferous Reticulate Spiriferidae. Q.J.G.S. 88, 516-75.

HIND, W. 1896-1905. The British Carboniferous Lamellibranchiata. 1,2. Pal. Soc. Monograph.

KNIGHT, J.B. 1941. Paleozoic Gastropod Genotypes. Geol. Soc. America. Special Paper No. 32.

McCOY, 1844. A synopsis of the characters of the Carboniferous Limestone Fossils of Ireland. 1st edition, London.

MOORE, E.W.J. 1941. The goniatite genus Dimorphoceras and its development in the British Carboniferous. Proc. Yorks. Geol. Soc. 24, 103-128.

_____. 1946. The Carboniferous goniatite genera Girtyoceras and Eumorphoceras. Proc. Yorks. Geol. Soc. 25, 387-445.

_____. 1950. The genus Sudeticeras and its Distribution in Lancashire and Yorkshire. Journ. Manch. Geol. Assoc. 2, 31-50.

MUIR-WOOD, H.M. The British Carboniferous Producti II Productus (sensu stricto); semireticulatus and longispinus groups. Mem. Geol. Surv., Palaeontology.

SHIMER, H.W. and R.R. SCHROCK. 1944. Index Fossils of North America. New York.

SPENCER, W.K. 1934-1940. The British Palaeozoic Asterozoa. Pal. Soc. Monograph.

THOMAS, E.G. 1940. Revision of the Scottish Carboniferous Pleurotomariidae. Trans. Geol. Soc. Glasgow, 20, 330-72.

THOMAS, I. 1910. The British Carboniferous Orthotetinae Mem. Geol. Surv. Palaeont. Vol. I, Part 2.

_____. 1914. The British Carboniferous Producti. I Genera Pustula and Overtonia. Mem. Geol. Surv. Palaeont. Vol. I, Part 4.

ULRICH, E.O. 1890. Palaeozoic Bryozoa. Ill. G.S. 8.

WEIR, J. 1931. The British and Belgian Carboniferous Bellerophontidae. Trans. Roy. Soc. Edin. 56.

WOODWARD, H. 1883. British Carboniferous Trilobites. Pal. Soc. Monograph.

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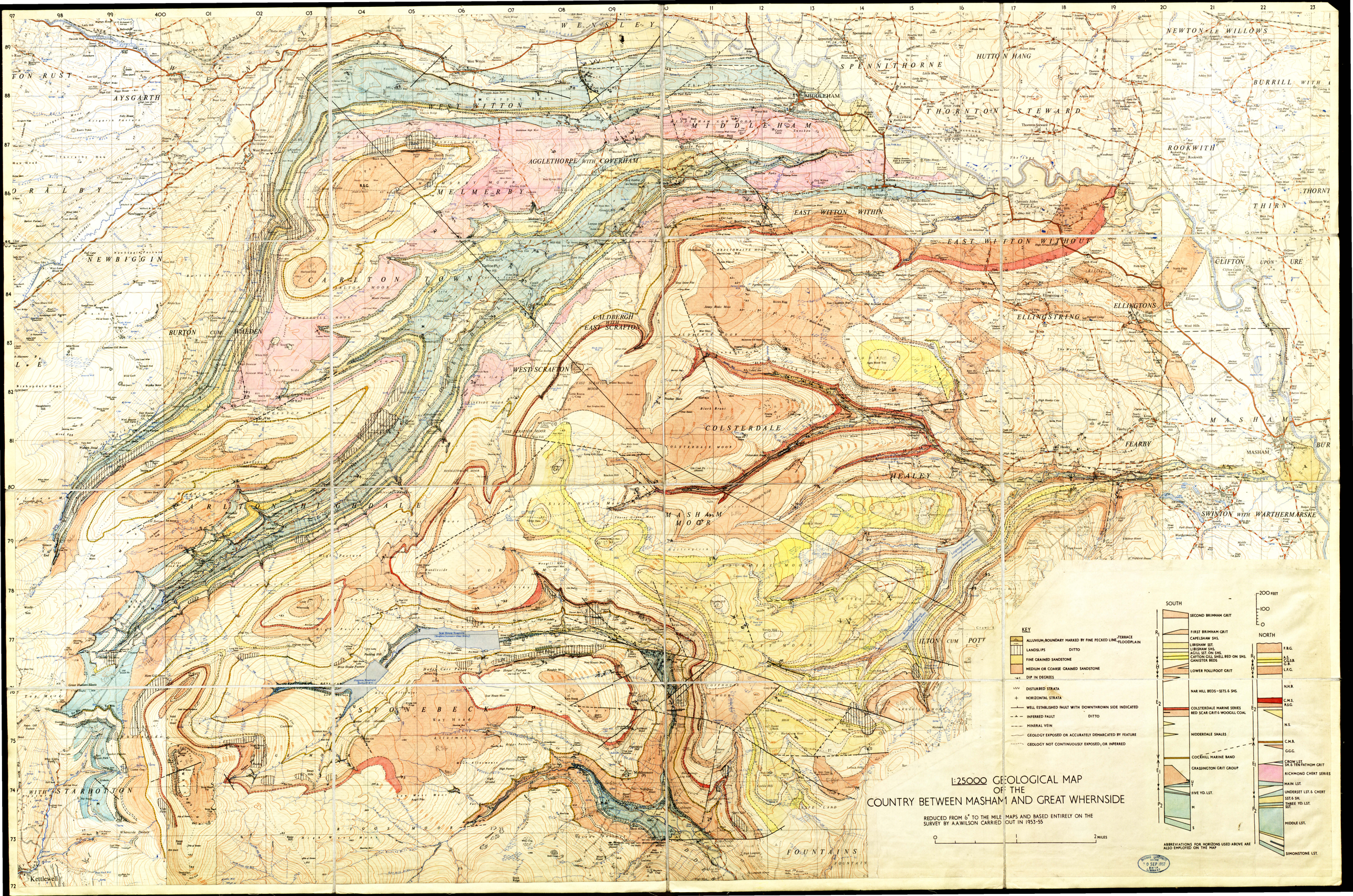

1:25000 GEOLOGICAL MAP
OF THE
COUNTRY BETWEEN MASHAM AND GREAT WHERNSIDE
REDUCED FROM 6" TO THE MILE MAPS AND BASED ENTIRELY ON THE SURVEY BY A.A.WILSON CARRIED OUT IN 1953-55
0
1
2 MILES
KEY
ALLUVIUM; BOUNDARY MARKED BY FINE PECKED LINE. TERRACE FLOODPLAIN
LANDSLIPS DITTO
FINE GRAINED SANDSTONE
MEDIUM OR COARSE GRAINED SANDSTONE
DIP IN DEGREES
DISTURBED STRATA
HORIZONTAL STRATA
WELL ESTABLISHED FAULT WITH DOWNTHROWN SIDE INDICATED
INFERRED FAULT DITTO
MINERAL VEIN
GEOLOGY EXPOSED OR ACCURATELY DEMARCATED BY FEATURE
GEOLOGY NOT CONTINUOUSLY EXPOSED; OR INFERRED
SOUTH
SECOND BRIMHAM GRIT
FIRST BRIMHAM GRIT
CAPELSHAW SHS.
LIBISHAW SST.
LIBISHAW SHS.
AGILL SST. ON SHS.
CATTON GILL SHELL BED ON SHS.
GANISTER BEDS
LOWER FOLLIFOOT GRIT
NAR HILL BEDS - SSTS. & SHS.
COLSTERDALE MARINE SERIES
RED SCAR GRIT & WOOGILL COAL
NIDDERDALE SHALES
COCKHILL MARINE BAND
GRASSINGTON GRIT GROUP
FIVE YD. LST.
M
S
NORTH
F.B.G.
A.S.
C.G.S.B.
G.B.
L.F.G.
N.H.B.
C.M.S.
R.S.G.
N.S.
C.M.B.
G.G.G.
CROW LST.
SH. & TEN FATHOM GRIT
RICHMOND CHERT SERIES
MAIN LST.
UNDERSET LST. & CHERT
SST. & SH.
THREE YD. LST.
SST.
MIDDLE LST.
SIMONSTONE LST.
200 FEET
100
0
ABBREVIATIONS FOR HORIZONS USED ABOVE ARE ALSO EMPLOYED ON THE MAP
WENSLEY
SPENNITHORNE
HUTTON HANG
NEWTON LE WILLOWS
BURRILL WITH
AYSGARTH
WEST WITTON
MIDDLEHAM
THORNTON STEWARD
ROOKWITH
AGGLETHORPE WITH COVERHAM
MELMERBY
EAST WITTON WITHIN
THIRN
NEWBIGGIN
CARLTON TOWN
EAST WITTON WITHOUT
CLIFTON UPON URE
BURTON CUM WALDEN
CALDBERGH WITH EAST SCRAFTON
ELLINGTONS
ELLINGSTRING
WEST SCRAFTON
COLSTERDALE
MASHAM
FEARBY
HEALEY
CARLTON HIGHDALE
MASHAM MOOR
SWINTON WITH WARTHERMARSKE
ILTON CUM POTT
STONEBECK UP
WITH STARBOTTON
FOUNTAINS
Kettlewell