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THE SILURIAN STRATA OF THE HOWGILL FELLS

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by

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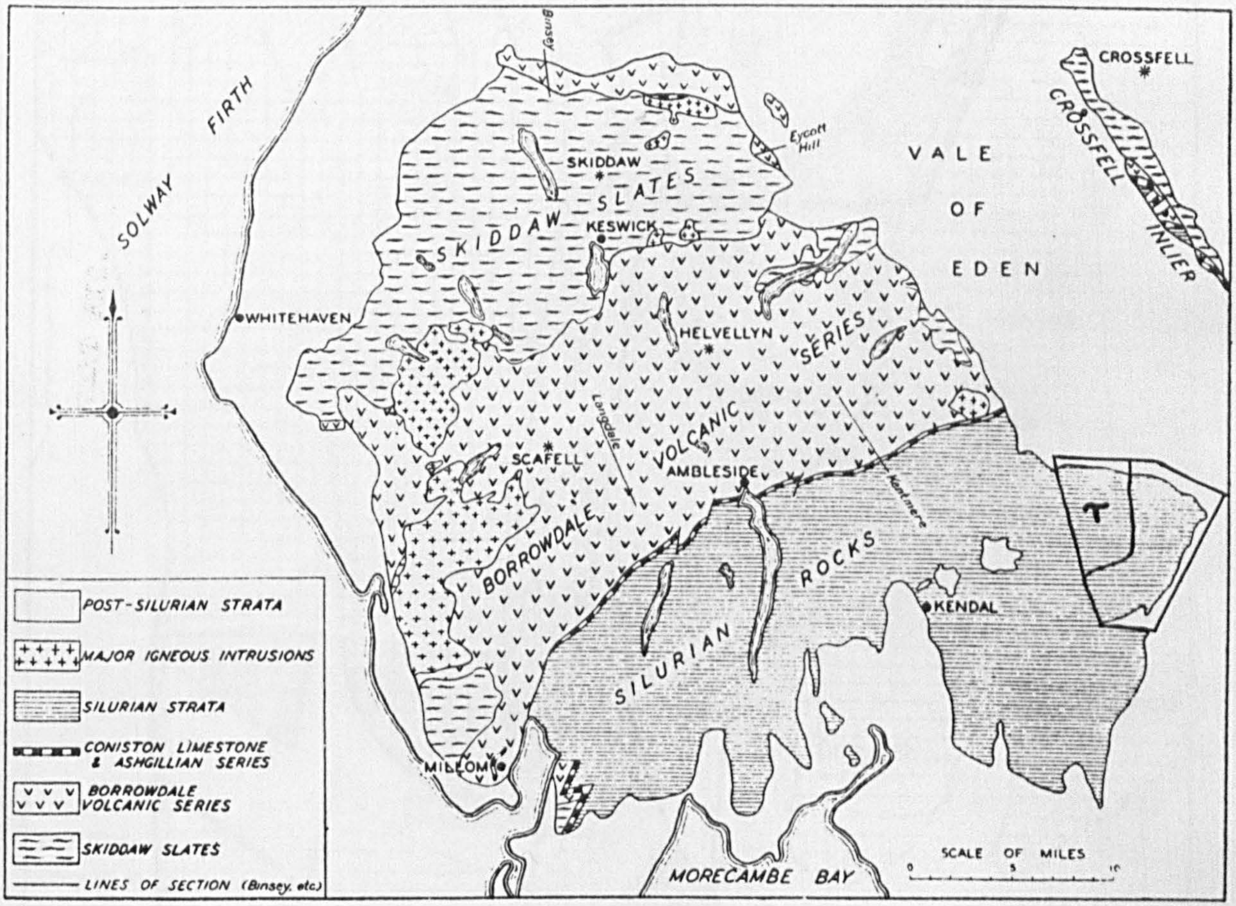
CHAPTER 1

INTRODUCTION AND ACKNOWLEDGEMENTS

The Howgill Fells form a most distinct topographical feature extending from N.W.Yorkshire into Westmorland. In plan they occupy a broadly triangular area with the town of Sedbergh at the southern apex. Tebay forms the north western limit of the fells and Ravenstonedale village the north east. The broad, flat Ravenstonedale valley between the village of the same name and Tebay in the west, bounds the northern edge of the hills whilst the deep valley of the R.Lune between Tebay and Sedbergh effectively demarcates the western margin. The Cautley valley in the east, which forms the pass through to Ravenstonedale from Sedbergh, is at a somewhat higher level than the Lune valley and has a watershed east of Harter Fell. The fells themselves stand out in marked contrast to the Carboniferous country to the east and north, and consist of deeply dissected rounded hills rising to well over 1500' in most cases, whilst Great Dummacks and The Calf exceed 2000'.

The writer has mapped in detail an area in the eastern half of the fells some 6 miles long by 3-4 miles wide and has carried out reconnaisance mapping in the rest of the fells. In the north the detailed map extends from the Cautley valley as far west as Bowderdale, and in the south almost as far west as the River Lune. The area is covered by the following Ordnance Survey 6" sheets:- SD69 NW,NE,SW,SE; SD79 NW,SW; NY60 NE,NW,SW,SE and NY70 SW. Text fig.1a illustrates the geographical and geological setting of the area. The Silurian rocks of the northern part of the Howgill Fells are overlain unconformably by Carboniferous conglomerates, limestones and shales, the actual unconformity being well exposed in several stream sections. To the east the Silurian and Ordovician are faulted against Carboniferous rocks along the line of the Dent Fault, whilst to the south the unconformable red conglomerate at the base of the Carboniferous forms a natural geological boundary. The Ordovician rocks are exposed in a series of complicated inliers in the Cautley valley and these are succeeded to the north and west by successively higher Silurian divisions until the Bannisdale Slates are seen in the region of the R.Lune, N.W. of Sedbergh and in the gentle slopes into Ravenstonedale. To

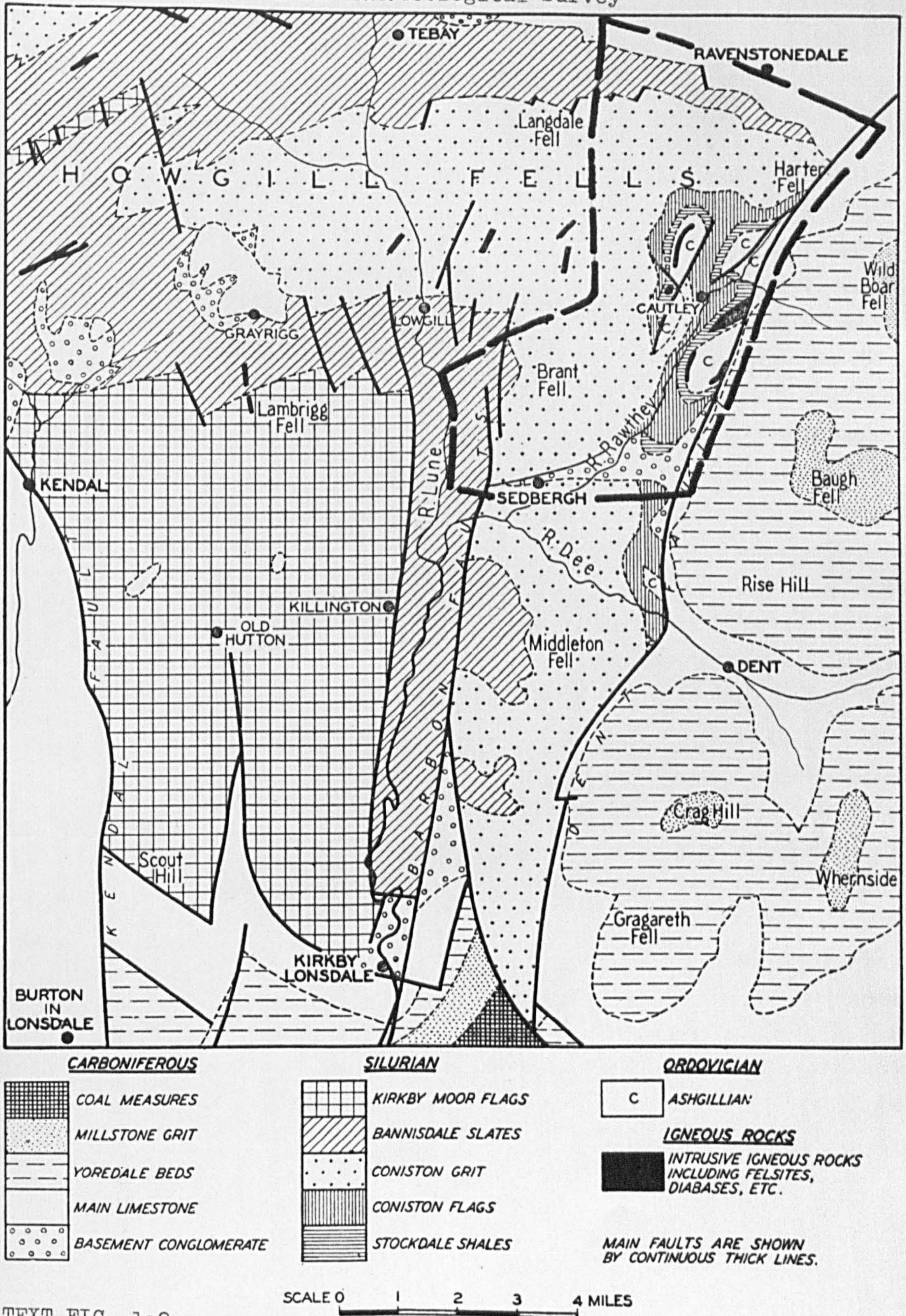
TEXT FIG. 1a1



Sketch-map showing the distribution of the pre-Carboniferous rocks of the Lake District.

after H.M.Geological Survey

after H.M.Geological Survey



TEXT FIG. 1a2

Geological sketch-map of the Fell country between Tebay, Kendal and Kirkby Lonsdale.

the south of Sedbergh are the Barbon and Middleton Fells, again consisting predominantly of Silurian strata, and to the west the main Lake District outcrop of the Silurian.

The Howgill Fells have received the attention of geologists since the first half of the nineteenth century but descriptions of the region are usually brief and included in works of a much greater scope. Thus, for example, the fells and their rocks are briefly mentioned by Phillips (1836) and a section given shows the undivided rocks of the Howgill Fells faulted against folded Carboniferous strata. Sedgwick (1846) in his account of the "Slate Rocks" of Cumberland, Westmorland, and Lancashire gives a lucid general study of the Howgill Fells and their environs and includes several sections. Sedgwick (1852) describes his "Ravenstonedale Section" and, like Phillips, includes a section from the Carboniferous across the Cautley valley to the Howgill Fells. The units recognized in this section are: Coniston Limestone, Coniston flags, Coniston Grits, Ireleth Slates and "coarse grit and slate, with calcareous concretions". In this work Sedgwick traced the Coniston Grits from Cautley Crags as far north as Ravenstonedale Common. Areas adjacent to the Howgill Fells were described by Hughes (1866,1867) and in the latter work reference is made to the region of Cautley Crags.

The greatest advances, however, in the understanding of the geology of the region were made in later years particularly by the researches of Professor T.McK.Hughes. Thus the Survey Memoirs by Aveline and Hughes (1872), and Aveline, Hughes and Strahan (1888) contained detailed descriptions of the strata, whilst the former work recognized the Stockdale Shales. All the strata from the base of these up to (and including) the Kirby Moor Flags were placed in the Upper Silurian. (The Survey workers did not at that time recognize Lapworth's divisions of Cambrian, Ordovician, and Silurian). More general works of the same period include Davis and Lees' "West Yorkshire" (1878) which gives a fairly comprehensive account of the distribution in Yorkshire of the "Upper" and "Lower Silurians". A section included in this work differs little from that given by Phillips (op.cit.) except in being less accurate. Bird (1881) also makes brief reference to the Howgill Fells. Dakyns et al. (1891) in the "Mallerstang Memoir" gave a detailed account of the eastern parts of the Howgill Fells, much of the groundwork having been done by Professor Hughes prior to his retirement from the Geological Survey.

These workers follow Marr and Nicholson (1888) in their work on the Stockdale Shales of Spengill but in addition describe several less complete sections from other parts of the district. In the important paper by Marr and Nicholson (op.cit.) on the Stockdale Shales of the Lake District several pages are devoted to the Cautley area and the Stockdale Shales of Spengill are correlated with those of the Lake District. Further notes on the geology of the Howgill Fells were given by Hughes (1894) in his paper on "Observations on the Silurian Rocks of North Wales" where he defines the "Tebay Mudstones" included by later workers in the Coniston Grits.

Marr (1900) refers to the presence of "Upper Slates" (sensu Otley 1820) in the Howgill Fells. Marr and Fearnsides (1909) in a paper dealing mainly with the glacial geology describe and map a "shatter belt" in the north of the fells which seems to be equivalent, at least in part, to the Gais Gill Fault of the present work (p. 75). Misses G.R.Watney and E.G.Welch (1911) described the Salopian of the Cautley district and produced a map of the Zones which they established. In attention to detail this work ranks on a par with the study of Marr and Nicholson (op.cit.) though of course far greater thicknesses of rock were involved. Summaries were given by the same writers in the previous year (1910). Marr (1913) made a further contribution to the Silurian stratigraphy in his paper dealing mainly with the Ordovician strata, following a brief note by Marr and Fearnsides (1911).

In more recent years the Silurian rocks of the Howgill Fells received brief or incidental reference in many works (e.g. Marr 1916,1925,1927) but it was not until Dr.Wilson's unpublished work (1954) on the Upper Llandovery that the strata were subjected to further scrutiny. Dr.Wilson examined with the greatest care beds from the sedgwicki Zone to the base of the Wenlock Series, recognized and defined the crispus and griestonensis Zones, and described some of the species from the higher divisions.

There have been numerous works on the main Lake District outcrop which have direct or indirect bearing upon the geology of the Cautley district but it would be superfluous to list these here since they have been made the subject of bibliographies on several occasions (e.g.Marr and Nicholson 1888; Dakyns et. al. 1890; Marr 1916; Wilson 1954; Mitchel 1956; and the Bulletins of the Ludlow Research Group). Those which have a direct bearing are dealt with at the appropriate points in the text below.

In the present thesis work has been concentrated particularly on those beds which have not been the subject of modern treatment with a view to producing a detailed and accurate map along the line of the Dent Fault. The writer suspected that a certain amount of variation took place in the beds about the Ordovician-Silurian boundary. Such has proved to be the case although a decision on the exact base of the Silurian will have to be deferred until study of the brachiopod faunas (shown below to occur across the point taken for the present to be the boundary) has been completed by Dr.Lamont. From the Lower Llandovery and Middle Llandovery strata many more species have now been recorded than were listed by Marr and Nicholson (op.cit.) and the Survey workers. This has enabled subdivision of the Lower Llandovery "*Dimorphograptus* Beds" into three Zones which not only allow correlation with other regions but enable faunal studies in these beds to be put on a firm stratigraphical basis. Throughout the district small outcrops of "*Dimorphograptus* Beds" occur, and these can now be placed more accurately thus assisting both mapping and palaeontological studies. The boundaries between the Lower, Middle and Upper Llandovery are described.

A similar approach has been adopted in the case of the Wenlock Series where the faunal sequences shown by particular sections have enabled considerable subdivision of lithologically monotonous strata. Four faunal Stages are defined each being subdivided into Zones and some of the latter into Subzones. Wider correlation in the case of the Wenlock Series is more difficult than in earlier strata although the general sequence of faunas noted elsewhere can be recognized. The strata contain several species more commonly recorded from the Continent. It is shown that in the Wenlock Series the base of Stage 4 cannot be defined at the present owing to the lack of exposure at this level.

The main purpose in examining the Ludlow Series has been to identify and map the lithological succession and to define by reference to particular horizons the major divisions. Faunal work on the Ludlow graptolites is only in its preliminary stages but has shown that some of the Zones identified elsewhere can be recognized. No *vulgaris* Zone occurs at Cautley and the Wenlock strata are followed immediately by beds yielding *P.nilssoni* and *M. scanicus*.

Faunal and stratigraphical studies are of necessity closely tied to the recognition of facies types. In Chapter 6 the facies types and their vertical distribution are described, whilst Chapter 7 deals with a single facet of facies study, that of palaeocurrent indicators. In this latter chapter the current variation throughout the Silurian is described as far as this is possible. The currents detected seem to fit in with the pattern of gradually changing environments of deposition which are suggested on independent grounds.

In the palaeontological section of the work over one hundred species of graptolites are described and some short evolutionary steps are suggested. Few shelly fossils have been described, a study of the shelly faunas being beyond the scope of the present work, but of those trilobites dealt with two are considered to be new genera.

Finally it is suggested that the Silurian strata of the Howgill Fells would yield interesting results to studies directed at the following aspects: a) the shelly faunas b) the mineralogy of the constituent facies c) the structural geology.

The author's collection of some twenty thousand fossils collected from the Howgill Fells is deposited in the Department of Geology, University of Hull.

The figures in brackets following the description of a rock colour are those used by the Geological Society of America Rock-colour Chart (1951).

Acknowledgements

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One of the most stimulating facets of this work has been the help I have received from workers in the same field both in this country and abroad. I should like to express my gratitude to Dr.I. Strachan of the Department of Geology at the University of Birmingham for many helpful suggestions, for the loan of material from the Geological Museum at Birmingham, for giving me the opportunity to examine some of the works in his exhaustive library of literature dealing with graptolites, and for his wholehearted support of the work. I am grateful also to Dr.A Lamont who has examined my collection of brachiopods; to Dr.J.K.Ingham of the Hunterian Museum, Glasgow for assistance in the field and many fruitful discussions and to Dr.K.Walton and Dr.S.Djulynski of the Department of Geology at the University of Edinburgh for their generosity during my visit to the sedimentological laboratory under their care.

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Finally I should like to thank my wife for her assistance in the stratigraphic collection of material and for her tolerance in the typing of the thesis.

CHAPTER 2

THE LLANDOVERY SERIES

Introduction

The term "Llandovery Series" was first used on the Geological Survey 1" sheets covering the Llandovery District (v. Challinor,J. 1951) and was later described by Murchison (1859) who divided it into Lower and Upper Llandovery. At a much later date the Series was redefined by Jones (1925, 1949) who recognised the divisions Lower, Middle, and Upper Llandovery, each being separated by an unconformity. Jones (1925) included in his Upper Llandovery both Murchison's Upper Llandovery and this latter author's distinct division of the Tarannon or Pale Shales. Terms synonymous with Llandovery Series and used at a later date in different areas are "Stockdale Shales" and "Valentian". Both were erected for the graptolitic facies, the former by Aveline and Hughes (1872) and the latter by Lapworth (1876). A summary and discussion on the usage of the above terms and their subdivisions is given by Curtis (in Whittard 1961, chart p.132). In view of the fact that "Llandovery Series" has priority over Valentian etc. (Whittard 1961, p.128) and that the succession of zones recognized in the Howgill Fells can be equated with those established in Wales it is both correct and convenient to use the term.

It was thought at one time that in part of the Lake District at least, the Silurian strata rested unconformably upon the Ordovician (Aveline 1872, 1876, 1888 (in Aveline and Hughes); Marr 1876) not so much because of angular discordance between the two, though Aveline (1872, p.442) implied this, but because of the conspicuous change in lithological and faunal characters which invariably took place at the boundary. Thus Aveline (1872 p.442) writes "..for there is not the slightest passage, either stratigraphically or palaeontologically, from the Coniston Limestone series into the lower division of the Upper Silurian.." He also believed that in one locality the Silurian completely overlapped the Ordovician. Other workers at the same time (e.g. Nicholson 1872) did not agree with the conclusion reached by Aveline. In the Cautley district itself Dakyns et al (1891 p.28) writes "... there is an abrupt change from the fauna of the Ashgill Shales to that of the Graptolitic

Mudstones, without, however, any stratigraphic unconformity."

In the following paragraphs the nature of the change from Ordovician to Silurian is examined particularly with regards to the variation shown by certain beds.

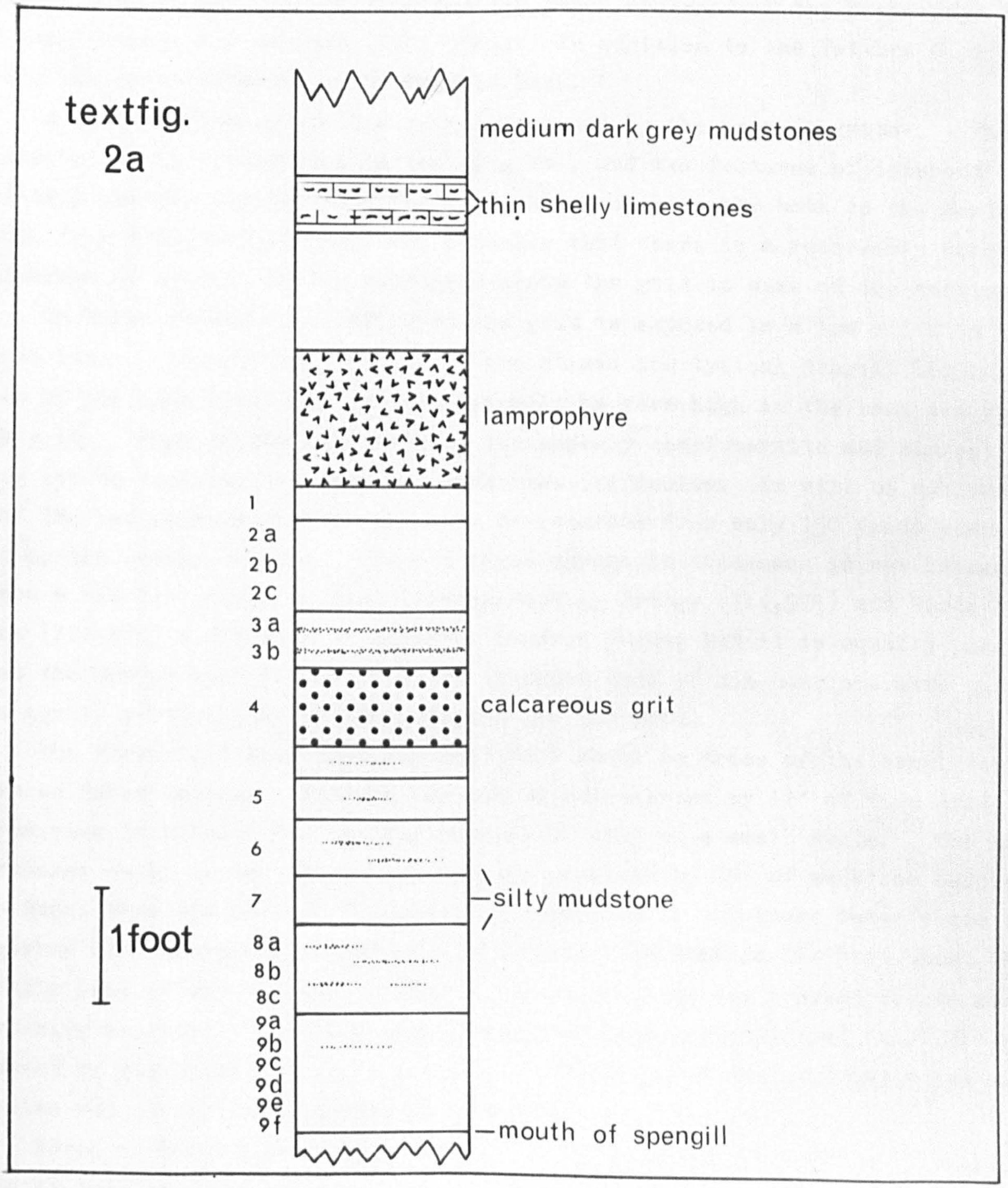
The highest Ordovician Strata and the Basal Beds of the Silurian

The Ashgill Shales Grit of Spengill was first recorded by Marr and Nicholson (1888 p.700), the discovery being attributed to Professor T.Mck. Hughes who, until his retirement from the Survey, worked on the Quarter Sheet 97NW which was subsequently described in 1891. The locality given by the above authors is " a few yards below the ford" which is located on the junction of Stockless Gill and Spengill. Dakyns et.al. (1891 p.25) write "A few yards below the forking of the beck and on the west bank a hard calcareous grit was noted by Professor Hughes ..." Marr and Nicholson (op cit.) record the following fossils:- Cornulites, Orthis protensa, Sow., Orthis biforata, Schloth., Strophomena siluriana, Dav., Meristella crassa, Sow? Of these all except the last were considered to be typical Ordovician fossils. Marr (1913 p.7) whilst examining the Ashgill Shales Grit of Watley Gill makes further reference to the grit on Spengill but notes that it seemed, by that time, to be covered over. The present writer has examined the Ashgill Shales inch by inch below the junction of Stockless Gill and Spengill and concludes that no grit exists in that part of the succession. However, some yards above the junction are several bands of silty and gritty mudstone and associated with them an 8" medium grey (N5) calcareous grit (see text figs.2a and b,c). This is overlain by 6" of argillaceous and gritty limestone followed by 2'1" of typical Ashgill Shales mudstone. The following 12" contain two thin, hard limestones (see text fig. 2a) containing numerous brachiopods and trilobites (e.g. Dalmanitina mucronata). Trenching has been carried out above this point and has shown that the succession is continuous and uninterrupted by faults until the strata described below as the Basal Beds of the Silurian are reached. Exactly 40' of strata are now exposed upstream of the 8" grit and below the Basal Beds, but above the two thin limestones just mentioned the beds are non-calcareous and only sparsely fossiliferous. The following have been obtained:- crinoids, Phyllonorina hisingeri, Dalmanitina mucronata.

The Ashgill Shales Grit was recorded in two further localities by the Survey workers. On Taithes Gill (= Ecker Secker Beck) it was described as a

TEXT FIG. 2a

Ashgill Shales exposed at the junction of Stockless Gill and Spengill. The numbers to the left of the column refer to lithological specimens contained in the Department of Geology, University of Hull.


textfig.
2a
medium dark grey mudstones
thin shelly limestones
lamprophyre
1
2 a
2 b
2 c
3 a
3 b
4
calcareous grit
5
6
7
silty mudstone
1foot
8 a
8 b
8 c
9a
9b
9c
9d
9e
9f
mouth of spengill

calcareous, pyritous conglomerate about 6' thick containing fragments of Coniston Limestone and shale. The locality given is "just above where the footpath from Lower Beckside crosses to Foxhole Rigg." This exposure seems to be covered over at the present time but 150 yards upstream of the footbridge 19' of conglomerate are exposed (697, 956). In addition to the Taithes Gill locality the grit was noted on Birksfield Beck.

A further five localities have been found by the present writer. Their distribution is illustrated in text fig.2b , and two features of interest immediately emerge, firstly that the grit thins considerably both to the North and South from Ecker Secker Beck, and secondly that there is a remarkably constant thickness of Ashgill Shales mudstones above the grit in some of the sections.

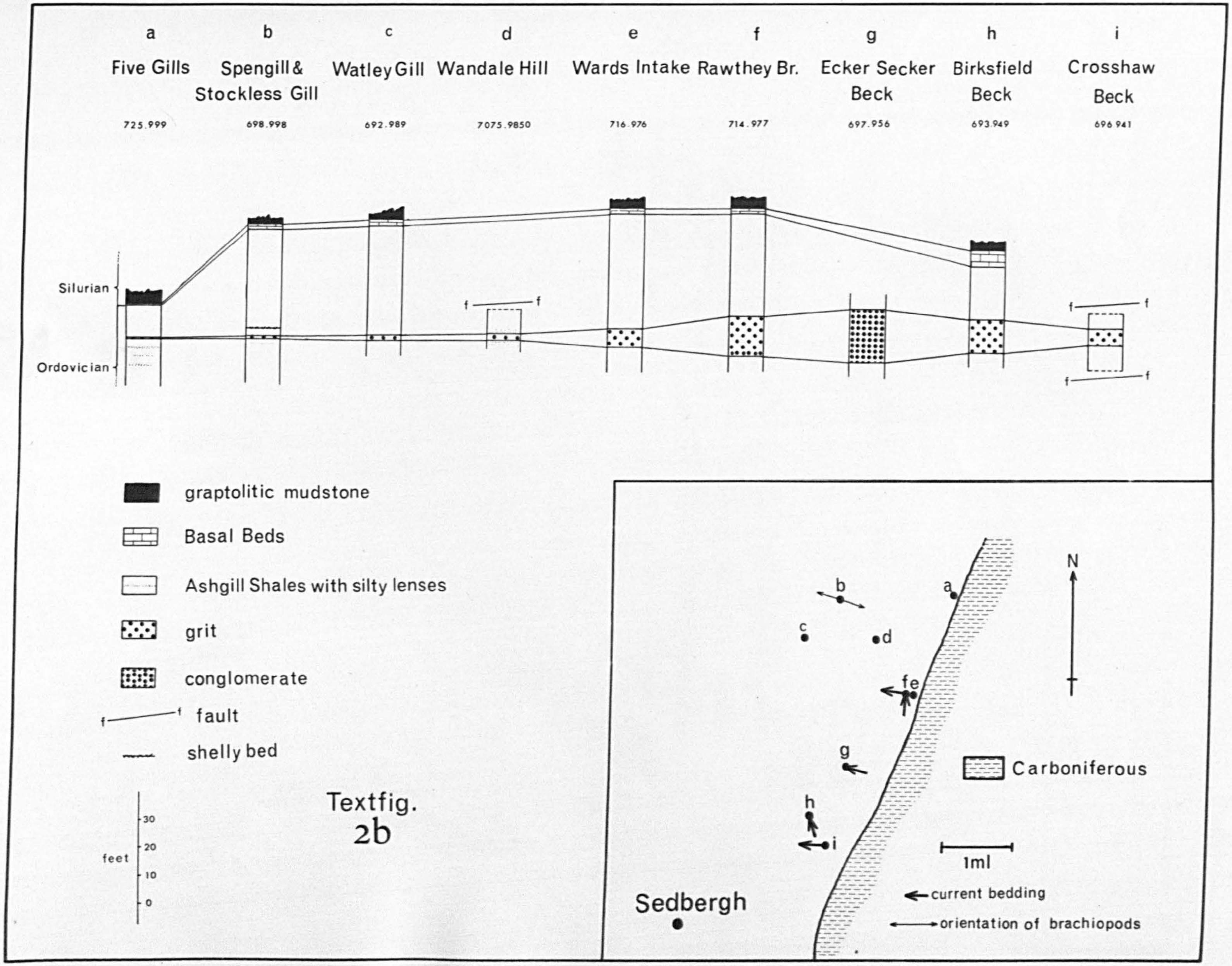
On Ecker Secker Beck (697,956) the grit is exposed in a low cliff on the right bank. Underlying the grit in the stream are typical Ashgill Shales, and beds of the same lithology can occasionally be seen high in the bank and above the grit. Much of the 19' division is coarsely conglomeratic and current bedding can be detected and measured with some difficulty. It will be noticed that the bed is much thicker than the 6' recorded from only 150 yards downstream by the Survey workers. Such a rapid change in thickness is not impossible since a similar change is seen between Rawthey Bridge (714,977) and Wards Intake (716,976) a distance of only two hundred yards, but it is equally possible that the Survey workers may not have included beds of non-conglomeratic texture (grit) particularly if the exposure was not good.

The Birksfield Beck locality (693,949) shows no trace of the conglomerate seen on Ecker Secker. Instead the bed is represented by 12' of fine grit, calcareous in places, and showing current bedding on a small scale. The best exposures occur in the stream bed and are overlain by 19' of mudstone before the Basal Beds are reached. A further reduction in thickness takes place to Crosshaw Beck where only 6' of grit is exposed low down in the left bank. (Much of this part of the section is almost inaccessible at the present due to recent lumbering activity. Further consequences of this are mentioned on p. 18 , with respect to the Birks Wood Beck section). The base of the grit has a few large pebbles and current bedding can be detected.

North of Ecker Secker Beck there is a considerable distance in which the beds at this level are not exposed and the nearest locality is more than $1\frac{1}{2}$ miles to the NE on the R.Rawthey near Rawthey Bridge (714,977) and Wards Intake

TEXT FIG. 2b

Correlation chart showing the variations seen in the Ashgill Shales Grit based on the assumption that the grit is of approximately the same age throughout the region.

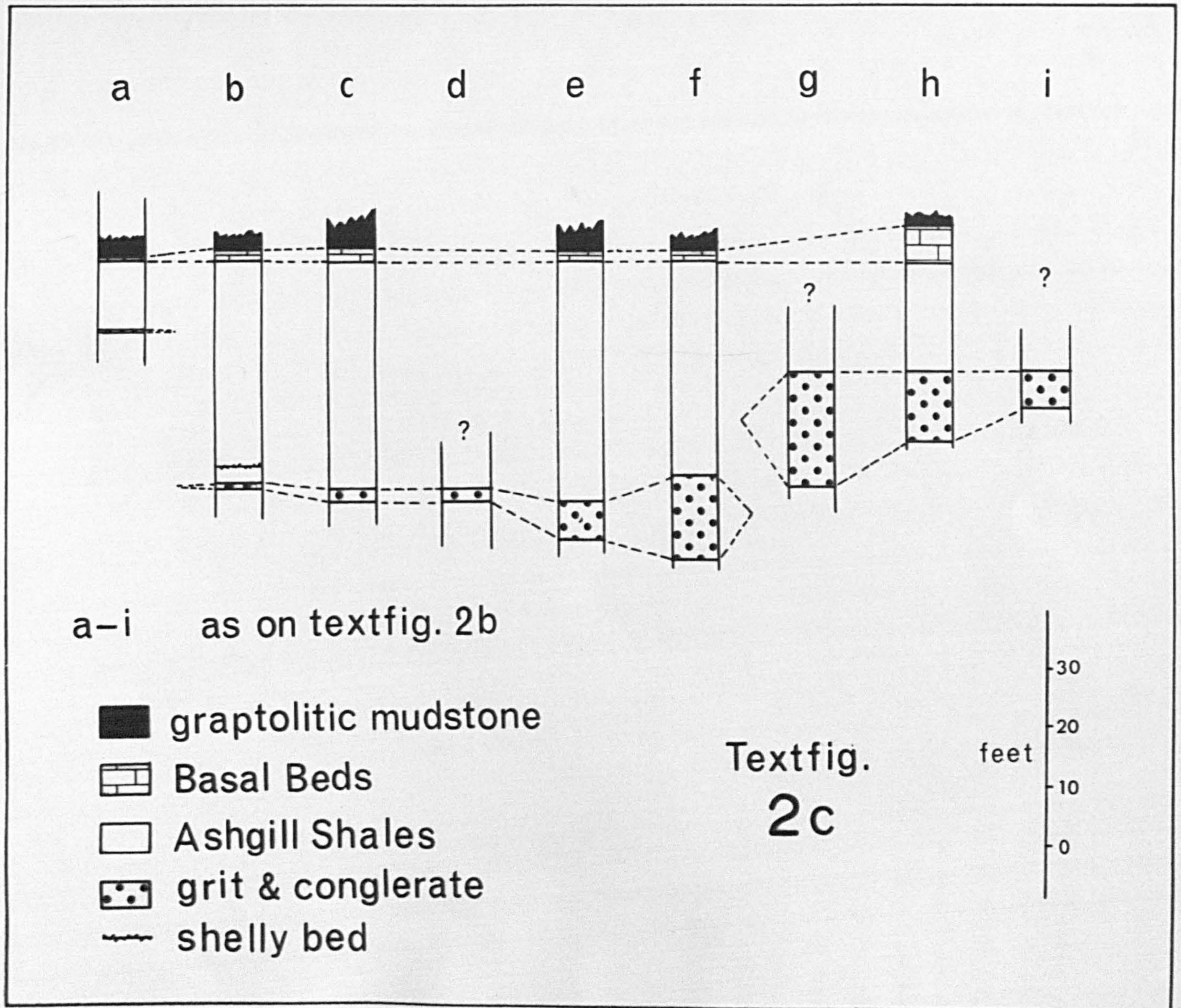


a
Five Gills
725.999
b
Spengill & Stockless Gill
698.998
c
Watley Gill
692.989
d
Wandale Hill
7075.9850
e
Wards Intake
716.976
f
Rawthey Br.
714.977
g
Ecker Secker Beck
697.956
h
Birksfield Beck
693.949
i
Crosshaw Beck
696.941
Silurian
Ordovician
graptolitic mudstone
Basal Beds
Ashgill Shales with silty lenses
grit
conglomerate
fault
shelly bed
feet
30
20
10
0
N
Carboniferous
1ml
current bedding
orientation of brachiopods
Sedbergh

Textfig. 2b

TEXT FIG. 2c

Correlation chart showing variation of Ashgill Shales Grit based on the assumption that equal thicknesses of fine-grained Ashgill Shales mudstones represent approximately equal periods of time.



a b c d e f g h i
?
?
?
a–i as on textfig. 2b
graptolitic mudstone
Basal Beds
Ashgill Shales
grit & conglerate
shelly bed
feet
30
20
10
0

Textfig. 2c

(716,976). The former shows good exposures of Ashgill Shales passing up to the Basal Beds of the Silurian and the grit itself is superbly exposed in a low cliff on the left bank. The base of the grit is conglomeratic for a few inches and pebbles are distributed sparadically throughout. Current bedding can be detected rather more easily at this locality than at any other. A total of 16'6" of beds crop out here whereas at the Wards Intake outcrop only a short distance upstream the same bed has thinned to 6'.

On Watley Gill the grit is fairly well exposed in the right band (v.text fig. 2h) and measures 2'1". It is overlain by 39' of mudstone and then the Silurian strata. A little over 2 miles to the ENE the Five Gills locality (725,999) shows a small thickness (6") of hard calcareous grit, itself containing pebbles of grit, at the top of several feet of silty beds. It is overlain by only 11' of mudstone before the Basal Beds are reached. It is not certain, therefore, what relationship holds, if any, between this grit and those described above from Spengill, Watley Gill, Wards Intake, and Rawthey Bridge where the grit is invariably overlain by approximately 40' of mudstone. If it is assumed that the fine grained Ashgill Shale mudstone does not vary greatly in thickness over the area it will be seen that there may be as many as three sets of grit deposits, each of local extent:-

a) The grit of Spengill, Watley Gill, Wards Intake, and Rawthey Bridge followed by about 40' of mudstone.

b) The grit of Birksfield Beck and (?)Ecker Secker overlain by about 20' of mudstone.

c) The Five Gills grit overlain by only 11' of mudstone.

Most of the exposures do not allow easy measurement of the current bedding foreset beds but those which have been measured suggest a current source from the SE quadrant (see text fig.7cl, and inset on test fig. 2b). The rapid change in thickness as seen at two localities, (Rawthey Bridge to Wards Intake and Ecker Secker Beck to Crosshaw)the probable current direction, coupled with the general decrease in thickness and grain size to the north and northwest strongly suggests gully-like deposits originating from the S to SE, and it is thought that the most likely form would be submarine channels related to a river draining a nearby landmass. The changing direction of distribution could result in either more than one deposit of grit or transgression of the deposit caused by gradual shift of the distributary.

At the very top of the overlying mudstones Wilson (1954) recorded small scale current bedding actually truncated by the Basal Beds of Watley Gill. The present writer did not detect this on Watley Gill but noticed a similar phenomenon on Spengill. The significance of such a feature is debateable since small scale truncated current bedding can be detected at various levels in the Ashgill Shales. If it is assumed that the Ashgill Shales Grit is approximately contemporaneous at all its localities then the variations in thickness of the fine grained mudstones which overlie it might be taken to indicate an unconformable relationship between the Silurian and Ordovician. In this event the above feature of truncated current bedding would not be surprising but taken by itself cannot be regarded as significant. The writer considers that the assumption just mentioned is probably invalid. Whatever the interpretation the Basal Beds of the Silurian are not markedly different, ligholo-gically, from the Ashgill Shales mudstones, (cf Aveline 1872) particularly from those portions which are hard, calcareous and fossiliferous. Sedimentation is thought to have continued without interruption until the top of the Basal Beds are reached, when influx of carbonaceous material takes place to add to the supply of mechanical detritus.

The Basal Beds of the Silurian, composed in part of limestone, can usually be distinguished in the first instance by their hard, massive nature in contrast to the softer Ashgill Shales below and dark graptolitic mudstones above. They were first described by Marr and Nicholson (1888 p.700) from the Spengill section, where they recorded a very hard limestone 6" thick and containing a few crinoids, which they took to be equivalent to the Atrypa flexuosa Band of Skelgill and Diplograptus acuminatus Zone of Browgill. Dakyns et. al (1891 p.29) follow Marr and Nicholson by using the same bed as the base of the Stockdale Shales. Marr (1913 p.11) again mentioned the Spengill exposure and recorded the following fossils:- Encrinurus punctatus var arenaceus Marr and Nich?, Cheirurus bimucronatus, Murch. var?, Phacops mucronatus, Leptaena cf quinquecostata, Orthis two spp., Strophomena two spp., Hyolithus. In the same publication he records the same bed from Birks Beck and Watley Gill and from the latter locality collected the following assemblage:- Cyphaspis cf rastritum Torn., Acidaspis, Phacops mucronatus, Hyolithus. Wilson (1954) was the first to accurately measure the beds of Watley Gill and Spengill but he disagreed with Marr, Dakyns et al. in considering the limestone to be non-crinoidal.

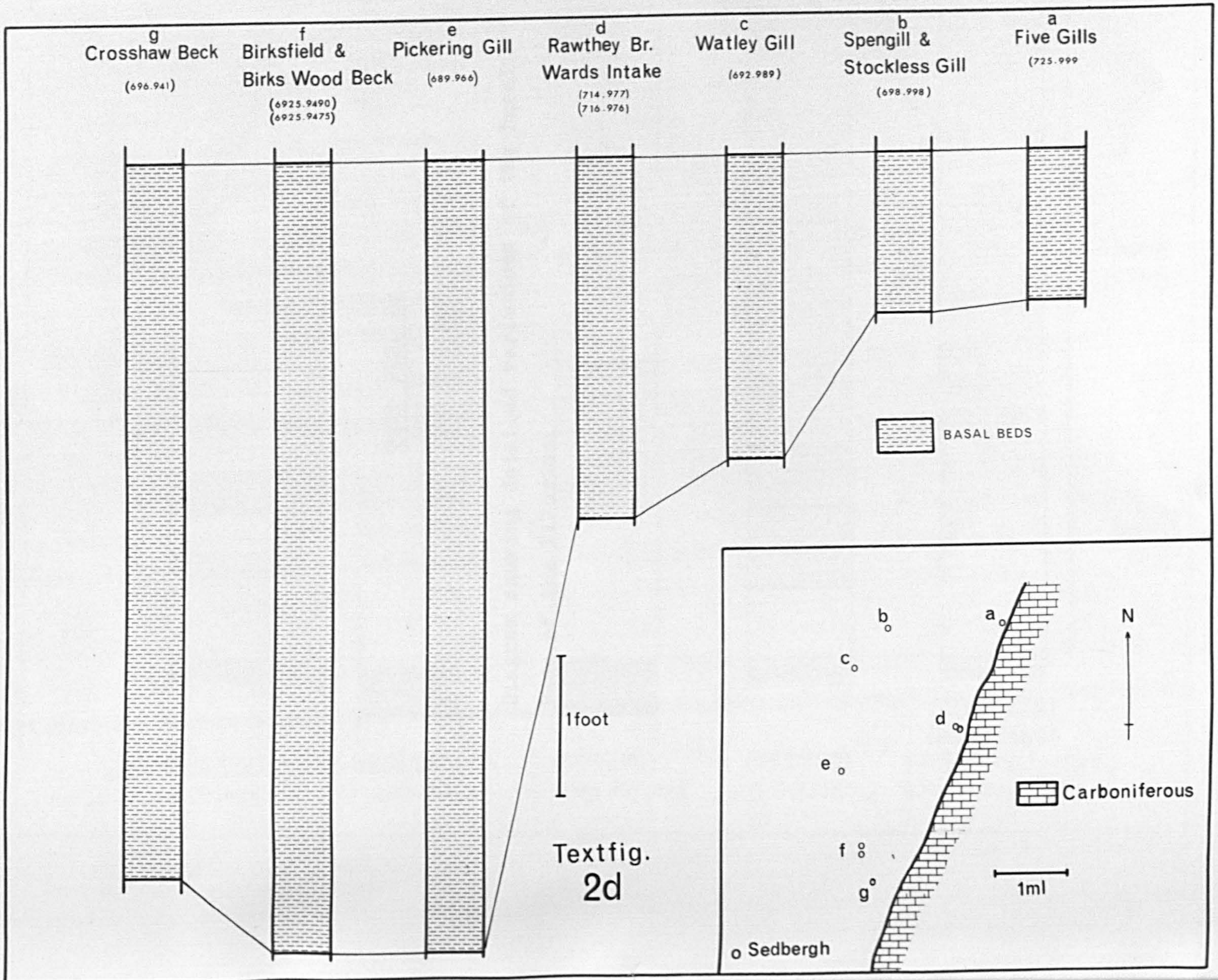
A further eight localities have been unearthed since the above works. These show that in general the Basal Beds increase in thickness to the south (see text fig.2d) and that the components of the beds - limestone and pale, non-calcareous mudstone - vary in thickness and position (v. text fig. 2e). On Five Gills (725,999) the Basal Beds are usually poorly exposed on the left bank several feet above the stream at the base of a small cliff of dark graptolitic mudstones. The exposure prior to digging out showed only the top of the 9½" limestone overlain by a few inches of shale which were apparently unconformably overlain by the mudstone above. Trenching along the foot of the cliff showed that in fact the limestone is broken in several places (see text fig. 2f) and the beds rotated to simulate unconformity. The top of the limestone is marked by a thin bed of clay indicating bedding plane shear. Underlying the limestone are 3½" of hard, non-calcareous mudstone and, dividing the mudstone from the Ashgill Shales below is a soft brown clay which again suggests bedding plane movement. Where the limestone is preserved as a rottenstone numerous fossils can be obtained, in particular:- Dalmanitina mucronata brevispina, Temple, small brachiopods and, more rarely, crinoid ossicles. In all the localities where the beds are sufficiently weathered crinoid ossicles have been obtained thus supporting Marr and Nicholson's original contention that the limestone was crinoidal.

The Ordovician strata in the region of Rawthey Bridge (714,977) and Wards Intake (716,976) have already been mentioned, Upstream of the grit at each locality are 42' of Ashgill Shales followed by the Basal Beds. Both exposures are, however, permanently underwater and though they can be very clearly seen (weathering yellowish) sampling is only carried out with difficulty. The thickness in each case is about 2'6" and most of this, to judge by the nature of the weathering, is made up to limestone.

On Pickering Gill (689,966) the Basal Beds are exposed high in the left bank at the base of dark graptolitic mudstones. The beds are underlain by Ashgill Shales but the grit is cut out by a fault. Most of the 5'7" division is of limestone, only the top 6" being of hard, non-calcareous mudstone. On top of the whole bed is a thin clay. Few fossils were obtained from this locality.

TEXT FIG. 2d

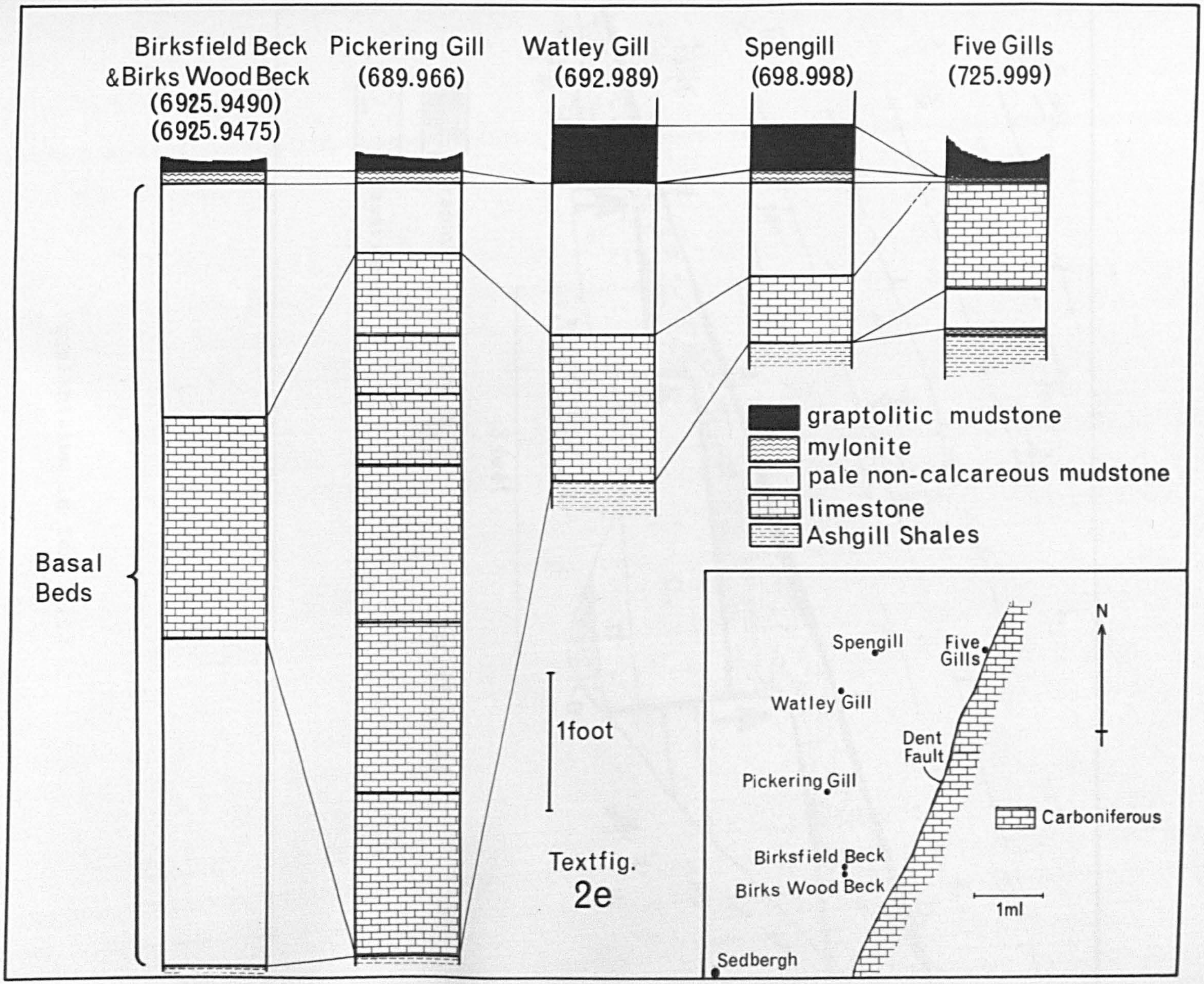
Diagram illustrating the overall variation in thickness of the Basal Beds of the Silurian.


g
Crosshaw Beck
(696.941)
f
Birksfield &
Birks Wood Beck
(6925.9490)
(6925.9475)
e
Pickering Gill
(689.966)
d
Rawthey Br.
Wards Intake
(714.977)
(716.976)
c
Watley Gill
(692.989)
b
Spengill &
Stockless Gill
(698.998)
a
Five Gills
(725.999
BASAL BEDS
1foot
N
a
b
c
d
e
f
g
Carboniferous
1ml
Sedbergh

Textfig.
2d

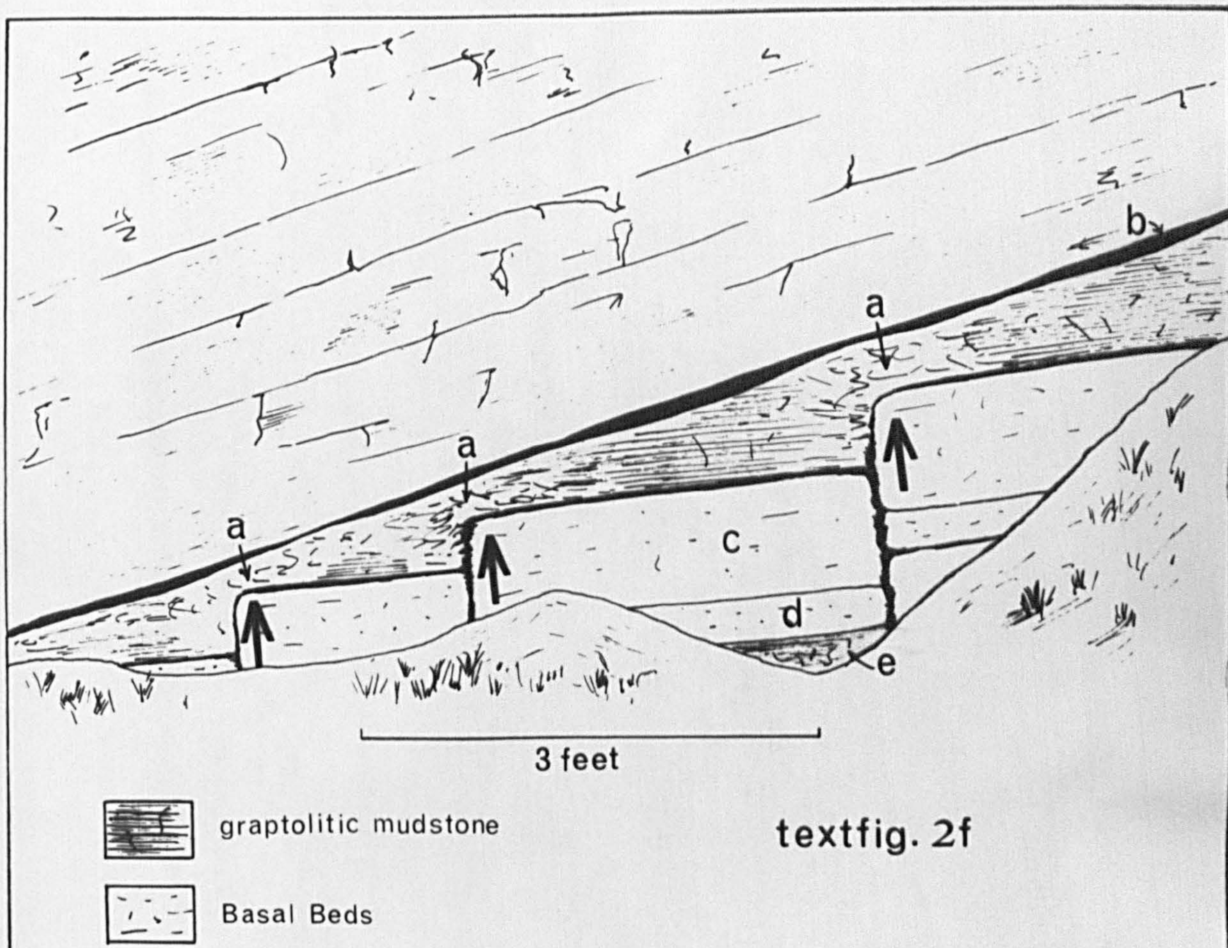
TEXT FIG. 2e

Diagram showing detailed variations of the Basal Beds of the Silurian.



Birksfield Beck
&Birks Wood Beck
(6925.9490)
(6925.9475)
Pickering Gill
(689.966)
Watley Gill
(692.989)
Spengill
(698.998)
Five Gills
(725.999)
Basal
Beds
graptolitic mudstone
mylonite
pale non-calcareous mudstone
limestone
Ashgill Shales
1foot
Spengill
Five
Gills
Watley Gill
Dent
Fault
Pickering Gill
Birksfield Beck
Birks Wood Beck
Sedbergh
N
Carboniferous
1ml

Textfig.
2e



textfig. 2f

explanation in text p.13

The Basal Beds also crop out on Birksfield Beck and Birks Wood Beck and, as in the case of Pickering Gill, are 5'7" thick. Unlike the last locality the lime content is much less and the lowest bed consists of 2'4" of hard, non-calcareous, barren mudstone which often shows mottling. This is followed by 1'7" of pyritous limestone containing the usual fossils but in the case of the Birksfield Beck exposure these are difficult to extract owing to the unweathered nature of the rock. Above the limestone is a 1'8" bed of similar mudstone to the lowest bed. Whilst the Birksfield Beck exposure is easily located since it forms a prominent feature across the stream the Birks Wood Beck locality had to be dug out. Unfortunately the recent lumbering operations alluded to above have reburied the exposure under a large pile of earth and logs and it will be some time before it becomes accessible again.

The final locality of significance is the most southerly exposure on Crosshaw Beck (696,941). This shows a slight diminution in thickness from the last described localities although the top of the beds have not been seen with certainty. A total of five feet were measured and although none of the beds are well exposed (once again a direct result of the lumbering) some at least are calcareous. It is probable that the five feet do in fact represent the full thickness and that the overlying softer mudstones have been weathered back.

The Basal Beds, situated as they are amongst relatively soft mudstones, act in a competent manner and upon folding the bedding planes demarcating the top and bottom tend to suffer bedding plane shear. This is usually represented by a small thickness of mylonite which at the surface weathers to clay. Davies (1929) who studied the faunal changes across the Ordovician-Silurian boundary dismissed the Cautley district as having the fossils in too bad a state of preservation. Wilson (1954) however, identified the <u>A.acuminatus</u> Zone on both Watley Gill and Spengill and recorded the Zone fossil itself. In the former locality the Zone occurs as a 4" band of dark mudstone welded to the top of the Basal Beds but at Spengill a thin clay, indicating some bedding plane movement, separates the two. All the other localities where the Zone might be expected to crop out have it removed by movement parallel to the bedding plane. Marr and Nicholson (1888) list the following fossils from the <u>acuminatus</u> Zone and its supposed equivalents such as the <u>A.flexuosa</u> Band:-
<u>Diplograptus acuminatus</u>, Nich. <u>Climacograptus normalis</u> Lapw. Monticuliporoid? <u>Homalonotus</u>? <u>Atrypa flexuosa</u> n.sp.

Marr's recordings from the Basal Beds of Spengill and Watley Gill have already been mentioned. The present writer has obtained the following fossils from the 4" mudstone:-

Akidograptus a. acuminatus (Nicholson)	A.a.praematurus Davies
Climacograptus normalis Lapworth	Glyptograptus sp.1
Climacograptus miserabilis (Elles & Wood)	Orthograptus vesiculosus Nicholson
Climacograptus medius Tornquist	Diplograptus m.modestus Lapworth
worm tubes.	

Graptolites do not occur in the Basal Beds and the presence or absence of the Glyptograptus persculptus Zone, widely recognized in Wales cannot be proven. It is clear, however, that a faunal change takes place in the Basal Beds from the Ashgill Shales below which contain D.m.mucronata, P.hisingeri and brachiopods. The Basal Beds are typified by D.m.brevispina Temple and brachiopods. Those species of trilobites recorded by Marr (1913 p.11), with the exception of mucronata, have not been found by the present writer but they also indicate a change in fauna. Since brachiopods are both common and occur across the change, the exact age determination of the Basal Beds probably rests with them. The writer's collection of brachiopods is being studied at the present time by Dr.Lamont but unfortunately this work is not yet complete. The base of the Silurian is, for the present at least, drawn at the bottom of the Basal Beds. It is probable that all the strata between this level and the top of the 4" mudstone are equivalent to the division Aa1 described by Marr and Nicholson from various parts of the Lake District. Davies (1929) records A.a.praematurus from a slightly lower level than A.a.acuminatus where as at Cautley the two occur together; the former albeit rarely.

The Lower Llandovery

The zone of A.acuminatus has been considered above and its unfortunately localized geographical extent defined. Overlying this zone are the zones of atavus, acinaces, cyphus and triangulatus which are described below.

The Monograptus atavus Zone

Marr and Nicholson (1888) and Dakyns et al (1891) record about 25' of dark graptolitic mudstone above the Basal Beds of Spengill which they attribute to the zone of Dimorphograptus confertus (Aa2). Both groups of workers give the following faunal list:

Climacograptus normalis, Monograptus revolutus
M.tenuis M.attenuatus
M.sandersoni Dimorphograptus confertus (rare)
D.Swanstoni (abundant) Diplograptus vesiculosus
D.modestus?

The form described as M.tenuis Portlock has since been shown to be M. atavus Jones. M.attenuatus Hopkinson is considered to be synonymous with M. gemmatus Barrande by Elles and Wood but Boucek and Pribyl (1951) consider it synonymous with M.capillaris (Carruthers). No fossils of this type have been found in these beds by the present writer. Dimorphograptus confertus swanstoni does not seem to be "abundant" since no specimens have been obtained and only a single specimensfrom Spengill has been seen in museum collections (Sedgwick Museum). On the other hand D.c.confertus is not uncommon. Bed Aa2 of Marr and Nicholson is 24'4" thick of which the lowest 4" belong to the acuminatus Zone. The fossils recorded by the above authors do not range throughout the 24' unit and the D.confertus Zone has been subdivided by the present author on the faunal changes which take place. The lowest 9' yield a fauna which links the beds with the M.atavus Zone as redefined by Jones (1909), following Lapworth's original usage (1900).

In a low cliff on the right bank of Spengill the acuminatus Zone is followed by five feet of dark grey (N3-N4) rusty-weathering, graptolitic mudstone. The same beds crop out high on the left bank above poorly exposed Basal Beds. In both exposures the mudstones are thinly bedded, cleaved into small subquadrangular fragments, but quite hard. The following fossils have been obtained:-

Climacograptus miserabilis (Elles & Wood) C.rectangularis (M'Coy)
Climacograptus normalis Lapworth C.aff minutus Carruthers
Climacograptus medius Tornquist
Diplograptus modestus diminutus Elles & Wood
Diplograptus modestus tenuis subsp. nov.
Orthograptus vesiculosus Nicholson
Dimorphograptus c.confertus (Nicholson) Rhaphidograptus toernquisti (Elles and Wood)
Monograptus atavus Jones.

Above this are four feet of similar beds, again represented in both banks, yielding all the above species with the exception of D.modestus tenius. In addition there are two further dimorphograptids: Dimorphograptus erectus nicholsoni subsp. nov. and D.epilongissimus sp. nov. The whole fauna of the nine feet of strata is very similar to that which Jones (1909) used to define the atavus Zone at Pont Erwyd and differs only in the lack of D.cf.extenuatus Elles & Wood, and in the presence of some new forms. The atavus Zone of Spengill may be contrasted with the underlying A.acuminatus Zone in the absence of the latter fossil and in the presence of M.atavus and D.confertus.

Confirmatory Sections: The Watley Gill section shows 15' of beds above the acuminatus Zone before a fault (represented by a crush zone) brings down higher strata. The lower beds are exposed in the left bank forming a low cliff and again, but less completely, in the right bank. Lithologically the strata are identical to those of Spengill and are similarly cleaved. From the lowest foot (2Wa) above the acuminatus Zone the following assemblage was collected:-

Climacograptus miserabilis Elles & Wood

Climacograptus medius Tornquist

Climacograptus normalis Lapworth

Climacograptus i.innotatus Nicholson

M.atavus Jones

The locality is important in showing that M.atavus appears very quickly after the onset of the graptolitic mudstone conditions, and in recording the presence of C.innotatus. Above locality 2Wa collection was made from 4' of similar beds (3Wa) which yielded the following:-

O.vesiculosus (Nicholson)

C.miserabilis (Elles & Wood)

C.medius Tornquist

M.atavus Jones

C.rectangularis (M'Coy)

C.normalis Lapworth

D.modestus diminutus (Elles & Wood)

The strata between this level and the above-mentioned fault (10 feet, 4 Wa) do not yield good fossils readily since the rock is cleaved into very small pieces. O.vesiculosus was not found, but in addition to the other species recorded from 3Wa D.e.nicholsoni and R.toernquisti were collected. All the fossils were obtained from the uppermost 6' of the 10' of beds. The fauna of 2-4Wa is typical of the atavus Zone and it is of interest that the

Zone is 6' thicker at this locality than on Spengill which is rather less than one mile to the NE.

The fact that the Birks Wood Beck section is obscured in the region of the Basal Beds has already been mentioned. As a result the lowest 4' of strata overlying the Basal could not be collected. Immediately above, however, are five feet of dark grey mudstones rather poorly exposed in the left bank (1Bi) but yielding numerous well preserved graptolites. The following were obtained:-

C.miserabilis (Elles & Wood)	?Diplograptus rarus sp. nov.
C.normalis Lapworth	?Diplograptus sp. A
C.rectangularis (M'Coy)	Orthograptus vesiculosus Nicholson
C.aff minutus Carruthers	D.erectus nicholsoni subsp. nov.
C.innotatus exquisitus subsp. nov.	R.toernquisti (Elles & Wood)
D.modestus diminutus Elles & Wood	M.atavus Jones

The presence of D.e.nicholsoni suggests that 1Bi is at the top of the atavus Zone. C.innotatus exquisitus, ?D.rarus, and ?D. sp. A have not been recorded from the Spengill and Watley Gill sections. A further 2' of beds are exposed (2Bi) before the section is obscured again and these are thought to represent the base of the succeeding Zone (see p. 19). Therefore, on Birks Beck there is a similar thickness of deposits in the atavus Zone as on Spengill.

The following sections have yielded typical atavus Zone assemblages immediately above the Basal Bed but with the fossils less well preserved:- Five Gills (faulted after 14' of mudstone); Birksfield Beck. Other less complete sections and exposures are described in the chapter dealing with the map (p. 71 et. seq.).

The Pristiograptus acinaces Zone

This zone is the least well defined of the Lower Llandovery Zones and is probably rather thinner than the atavus and cyphus Zones which occur respectively below and above it. Some of the characters of the previous zone are retained, particularly in the lower beds, whilst the first appearance of monograptids other than atavus is typical.

Downstream of 1Bi on Birks Wood Beck (which yields an atavus Zone fauna) are two feet of dark mudstone exposed in the left bank of the stream (2Bi). Fossils are well preserved, abundant and the following were collected:-

C.normalis Lapworth	?Diplograptus rarus sp. nov.
C.miserabilis (Elles & Wood)	?Diplograptus sp. A
C.aff medius Tornquist	Dimorphograptus e. nicholsoni subsp. nov.
C.rectangularis (M'Coy)	Monograptus atavus Jones
C.aff minutus Carruthers	Climacograptus psuedonormalis sp. nov.
D.m.diminutus Elles and Wood	Glyptograptus tamariscus Nicholson s.l.

All these species except the last two were recorded from the preceding zone but the presence of G.tamariscus s.l. must be regarded as indicative of a higher level. Monograptids other than atavus have not yet appeared, however, in these lowest two feet.

On Spengill where collection was made from the lowest four feet of the Zone (S9-13) the following fauna was obtained:-

C.normalis Lapworth	R.toernquisti (Elles & Wood)
C.miserabilis (Elles & Wood)	M.atavus Jones
C.medius Tornquist	G.tamariscus Nicholson s.l.
C.rectangularis (M'Coy)	Pristiograptus cyphus Lapworth
C.aff. minutus Carruthers	P. aff acinaces Tornquist
O.vesiculosus (Nicholson)	P.incommodus Tornquist

This assemblage is similar to that of 2Bi but differs in having other monograptids. A single proximal end of P.cyphus has been obtained and the forms listed as P.aff acinaces are always flattened thus making identification difficult. However, the presence of these forms and G.tamariscus s.l. is indicative of the P.acinaces Zone. Locality S9-13 is best exposed in the steep right bank immediately above the atavus Zone. The same strata are only poorly exposed in the left bank.

Upstream of the poor left bank exposures are good exposures of S13-17 cropping out as a small spur which deflects the stream some yards to the west. Unlike the lower strata these beds are not so closely cleaved and clearly illustrate the true nature of the hard mudstones. The word "shale" (as in "Skelgill Shales") is an inadequate descriptive term. Fossils are fairly well preserved and the following collection was made:-

C.miserabilis (Elles & Wood)	D.epilongissimus sp. nov.
C.normalis Lapworth	M.atavus Jones *

C.rectangularis (M'Coy)
C.medius Tornquist
O.vesiculosus (Nicholson)
R.toernquisti (Elles & Wood)
D.c.confertus Nicholson
D.e.nicholsoni mut *
M.incommodus Tornquist
P.aff. acinaces Tornquist (common)
P.concinnus Lapworth
P.gregarius Lapworth
P.cyphus Lapworth (abundant)
M.revolutus Kurck s.l.

Whilst many of these species occur in lower strata some (marked with an asterisk) have shown slight changes which are dealt with in the systematic descriptions. The presence in abundance of P.cyphus taken together with the occurrence of P.gregarius, and M.revolutus suggests that the 3' bed from which collection was made contains a mixture of acinaces and cyphus Zone forms and the boundary between the two cannot, therefore, be placed more accurately. On Spengill the acinaces Zone is between 4' and 7' thick.

The acinaces Zone was defined by Jones (1909) at Pont Erwyd and whilst the Cautley Zone has a very similar fauna it differs in its lack of C.hughesi and O.mutabilis. It is possible that the C.hughesi of Pont Erwyd is replaced at Cautley by the form described here as C.aff minutus. The two may be very close but so far no specimens of the latter have been obtained in relief.

The Pristiograptus cyphus Zone

Above the acinaces Zone of Spengill are 7' of strata (S17-20 & S20-24) identical in lithology to the beds below and rather better exposed high in the right bank than in the scree slopes of the left. From S17-20 the following assemblage was obtained:-

C.miserabilis (Elles & Wood)
C.normalis Lapworth
C.aff. minutus Carruthers
C.rectangularis (M'Coy)
C.medius Tornquist
O.vesiculosus (Nicholson)?
M.incommodus Tornquist
P.aff. acinaces Tornquist
P.cyphus Lapworth
R.toernquisti (Elles & Wood)

The species listed in the left hand column are now far less common than in earlier beds and C.normalis, the most abundant of these, is represented by only seven specimens. C.miserabilis and O.vesiculosus are not found above this level. P.cyphus is quite common but there is a temporary absence of

P.gregarius and M.revolutus which occur in S13-17. Locality S20-24 has yielded:-

C.normalis Lapworth	M.incommodus Tornquist
C.rectangularis (M'Coy)	D.c.confertus Nicholson*
C.medius Tornquist *	D.epilongissimus sp. nov. *
R.toernquisti (Elles & Wood)	D.erectus erectus Elles & Wood*
G.tamariscus Nicholson s.l.	M.t.triangulatus (Harkness)

Those species marked with an asterisk do not survive into the succeeding Zone. The single specimen of M.t.triangulatus was obtained in the top few inches of S20-24 and it is probable that these beds should be included in the succeeding Zone. Further collecting at more closely spaced intervals will be necessary to determine this.

The cyphus Zone was first used by H.Lapworth (1900) but redefined at Pont Erwyd by Jones (1909). At Cautley C.hughesi, O.mutabilis, O.v.cf. penna have not been obtained but common presence of P.cyphus and the appearance in S13-17 of P.gregarius and M.revolutus illustrates the equivalence in age between the two localities. In view of the fact that P.aff. acinaces is recorded from S17-20 it is interesting to note that Jones (op. cit. table 2) records the presence of M. ?rheidolensis (= P.acinaces) in his cyphus Zone.

Zone of M.triangulatus

Marr and Nicholson (1888 p.701) thought it probable that their fimbriatus shales of Spengill followed the Dimorphograptus Beds quite normally and that the two groups were not fault bounded. The succession is now completely exposed, though poorly on the junction and the interpretation of the above authors' can be seen to be correct. They also note (op. cit. p.702) that a crush zone divides the fimbriatus shales from the higher beds upstream (sedgwicki Zone) and that the top is, therefore, not seen. This is also true, and, what is more important, the top of the "fimbriatus" shales has not been seen with certainty anywhere in the Cautley district that has so far been examined in detail. The thickness of strata at this horizon as seen on Spengill is not given but Marr and Nicholson record the following species:-

M.fimbriatus Nich., M.gregarius Lapw., M.attenuatus Hopk., M.triangulatus Harkness, Rastrites peregrinus Barr., Diplograptus sinuatus Nich., Climacograptus normalis Lapw..

Between the cyphus Zone and the fault upstream there are 16'4" of very dark graptolitic mudstones followed by 10'7" (minimum) of non-graptolitic mudstones. The latter were clearly not exposed in the past but are now well exposed high in the right bank where continuous succession can be traced down to the graptolitic beds below. The non-graptolitic mudstones closely resemble the finer Ashgill Shales mudstones in many respects (see p. 88) and represent the first major intercalation of non-graptolitic rock in the succession. This is also the case on Skelgill (Marr and Nicholson 1888 p.661, fig.1) but at Pont Erwyd the graptolitic mudstone occurs as relatively thin bands in unfossiliferous mudstones (see for example Sudbury 1958, p.448, fig.1)

The 16'4" division of graptolitic mudstone has been divided into approximately 4' units and collection made from these. Of these beds the lowest (S24-28) are the most fossiliferous and these yielded the following species:-

C.normalis Lapworth	M.atavus Jones
C.aff. minutus Carruthers	M.incommodus Tornquist
C.rectangularis (M'Coy)	M.sandersoni Lapworth
G.tamariscus (Nicholson)s.l.	P.gregarius Lapworth
G.sinuatus (Nicholson)	M.revolutus Kurck s.l.
Petalograptus sp.	M.t.triangulatus (Harkness)
Petalograptus minor Elles	Rastrites longispinus Perner
R.toernquisti (Elles & Wood)	Rastrites spina Richter

Whilst containing elements of the cyphus Zone the incoming of several new forms clearly distinguishes the two Zones. Of particular importance is the presence of the first species of Rastrites and Petalograptus which do not occur in the lower beds. The recording of M.t.triangulatus slightly below this level has already been mentioned and it is certain that detailed collection across this junction will show that this species precedes R.longispinus thus confirming the order of appearance maintained by Sudbury (1958) at Pont Erwyd.

The overlying divisions of S28-32 and S32-36, whilst being less fossiliferous generally, contain the same species and see the first appearance of several others. Thus C.hughesi and C.extremus were found in S28-32 and above, whilst D.magnus occurs in S32-36. In the succeeding units (S36-39,7 and S39,7-S40,4) several more species are found for the first time: O.cyperoides, P.ovatoelongatus, Petalograptus sp. M.limatulus.

Above the graptolitic mudstones the 10'7" unit contains only a sparse and stunted fauna of small brachiopods and trilobites.

On Watley Gill three feet of the triangulatus Zone (5Wa) is contained between two faults. Downstream of one fault is the atavus Zone (described above p.17) and upstream of the other are Middle Llandovery Beds. The locality 5Wa gave the following assemblage:-

P.gregarius Lapworth	G.sinuatus (Nicholson)
R.toernquisti (Elles and Wood)	G.t.tamariscus (Nicholson)
C.hughesi (Nicholson)	M.triangulatus separatus (Sudbury)
O.cyperoides (Tornquist)	G.tamariscus aff. linearis (Perner)
M.aff. argutus Lapworth	

The presence of M.t.separatus suggests that the beds are pre-magnus Zone in age and the fauna as a whole is typical of the triangulatus Zone.

Two important considerations result from the above description. Firstly in none of the sections examined at Cautley, is the Lower Llandovery-Middle Llandovery boundary exposed, and the full characters of the triangulatus Zone cannot yet be determined. Evidence is adduced below to show that the magnus Zone is present on the Birks Beck section. The second point is that the highest known graptolitic beds of the triangulatus Zone on Spengill cannot be regarded as exhausted from the point of view of collecting. Fossils are not readily obtained from the small, cleaved fragments of rock and it is particularly difficult to obtain well preserved specimens. However, some of those which have been obtained e.g. M.limatulus and D.magnus are suggestive of higher horizons, and it is not impossible that the magnus Zone is incorporated in the top of the "fimbriatus" beds.

The triangulatus Zone was fully defined by Jones and Pugh (1935) after an earlier less clear definition by Jones and Pugh (1916). Many of the forms listed by these authors have already been found but notably absent are M.communis and M.fimbriatus both of which occur at a higher level (see below). The latter species is recorded from Spengill by Sudbury (1958) but only doubtful fragments have been obtained from there by the present writer. The species probably occurs in the higher beds of the triangulatus Zone on Spengill since it certainly seems to be absent from S24-28.

The Wards Intake Section (716,976)

Mention of the Wards Intake and Pickering Gill Section has been withheld until this point since both show some differences from the succession outlined above. The Basal Beds of Wards Intake have already been described. They are overlain in the right bank by dark graptolitic mudstones which are continuously exposed either beneath the water or low down in the bank. The succession is apparently quite uninterrupted by faults and reaches a thickness of 57' in which there are no intercalations of non-graptolitic mudstone. On Spengill 40'4" of graptolitic mudstones are exposed prior to the first bed of non-graptolitic mudstone. Thickness changes have already been noted in the case of the atavus Zone which is thicker on Watley Gill than on Spengill so that the thickness of 57' is not, in itself, abnormal. The faunal content, however, indicates a relatively low horizon.

The most unfortunate feature of the section is the difficulty of obtaining fossils mainly because of the hardness and problem of splitting the rock parallel to the bedding plane. The hardness is almost certainly a result of baking by the Bluecaster diabase sill which crops out slightly upstream where it is intruded at a slightly higher horizon.

In spite of the difficulty graptolites have been collected. A 3' bed (15Wi) between 26' and 29' above the top of the Basal Beds yielded: C.miserabilis, C. ?normalis, Dimorphograptus sp., M. ?atavus. On Spengill the last occurrence of miserabilis is 20' above the base. At a point between 38' and 40' above the Basal Beds (14Wi) the following assemblage was obtained:- M.atavus, C.ex. gr. rectangularis, M. ?incommodus, Locality 11Wi (46'-48' above the Basal Beds) yielded M.aff. incommodus, C.normalis, C. ?rectangularis and C. ?medius, whilst immediately above this horizon C. ?rectangularis, C.?medius, R.toernquisti, Monograptus spp. and G.tamariscus s.l. were collected from 6' of strata (13Wi). The highest level at which fossils were obtained (12Wi) is between 54' and 57' above the top of the Basal Beds. Fossils were rather better preserved here and the following species obtained:-

R.toernquisti (Elles & Wood)	P.cyphus Lapworth
G.tamariscus (Nicholson)	C. ?medius Tornquist
C. aff. minutus Carruthers	C. ?rectangularis (M'Coy)
M.incommodus Tornquist	?O. vesiculosus (Nicholson)

The whole fauna is indicative of a pre-triangulatus Zone age, and the full 57' is assigned to the atavus to cyphus zones. The incoming of M.incommodus and G.tamariscus and finally of P.cyphus shows that the changes in the "Dimorphograptus Beds" observed in other sections will also operate in this case.

Pickering Gill Section (689, 966)

This section is similar to that of Wards Intake in that a considerable thickness (approximately 60') of dark mudstone is seen above the Basal Beds. The locality has yielded fossils even less readily than the previous section but the following were obtained (figures are in feet above the top of the Basal Beds):-

60'	R.toernquisti (Elles & Wood)	Glyptograptus sp.
53'	O.vesiculosus (Nicholson)	R.toernquisti (Elles & Wood)
	G.t.tamariscus (Nicholson)	C. ? medius Tornquist
	G.cuneatus sp. nov.	O. attenuata sp. nov.
	G.tamariscus ?subsp.	C. ? tangshanensis linearis Packham
	P. acinaces Tornquist	P. ? cyphus Lapworth
48'	M. aff. incommodus Tornquist	
36'	C. miserabilis (Elles & Wood)	C. aff. medius Tornquist

As in the case of Wards Intake these beds clearly represent a thickened pre-triangulatus Zone succession.

Conclusions:

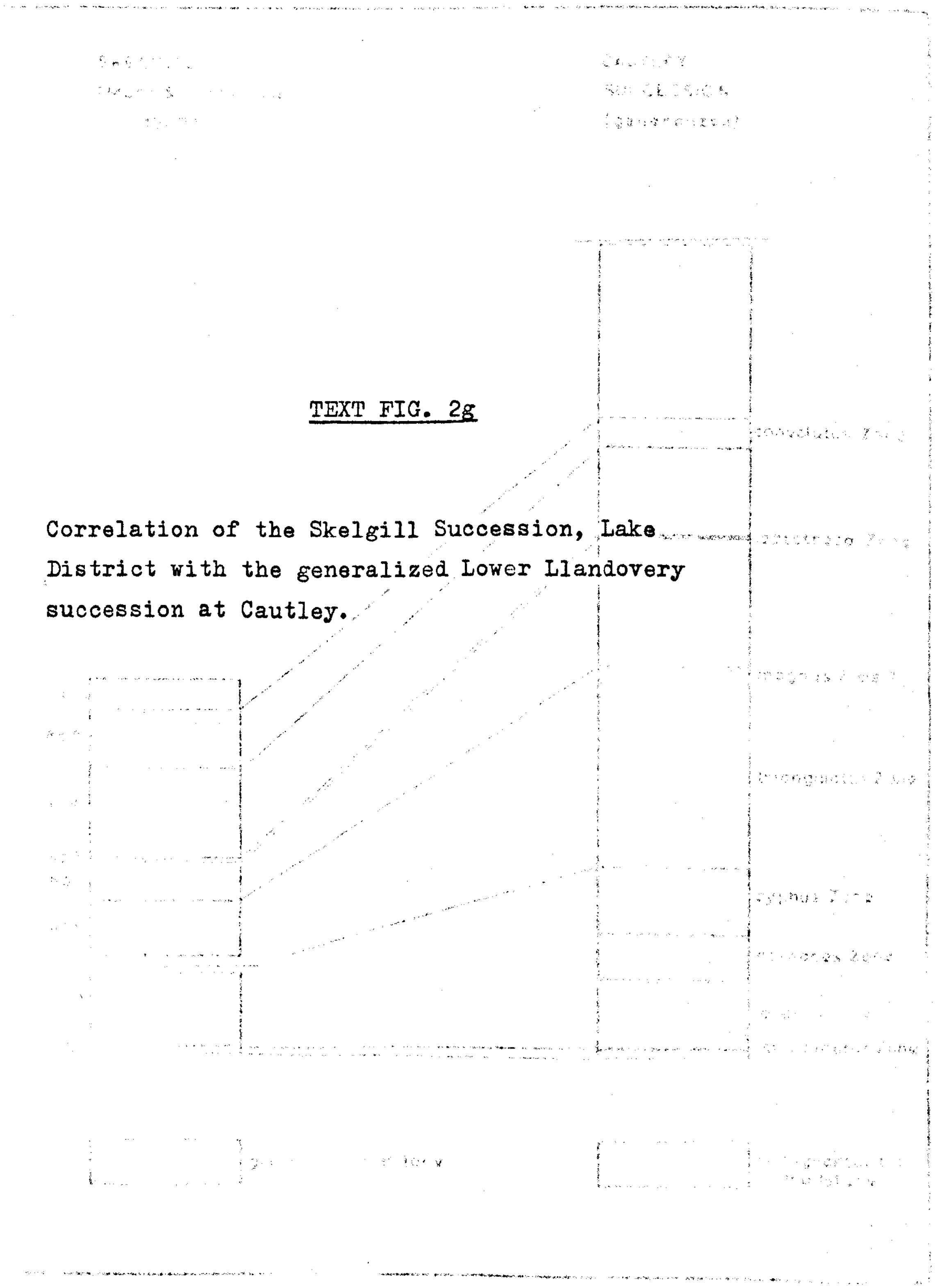
a) The Dimorphograptus Beds of Marr and Nicholson can be subdivided into three zones (atavus, acinaces, and cyphus) which are at least approximately equivalent to a similar zonal sequence established in Wales (The correlation throughout the Cautley area, and of the Cautley area with other regions is summarized in text figs. 2g and 2m).

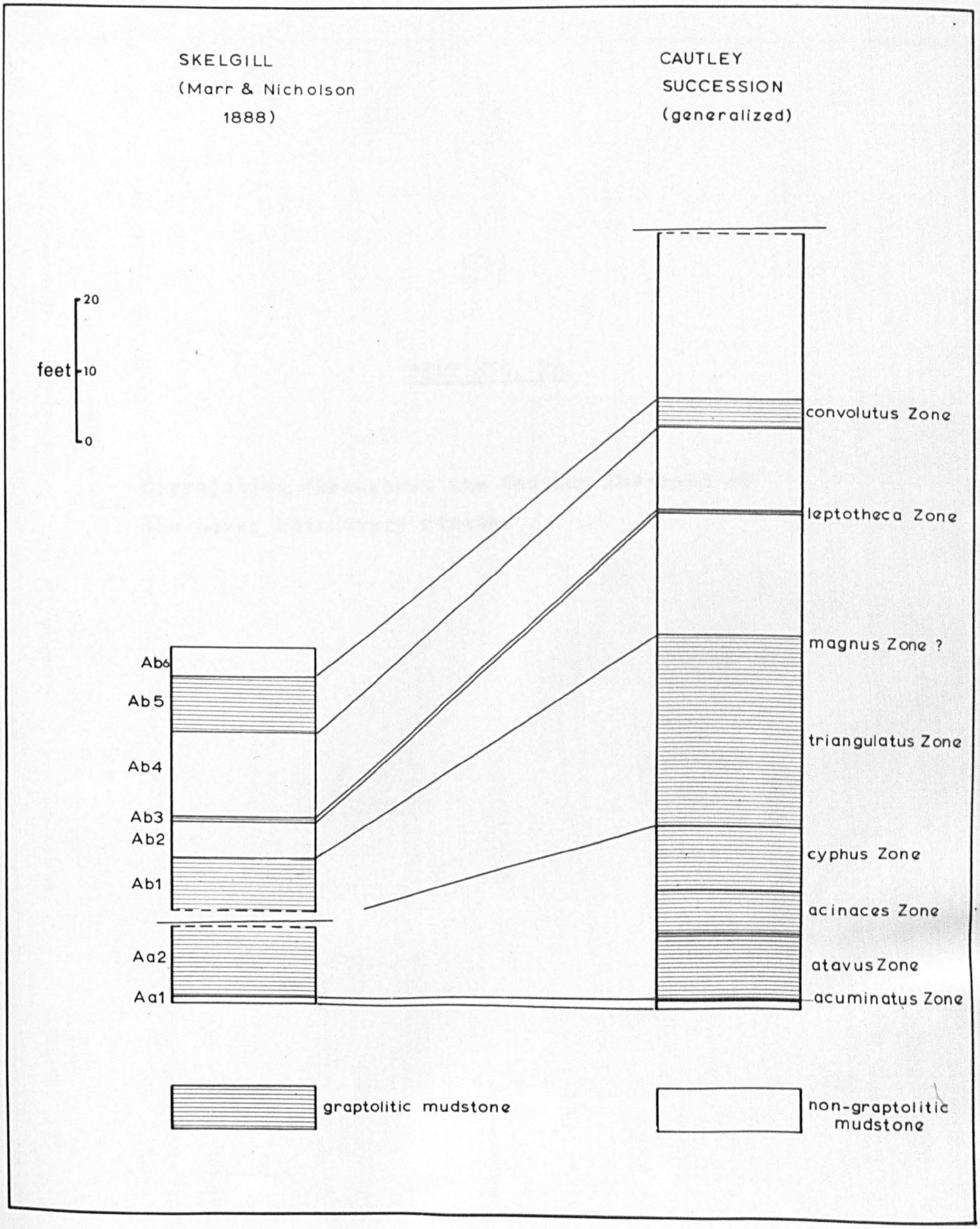
b) The atavus Zone. M. atavus appears within a foot of the base, and the zone is broadly divisible into a lower, portion with a typical assemblage, and an upper part which sees the appearance of D.erectus nicholsoni, D. epilongissimus, ?Diplograptus rarus, C.i.exquisitus, and ?Diplograptus sp. A. All except the last of these persists into higher strata.

c) The acinaces Zone is also divisible into lower and upper portions. The lower part has strong affinities with the preceding Zone but is identified by the presence of G.tamariscus whilst the upper part sees the appearance of monograptids other than atavus. Other species which first appear in the atavus Zone have shown slight changes by the time the upper part of the acin-

TEXT FIG. 2g

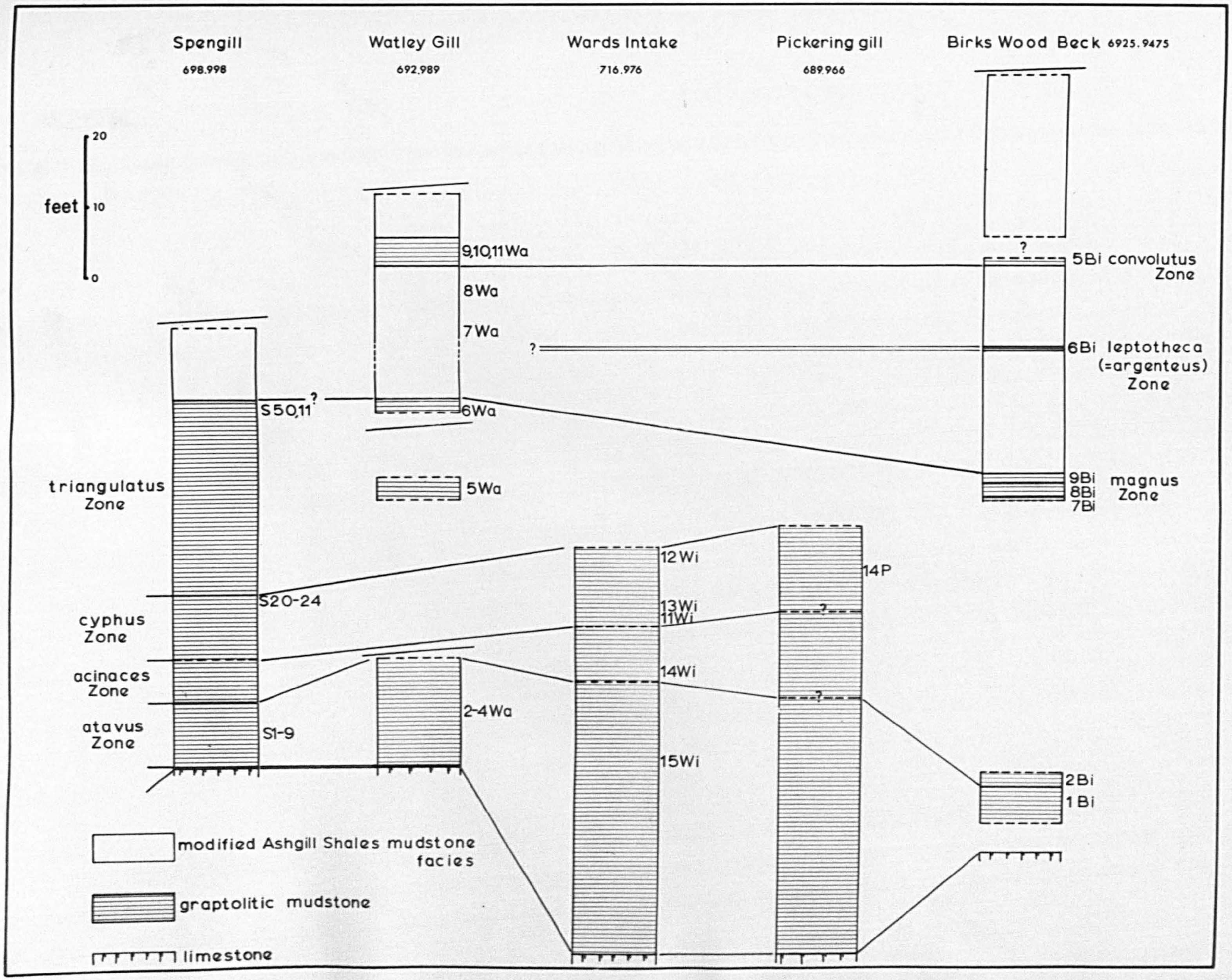
Correlation of the Skelgill Succession, Lake District with the generalized Lower Llandovery succession at Cautley.




SKELGILL
(Marr & Nicholson
1888)
CAUTLEY
SUCCESSION
(generalized)
feet
20
10
0
Ab6
Ab5
Ab4
Ab3
Ab2
Ab1
Aa2
Aa1
convolutus Zone
leptotheca Zone
magnus Zone ?
triangulatus Zone
cyphus Zone
acinaces Zone
atavus Zone
acuminatus Zone
graptolitic mudstone
non-graptolitic mudstone

TEXT FIG. 2m

Correlation throughout the Cautley District of the Lower Llandovery strata.



Spengill
698.998
Watley Gill
692.989
Wards Intake
716.976
Pickering gill
689.966
Birks Wood Beck 6925.9475
feet
20
10
0
9,10,11Wa
8Wa
7Wa
6Wa
5Wa
2-4Wa
5Bi convolutus Zone
6Bi leptotheca (=argenteus) Zone
9Bi
8Bi
7Bi
magnus Zone
2Bi
1Bi
S50,11
S20-24
S1-9
triangulatus Zone
cyphus Zone
acinaces Zone
atavus Zone
12Wi
13Wi
11Wi
14Wi
15Wi
14P
modified Ashgill Shales mudstone facies
graptolitic mudstone
limestone

aces Zone is reached.

d) The cyphus Zone is fairly uniform but is distinguished from the acinaces Zone by the appearance of P.cyphus in abundance and by the presence of P. gregarius and M.revolutus s.l.

e) The Zones of atavus, acinaces and cyphus thicken from 24' on Spengill to at least 57' on a line from Wards Intake to Pickering Gill. South of this line, on Birks Beck, the atavus Zone is demonstrably of the same thickness as on Spengill and it is possible that the ENE-WSW line is one upon which greater deposition of graptolitic muds took place. It is approximately along this line that Wilson (1954) deduced an axis of non-deposition during part of the U.Llandovery.

f) The top of the triangulatus Zone, and hence of the Lower Llandovery, cannot be demonstrated on the information known at present, unless locality 7Bi (see below p. 26) represents this topmost bed.

The Middle Llandovery

It will be demonstrated below that the beds above the convolutus Zone are always faulted so that the upper boundary of the Middle Llandovery cannot be defined. The argenteus and convolutus Zones were identified on Watley Gill by Marr (1913 p.11) but a more complete section is seen on Birks Wood Beck.

The last locality described from Birks Wood Beck was 2Bi which yielded fossils indicating the base of the acinaces Zone. Downstream of 2Bi the strata are obscured for about 50' and the beds at both ends of this unexposed part dip downstream at 46°. There is room for approximately 38' of beds between 2Bi and the next exposure (7Bi). The localities of 7Bi, 8Bi, and 9Bi (the last being the youngest) consist of 4' of black graptolitic mudstone made up of three beds which are respectively 6", 2', and 1'6" thick.

The assemblages are as follows:-

	A	B	C
7Bi	M.t.separatus	R.toernquisti	P. minor
		P.gregarius	
		G.incertus	
		R. aff. longispinus	
8Bi		G.incertus	P.gregarius

	A	B	C
9Bi	G. ?enodis latus	R. longispinus	P. gregarius
	M. fragilis	C. hughesi	D. magnus
		G. tamariscus	P. ovatoelongatus
		M. aff. argutus	M. pseudoplanus
		G. sinuatus	M.t. fimbriatus
		P. leptotheca	
		R. toernquisti	
		C. extremus	
		M. aff. intermedius	

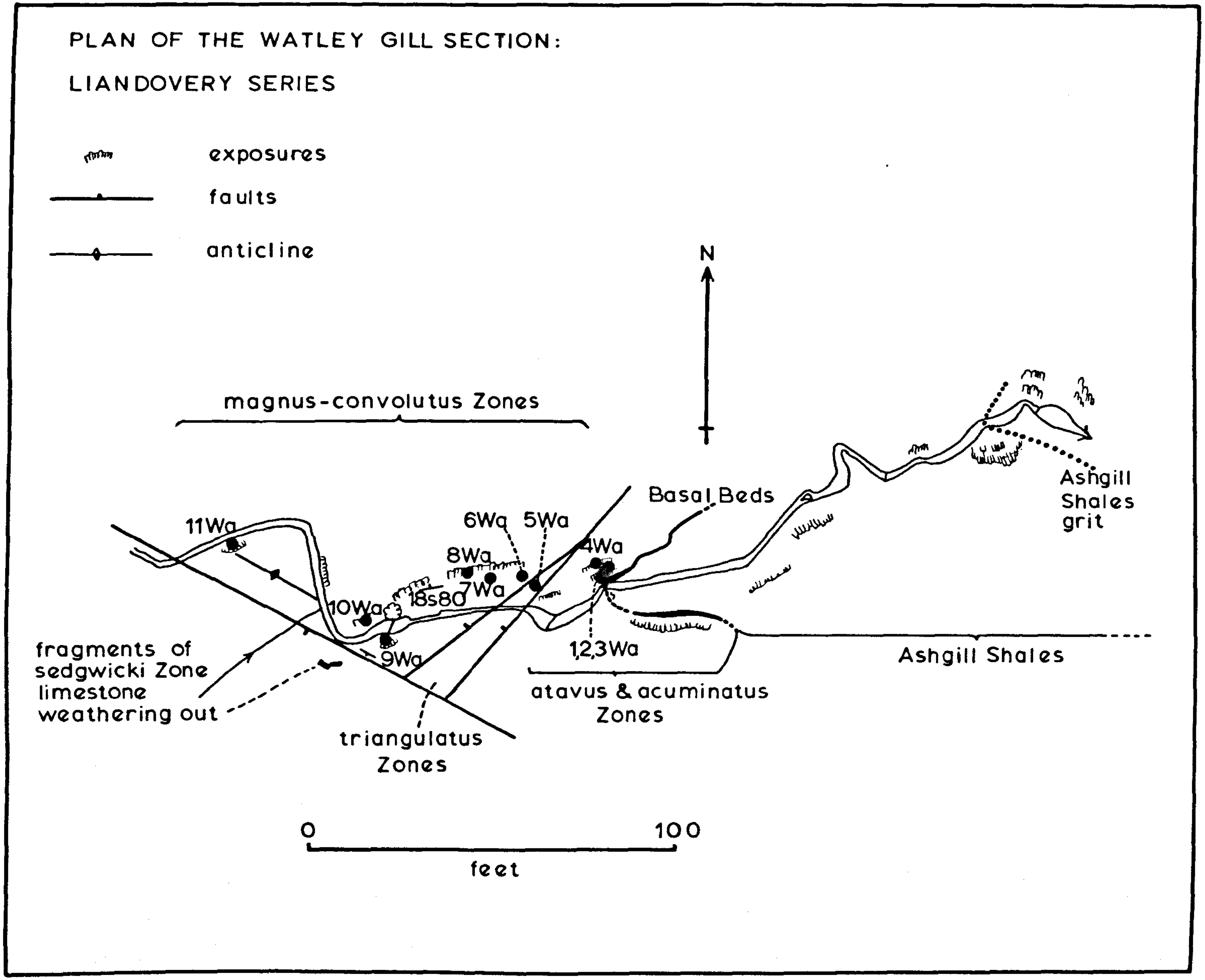
Those species contained in the right hand column are those which were recorded by Sudbury (1958) from the D. magnus band of Pont Erwyd, whilst species in column B are those which range both below and above the magnus Zone. Column A contains only pre-magnus species and new forms. Considering the doubt about G. ?enodis latus localities 8Bi and 9Bi are indicative of at least approximate equivalence with the magnus Zone. Locality 7Bi on the other hand contains M.t.separatus which Sudbury (1958) did not record above horizon C of the Rheidol Gorge. If the species is restricted to pre-magnus Zone beds then the magnus Zone follows immediately upon the triangulatus Zone in this district. Further collecting will be needed to settle this question.

On Watley Gill the presence of a fault-bounded exposure of the triangulatus Zone (5Wa) has already been described. Immediately upstream of 5Wa, on the left bank, are 2' of rather stripy mudstones (6Wa, V. text fig. 2h) which yielded the following assemblage:-

C. rectangularis (M'Coy)
G. tamariscus (Nicholson) s.l.
? Glyptograptus sp. A
C. extremus H.Lapworth
R. toernquisti (Elles & Wood)
M. communis rostratus Elles & Wood
M.t.fimbriatus (Nicholson)
M. aff. argutus Lapworth

This fauna is not diagnostic of a particular level but in view of the succession above is probably equivalent to the magnus Zone of Birks Wood Beck.

Above 6Wa are 22' of non-graptolitic mudstones yielding small brachiopods (7Wa) and above this trilobites such as Phacops glaber (8Wa). It is



PLAN OF THE WATLEY GILL SECTION:
LIANDOVERY SERIES
exposures
faults
anticline
N
magnus-convolutus Zones
11Wa
6Wa
5Wa
8Wa
4Wa
7Wa
18s80
10Wa
9Wa
1,2,3Wa
Basal Beds
Ashgill Shales grit
Ashgill Shales
fragments of sedgwicki Zone limestone weathering out
triangulatus Zones
atavus & acuminatus Zones
0
100
feet

TEXT FIG. 2h

almost certainly from this division that Marr (1913 p.11) recorded his argenteus Zone defined by the following assemblage:- M. argenteus, M.leptotheca M. convolutus, M. nicoli, M. limatulus, M. communis, M. gregarius, R. hybridus, C. hughesi, D. sinuatus, D. bellulus.

This locality is not visible at the present time owing to a considerable amount of scree but immediately above its probable position Phacops glaber can be obtained from calcareous nodules in the non-graptolitic mudstone, and, upstream, at the top of a 9' waterfall are graptolitic mudstones from which a convolutus Zone assemblage can be obtained:-

10Wa	9Wa	11Wa
C. extremus	C. extremus	C. extremus
C. hughesi	C. hughesi	C. hughesi
C. ex. gr. scalaris	C. ex. gr. normalis	C.ex.gr. scalaris
M. convolutus	C. rectangularis	C.ex.gr. normalis
M. denticulatus	G.t.linearis	G.t.tamariscus aff. form B
M. limatulus	O. cyperoides	O. insectiformis
R. spina	O. bellulus	O. bellulus
	P. leptotheca	P. leptotheca
	M. limatulus	M. decipiens
	M. lobiferus	M. lobiferus
	M. aff. involutus	M. argutus
	M. ex. gr. sandersoni	M. ?convolutus
	M. communis	
	M. argutus	
	M. decipiens	
	M. regularis	
	M. cf. concinnus	
	R. fugax	
	R. spina	

Upstream of these localities are 6' of non-graptolitic mudstone (seen in left bank only). A fault crosses the stream and is detected near the top of the waterfall by the presence of a crush zone. The displacement seems to bring in the sedgwicki Zone since limestone blocks identical to the limestone seen in this zone on Spengill can be seen weathering out of the right bank.

Marr (1913) mentions that this fault brings up Dimorphograptus Beds again but the writer can find no evidence for this.

Returning to the Birks Wood Beck section it is seen that above the magnus Zone are 17' of non-graptolitic mudstones followed by a 6" graptolitic band from which the following species were obtained:-
M. aff argenteus, M. argenteus cygneus, P. gregarius, M. revolutus s.l., M. argutus, M.lobiferus, M.denticulatus, M.aff undulatus, P.leptotheca, M.communis, M.c.rostratus, M.aff convolutus, P.concinnus, O.bellulus, G.t.aff varians, G.t.angulatus, G.t.tamariscus, G.t. tamariscus aff form B, P. minor finitimus, gastropod.

This fauna is indicative of the argenteus Zone as defined by Marr (= leptotheca Zone as defined by Jones and Pugh 1916). It is in a similar position to the argenteus Zone of Watley Gill (Marr 1913 p.11). Overlying the 6" bed are 11'6" of non-graptolitic mudstone followed by 1' (seen) of dark graptolitic rock which is poorly exposed in the right bank just above stream level. The following species, indicating correlation with the convolutus Zone of Watley Gill, were obtained:-
C.extremus, C.hughesi, C.ex. gr. scalaris, O.bellulus, M.denticulatus, M. ?convolutus, P.leptotheca, M.lobiferus, Rastrites sp.

This bed is overlain by 18-23' of non-graptolitic mudstone before a fault brings down U. Llandovery mudstones.

Conclusions:

a) The highest strata of the Middle Llandovery seen in the area are the non-graptolitic mudstones immediately above the convolutus Zone. These reach a thickness of 18'-23' on Birks Wood Beck but, as on Watley Gill, they are fault bounded at the top and the sequence into higher strata cannot be observed.

b) The magnus Zone is shown to exist below the argenteus (= leptotheca) Zone and this might possibly be incorporated in the top of the fimbriatus beds.

c) The general succession of magnus, argenteus and convolutus Zones is in accord with work done in Wales and with Marr and Nicholson's work in the Lake District though the number of species now known exceeds those recorded by the above authors, and particularly those listed for the Cautley district.

The Upper Llandovery

These beds were studied in great detail by Wilson (1954) who recognized and delimited the following Zones : sedgwicki, maximus, turriculatus, crispus, and griestonensis. It was shown that considerable variations in thickness occurred over the region and that the "red" mudstones thinned out on an approximately NE-SW axis. Some of the graptolites of the higher beds (crispus and griestonensis Zones) were described. The present writer has only examined the Spengill section in detail since it shows the sequence of faunas and lithological types almost uninterrupted by dislocation and provides a useful basis both for description of the faunal content of the higher beds and for mapping throughout the region. The lithological sequence, the faunas, and the plan of Spengill are shown respectively in text figs.i, j, k, and l , and need little in the way of explanation. In the systematic descriptions below only those species not dealt with by Wilson are described and in text fig. 2k species recorded by the above author from the crispus and griestonensis Zones are omitted.

On text fig. 2i those graptolitic bands marked with an asterisk are probably new bands but only one of these (S140,11) has zonal significance. This band yielded a specimen of Rastrites maximus and strata up to this level ought, therefore, to be included in the subzone of R.maximus. In addition to this species the following were obtained:-

C.extremus, P.obesus, Pristiograptus regularis, M.marri, M? runcinatus pseudopertinax subsp. nov., M.turriculatus, M.planus, M.halli, R.linnaei.

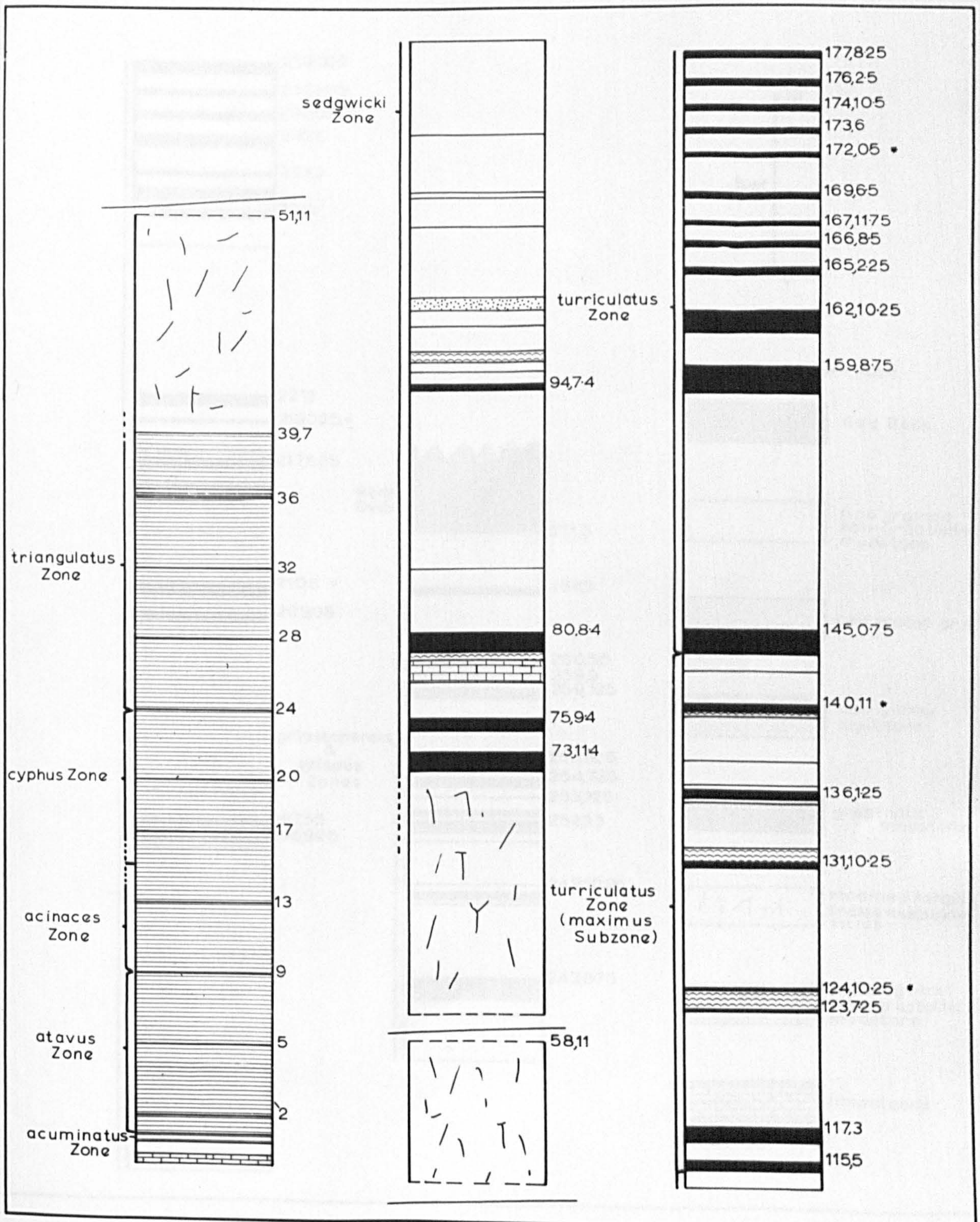
The thickness of the maximus Subzone is 25'9¼".

Intruded near the top of the turriculatus Zone is a felsite sill. Its upper boundary can be traced for some distance and is quite concordant with the bedding, occurring always beneath two prominent mudstone bands which underlie a 7¼" ash. Traced downstream on the right bank it thins rapidly and after a few yards dies out altogether. From this point to approximately fourty yards downstream the bedding plane upon which the sill is intruding is marked by a breccia which has a distinct "burnt" appearance. The position of both sill and breccia is shown on text fig. 21.

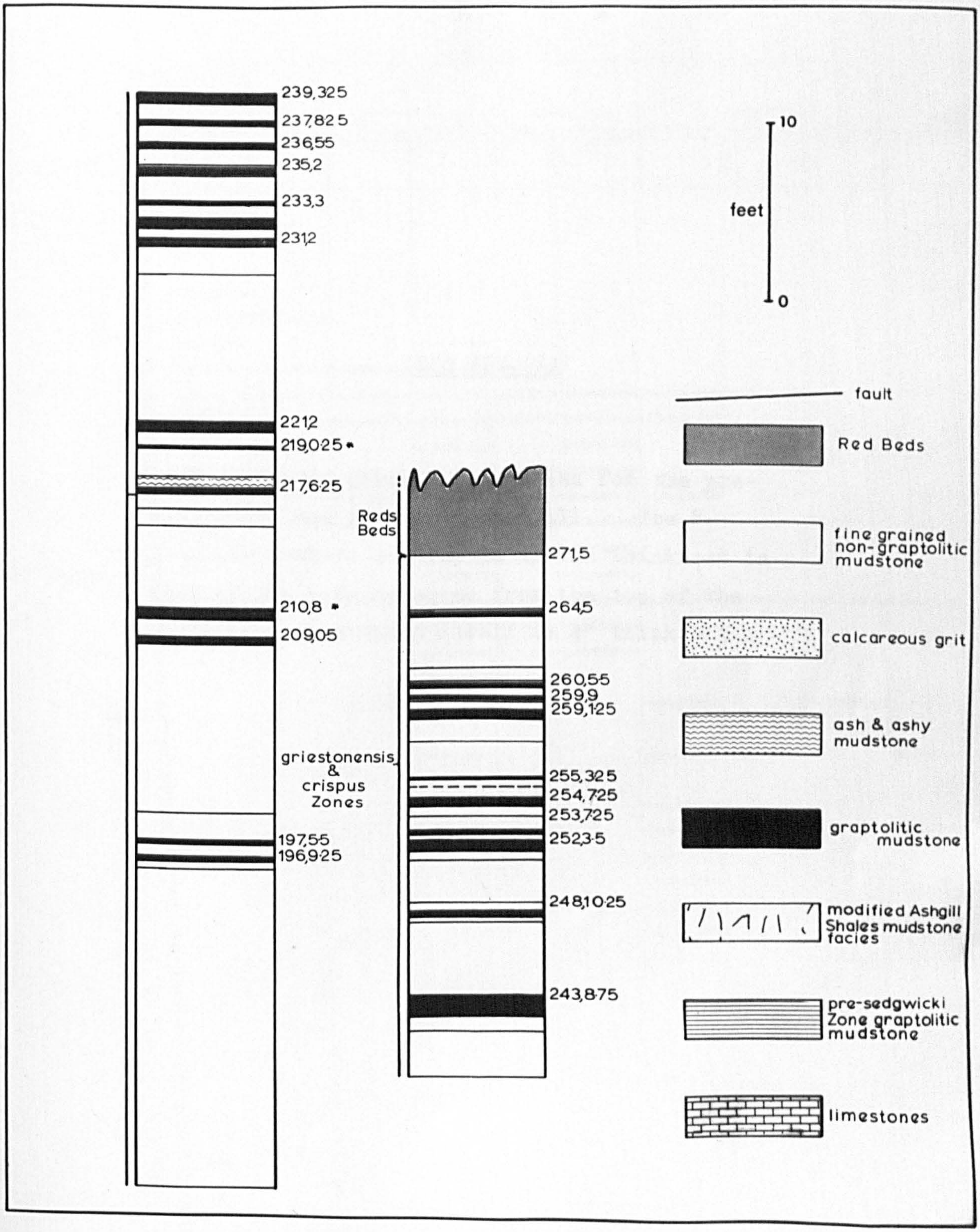
TEXT FIGS. 2i1 & 2i2

Diagram showing the Llandovery succession as exposed on Spengill. An asterisk by the side of graptolitic mudstone indicates that the band is thought to be a new recording of the facies.

TEXT FIG. 2il

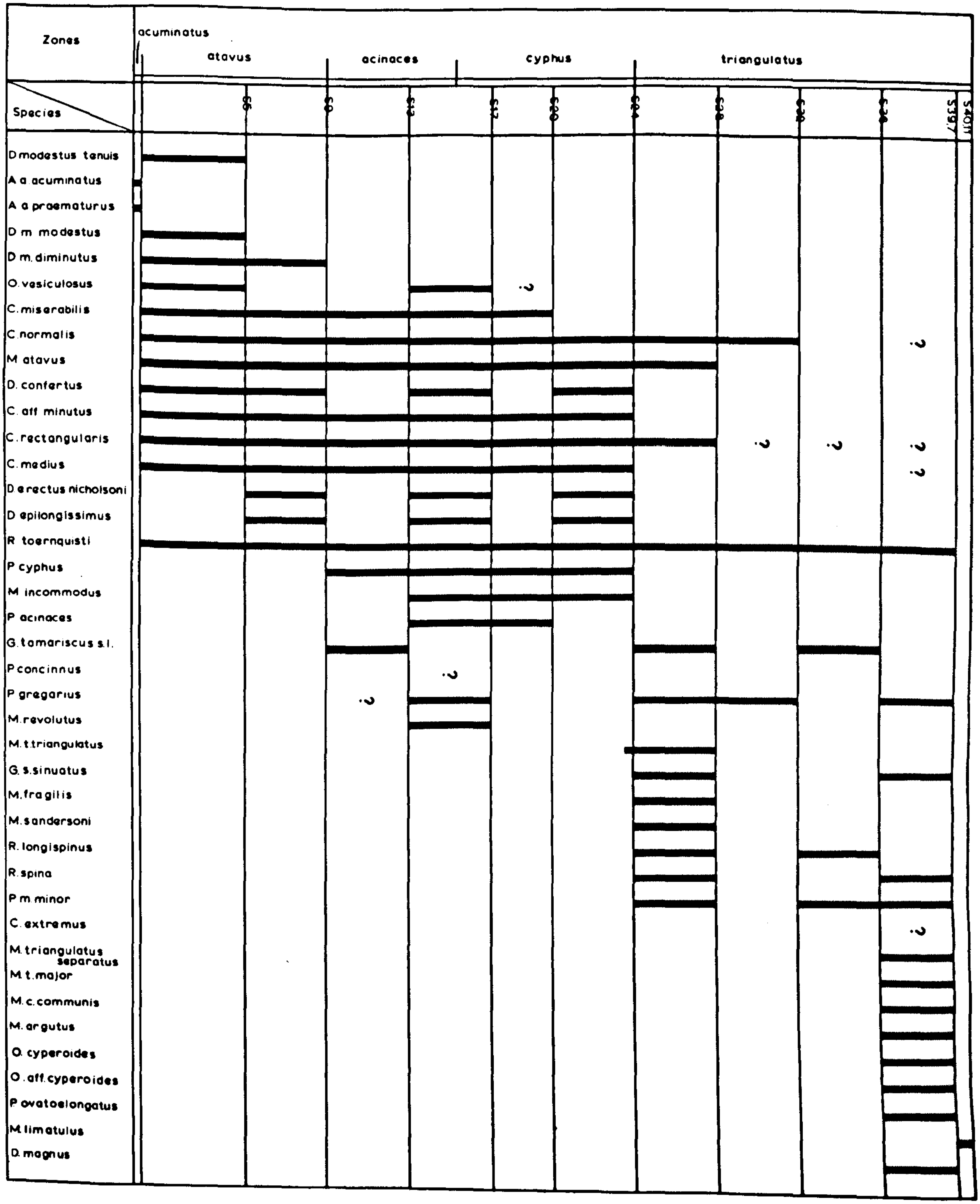


sedgwicki Zone
turriculatus Zone
turriculatus Zone (maximus Subzone)
triangulatus Zone
cyphus Zone
acinaces Zone
atavus Zone
acuminatus Zone
51,11
39,7
36
32
28
24
20
17
13
9
5
2
94,7·4
80,8·4
75,9·4
73,11·4
58,11
177,8·25
176,2·5
174,10·5
173,6
172,05
169,6·5
167,11·75
166,8·5
165,2·25
162,10·25
159,8·75
145,0·75
140,11
136,1·25
131,10·25
124,10·25
123,7·25
117,3
115,5


239,325
237,825
236,55
235,2
233,3
231,2
221,2
219,025 *
217,625
210,8 *
209,05
197,55
196,925
griestonensis & crispus Zones
Reds Beds
271,5
264,5
260,55
259,9
259,125
255,325
254,725
253,725
252,35
248,1025
243,875
10
feet
0
fault
Red Beds
fine grained non-graptolitic mudstone
calcareous grit
ash & ashy mudstone
graptolitic mudstone
modified Ashgill Shales mudstone facies
pre-sedgwicki Zone graptolitic mudstone
limestones

TEXT FIG. 2j

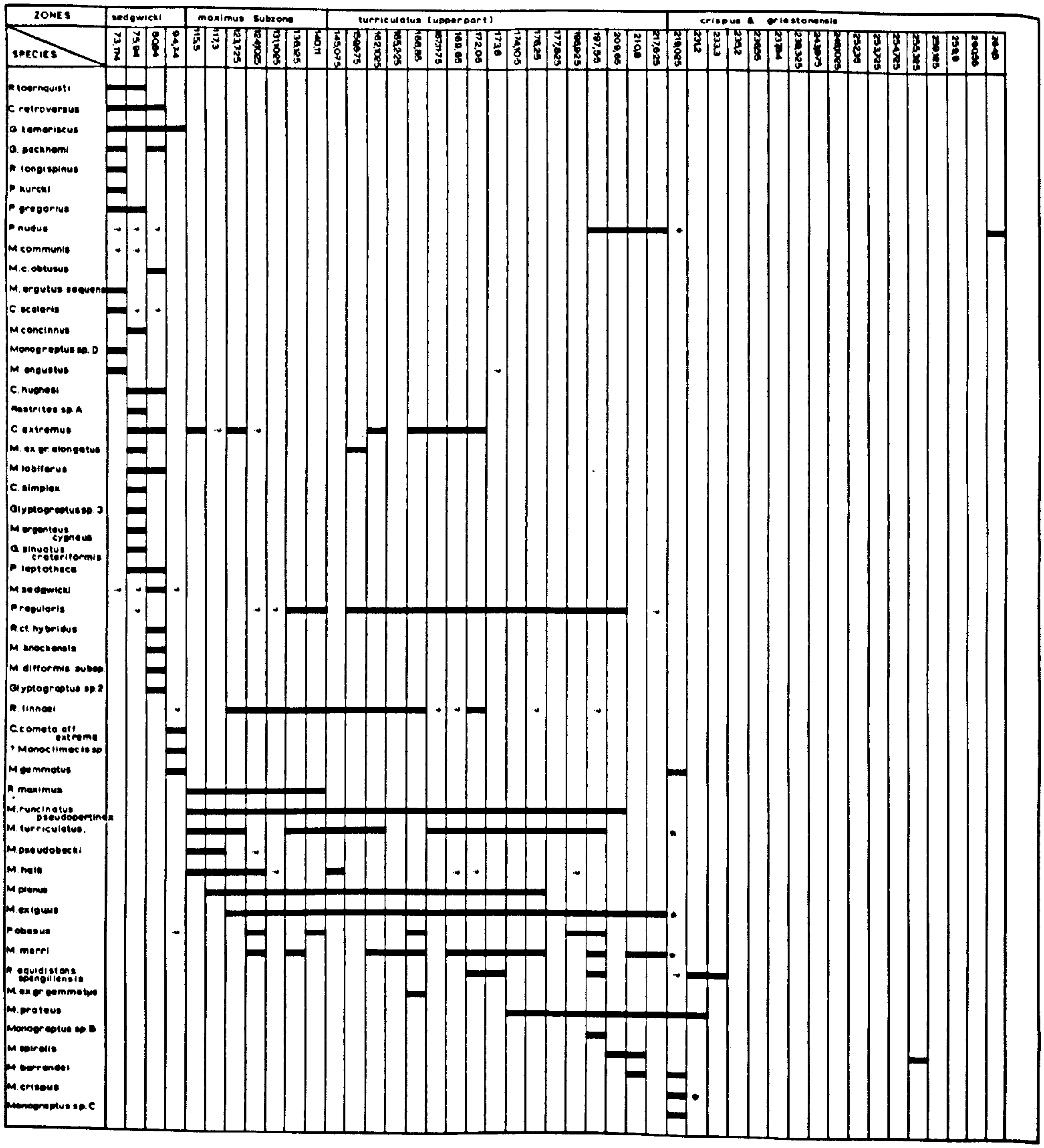
Range chart of graptolite species for the pre-sedgwicki Zone strata of Spengill. The S-locality numbers correspond to the thickness in feet of the beds measured from the top of the acuminatus Zone which itself is 4" thick.



Zones
acuminatus
atavus
acinaces
cyphus
triangulatus
Species
S39.7
S40(1)
D.modestus tenuis
A.a.acuminatus
A.a.praematurus
D.m.modestus
D.m.diminutus
O.vesiculosus
C.miserabilis
C.normalis
M.atavus
D.confertus
C.aff.minutus
C.rectangularis
C.medius
D.erectus nicholsoni
D.epilongissimus
R.toernquisti
P.cyphus
M.incommodus
P.acinaces
G.tamariscus s.l.
P.concinnus
P.gregarius
M.revolutus
M.t.triangulatus
G.s.sinuatus
M.fragilis
M.sandersoni
R.longispinus
R.spina
P.m.minor
C.extremus
M.triangulatus separatus
M.t.major
M.c.communis
M.argutus
O.cyperoides
O.aff.cyperoides
P.ovatoelongatus
M.limatulus
D.magnus

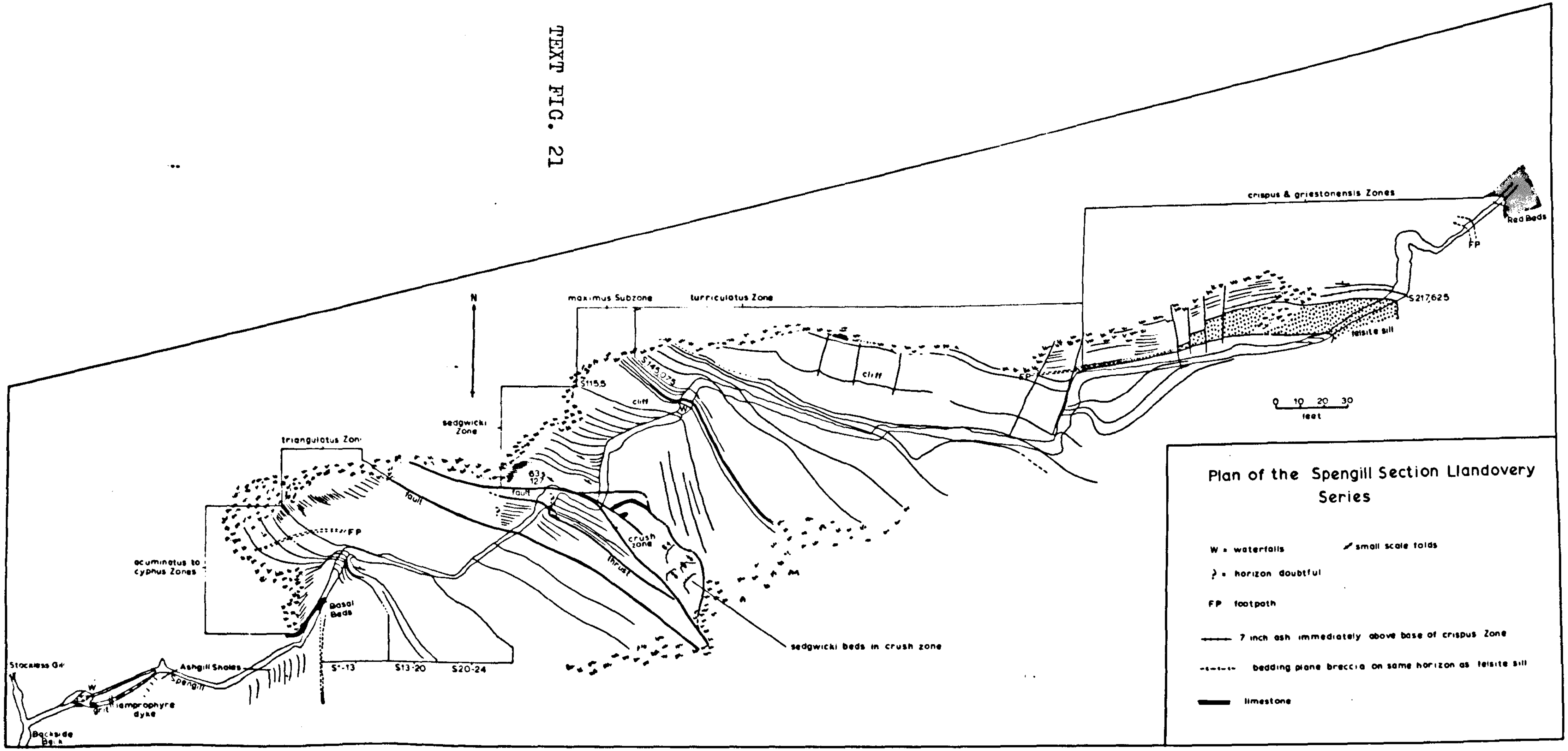
TEXT FIG. 2k

Range chart of graptolite species from the post-*triangulatus* beds of Spengill. Species recorded by Wilson (1954) from the *crispus* & *griestonensis* Zones are omitted here but species which range into these Zones from below are marked with an asterisk.



ZONES
SPECIES
sedgwicki
maximus Subzone
turriculatus (upper part)
crispus & griestonensis
73,114
75,94
80,84
94,74
115,5
117,3
123,725
124,025
131,025
138,125
140,11
145,075
159,875
162,025
165,225
166,85
167,175
169,65
172,05
173,6
174,105
176,25
177,825
196,925
197,55
209,65
210,8
217,625
218,025
231,2
233,3
235,2
236,55
237,84
238,325
243,875
248,025
252,35
253,725
254,725
255,365
258,185
259,8
260,56
264,6
R toernquisti
C retroversus
G tamariscus
G. packhami
R longispinus
P kurcki
P gregarius
P nudus
M communis
M.c. obtusus
M. argutus sequens
C scalaris
M concinnus
Monograptus sp. D
M angustus
C. hughesi
Rastrites sp. A
C extremus
M. ex gr elongatus
M lobiferus
C. simplex
Glyptograptus sp. 3
M argenteus cygneus
G. sinuatus crateriformis
P leptotheca
M sedgwicki
P regularis
R cf. hybridus
M. knockensis
M. difformis subsp.
Glyptograptus sp 2
R. linnaei
C.cometa aff. extrema
? Monoclimacis sp
M gemmatus
R maximus
M. runcinatus pseudopertinax
M. turriculatus.
M pseudobecki
M. halli
M planus
M exiguus
P obesus
M. marri
R equidistans spengillensis
M. ex gr gemmatus
M. proteus
Monograptus sp. B
M spiralis
M barrandei
M crispus
Monograptus sp. C

TEXT FIG. 21



Plan of the Spengill Section Llandovery Series
W = waterfalls
small scale folds
? = horizon doubtful
FP footpath
7 inch ash immediately above base of crispus Zone
bedding plane breccia on same horizon as felsite sill
limestone
0 10 20 30
feet
N
crispus & griestonensis Zones
Red Beds
FP
S217,625
felsite sill
maximus Subzone
turriculatus Zone
S145,075
S115,5
cliff
sedgwicki Zone
triangulatus Zone
fault
crush zone
thrust
sedgwicki beds in crush zone
acuminatus to cyphus Zones
Basal Beds
S13-20
S20-24
Ashgill Shales
Spengill
lamprophyre dyke
grit
Stockless Gill
Backside Beck

CHAPTER 3

THE WENLOCK SERIES

The Wenlock Strata of the Cautley district have received incidental reference in several works but studies describing various aspects in detail are few. Prior to the paper by Harkness and Nicholson (1868) the term "Coniston Flags" included the Stockdale Shales. Thus Sedgwick (1851) in a paper on the Palaeozoic rocks of Westmorland described his "Ravenstonedale Section" in which the Coniston Flags overlie the Coniston Limestone on the south eastern slopes of Harter Fell without intervening rock units. Aveline and Hughes (1872, 1888) described the Coniston Flags in the region mainly south and west of the Cautley district but do make reference to the area. The presence of Coniston Flags on Hebblethwaite Hall Gill, for example, is briefly mentioned. In addition a section from Orton Scar across the R.Lune to Sedbergh is given and of the slopes of Crook, Winder, and Knott they write that there is "... a belt of grit occurring between the Flags in the R.Rawthey and those on the fell side. There is strong evidence that these grits are faulted in, but whether they should be referred to the Coniston Grits or are a gritty series in the Coniston Flags, there is not sufficient evidence to show." Dakyns et. al. (1891) gave a rather more lengthy description of the Coniston Flags and their general distribution along the valleys of the R.Rawthey, Crosshaw Beck, Hebblethwaite Hall Gill, and Wandale Hill. Watney and Welch (1911 A,B, 1910) were the first workers to attempt a detailed faunal study and in their longer paper of 1911, following the summaries of 1910, divided the "Wenlock Series" into the following Zones:-

C4 Zone of _Cyrtograptus lundgreni_ Tullb.
C3 Zone of _Cyrtograptus rigidus_ Tullb.
C2 Zone of _Monograptus riccartonensis_ Lapw.
C1 Zone of _Cyrtograptus murchisoni_ Carr.

The Wenlock Series is said to crop out in three areas, (the Rawthey area, Wandale Hill, and Harter Fell), each being characterized by distinct ligholo- gies which are, respectively, blue flags, yellow sandy beds, and red flags and grits. The "yellow sandy beds" of Wandale Hill are lithologically identical in the writer's view to those of the R.Rawthey region being merely more deeply weathered. In many localities the unweathered rock can be seen (e.g. Wandale Hill Gill B (706,984)). Similarly those beds on Harter Fell are secondarily stained red, presumably because of the proximity at one time of the Basal Conglomerate of the Carboniferous, and the normal "blue flag" lithology is commonly observed. No grits of Wenlock age have been detected in the Harter Fell area.

The Lower Boundary of the Wenlock Series

Dakyns et al (1891 pp.30,37) mention the gradual change from the Stockdale Shales into the Coniston Flags with particular reference to Spengill. Watney and Welch (1911) observe that the boundary is exposed in several localities but no details of the lithological changes involved are given. Marr (1927 p.495) briefly described the lithological changes and was clearly familiar with the details of many sections. Thus, writing of the boundary, he remarks that it is characterised by "... by alternating stripes of green beds of the Browgill type and blue-grey beds of the Brathay type. This is seen in several places, and is well displayed in the stream section of Spengill, Cautley." This particular section is now rather obscured and the change is better seen, for example, at the mouth of Wandale Beck and on Pickering Gill. Wilson (1954) defined the base of the Wenlock Series by pinpointing a particular bed. He drew the boundary at the bottom of massive non-graptolitic mudstones which are distinct from the grey beds below in having a bluish tint and in the lack of thin ash bands. After a few feet these massive mudstones begin to alternate with very thin graptolitic mudstone bands. The present writer has shown (p. 96) that the graptolitic mudstone was often in the process of being destroyed by worms living on the sea bed, the result of complete reworking being a homogeneous non-banded mudstone with a faint bluish hue. It is suggested that the blue tinge is a result of reworking of graptolitic mud by worms. Graptolites are preserved in the earliest of the bands and the faunal content emphasizes the correctness of the position at which Wilson drew the base of the Wenlock Series.

In the description below the Wenlock Series is divided as follows:-

Stage 4 Zone of C.lundgreni (subzones)

Stage 3 ?Zone of C.ellesi

Stage 3	Zone of <u>C.rigidus mut.</u>	
	Zone of <u>M.flexilis belophorus</u>	
Stage 2	Zone of <u>M.antennulatus</u>	
	Zone of <u>M.riccartonensis</u> (Subzones)	
	Zone of <u>C.murchisoni</u>	
Stage 1	Zone of <u>C.centrifugus-C.insectus</u> (Subzones)	

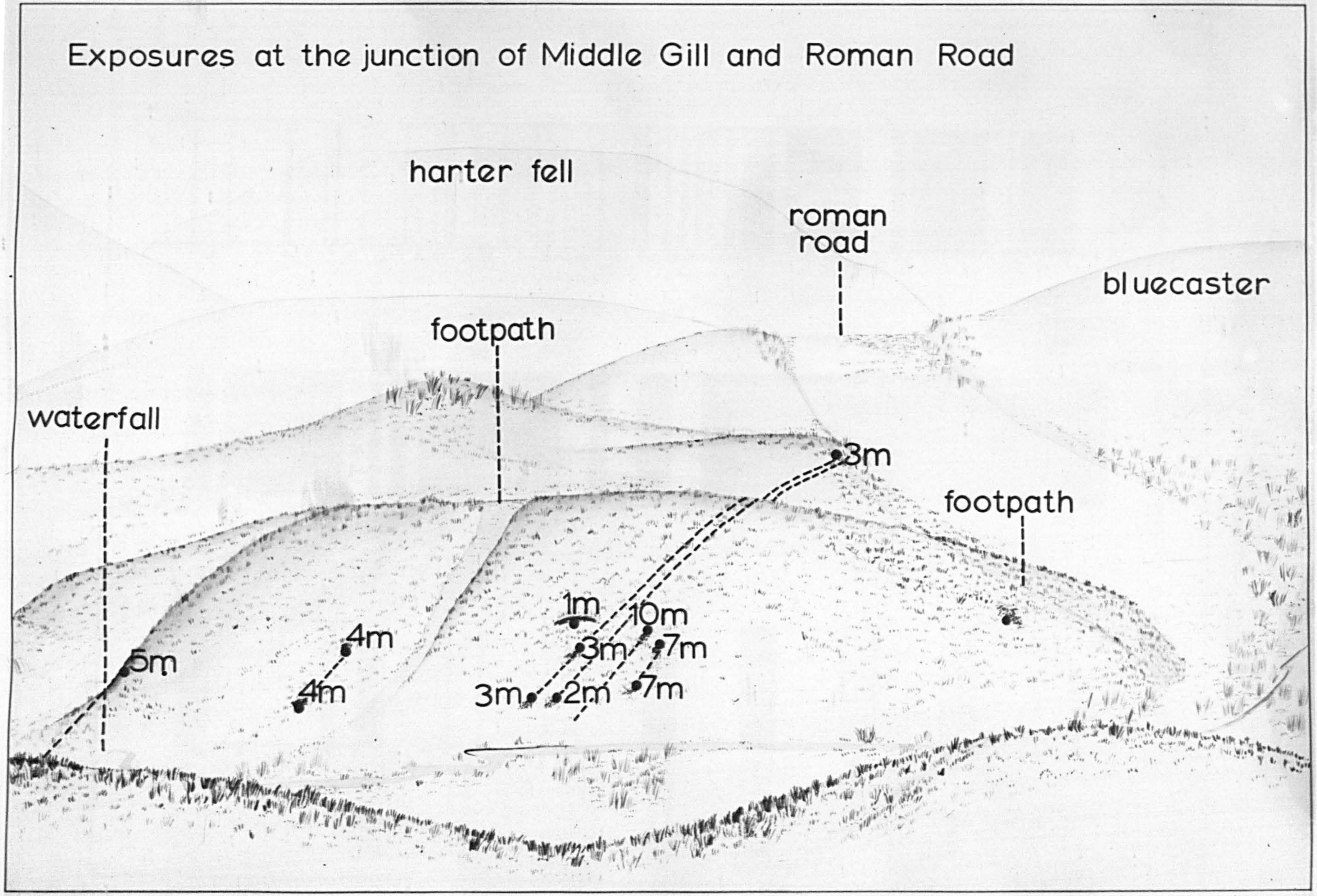
<u>Stage 1</u>

The first Wenlock Stage is exposed in many stream sections but is seen in its entirety only in the sections exposed on Hebblethwaite Hall Gill and near the mouth of Wandale Beck. Others sections showing the strata in varying degrees of completeness are:- Stockless Gill (695,000); Spengill (700. 999); Pickering Gill (689,966); Wandale Hill Gills A and B (7040,9795; 706, 984); Five Gills (725,999); Wandale Beck (711,997); mouth of Birksfield Beck (691,949); Whinny Gill (700,944); Cais Gill (710,010). The Near and Middle Gills sections which were dealt with by Watney and Welch (1911) have only poor exposures of this stage. Text fig. 3a illustrates the degree of exposure at the junction of Middle Gill and the Roman Road. Clearly few deductions can be made from sections of this nature.

Text fig. 3b is a detailed stratigraphical column of the first Stage exposed on the R.Rawthey a little upstream of the mouth of Wandale Beck. The total thickness is 65'10½" of which the lowest 14'9¼" contain no graptolitic mudstone and yield only worm tubes. The base is drawn at the position described above and is underlain by about 30' of grey beds. Above the 14'9¼" unit graptolitic mudstones gradually become predominant after appearing first as thin bands.

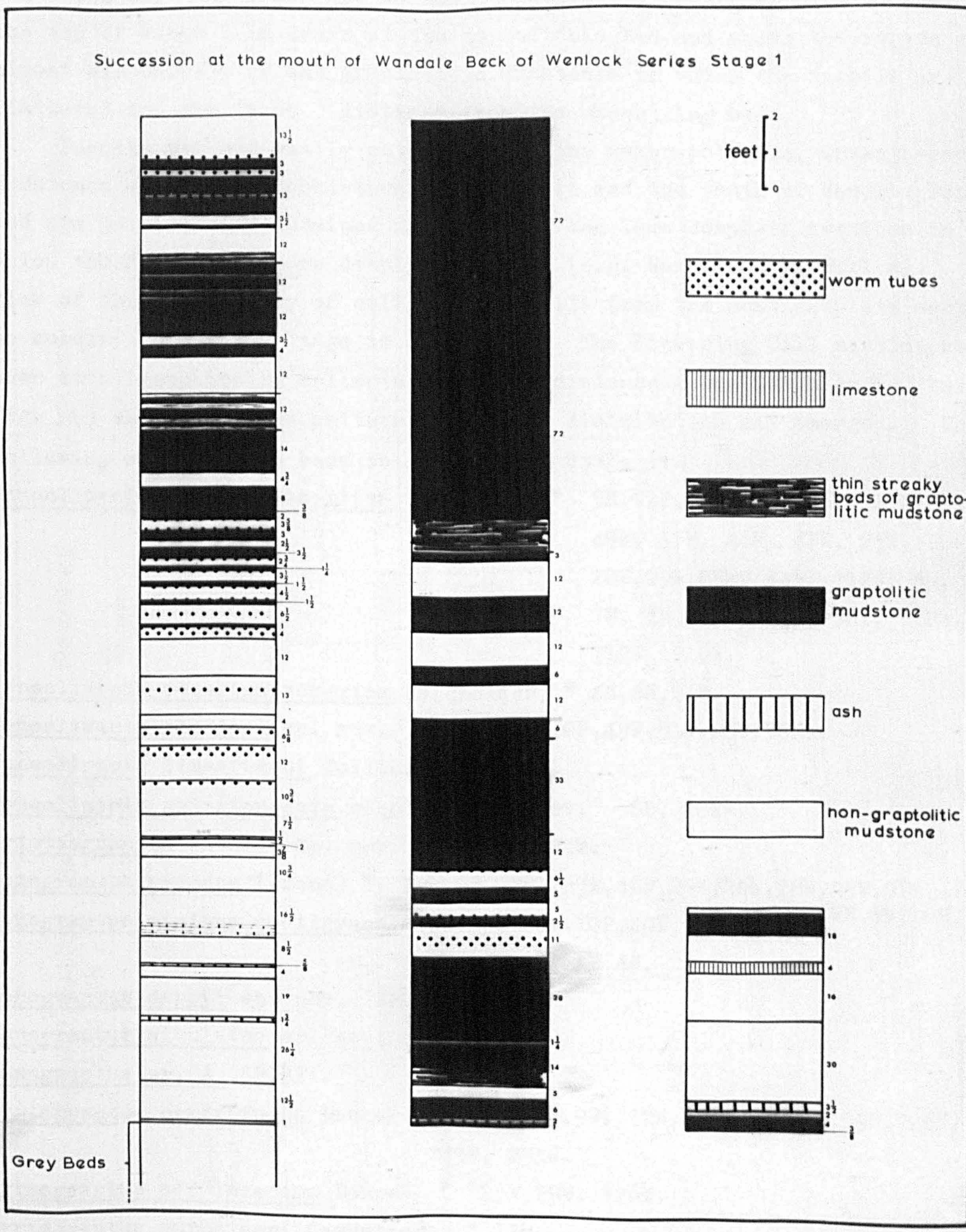
The equivalent strata of Hebblethwaite Hall Gill, also underlain by about 30' of grey beds total 59'10" in thickness showing a slight decrease from further north. At the base are approximately 10' of beds without graptolitic mudstone and the 5' immediately above this have only thin banded mudstone streaks from which no fossils have been obtained.

Almost at the top of Stage 1 is a 4" limestone which, together with some thin bands of graptolitic and non-graptolitic mudstone can be traced over the


Exposures at the junction of Middle Gill and Roman Road
harter fell
roman road
bluecaster
footpath
waterfall
3m
footpath
1m
10m
4m
3m
7m
5m
4m
3m
2m
7m

TEXT FIG. 3a.

TEXT FIG. 3b



Succession at the mouth of Wandale Beck of Wenlock Series Stage 1
feet
2
1
0
worm tubes
limestone
thin streaky beds of graptolitic mudstone
graptolitic mudstone
ash
non-graptolitic mudstone
Grey Beds

whole area (v. text fig. 3c). Above the 4" limestone is a bed varying from 1'4" to 1'10½" which has the bottom 9" composed of non-graptolitic mudstone. The top of Stage 1 is drawn at the top of this bed and above the strata are almost exclusively of the graptolitic mudstones in which the fossils are flattened and the fauna distinct from the underlying beds.

Fossils are not easily obtained from the water-polished, unweathered mudstones exposed on Hebblethwaite Hall Gill and the mouth of Wandale Beck and are more readily obtained from some of the less complete sections in which the strata are more deeply weathered (e.g. Wandale Hill Gill A). In view of this difficulty of collecting fossils from the most complete sections no subdivision of the Stage is attempted. The Pickering Gill section has been stratigraphically collected for some distance above its base (v. text fig. 3d) but no obvious pattern of species distribution has emerged. The following species have been collected from Stage 1:-

Monoclimacis vomerina basilica (Lapworth) * 5H, ?3P, 4P, 5P, ?6P, 10P, 51W, 49W, 37W, 46W, 47W, 25W, 26W, 28W, 29W, 8Ra, 3Ab, ?12N, 8N, 10N, 1M, 4M, 51W, 49W, 9Fi, ?8Ra, ?8N ?12N, ?10N.

Monoclimacis vomerina vomerina (Nicholson) * 4M, 6M, 11M.

Monoclimacis shottoni sp. nov. 3P, 5P, 6P, 10P, 49W, 51W, 28W, ?8Ra.

Monoclimacis linnarssoni Tullberg ?47W, 4M.

Monoclimacis griestonensis nicoli subsp. nov. 8P, ?8Ra.

Pristiograptus watneyi sp. nov. * 37W, ?1M.

Monograptus priodon (Bronn) * 5P, 10P, ?8P, 37W, 46W, 25W, 26W, 28W, 29W, 9Fi, ?8Ra, 12N, 8N, 10M, 1M, 4M

Monograptus minimus cautleyensis subsp. nov. 10P, 49W, 37W, 28W, 1M, 4M.

Monograptus danbyi sp. nov. 8P.

Monograptus simulatus sp. nov. 28W, 4M.

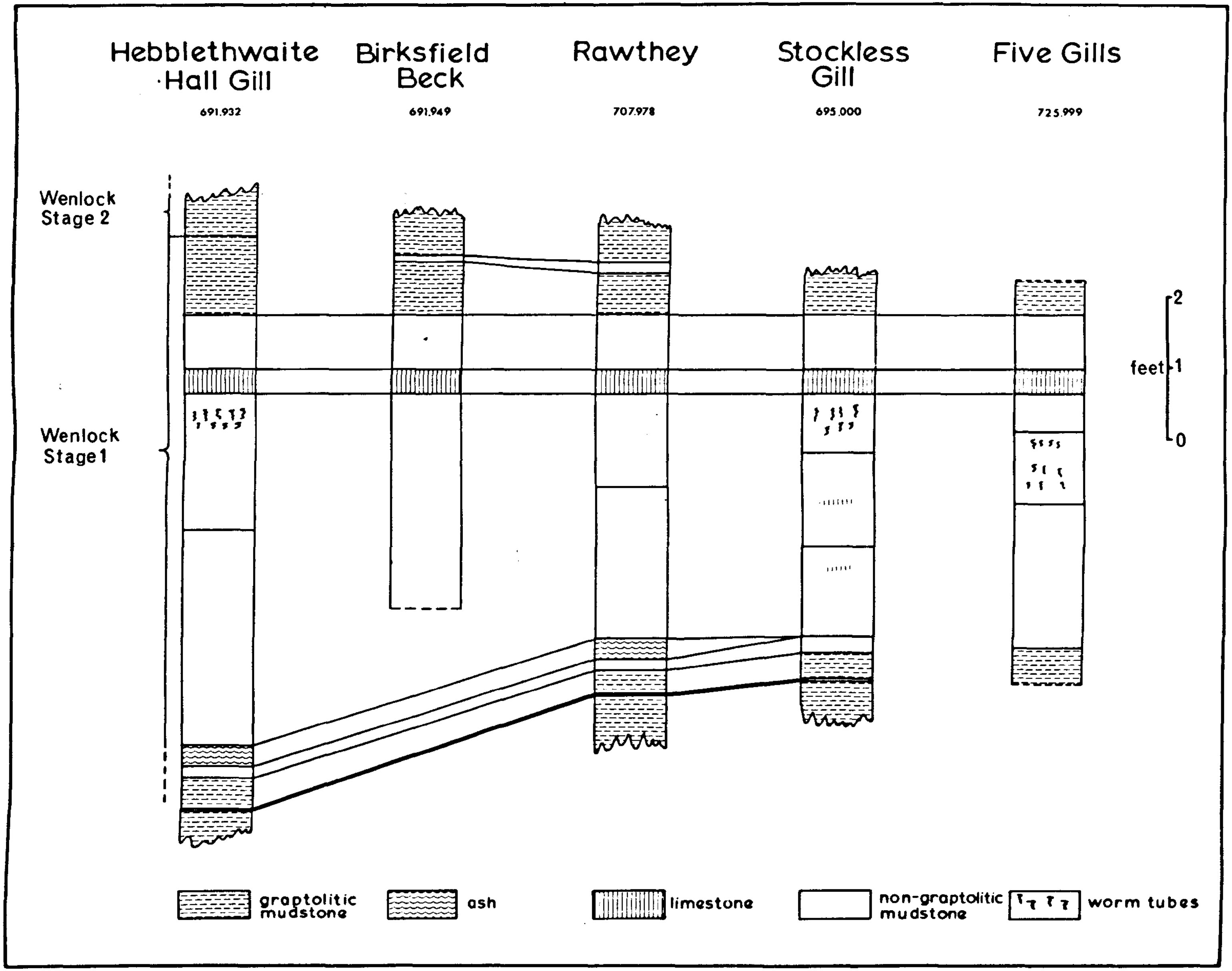
Monograptus sp. A 5P, 8Fi.

Cyrtograptus centrifugus Boucek 10P, 8P, 28W, 9Fi, 12N, 8N, 1M, 4M, 1F, 29N, ?26W, ?46W, ?49W, ?51W.

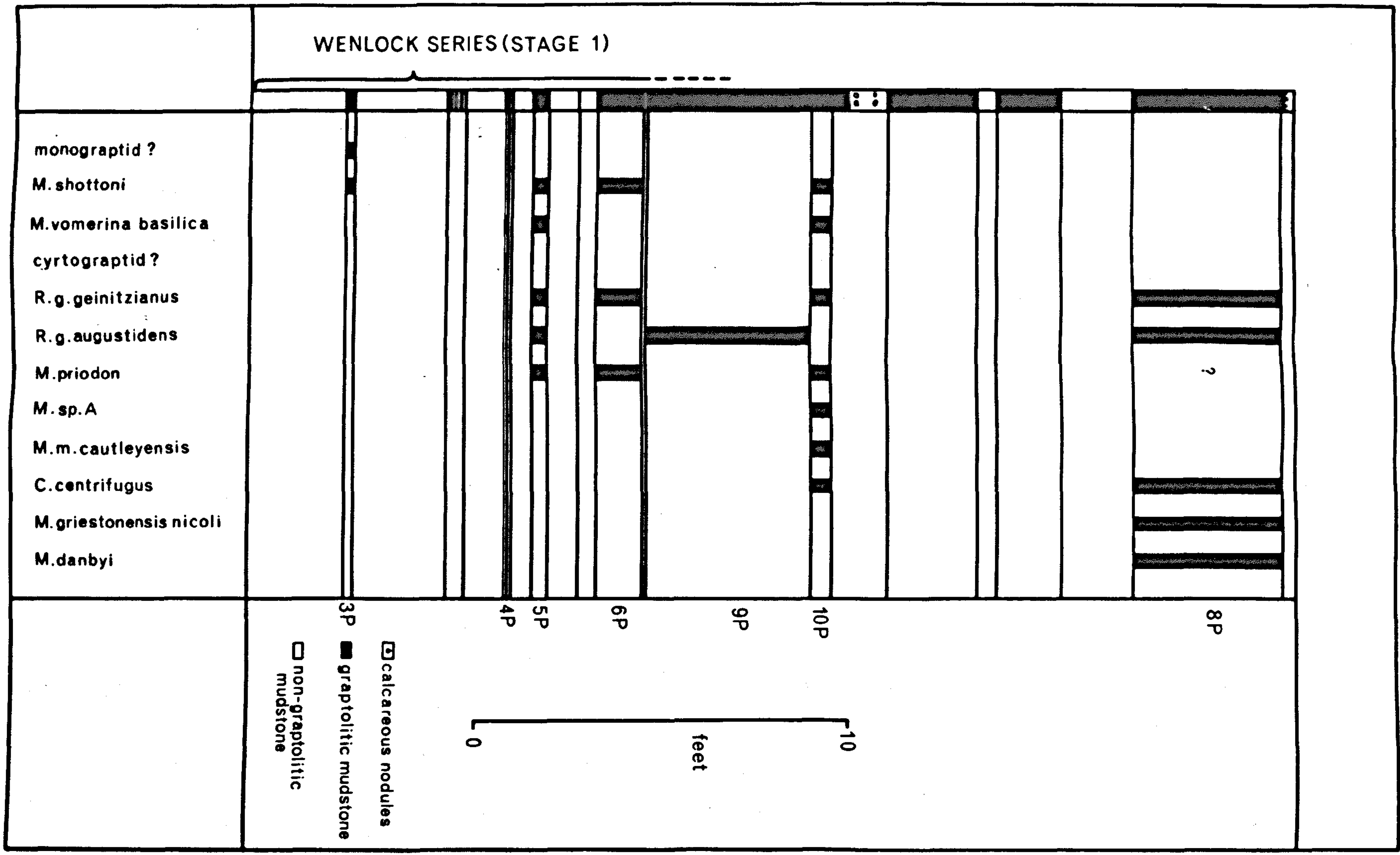
Cyrtograptus aff insectus Boucek * 28W, 29W, ?26W.

Cyrtograptus murchisoni Carruthers * 37W.

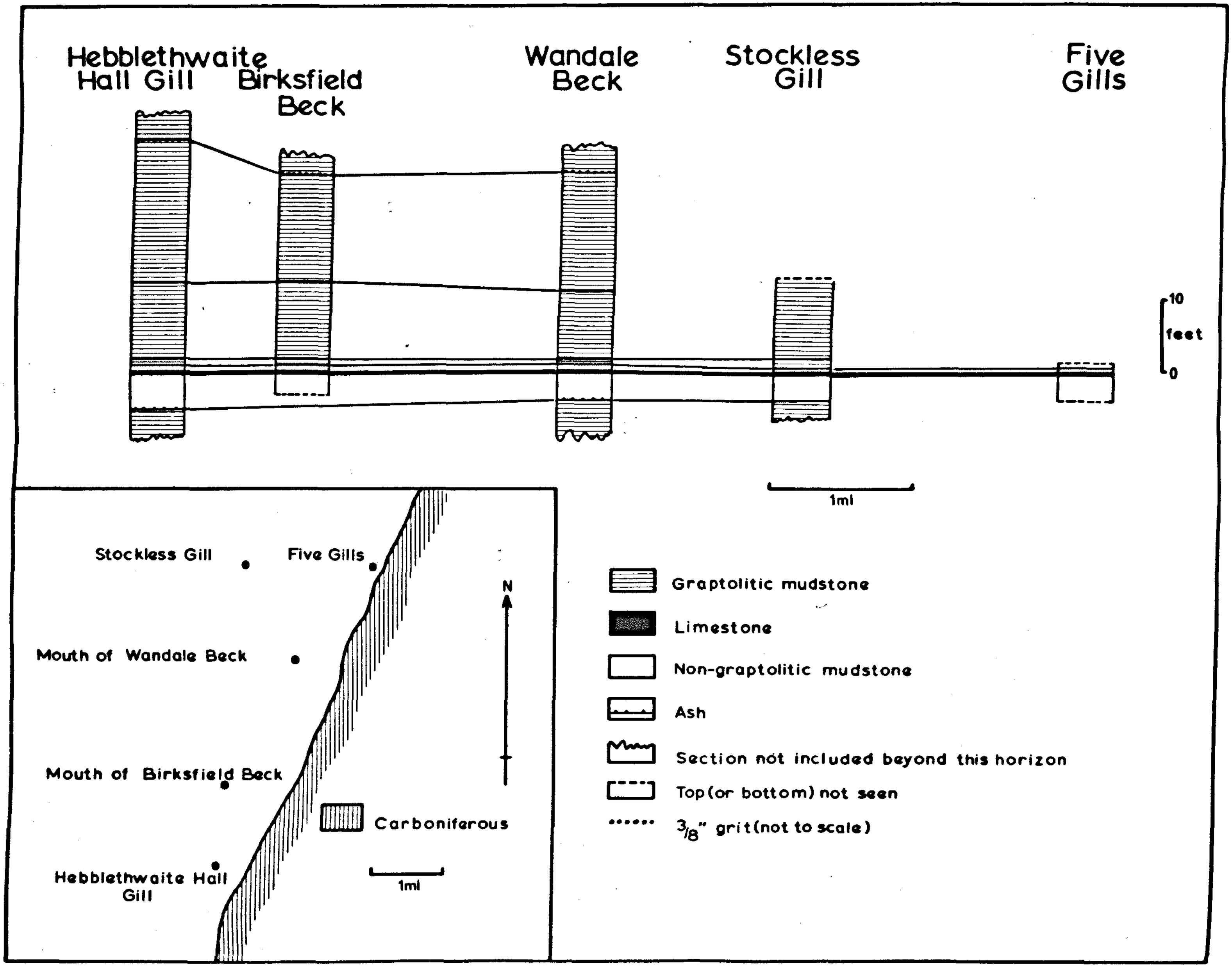
Retiolites g. geinitzianus Barrande. 28W, 26W, 25W, 29W, 1M, 4M, 5H, 5P, 6P, 10P, 8P, 49W, 37W, 47W.


Hebblethwaite Hall Gill
691.932
Birksfield Beck
691.949
Rawthey
707.978
Stockless Gill
695.000
Five Gills
725.999
Wenlock Stage 2
Wenlock Stage 1
feet
2
1
0
graptolitic mudstone
ash
limestone
non-graptolitic mudstone
worm tubes

TEXT FIG. 3c


WENLOCK SERIES (STAGE 1)
monograptid ?
M. shottoni
M. vomerina basilica
cyrtograptid ?
R. g. geinitzianus
R. g. augustidens
M. priodon
M. sp. A
M. m. cautleyensis
C. centrifugus
M. griestonensis nicoli
M. danbyi
?
3P
4P
5P
6P
9P
10P
8P
calcareous nodules
graptolitic mudstone
non-graptolitic mudstone
0
feet
10

TEXT FIG. 3d


Hebblethwaite Hall Gill
Birksfield Beck
Wandale Beck
Stockless Gill
Five Gills
10
feet
0
1ml
Stockless Gill
Five Gills
Mouth of Wandale Beck
Mouth of Birksfield Beck
Hebblethwaite Hall Gill
N
Carboniferous
1ml
Graptolitic mudstone
Limestone
Non-graptolitic mudstone
Ash
Section not included beyond this horizon
Top (or bottom) not seen
3/8" grit (not to scale)

TEXT FIG. 3e

Retiolites g. augustidens Elles & Wood 5P,9P,8P,51W,37W,25W,26W,28W,29W,7Bf, 8N,2M,3M,4M.

Aulacopleura sp.

orthocone cephalopods, small brachiopods, crinoids, conularids, phyllocarids crustaceans.

Of this faunal list only the six graptolites marked with an asterisk pass into the succeeding Stage, whilst of the ten remaining species only R.g.geinitzianus was identified by Watney and Welch (1911). It is probable that the species recorded here as C.centrifugus Boucek was taken by Watney and Welch to be C.murchisoni var. crassiusculus Tullberg which Boucek (1933) considers to be synonymous with C.murchisoni bohemicus Boucek. C.centrifugus may precede C.aff. insectus on the evidence offered by the Pickering Gill section (v. text fig. 3d). As has been stated Stage 1 is not subdivided and the Zonal name of C.centrifugus-C.insectus is adopted.

On the mouth of Wandale Beck section locality 49W has yielded the following assemblage:- Monoclimacis shottoni, M. vomerina basilica, M.v.vomerina, Monograptus minimus cautleyensis, Cyrtograptus sp. and R.g.geinitzianus, whilst locality 51W which occurs some 12' below the top of the Zone contained: M.shottoni, M.v.basilica, M.v.vomerina, Cyrtograptus sp. and R.g.augustidens.

The highest beds of the Zone which have yielded fossils are exposed on Wandale Hill Gill B. Here the typical assemblage of fossils is found in the lower horizons (localities 47W and 46W) but just before the non-graptolitic mudstone dies out (37W) C.centrifugus is replaced by C.murchisoni. The other species are, however, typical of Stage 1 and include:-
M.minimus cautleyensis, M.vomerina basilica, P.watneyi, M.priodon, R.g.geinitzianus and R.g.augustidens. Upstream the next beds yielding graptolites indicated the riccartonensis Zone.

Wandale Hill Gill A has 16'5" of the centrifugus-insectus Zone exposed. The lowest beds are separated from the grey beds by a small fault which cuts out the non-graptolitic mudstones typical of the base of the Zone, whilst the top is faulted against the riccartonensis Zone. Graptolites are well preserved, abundant, and because of the weathered nature of the rock can be collected easily. The species listed above as typical of the Zone (p. 34) were collected with the exception of C.murchisoni and P.watneyi (known only from the top of the Zone), M.danbyi (known only from the lower beds) and M.linnarssoni.

The Hebblethwaite Hall Gill section, though well exposed in both banks, is not easy to collect partly because of the water-smoothed, unweathered rock in some places and the cleaved and jointed nature of the rock away from the stream. The beds below the 4" limestone have yielded (at 5H):- R.g.geinitzianus, M.v.vomerina, M.v.basilica, Cyrtograptus sp. Upstream are the murchisoni and riccartonensis Zones.

The centrifugus-insectus Zone is also exposed on Whinny Gill where the stream bends to the NW on meeting High Pasture Wood. Two small faults bring down the grey beds against the red beds and then Stage 1 against the grey beds. The Zone is poorly exposed either low in the right bank or beneath the water until the stream turns sharply to the SW. Localities 3Wh-5Wh contain a typical assemblage of C.centrifugus, M.shottoni, M.v.basilica, M.priodon and R.g.angustidens. At the bend localities 2Wh and 12Wh have a murchisoni fauna of M.priodon, C.murchisoni Carruthers and M.v.basilica whilst a short distance downstream locality 1Wh contains numerous specimens of M.riccartonensis.

Other sections and exposures, generally less complete, are described in the chapter dealing with map description.

Stage 2

The base of Stage 2 is as described for the top of Stage 1. Above the junction is a marked change in faunal content and slight but important changes in lithology. The deposition of graptolitic mudstone now takes place to the almost complete exclusion of other rock types, and coincides with a gradually increasing grain size, lime content and bottom current activity together with a decrease in primary pyrite content. The fossils are usually preserved as flattened films in the rock. Generally speaking the variety of species found in this Stage is less than both above and below, each Zone being characterized by a small but typical assemblage. The top of the Stage is drawn at the base of the flexilis belophorus Zone which sees the incoming of a distinctly more varied fauna containing species which reach predominence in higher Zones. Stage 2 is divided into three Zones:

Zone of Monograptus antennulatus

Zone of Monograptus riccartonensis

Zone of Cyrtograptus murchisoni

Zone of C.murchisoni

The murchisoni Zone is one of the thinner but most conspicuous Zones. Its base is marked by the disappearance of the following species which were characteristic of the preceding Zone:- M.shottoni, M.minimus cautleyensis, Monograptus sp.A, R.g.geinitzianus, R.g.augustidens, C.centrifugus, M.simulatus, M.linnarssoni, M.griestonensis nicoli and M.danbyi. The top of the Zone is marked by the appearance of M.riccartonensis. M.priodon and M.v. basilica are the two most common species of the murchisoni Zone but many of the bedding planes are crowded with flattened proximal ends of cyrtograptids. Occasional specimens with secondary cladia show that these are C.murchisoni Carruthers and that the species which comes in first at the top of the centrifugus-insectus Zone is now relatively common.

A single bedding plane some 2' above the base contains numerous adult cyrtograptid rhabdosomes but often so crowded together that little detail can be ascertained. This bedding plane is typically slightly calcareous and contains specimens of C.aff insectus and probably also of C.murchisoni Carruthers. The former species has not been found above this point, and cyrtograptids generally are restricted to the bottom half of the Zone. The complete fauna is:-

C.murchisoni Carruthers 50W,68Bf,?9H,12Wh.

C.aff. insectus Boucek 50W, ?9H.

M.v.vomerina (Nicholson) ?53W, ?54W.

M.v.basilica (Lapworth) 53W,9H,6Bf.

M.priodon (Bronn) 53W,9H,6Bf,12Wh.

This assemblage differs from that defined by Elles (1900) only in the lack of M.riccartonensis, R.geinitzianus, and Stomatograptus sp. The species M.Hisingeri var. recorded by Elles may be synonymous with P.watneyi which could be expected in the Cautley murchisoni Zone since it occurs both above and below.

The murchisoni Zone is seen in its entirety at the mouth of Wandale Beck section where it overlies the centrifugus-insectus Zone of Stage 1. The strata are well exposed in the left bank and in the river bed where they strike across to the mouth of Wandale Beck. Any single bed may be traced for as much as twenty yards, but from the water-smoothed rock fossils are not easily obtained. Locality 50W (2' to 6' above the base of the Zone) yields M.priodon, M.v.basilica, C.aff. insectus and C.murchisoni. A 2'3½" bed immediately above (52W) contains M.priodon and M.vomerina s.l. but no cyrtograptids. This is followed by a bed of exactly the same thickness from which no fossils were obtained, but the succeeding bed (1'11", 53W) contains M.riccartonensis, M.v.vomerina, M.v.basilica, and M.priodon. The thickness of the murchisoni Zone is, therefore, 10'7".

On Hebblethwaite Hall Gill the strata near the top of the centrifugus-insectus Zone are well exposed in the stream bed and right bank. Immediately overlying this Zone are two beds totalling 5'6½" (9H) which yielded M. v.basilica, M.priodon, ?C. murchisoni, diminutive brachiopods and a crinoid bed. Overlying 9H are two beds respectively 2'7" and 2'8" thick from which fossils were not obtained, and immediately above these are 2' of strata from which M.riccartonensis, and M.irfonensis inclinatus were collected. The total thickness of the murchisoni Zone is 10'9½", that is slightly thicker than on the mouth of Wandale Beck section.

Some distance south of the mouth of Birksfield Beck (691,949) the murchisoni Zone is exposed overlying the centrifugus-insectus Zone. Locality 6Bf contained M.v.basilica, M.priodon, and C.murchisoni, whilst 5Bf which is located 51 yards upstream of the footbridge and 11' above the base of the murchisoni Zone yielded abundant M.riccartonensis. At this locality therefore, the murchisoni Zone is of similar thickness to the above described localities.

Zone of M.riccartonensis

The base of this Zone has been defined above and must correspond at least approximately with that chosen by Watney and Welch (1911). The upper limit of the Zone is marked by the disappearance of the name fossil. It can be distinguished from the preceding Zone not only by the presence of riccartonensis but by the absence of cyrtograptids. M.priodon has only been doubtfully recorded except at the very base and is largely replaced by M.riccartonensis. This latter species is extremely common and often occurs to the exclusion of other forms. M.v.basilica, however, is also fairly common and the two species are typical of much of the Zone. The riccartonensis Zone can be conveniently subdivided into three subzones:-

Subzone C (appearance of several forms for first time e.g. P.dubius.

Subzone B (M.riccartonensis and M.vomerina basilica.)

Subzone A (incoming of M.riccartonensis, presence of M.priodon)

Subzone A contains M.priodon which is far more abundant in lower strata and has been only doubtfully recorded above this point. On the mouth of Wandale Beck section the subzone is only 1'11" thick. M.irfonensis inclinatus subsp. nov. has been recorded from this position on the Hebblethwaite Hall Gill section.

Subzone B forms the bulk of the Zone and is characterized by the typical association of M.riccartonensis and the less common M.v.basilica. The same two species are found in Subzone C but M.v.basilica is much less common. In addition, however, are P.dubius, M.antennulatus, S.spinosus praespinosus, and rarely, M.sedberghensis, M.irfonensis inclinatus, M.flexilis belophorus, and flemingii-like fragments.

This pattern of subzones can be demonstrated on several stream sections and holds good throughout the region. Thus above Subzone A on the mouth of Wandale Beck section are 48' of beds yielding M.riccartonensis commonly and M.v.basilica more rarely (localities 54W to 62W). Subzone C, fault-bounded at the top, is only 10' thick and contains M.riccartonensis, M.antennulatus, and P.dubius (localities 63W to 65W). The total thickness of the riccartonensis Zone on this section is 60'4" (top not seen)

Immediately above the fell road on Wandale Hill Gill B M.riccartonensis can be obtained in abundance from the poor exposures in the stream bed (38W). There are no exposures for a short distance where there is room for about 6' of strata. Ten feet of weathered mudstone are then exposed downstream of a small fault (localities 39-40W) which yield M.riccartonensis, M.irfonensis inclinatus, M.antennulatus, M. sedberghensis. Above the fault are 15' of mudstones (41-42W) containing M.riccartonensis, M.irfonensis inclinatus, S. spinosus praespinosus, P.dubius, and small brachiopods. Upstream is a region of poor exposure where there is room for 22' of beds and above this the Zone of M.flexilis belophorus. The total thickness of the riccartonensis Zone is about 66'.

The stream section of Middle Gill is better exposed in Stage 2 than in Stage 1 and the pattern of Subzones is maintained. Thus the lower beds of Middle Gill (6M) yield only M.riccartonensis and M.v.basilica with the latter fairly common upon some bedding planes, whilst the higher strata (11M-13M) contain M.riccartonensis, P.dubius, M.antennulatus, M.flexilis belophorus, and flemingii-like fragments. These beds are overlain by the M.antennulatus

Zone containing only the name fossil, P.dubius, and rarely M.v.basilica. On Near Gill the higher beds of the riccartonensis Zone are not well exposed but the overlying antennulatus Zone is present and will be described below.

On Hebblethwaite Hall Gill the top of the Zone is not seen but 68' of strata are exposed. At the base locality 8H yields M.riccartonensis and M.irfonensis inclinatus. Locality 6H twenty feet above the base contains numerous specimens of M.riccartonensis whilst 7H, in the highest 6'-7' seen, contains M.riccartonensis and P.dubius in association suggesting that Subzone C is present.

An interesting feature of the riccartonensis Zone is the presence of a $\frac{3}{8}$" calcareous grit which is remarkably widespread and constant in thickness. It occurs in Subzone B and at the mouth of the Wandale Beck section is 14'11$\frac{1}{2}$" above the base. On the Hebblethwaite Hall Gill section it is twenty feet above the base and immediately underlies locality 6H. It is clear, therefore that a general expansion of the beds takes place to the south in this Zone. The same grit has also been observed on the Wandale Beck section (711, 997) and south of the mouth of Birksfield Beck.

The complete faunal list of the riccartonensis Zone is as follows:-

Subzone C.
- M.riccartonensis Lapworth
- M.antennulatus Meneghini
- M.i.inclinatus subsp. nov.
- P.dubius (Suess)
- S.s.praespinosus subsp. nov.
- M.sedberghensis sp. nov. 40W only
- M.v.basilica (Lapworth)
- M.watneyi sp. nov.
- M.flexilis belophorus (rare) 13M only

Subzone B
- M.riccartonensis Lapworth
- M.v.basilica (Lapworth)
- B.pulchellus 30W only

Subzone A
- M.riccartonensis Lapworth
- M.priodon (Bronn)
- M.v.basilica (Lapworth)

Subzone A   M.irfonensis inclinatus subsp. nov.
             M.v.vomerina (Nicholson)

Zone of Monograptus antennulatus

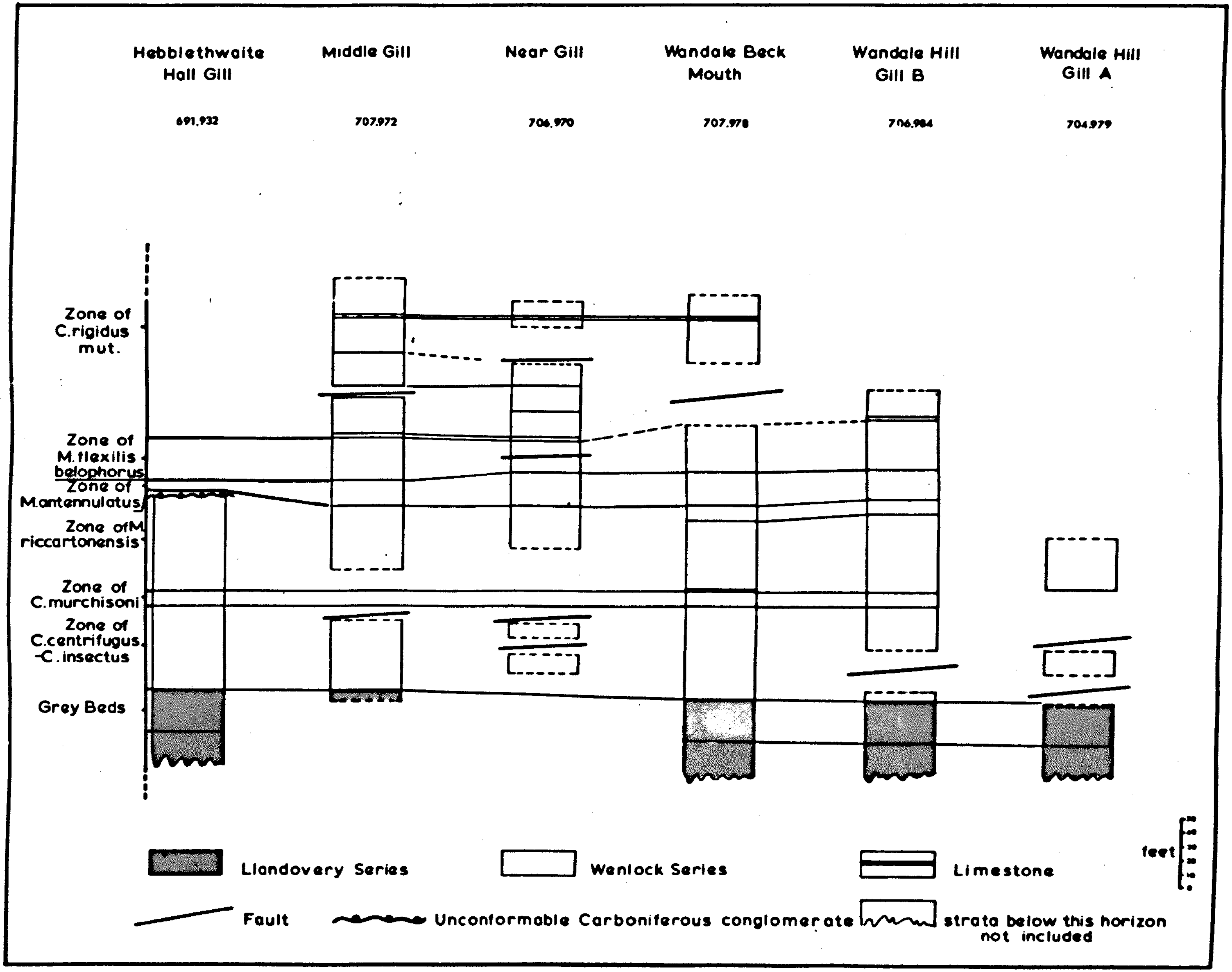
The antennulatus Zone was almost certainly included by Watney and Welch (1911) in their riccartonensis Zone but neither this Zone nor the overlying one of flexilis belophorus contains M.riccartonensis. M.antennulatus and P.dubius are the two typical species of the Zone with M.v.basilica now only rarely recorded. The base of the Zone is taken at the upper limit of M. riccartonensis. M.antennulatus and P.dubius both appear in the riccartonensis Zone (Subzone C) but are now quite common. The faunal list is as follows:-

M.antennulatus Meneghini
P.dubius (Suess)
M.kingi sp. nov. 14N only, two specimens
M.v.basilica (Lapworth)
P.meneghini meneghini (Gortani) 13N only, one specimen.
S.spinosus praespinosus subsp. nov. 13N
flemingii-like fragments 13N,14N.

This assemblage is not dissimilar to that recorded by Elles (1900) from the riccartonensis Zone of the Welsh Borderland but lacks M.riccartonensis and others, and in addition contains P.m.meneghini and S.s.praespinosus.

The antennulatus Zone is invariably present between the riccartonensis Zone below and the flexilis belophorus Zone above and represents a period of deposition of rather poorly fossiliferous strata characterized by the two species antennulatus and dubius. The other listed species have either been recorded from 13N only or are rare. The top of the Zone is defined by the appearance of several forms in abundance which were recorded rarely from lower down (M.kingi, M.flexilis belophorus) and by the appearance of others for the first time (M.f.flemingii, P.dubius pseudolatus). Near Gill, Middle Gill the R.Rawthey (mouth of Wandale Beck) are the three sections where the beds are best displayed (v. text figs. 3f,g-j).

The Near Gill and Middle Gill sections are illustrated on text fig. g,h, i, and j. On the R.Rawthey downstream of the mouth of Wandale Beck


Hebblethwaite Hall Gill
Middle Gill
Near Gill
Wandale Beck Mouth
Wandale Hill Gill B
Wandale Hill Gill A
691.932
707.972
706.970
707.978
706.984
704.979
Zone of C.rigidus mut.
Zone of M.flexilis belophorus
Zone of M.antennulatus
Zone of M riccartonensis
Zone of C.murchisoni
Zone of C.centrifugus -C.insectus
Grey Beds
Llandovery Series
Wenlock Series
Limestone
feet
Fault
Unconformable Carboniferous conglomerate
strata below this horizon not included

TEXT FIG. 3f

24'9" of strata are exposed in a cliff on the left bank above the riccartonensis Zone. They are overlain by 15' of cleaved mudstones from which no fossils could be obtained but localities 64W and 65W in the 24'9" unit yielded M.antennulatus and P.dubius. The top of the Zone cannot be defined on this section in view of the cleaved and poorly exposed nature of the overlying strata.

Stage 3

The third Wenlock Stage is typified by the presence of several species for the first time and the increased abundance of some forms recorded from earlier strata. M.kingi is a characteristic species of Stage 3 whilst P. dubius, P.m.meneghini and M.f.flemingii etc. become far more common. Other species (e.g. M.antennulatus) only survive for a short time in Stage 3 having reached their acmes at lower levels. Above the lowest beds of Stage 3 C. rigidus mut., M.flexilis, and C.linnarssoni all appear for the first time and are typical of the second Zone. Stage 3 is divided as follows:-

?Zone of Cyrtograptus ellesi

Zone of Cyrtograptus rigidus mut.

Zone of Monograptus flexilis belophorus

Nowhere in the Cautley district has the top of the C.rigidus mut. Zone been seen and there is some evidence to suggest that strata equivalent to the ellesi Zone of the Welsh Borderland exist. Similarly the top of the Stage cannot be defined since the small thickness of the ?Zone of C.ellesi located on Ecker Secker Beck is also fault bounded.

Zone of Monograptus flexilis belophorus

Watney and Welch (1911) marked the top of their M.riccartonensis Zone by the incoming of C.rigidus and the Zone here described as flexilis belophorus was, therefore, included by them in their riccartonensis Zone. These authoresses record the following species from the riccartonensis Zone:- M.riccartonensis, M.vomerinus var.α, M.vomerinus var.β, Retiolites spinosus, M.capillaceus, M.dubius, M.hisingeri (Common), M.flexilis (very rare). Clearly most of these species reflect collection from the author's riccartonensis and antennulatus Zones but the recording of M.flexilis as "very rare" suggests collection from the flexilis belophorus Zone. The fauna recorded from the flexilis belophorus Zone is listed below.

M.flexilis belophorus Meneghini 16M,18M,19M.

M.ex. gr. flexilis 43W

M.kingi sp. nov. 19N,18N,16M,18M,43W,44W.

P.dubius dubius (Suess) 19N,18N,16M,17M,18M,43W,44W.

P.dubius pseudolatus subsp. nov. 18N,19N.

M.antennulatus Meneghini 18N,17M

P.m.meneghini (Gortani) 16M

S.spinosus praespinosus subsp. nov. 43W,44W.

M.flemingii flemingii 19N.

flemingii-like fragments.

This faunal assemblage retains some of the characters of the earlier beds particularly in the continued appearance of some of the less common species such as S.s.praespinosus, P.m.meneghini, M.f.belophorus and flemingii-like fragments. M.antennulatus, however, is less common than in earlier beds and is last seen in locality 17N on the Near Gill section. P.d.dubius is now abundant and occurs with P.d.pseudolatus which appears for the first time. M.kingi appears for the first time in abundance and is one of the most characteristic species of Stage 3, surviving into Stage 4 only in a modified form. The base of this Zone is taken at the point of appearance of all these species together and can be strongly contrasted with the relatively barren Zone at the top of Stage 2. The top of the Zone is very easily defined and taken at the point which sees the influx of M.f.flexilis, C.rigidus mut. and C.linnarssoni.

The presence of M.f.flemingii, flexilis-like and flemingii-like species in the flexilis belophorus Zone, taken in conjunction with the absence of riccartonensis, murchisoni, priodon etc. suggests that these beds are of later age than the riccartonensis Zone as defined in the Welsh Borderland by Elles (1900).

On Near Gill the Zone is represented by 22' of strata (18N,19N) exposed in the stream bed and low in the left bank. Exposure is not quite continuous and there is room for 3' of beds between 18N and 19N and also between 18N and the top of the preceding Zone (15N). Locality 18N yielded the follow[illegible] species:- M.antennulatus, M.kingi, P.d.dubius, P.d.pseudo latus, M.flexil[illegible] belophorus. Moving downstream and up the succession there is a short gap [illegible] the exposures at the head of the waterfall followed by 2' of beds exposed under water and in the left bank (19N) immediately underlying locality 16N. From 19N the following species were collected:- M.kingi, P.d.dubius, P.d. pseudolatus, M.f.belophorus, M.f.flemingii and flemingii-like forms. Locality 16N sees the appearance of M.f.flexilis, C.linnarssoni, C.rigidus mut. etc.

The Middle Gill section yields fossils less prolifically but they have been collected from three localities (16M,17M and 18M). Immediately overlying 18M are beds yielding M.f.flexilis, C.rigidus mut. etc. and below 16M are the relatively barren strata of the antennulatus Zone. The beds are not completely exposed and 17M and 18M are separated by a gap with room for 9'. The maximum thickness, assuming no fault repetition, is 30'. This figure is rather higher than obtained for Near Gill but in this section also the beds are not completely exposed. Locality 16M contains P.d.dubius, M.flexilis belophorus, M.kingi, M.antennulatus, P.m.meneghini, and flemingii-like forms. Immediately above are 11' of mudstones exposed above the stream in the right bank in which the top 2' are the most fossiliferous (17M). P.d.dubius, and M.antennulatus have been collected. Locality 18M at the top of the Zone also yields fossils sparingly but P.d.dubius, M.kingi, and M. ?v.basilica were obtained. (It is possible that recordings of M. ?v. basilica made from Stage 3 represent extreme distal fragments of M.kingi particularly in view of the fact that no proximal ends have been obtained).

On Wandale Hill Gill B the base of the flexilis belophorus cannot be seen because of the degree of exposure but localities 43W and 44W immediately underlie beds containing C.rigidus mut., M.f.flexilis, and contain the following species:

44W M.kingi, P.d.dubius, S.s.praespinosus.
43W M.kingi, P.d.dubius, S.s.praespinosus.
M.ex. gr. flexilis, (?flexilis belophorus see p.269)
P.ex. gr. dubius.

The Zone here comprises approximately 30' of strata compared with 30' and 22' obtained for Middle Gill and Near Gill respectively.

Zone of Cyrtograptus rigidus mut.

The rigidus mut. Zone comprises the greater part of the known thickness of Stage 3 and is characterized by graptolites of the flemingii group, C.rigidus mut, M.f.flexilis, and M.kingi. The lower boundary and distinction from the flexilis belophorus Zone has already been mentioned and is well defined. On the other hand the upper boundary cannot be defined at all since the strata are either faulted against higher beds or obscured by drift. The fauna of Stage 4 so far as it is known seems quite distinct from that of Stage 3 and will be described below. The fauna of the Zone of C.rigidus mut. is as follows:-

C.rigidus mut. 16N,17N,20N,21N,22N,19M,30M,45W,48W,6Cr.

M.antennulatus 16N

M.kingi 16N,17N,20N,21N,22N,23N,19M,20M,?21M,?22M,23M,25M,26M,27M,28M,29M,30M 45W,48W,67W,68W,68W.

S.spinosus praespinosus 16N,17N,20N,67W.

P.dubius dubius 16N,17N,20N,21N,19M,20M,?26M,?27M,?28M,48W,67W,69W,5Cr,4Cr

P.dubius pseudolatus 16N

P.m.meneghini 16N,17N,20N,21N,22N,23N,21M,22M,26M,30M,68W.

M.f.flexilis 16N,17N,19M,20M,21M,23M,26M,27M,45W,67W,68W,5Cr,?3Cr.

M.f.flemingii 16N,21N,22N,2[illegible]N,24N,?21M,22M,29M,30M,5Cr,?3Cr,2Bd.

C.linrarssoni 16N

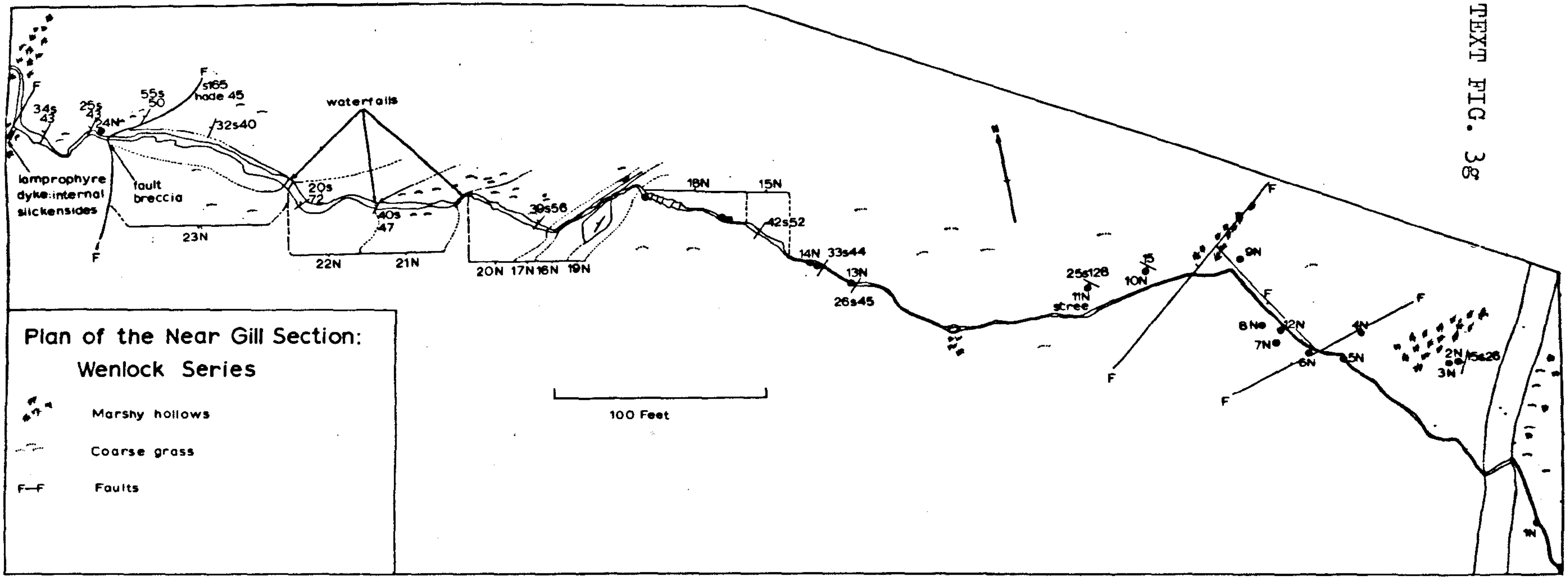
?M.v.basilica ?(10N,17N,19M,20M,22M,23M,24M)

Of this faunal list M.antennulatus and P.dubius pseudolatus are found only at the base (16N) and are not typical whilst ?M.v.basilica very probably represents extreme distal fragments of M.kingi. In contrast to earlier strata M.kingi and P.d.dubius are now very common species whilst P.m.meneghini, S.s.praespinosus, and M.f.flemingii are quite common having occurred only rarely in the lower beds. C.linnarssoni has not been obtained with certainty above the lowest bed. Of those species listed only P.d.dubius and M.f.flemingii persist unchanged into Stage 4.

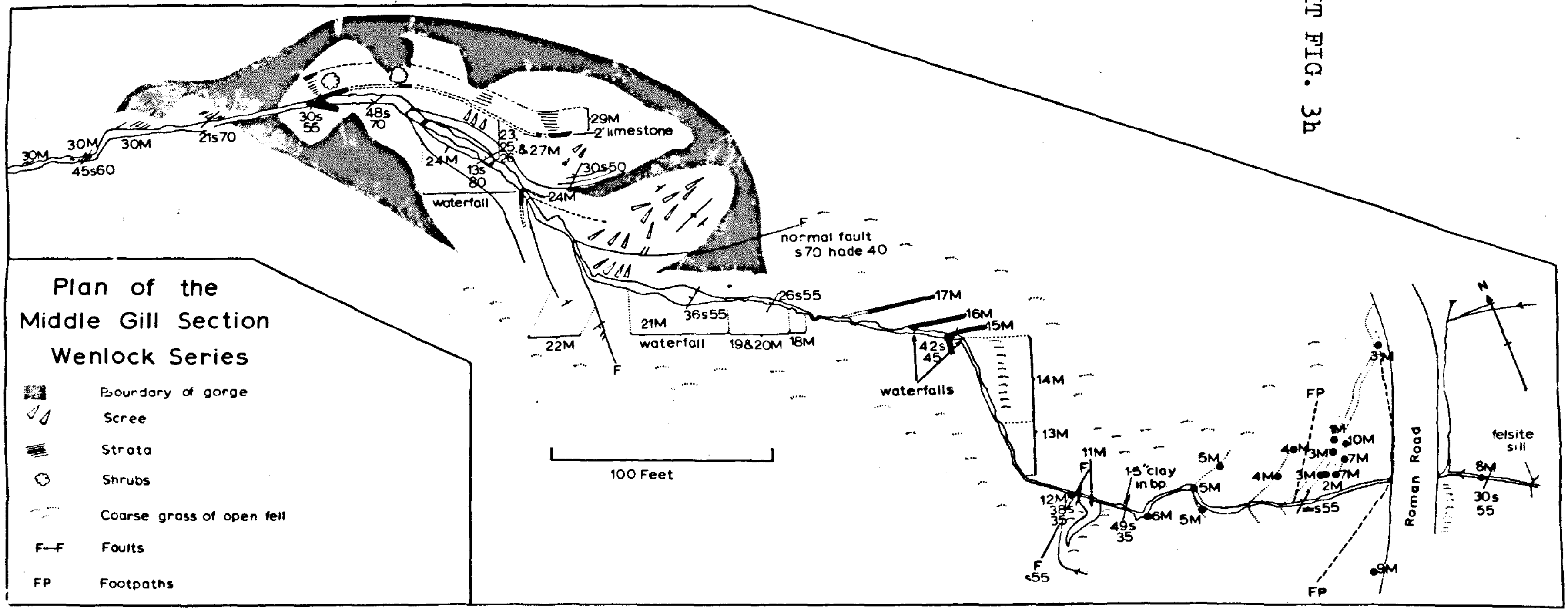
The Near Gill section provides the best exposures through the lowest part of the Zone and in all there are 69' of strata exposed. A fault cuts out approximately 30' of strata between 23N and 24N whilst 10' above the 2' limestone of 24N is a fault along which a lamprophyre dyke is intruded. This brings down beds containing C.lundgreni etc. and the top of the C.rigidus mut. Zone is not, therefore, exposed on Near Gill.

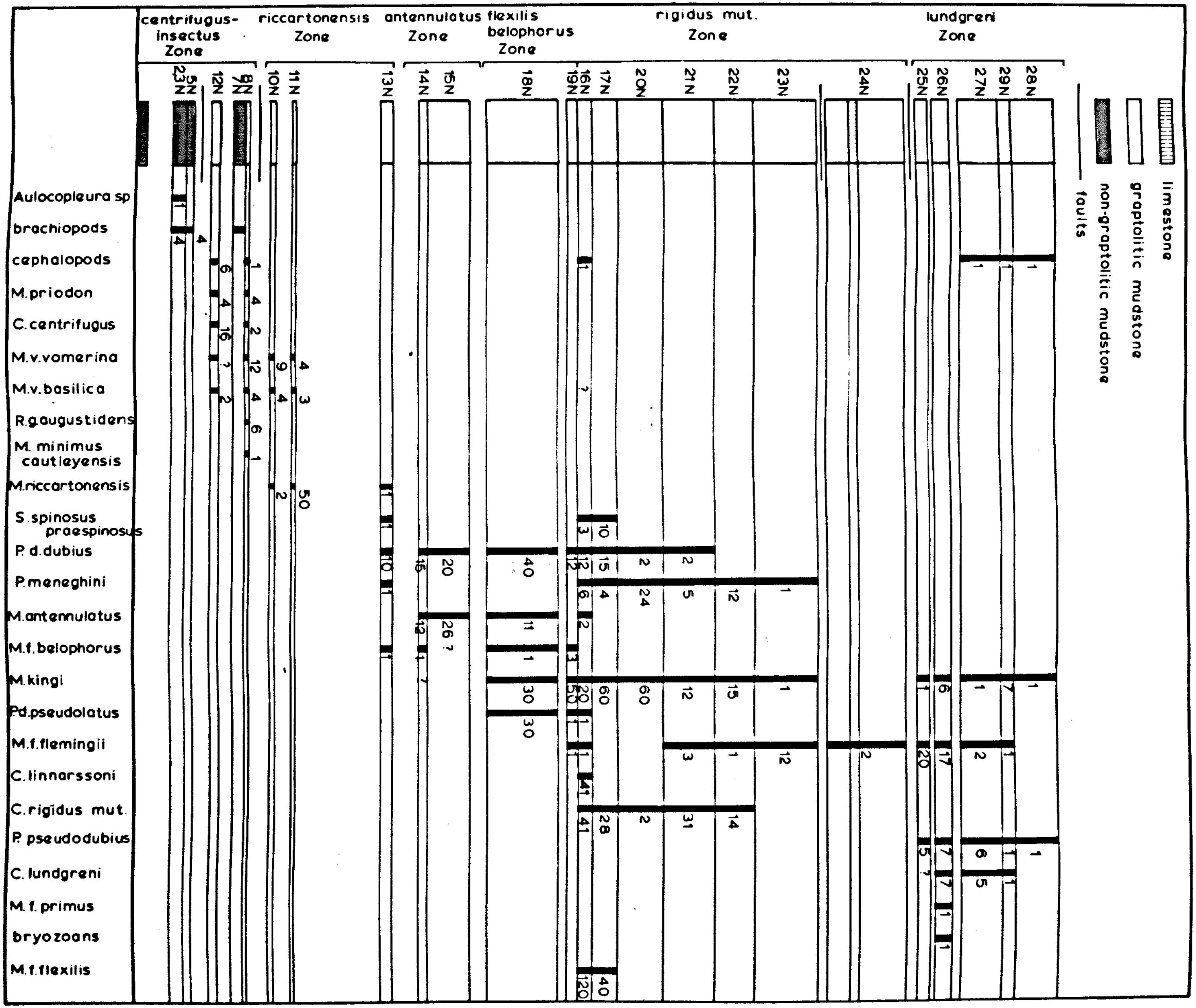
A short distance upstream of Handley's Bridge on the R.Rawthey (7065,9770)

TEXT FIG. 38


Plan of the Near Gill Section:
Wenlock Series
Marshy hollows
Coarse grass
F—F Faults
100 Feet
waterfalls
lamprophyre
dyke: internal
slickensides
fault
breccia
s165
hade 45
34s
43
25s
43
24N
55s
50
32s40
20s
72
40s
47
23N
22N
21N
20N
17N
16N
19N
39s56
18N
15N
42s52
14N
33s44
13N
26s45
25s128
11N
10N
15
scree
9N
8N
7N
12N
6N
5N
4N
2N
3N
15s26
1N
F

TEXT FIG. 3h

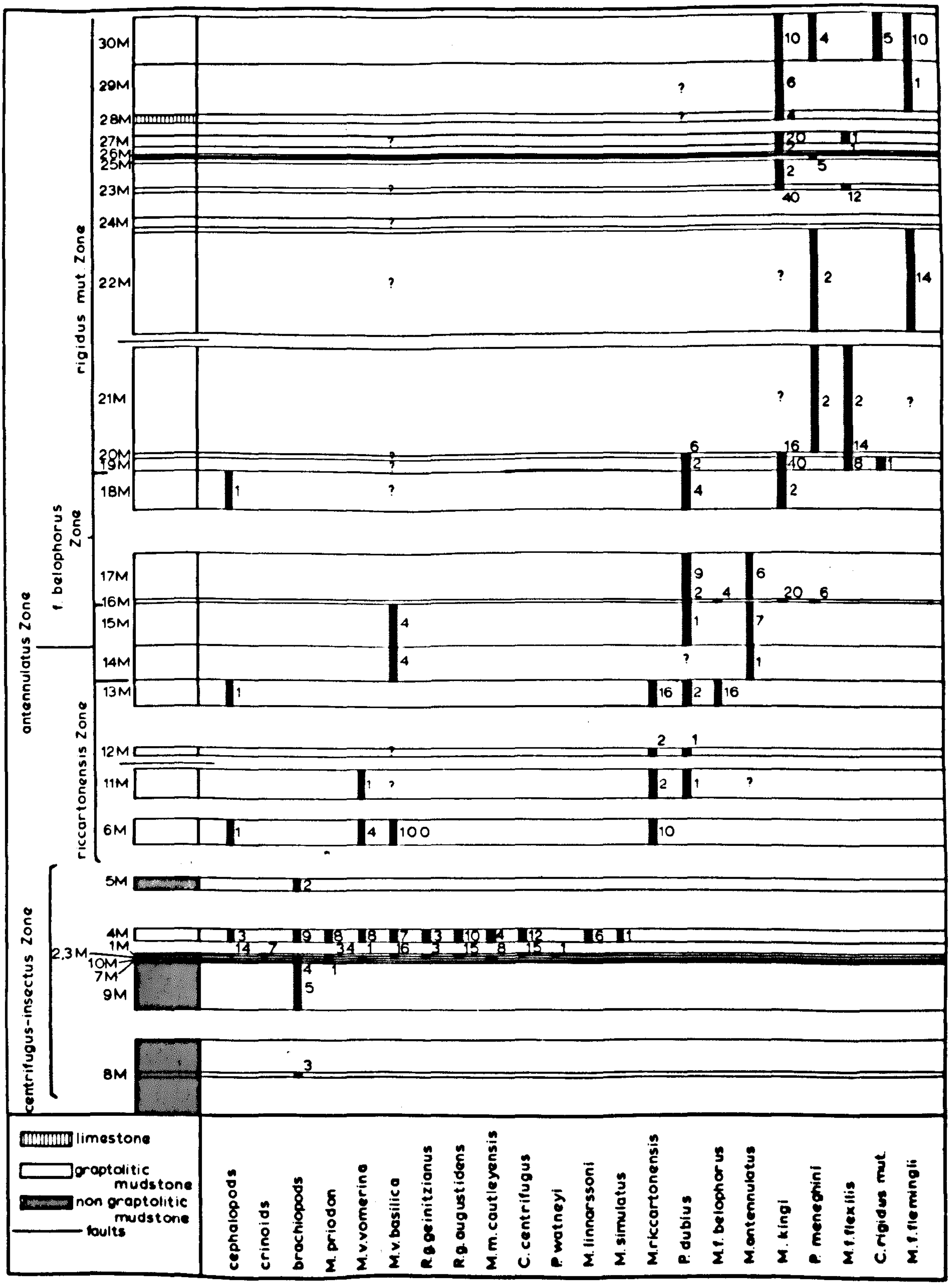

Plan of the
Middle Gill Section
Wenlock Series
Boundary of gorge
Scree
Strata
Shrubs
Coarse grass of open fell
F—F Faults
FP Footpaths
100 Feet
30M
30M
30M
45s60
21s70
30s 56
48s 70
29M
2' limestone
23, 25 & 27M
26
24M
13s 80
30s50
waterfall
24M
F
normal fault s70 hade 40
22M
F
21M
waterfall
36s55
19&20M
18M
26s55
17M
16M
15M
42s 45
waterfalls
14M
13M
11M
F
12M
38 35
F s55
1·5" clay in bp
49s 35
6M
5M
5M
5M
4M
4M
3M
3M
2M
1M
10M
7M
7M
s55
FP
FP
3M
9M
Roman Road
felsite sill
8M
30s 55
N



centrifugus-insectus Zone
riccartonensis Zone
antennulatus Zone
flexilis belophorus Zone
rigidus mut. Zone
lundgreni Zone
23N 5N 12N 7N 8N 10N 11N 13N 14N 15N 18N 19N 16N 17N 20N 21N 22N 23N 24N 25N 26N 27N 29N 28N
Aulocopleura sp
brachiopods
cephalopods
M. priodon
C. centrifugus
M. v. vomerina
M. v. basilica
R. g. augustidens
M. minimus cautleyensis
M. riccartonensis
S. spinosus praespinosus
P. d. dubius
P. meneghini
M. antennulatus
M. f. belophorus
M. kingi
Pd. pseudolatus
M. f. flemingii
C. linnarssoni
C. rigidus mut.
P. pseudodubius
C. lundgreni
M. f. primus
bryozoans
M. f. flexilis
limestone
graptolitic mudstone
non-graptolitic mudstone
faults

TEXT FIG. 3i

TEXT FIG. 3j

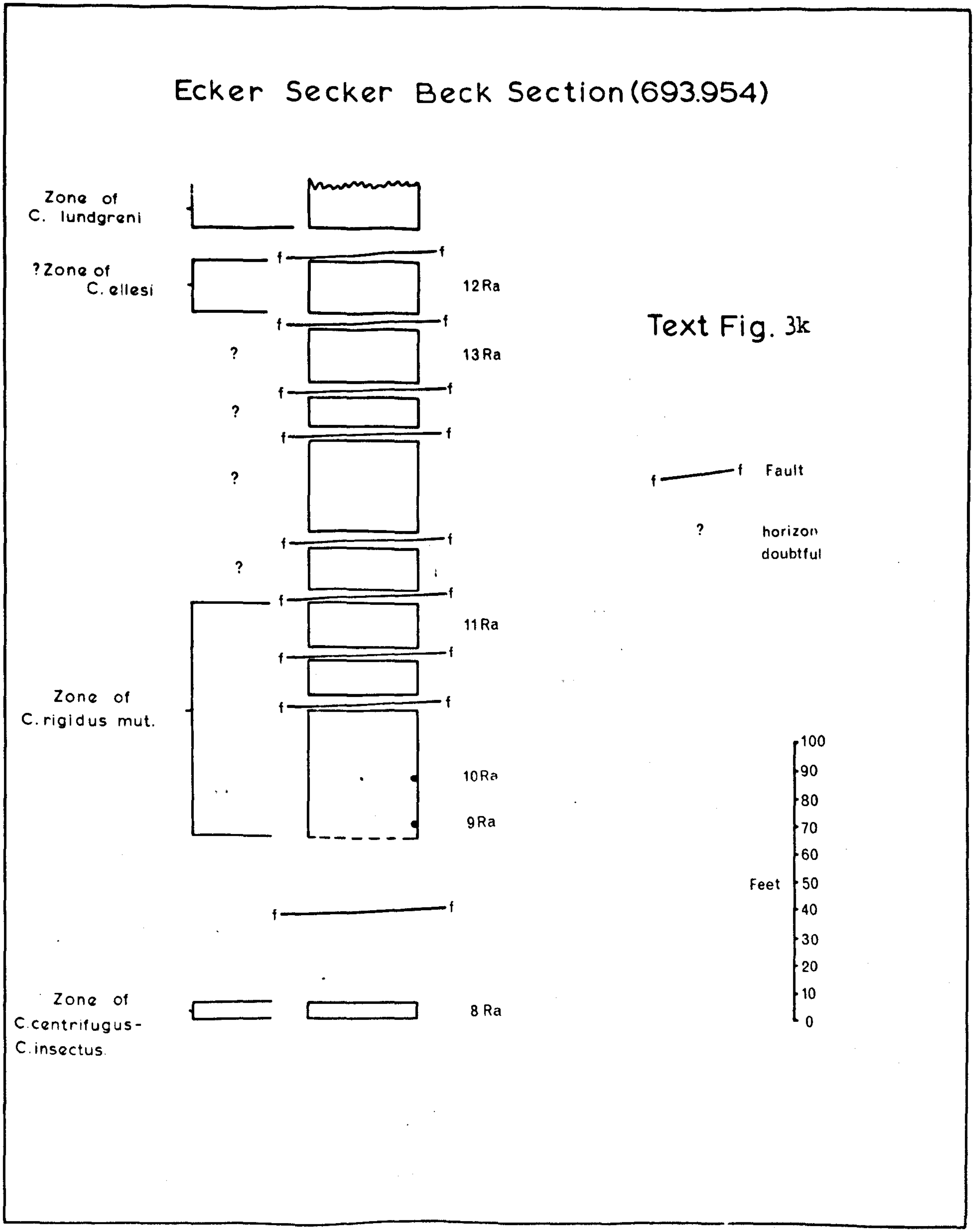

rigidus mut. Zone
f. belophorus Zone
antennulatus Zone
riccartonensis Zone
centrifugus-insectus Zone
30M
29M
28M
27M
26M
25M
23M
24M
22M
21M
20M
19M
18M
17M
16M
15M
14M
13M
12M
11M
6M
5M
4M
1M
2,3M
10M
7M
9M
8M
limestone
graptolitic mudstone
non graptolitic mudstone
faults
cephalopods
crinoids
brachiopods
M. priodon
M.v. vomerina
M.v. basilica
R.g. geinitzianus
R.g. augustidens
M.m. cautleyensis
C. centrifugus
P. watneyi
M. linnarssoni
M. simulatus
M. riccartonensis
P. dubius
M.f. belophorus
M. antennulatus
M. kingi
P. meneghini
M.f. flexilis
C. rigidus mut.
M.f. flemingii

the 2' limestone of the rigidus mut. Zone is exposed and here is underlain by 30' of strata before a fault brings up lower beds. Above the limestone are about 15' of beds followed by a fault which brings down Stage 4 yielding C. lundgreni etc.

On the Middle Gill section there is in all a thickness of 100' of beds but once again a fault cuts the section between 21M and 22M so that the exact thickness between the base and the 2' limestone cannot be determined. A suggested correlation of strata is shown in text fig. 3f and if correct only about 10' are missing on Middle Gill. One quarter of the total thickness seen is found on top of the limestone where, above locality 30M, the section finally peters out under the drift-covered lower part of the valley. The fauna throughout this 110' of strata is given in the faunal list above and in text fig. 3j and shows minor acmes of some species at certain horizons.

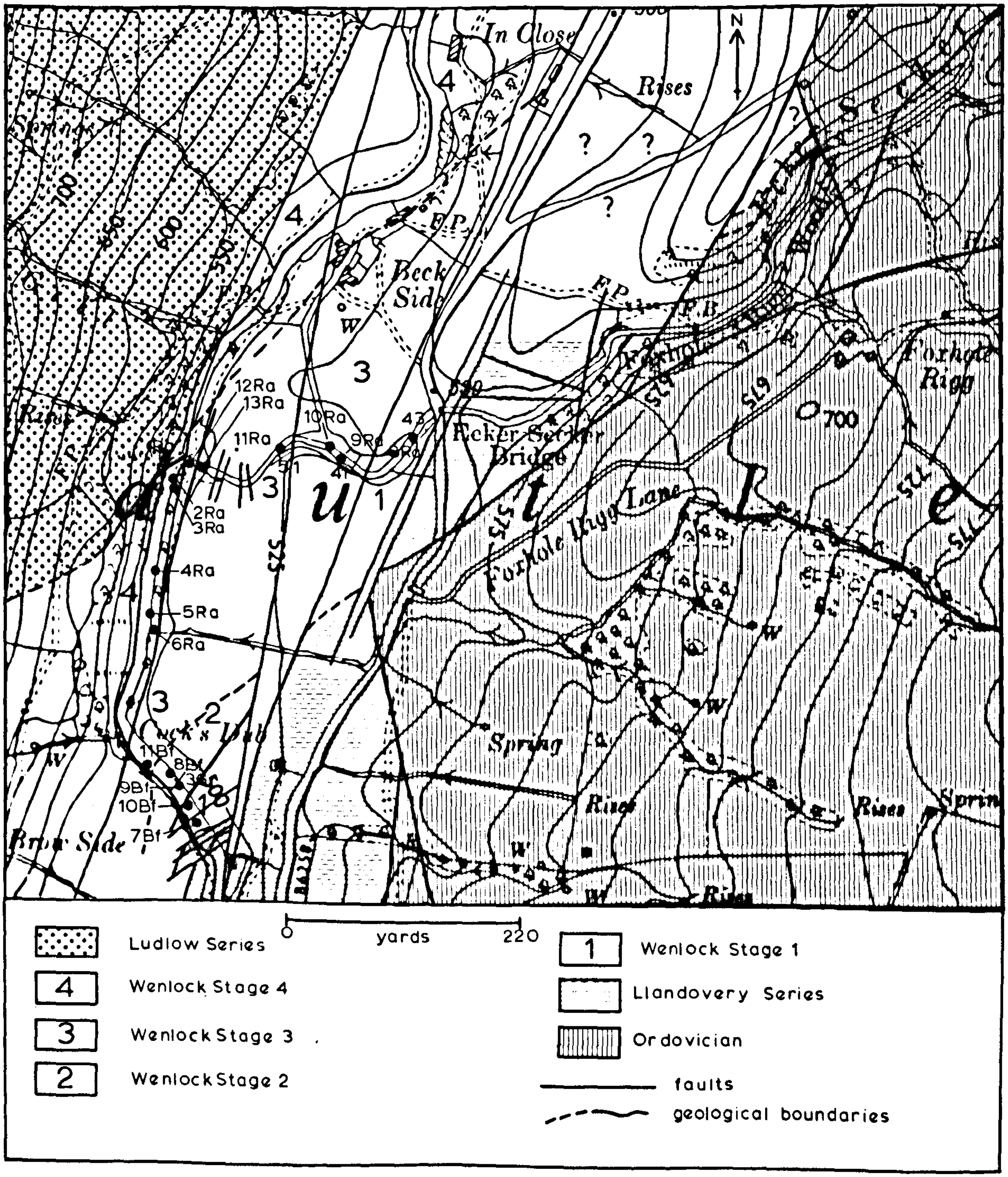
?Zone of Cyrtograptus ellesi

The section in Ecker Secker Beck near its confluence with the R.Rawthey may provide a clue as to the nature of the strata between the highest beds of Stage 3 so far described and the lowest beds of Stage 4 (described below). The highly faulted succession exposed in this stream is illustrated in text figs.3k and 3l . Locality 8Ra is located a few yards downstream from the main road where the stream flows parallel to the strike. The fauna indicates Stage 1 and the centrifugus-insectus Zone (M.priodon, R.g.geinitzianus, M.v. basilica, ?M.v.vomerina, ?M.shottoni). The stream then bends and flows to the NW at right angles to the strike and, after a gap in which 65' of beds could be present, 47' of strata containing localities 9Ra and 10Ra are exposed. M.kingi is found at 10Ra and M.kingi, P.d.dubius, M.flexilis, and C. rigidus mut. at 9Ra. These strata must belong to Stage 3 and not to the riccartonensis Zone as stated by Watney and Welch (1911, p.221). Locality 11Ra yields hundreds of specimens of M.kingi and locality 13Ra specimens of P.d. dubius. A few yards upstream of the mouth of Ecker Secker Beck locality 12Ra yields the following species:- P.d.dubius, M.flemingii primus, C.cf ellesi and M.kingi . This fauna clearly has affinities with Stage 3 but the presence of C.cf. ellesi and M f.primus suggests that the strata may be higher than the rigidus mut. Zone. From the base of locality 9Ra to the top of 12Ra about 167' are exposed though the section is cut by several faults. The major fault at the mouth of Ecker Secker Beck brings down Ludlow strata and



Ecker Secker Beck Section (693.954)
Zone of
C. lundgreni
? Zone of
C. ellesi
12 Ra
13 Ra
?
?
?
?
11 Ra
Zone of
C. rigidus mut.
10 Ra
9 Ra
Zone of
C. centrifugus-
C. insectus.
8 Ra
f
f
Fault
?
horizon
doubtful
Feet
100
90
80
70
60
50
40
30
20
10
0

Text Fig. 3k


In Close
Rises
N
Beck Side
Ecker Secker Bridge
Forhole Rigg Lane
Forhole Rigg
Spring
Rises
Brow Side
12Ra
13Ra
10Ra
11Ra
9Ra
2Ra
3Ra
4Ra
5Ra
6Ra
11Bf
8Bf
9Bf
10Bf
7Bf
700
0
yards
220
Ludlow Series
Wenlock Stage 4
Wenlock Stage 3
Wenlock Stage 2
Wenlock Stage 1
Llandovery Series
Ordovician
faults
geological boundaries

TEXT FIG. 31

therefore has a vertical component of several hundred feet with a downthrow to the West. The smaller faults a few yards upstream of the main road bridge over Ecker Secker Beck also throw down to the West and it is likely that between localities 8Ra and 9Ra there is a fault bringing in higher beds to the West. If the several faults along this stream continuously bring in higher strata to the west, perhaps as step faults connected with the major dislocation at the stream mouth, then it is suggested that a considerable thickness of strata may separate the C.rigidus mut. and C.lundgreni Zones and that some of these beds may be assigned to the C.ellesi Zone. Finally whilst a painstaking re-examination of the Ecker Secker Beck section might detect the top of the C.rigidus mut. Zone it is unlikely that it will reveal the base of Stage 4.

Stage 4

As has been pointed out above the base of this Stage cannot be fixed on the evidence available. At the upper limit, however, the change into the Ludlow Series has been observed and a definite line can be drawn between the two Series. No single section shows the Stage in its entirety and the general sparsity of fossils (or at least the difficulty of obtaining them) has made correlation between the various fault blocks difficult. The lithology is very uniform throughout and there is a lack of both palaeontological and lithological marker horizons. Four broad divisions can, however, be recognized to each of which the title "Subzone" has been tentatively given.

	Subzone d	approx.	25'	
	Subzone c	"	180'	
Stage 4	Subzone b	"	200'	450' +
	Subzone a	"	50'	

The fauna obtained from the respective Subzones is as follows:-

Subzone d: P.pseudodubius (Boucek), M.f.flemingii Salter, P.dubius (Suess), Gothograptus nassa (Holm), Delops obtusicaudatus howgillensis, subsp. nov., brachiopods, gastropods, and orthocone cephalopods.

Subzone c: M.f.flemingii Salter, M.f.primus Elles & Wood, P.d.dubius (Suess) Favosites sp. crinoids.

Subzone b: P.dubius dubius (Suess), P.aff pseudodubius (Boucek), M.f.flemingii Salter, M.kingi sp. nov., C.lundgreni Tullb., C.carruthersi?

Subzone a: C.lundgreni Tullb., P.d.dubius (Suess), P.pseudodubius (Boucek), M.kingi sp. nov., M.f.flemingii Salter, M.f.primus Elles and Wood, Favosites sp.

It is not proposed to consider these broad subzones in stratigraphical order but to describe first those divisions which can be most easily related to established horizons. In view of the fact that Stage 4 is not completely known it is not subdivided into Zones although it is known that C.lundgreni is restricted to the lower half of the strata examined so far.

Subzone a

Although the Near Gill and Handley's Bridge sections through Stage 3 are faulted at the top it is thought that the strata brought down by these faults are relatively low in Stage 4. These beds are the most richly fossiliferous of Stage 4 and in the case of the two localities mentioned the rock splits fairly well along the bedding planes. At the Handley's Bridge locality in particular the bedding planes are well defined possibly as a result of some gentle folding which occurs here (72W). The species collected at 72W were C.lundgreni, M.f.flemingii, P.ex. gr. dubius, and Favosites sp. Immediately downstream of the fault and lamprophyre dyke on Near Gill are several fossiliferous localities in fairly well bedded rock containing numerous small calcareous nodules. Localities 25N to 30N yield the following species:- C.lundgreni, M.kingi, M.f.flemingii, M.f.primus, P.dubius, P.pseudodubius. In each case there is about 50' of fairly well bedded mudstone overlain by unfossiliferous, harder mudstone. On Near Gill there is room for a further 80' of beds before the tear fault on the R.Rawthey. The Middle Gill section may at one time have shown the change from Stage 3 to Stage 4 but at the present the whole of the lower part of the valley is drift covered and there have been recent mud slips down the valley sides. Between the last exposure of Middle Gill (30M) and the road there is room for approximately 125' of strata. At the road itself Watney and Welch (1911) obtained the following species:- C.lundgreni, M.dubius, and M.flemingii var δ. These beds are probably part of Subzone "b" of the present description. Other localities with strata equivalent to those of Handley's Bridge and Near Gill have not been seen.

Subzone d

The top of this Subzone is well defined being the top of Stage 4 and of the Wenlock Series and capped by the basal Ludlow limestone. The 25' of beds comprising the Subzone are seen beneath the basal limestone in the following sections: Mouth of Backside Beck (700, 971); mouth of Ecker Secker Beck; Hobdale Beck and Spengill.

At the mouth of Ecker Secker Beck to the west of the main N-S dislocation the basal Ludlow limestone can be seen beneath the water where it weathers to a yellowish hue. Approximately 9' - 12' below its base, on the left bank of the R.Rawthey, are some small exposures (2Ra,3Ra) which yield P.pseudodubius and M.f.flemingii. Altogether some 220' of beds are exposed between the limestone and Cock's Dub (691 , 951) before the main N-S fault again cuts the Rawthey to bring up lower strata to the east. Localities 5Ra and 6Ra are located about 170' -180' below the limestone and yield M.f.flemingii in abundance despite the proximity of 6Ra to a large fault breccia. A short distance upstream locality 4Ra contains a crinoid bed with the fossils more or less in the place of growth and with the arms orientated parallel to each other. These beds downstream from 2Ra and 3Ra are placed in Subzone c.

The Hobdale Beck section (6805,9455) is very similar. Locality 2Bd is found about 20' below the top of Stage 4 (though most of the calcareous beds appear to be cut out by a fault) and yields numerous specimens of M.f.flemingii whilst locality 3Bd at a slightly higher level contains P.pseudodubius.

On Spengill (6995,0020) specimens of M.f.flemingii have been obtained within 3'-4' of the base of the calcareous beds.

A few yards downstream from the mouth of Backside Beck (7000,9705) the basal Ludlow limestone is exposed at the top of a low cliff in the right bank and just to the east of the Rawthey Tear Fault. Twenty two feet of beds are exposed below the limestone and these have rather more calcareous nodules than usual. At various points shelly fossils can be obtained:- D.obtusicaudatus howgillensis (hypostome), together with brachiopods, gastropods and orthocone cephalopods preserved in full relief in pyrite. Graptolites have not been found from this locality.

The faulted sliver of Wenlock beds (4W) on the slopes of Wandale Hill (see text fig.5b) most probably belong to Subzone d since, in addition to M.f.flemingii and P.dubius, it has yielded G.nassa.

Subzones b and c

Between Subzones "a" and "d" is a considerable thickness of poorly fossiliferous strata. It has already been mentioned that the mouth of Middle Gill may represent a position about 125' above the base of Stage 4, and here C. lundgreni is still present. Similarly the Crosshaw Beck section which also seems to represent the lower half of Stage 4 to judge by its lithology (Subzone b is partly recognizable by the hard, barren, and relatively coarse grained nature of the mudstones) contains at 1Cr and 2Cr the following forms:- C.lundgreni ?, P.aff pseudodubius, and M.kingi. The last fossil has not been found in the higher strata of Stage 4 and is taken, with C.lundgreni, to be an indicator of Subzones a and b. Subzones a and b are, therefore, separated from one another mainly on the grounds of lithology and the relative abundance of the contained fossils. Apart from its occurrence on Crosshaw Beck Subzone c seems to crop out between Handley's Bridge and the mouth of Backside Beck, and again between Low Wardses and Beck Side (6925,9950).

It has been shown above that in the cases of Hobdale Beck and Ecker Secker Beck the beds below the Subzone d are typified by the abundance of M.f. flemingii. Locality 11P on Pickering Gill also seems to be about this horizon and it yields M.f.flemingii and P.pseudodubius. Shelly fossils occur occasionally in Subzone c such as the crinoid bed of 4Ra, (a specimen of Favosites sp. was obtained from a nodule slightly downstream of 4Ra), but are more common in Subzone d as at the mouth of Backside Beck.

A locality on the slopes of Wandale Hill (3W, 7000,9820) has yielded obscure fragments of a form possibly referable to C.carruthersi Lapworth. Other species from the same locality, suggesting Subzone b, are: C.lundgreni, P. dubius, M.f.flemingii and M.f.primus.

Thickness of the Wenlock Series

Watney and Welch (1911 p.217) give the following thicknesses for the various Zones:

Zone of C.lundgreni	300'-400'
Zone of C.rigidus	178'
Zone of M.riccartonensis	160'
Zone of C.murchisoni	100'
	738'-838'

The centrifugus-insectus Zone measured at the mouth of Wandale Beck is 65'10½" thick and on Hebblethwaite Hall Gill some three miles to the SSW is 59'9¾" showing a slight thinning to the south. The murchisoni Zone on the other hand thickens slightly to the south from 10'7" at the mouth of Wandale Beck to 10'9½" on Hebblethwaite Hall Gill. The two Zones are equivalent to the murchisoni Zone of Watney and Welch and thickness, therefore, is actually rather thinner than suggested by them being 76' in the north and 70'7" in the south.

The riccartonensis Zone is not usually fully seen but at the mouth of Wandale Beck it measures 60'4" (14'1½" between the base and the ⅜" calcareous grit) whilst on Hebblethwaite Hall Gill it is at least 68' (20' between the base and the ⅜" calcareous grit). Clearly the Zone is thickening to the South. Measurement of the antennulatus Zone is more difficult but it seems to be about 20' thick in the north but has not yet been seen in the south. Equally difficult to measure is the flexilis belophorus Zone but measurements on Wandale Hill Gill B, Near Gill etc. (v. text fig. 3f) suggest a thickness of approximately 30'. The three Zones (riccartonensis, antennulatus, and flexilis belophorus) are equivalent to the riccartonensis Zone of Watney and Welch, and the total thickness in the north is little more than 110' which is again rather less than that assigned to it by Watney and Welch. In the south it may be rather thicker if the tendencies seen in the murchisoni and riccartonensis Zones are continued into the antennulatus and flexilis belophorus Zones.

In view of the faulted nature of the top of the C.rigidus mut. and ?C. ellesi Zones only minimum thicknesses can be given. Thus the Middle Gill section shows a thickness of 100' whilst a small thickness (about 10') may be faulted out giving a total of 110'. The Ecker Secker Beck section strongly suggests that there may be a much greater thickness of beds and on this section a minimum of 18' can be assigned to the ?Zone of C.ellesi giving a minimum total for the two Zones of 128'. A value of 200' is probably nearer the actual figure in view of the strata between 9Ra and 12Ra on the Ecker Secker Beck section (v. text fig. 3k,l). In the High Pasture - Crosshaw area the strata are folded and appear to be coarser grained. As in the case of some of the earlier beds it is thought that thickening takes place in this direction.

Finally Stage 4 has a thickness of about 450' but accurate measurement is impossible due to exposure failure.

A minimum figure for the thickness of the Wenlock Series is approximately 760' and a maximum figure in the region of 850'. These figures agree quite well with those obtained by Watney and Welch (op. cit.) but it is important to realize that the earlier Zones of Stages 1 and 2 are much thinner than suggested by their work.

Conclusions

a) The Wenlock Series can be conveniently divided into four faunal Stages each retaining features of the preceding Stage in its lowest beds but having distinct characteristics of its own.

b) Although lithologically very uniform the Series contains some marker bands (e.g. the sequence at the boundary of Stages 1 and 2) and some general changes (see chapter 6)which can be used to supplement the faunal succession.

c) The Stages can be subdivided into Zones but for the reasons stated this is not done in the cases of Stages 1 and 4 except in a general way in order to guide further work upon them.

d) There may be a general increase in thickness of the sediments towards the south above Stage 1. This has been shown in the murchisoni and riccartonensis Zones and the increase in grain size to the South in the higher Zones (seen in the Crosshaw - High Pasture area) may reflect the same process at higher levels.

e) The base of Stage 4 cannot be determined and in Stage 3 the succession is incomplete.

Reference Sections

Stage 1: Base of Stage 1 (= Base of Wenlock Series), mouth of Wandale Beck section on the R.Rawthey, exposed in right bank (7070,9780), details see text and text figures.

Stage 2: Base of Stage 2 (= top of Stage 1), mouth of Wandale Beck section on the R.Rawthey, exposed in left bank and stream bed (7065,9780).

Stage 3: Base of Stage 3 (= top of Stage 2), Near Gill section at the base of locality 18N (7045,9710), strata exposed in left bank.

Stage 4: Base of Stage 4 and hence top of Stage 3, cannot be defined. The top of Stage 4 (= base of Ludlow Series and top of Wenlock Series), mouth of

Ecker Secker Beck on the R.Rawthey. Boundary exposed in stream bed, and right bank of river (6915,9535).

Correlation of Strata

The table below (t.f.3m)shows the correlation of the Zones and Stages established with those described by Watney and Welch (1911).

Stage 1 (= centrifugus-insectus Zone) is equivalent to strata described by Shotton (1935) from the Cross Fell region as the Zone of M.crenulatus, Brathay Flags (locality "g", Swindale Beck). Thus the form described here as M.shottoni sp. nov. is the same as the form listed as "M.vomerinus var crenulatus (Tornquist); common", and the species listed as "Monograptus dextrorsus Linnarsson, var." is synonymous with the form described here as M. minimus cautleyensis subsp. nov. Other specimens in the Sedgwick Museum collected from this locality ("g") are of M.danbyi sp. nov. and M.simulatus sp. nov. type. Both Retiolites geinitzianus augustidens and M.priodon found at Cross Fell have been recorded from Cautley whilst the form listed by Professor Shotton as M.pandus (Lapworth) was possibly identified from those specimens of priodon which have been flattened and compressed (see text fig. 8d). Since 1935 cyrtograptids have also been found at Cross Fell. (Strachan 1960) and these recordings possibly account for the forms listed by Shotton as M.spiralis (Geinitz). The whole fauna is clearly identical with the centrifugus-insectus Zone of Cautley.

Text fig.3m illustrates the suggested correlation of the Cautley sequence with that of the Welsh Borderland established by Elles (1900). The centrifugus-insectus and murchisoni Zones at Cautley are probably equivalent to the single Zone of murchisoni at Pencerrig etc. Of the species listed by Elles C.murchisoni var crassiusculus (= C.m.bohemicus Boucek), M.vomerinus var. β (= M.v.gracilis) and Stomatograptus sp. have not been recorded by the present writer though the first two were listed by Watney and Welch (1911). Unfortunately it has proved impossible to trace Watney and Welch's collection but C.m.var. crassiusculus is probably synonymous with C.centrifugus whilst as suggested below (p. 188) their M.vomerinus var β is the form described in this work as M.v.basilica (Lapworth). Apart from these differences the fauna given by Elles is close to that at Cautley but, as has been shown, it has been found convenient to divide the original Zone of murchisoni into two.

The faunal changes into the riccartonensis Zone given by Elles (1900) include the appearance in abundance of the name fossil together with M.capillaceous (= M.antennulatus) and, rarely, P.dubius. In the Cautley Wenlock the last two species occur rather uncommonly in the Subzone c of the riccartonensis Zone but then typify the overlying Zone of antennulatus where riccartonensis is absent. The species M.priodon and M.vomerinus var.α (= M.v.vomerina) recorded by Elles from the riccartonensis Zone do not range above the base of the riccartonensis Zone at Cautley and even here are not common.

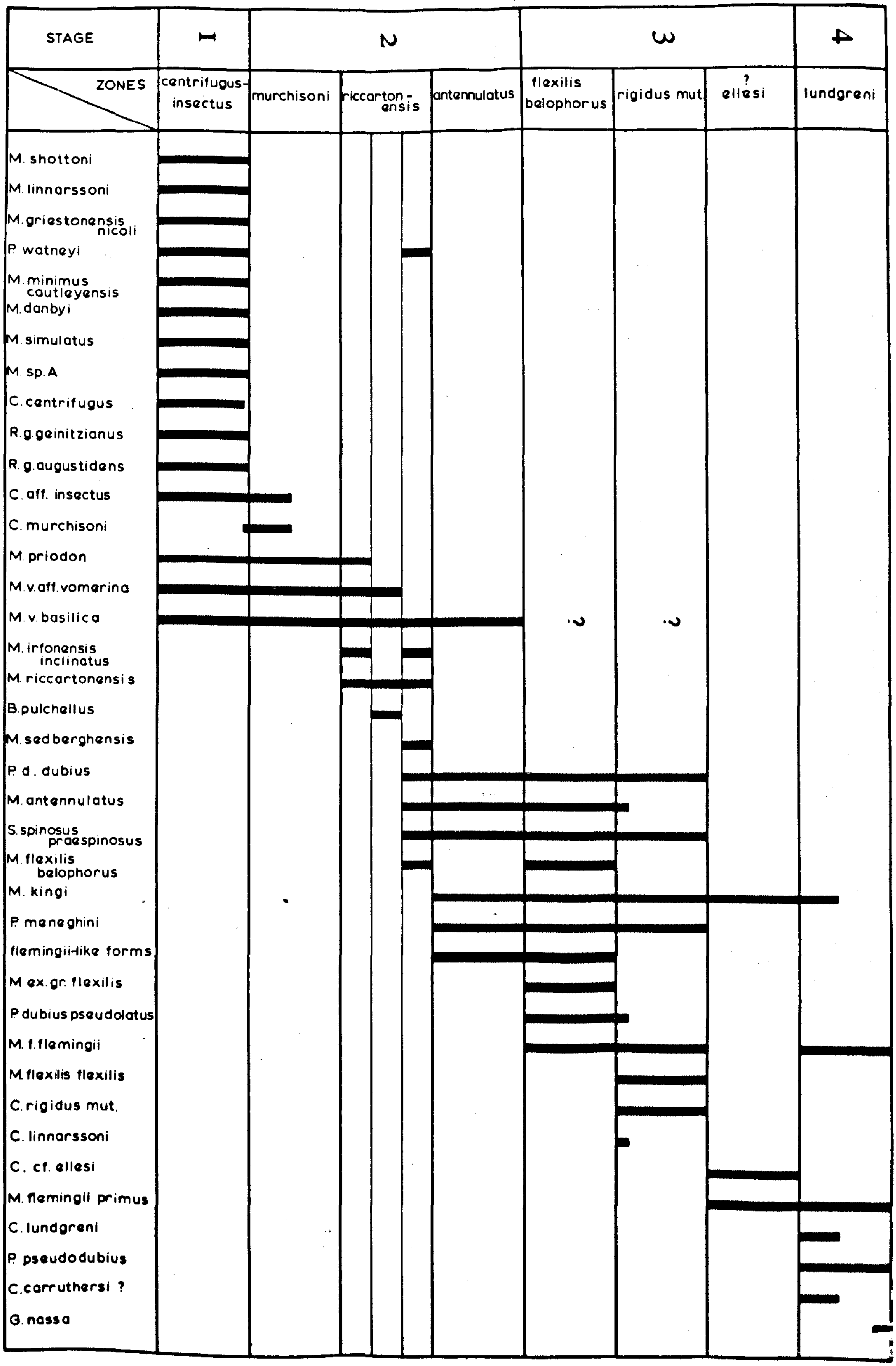
The C.symmetricus Zone (= C.rigidus) was defined by Elles as containing in addition to the name fossil, M.dubius, M.hisingeri var, M.vomerinus var.α M.v.var. and M.priodon. Elles and Wood (1912) record also M.flemingii primus. The Zone of flexilis belophorus has more affinities with higher strata than the riccartonensis Zone in particular the presence of M.f.flemingii, flemingii-like forms, flexilis-group species and M.kingi. On the continent P.m.meneghini is only found in higher strata (v. Pribyl 1944) whilst flexilis belophorus is recorded from the Zone of M.flexilis (v. Pribyl 1942). Furthermore the top of the flexilis belophorus Zone is marked by the appearance of C.linnarssoni and M.flexilis (considered by Elles(1900)and Elles and Wood (1912) to be typical of the linnarssoni Zone) and what is probably a late mutation of C.rigidus. Considering these facts the flexilis belophorus Zone is equated with the C.rigidus Zone of the Welsh Borderland (though lacking the name fossil) and the rigidus mut. Zone with that of C.linnarssoni.

Correlation further afield is more difficult but the presence, for example, of some Continental species may provide a clue for at least general correlation. The term centrifugus-insectus Zone is not intended to imply equivalence with the Zones of centrifugus and insectus recognized in Bohemia but is used in a purely descriptive manner. Nevertheless the presence of C. centrifugus at the base of the Wenlock Series suggests at least approximate equivalence. Other species recorded from the centrifugus Zone in Bohemia and found in the centrifugus-insectus Zone at Cautley are: M.v.vomerina and R.g.geinitzianus. Neither species is diagnostic and others recorded from the Cautley Zone (e.g. M.linnarssoni and R.g.augustidens) appear to be more typical of lower horizons in Bohemia. The situation is made more difficult by the fact that the species C.murchisoni described from Bohemia may not be conspecific with Carruthers' species and thus casts some doubt upon the supposed equivalence of the murchisoni Zones of the two countries. What is clear,

<table>
<tr><th>Elles & Wood (1901-18)</th><th>Zones established in present work</th><th>Watney & Welch (1911)</th></tr>
<tr><td>Zone of C. lundgreni</td><td>Zone of C. lundgreni</td><td>Zone of C. lundgreni</td></tr>
<tr><td>Zone of C. rigidus (=ellesi)</td><td>? Zone of C. ellesi</td><td></td></tr>
<tr><td>Zone of C. linnarssoni</td><td>Zone of C. rigidus mut.</td><td>Zone of C. rigidus</td></tr>
<tr><td>Zone of C. symmetricus (=rigidus)</td><td>Zone of M. flexilis belophorus</td><td rowspan="3">Zone of M. riccartonensis</td></tr>
<tr><td rowspan="2">Zone of M. riccartonensis</td><td>Zone of M. antennulatus</td></tr>
<tr><td>Zone of M. riccartonensis</td></tr>
<tr><td rowspan="2">Zone of C. murchisoni</td><td>Zone of C. murchisoni</td><td rowspan="2">Zone of C. murchisoni</td></tr>
<tr><td>Zone of C. centrifugus - C. insectus</td></tr>
</table>

TEXT FIG. 3m

TEXT FIG. 3n


STAGE
1
2
3
4
ZONES
centrifugus-insectus
murchisoni
riccarton-ensis
antennulatus
flexilis belophorus
rigidus mut.
? ellesi
lundgreni
M. shottoni
M. linnarssoni
M. griestonensis nicoli
P. watneyi
M. minimus cautleyensis
M. danbyi
M. simulatus
M. sp. A
C. centrifugus
R. g. geinitzianus
R. g. augustidens
C. aff. insectus
C. murchisoni
M. priodon
M. v. aff. vomerina
M. v. basilica
?
?
M. irfonensis inclinatus
M. riccartonensis
B. pulchellus
M. sedberghensis
P. d. dubius
M. antennulatus
S. spinosus praespinosus
M. flexilis belophorus
M. kingi
P. meneghini
flemingii-like forms
M. ex. gr. flexilis
P. dubius pseudolatus
M. f. flemingii
M. flexilis flexilis
C. rigidus mut.
C. linnarssoni
C. cf. ellesi
M. flemingii primus
C. lundgreni
P. pseudodubius
C. carruthersi ?
G. nassa

however, is that a general sequence of similar faunas is found in both regions.

Other species more commonly recorded from the Continent are: P.m.meneghini, P.pseudodubius, M.minimus and C.insectus. The latter is described here as C.aff insectus although it is not completely known and may show some differences from Boucek's species. The Cautley specimens of M.minimus are sufficiently distinct to warrant description as a new subspecies, cautleyensis, and is therefore of little use as a stratigraphic indicator. P.m. meneghini is recorded from the M.flexilis Zone of Bohemia and doubtfully from the C.rigidus Zone. At Cautley it appears first in the antennulatus Zone and continues into the flexilis belophorus Zone (equivalent to the rigidus Zone of the Welsh Borderland) but becomes most common in the rigidus mut. Zone (equivalent to C.linnarssoni Zone, Wales and M.flexilis Zone, Bohemia) P.pseudodubius is recorded from the lundgreni Zone at Cautley and is found at a similar level in Bohemia.

CHAPTER 4

THE LUDLOW SERIES

Previous work on the Ludlow Series of the Cautley district follows much the same pattern as work on the Wenlock Series, most workers having considered the two Series at the same time. Sedgwick (1852) in his "Ravenstonedale Section" recognized the following divisions overlying the Coniston Flags: " b. coarse hard grit, alternating with thin bands of slate and flagstone (= Coniston grit). a' Slate, with conglomerate and calcareous concretions (= Ireleth slates) and a. Coarse grit and slate with calcareous concretions. Graptolites Ludensis" His divisions a' and a are approximately equivalent to beds later known as Bannisdale Slates. Sedgwick (op. cit.) was also the first worker to trace the Coniston Grits through the Cautley district. Thus he writes "... tracing it from Cautley Crags through the south end of the Screes; thence, across Winsterdale, to a high mountain ridge called Adamthwaite Bank; and lastly to the north flank of Harter Fell. It is chiefly composed of hard grey grits, which alternate with thin bands of slate and flagstone..." Sedgwick's description of the lithological nature of the rocks and the alternation of facies was not bettered by later workers in the same region.

Aveline and Hughes (1888) recognized two divisions above the Stockdale Shales, the Coniston Flags and Grits and the Bannisdale Slates. The Coniston Flags and Grits were considered to be Wenlock in age and the Bannisdale Slates in part Wenlock and in part Ludlow. In this work they also refer to the Riggs south of Sedbergh, and to Cautley Crags and Cautley Spout where Cardiola interrupta, Pterinea tenuistriata, Orthoceras subundulatum, and Lituites giganteus were collected. A description is given of the Winder Grit and its position noted as within 1200' of the base of the Coniston Grits.

Dakyns et al. (1891) described the Coniston Grits and Bannisdale Slates with particular reference to the Cautley district. Together with the Coniston Flags and Stockdale Shales these divisions were included in the Upper Silurian. The Coniston Grits were divided into three lithological units but the present writer has been unable to recognize these. The total thick ness of the Coniston Grits was thought to be not less than 3000'. The distribution of the Bannisdale Slates in the Ravenstonedale area is given and from Wyegarth Gill they recorded Graptolites, Acidaspis, Cardiola, Pterinea Orthoceras.

The Ludlow rocks of the district were again examined by Watney and Welch (1911) who laid emphasis on the faunal content of the rocks and did not establish a detailed lithological succession. On the question of the passage between the nilssoni and leintwardinensis Zones (which were identified by them them) they write "... but, since the watershed occurs in the Ludlow rocks, no complete sedtion is found, and hence it has not been possible to trace the passage between the Nilssoni and the Leintwardinensis Zones." It was considered that the Zone of Phacops obtusicaudatus might possibly be equivalent to the M.vulgaris Zone of the Welsh Borders.

Since this work the Ludlow strata of the Cautley area have received mention in several papers (e.g. Marr 1913,1916) but no further detailed work has been undertaken. The nature of the Wenlock-Ludlow boundary is described in detail below and a stratigraphical succession overlying the "Phacops obtusicaudatus" Beds is established.

The Base of the Ludlow Series

Watney and Welch (op. cit.) place the "Phacops obtusicaudatus" Bed at the base of the Ludlow Series and describe it as a yellow, sandy bed. As will be pointed out below (p. 93) the lithology is in fact limestone. Text fig. 4a shows the variation of the basal limestone throughout the region. Where it is well exposed it is clear that the limestone is bipartite and contains a thin bed of graptolitic mudstone. This is best seen on Ashbeck Gill, Knott, and Spengill but has also been observed south of the region in the Barbon Fells. It has been shown above that M.f.flemingii and P.pseudodubius occur commonly only a few feet below the base of the limestone and that G. nassa probably occurs here more rarely.

The graptolitic mudstone within the basal limestone contains graptolites and has yielded the following assemblage:-

Pristiograptus nilssoni (Barrande)	2S
Monograptus scanicus Tullberg	1Ra
Monograptus c.chimaera Barrande	5Bd
Monograptus colonus compactus Wood	5Bd

Monograptus chimaera salweyi (Lapworth)	1Ra
Monograptus varians Wood	2S
Pristiograptus vicinus (Perner)	1As,2S

This assemblage is clearly a nilssoni Zone fauna and the basal limestone cannot, therefore, be equivalent to the vulgaris Zone of the Welsh Borderlands as suggested by Watney and Welch, unless the lowest part of the bipartite limestone be placed in this position. The fauna beneath the limestone is indicative of the Wenlock Series and the lower part of the limestone is the only bed which might be attributed to the vulgaris Zone. The actual recognition of such a Zone by name is, however, quite unnecessary and would contribute nothing to the elucidation of the stratigraphy of the region.

The presence of M.scanicus so close to the base of the Ludlow Series is of interest and because of its occurrence both here and at higher levels the lowest Ludlow graptolite Zone is termed the nilssoni-scanicus Zone.

Ashbeck Gill and Knott (v. text fig. 4a) both show the same pattern of deposition, and, though the exposures in each case are not perfect, a lower limestone (10' thick on Knott) is separated from an upper limestone (20' thick on Ashbeck Gill) by a thin band of graptolitic mudstone. The overlying beds on Knott seem to be about 22' of graptolitic mudstone before the first of the Ludlow greywackes come in.

A similar sequence is seen on Spengill though here the relative thicknesses of the limestones are reversed. The lowest is a poorly calcareous, pyritous limestone about 15' thick which has usually to be dug out. This is followed by about 6' of graptolitic mudstone containing P.nilssoni, P.vicinus and M.varians. Above this bed are 9' of poorly exposed pyritous limestone. The limestone at this locality seems to be only locally highly calcareous and only fragmentary fossils were obtained. Watney and Welch, however, record P.obtusicaudatus. This section differs from those just described in that the upper limestone is immediately followed by 8' of greywacke. Even further north (Gaisgill) limestone (presumed to be the upper limestone) is followed directly by greywacke. In both instances however, this thin greywacke is followed by graptolitic mudstone. In the case of Spengill a fault brings down greywackes after only 12' of these latter mudstones but on Gaisgill the graptolitic mudstone is followed by 40' of coarse greywacke before a thin (4', 3Ga) graptolitic mudstone band is seen.

On Stockless Gill there are at least 50' of graptolitic mudstone overlying the basal Ludlow limestone, and a similar thickness is represented in the gully draining the western slopes of Wandale Hill, and on Screes Gill.

The mouth of the Ecker Secker Beck section provides another feature of interest with respect to the basal limestone. At this locality the lowest limestone is 4'-5' thick and is overlain by about 6' of graptolitic mudstone (1Ra) containing M.scanicus and M.chimaera salweyi. The upper limestone is missing and coarse greywackes follow directly upon the graptolitic mudstone for a thickness of at least 10' after which a thin graptolitic mudstone band is found intercalated in the greywackes. A considerable thickness of rock is missing since the upper part of the limestone, the second Ludlow graptolite band, and much of the overlying greywacke are absent. The slumped beds north of Cross Haw and exposed on the R.Rawthey and the slumped beds of the Cross Keys region are thought to represent masses of sediment slumped respectively south and north off an axis in the region of Ecker Secker. Such strata (100' + at Crosshaw and 60-70' at the Cross Keys) are seen nowhere else in the region and at the northern locality are known to overly the lowest part of the basal limestone. Furthermore, whilst measurement of the direction of slumping is not easy, those beds in the southern outcrop appear to have moved from the north and those in the northern outcrop from the south (v. text fig. 4b) At each locality the slumped unit consists of beds of undisturbed or relatively undisturbed graptolitic mudstones alternating with obvious slumped beds and homogeneous strata in which no internal features can be seen.

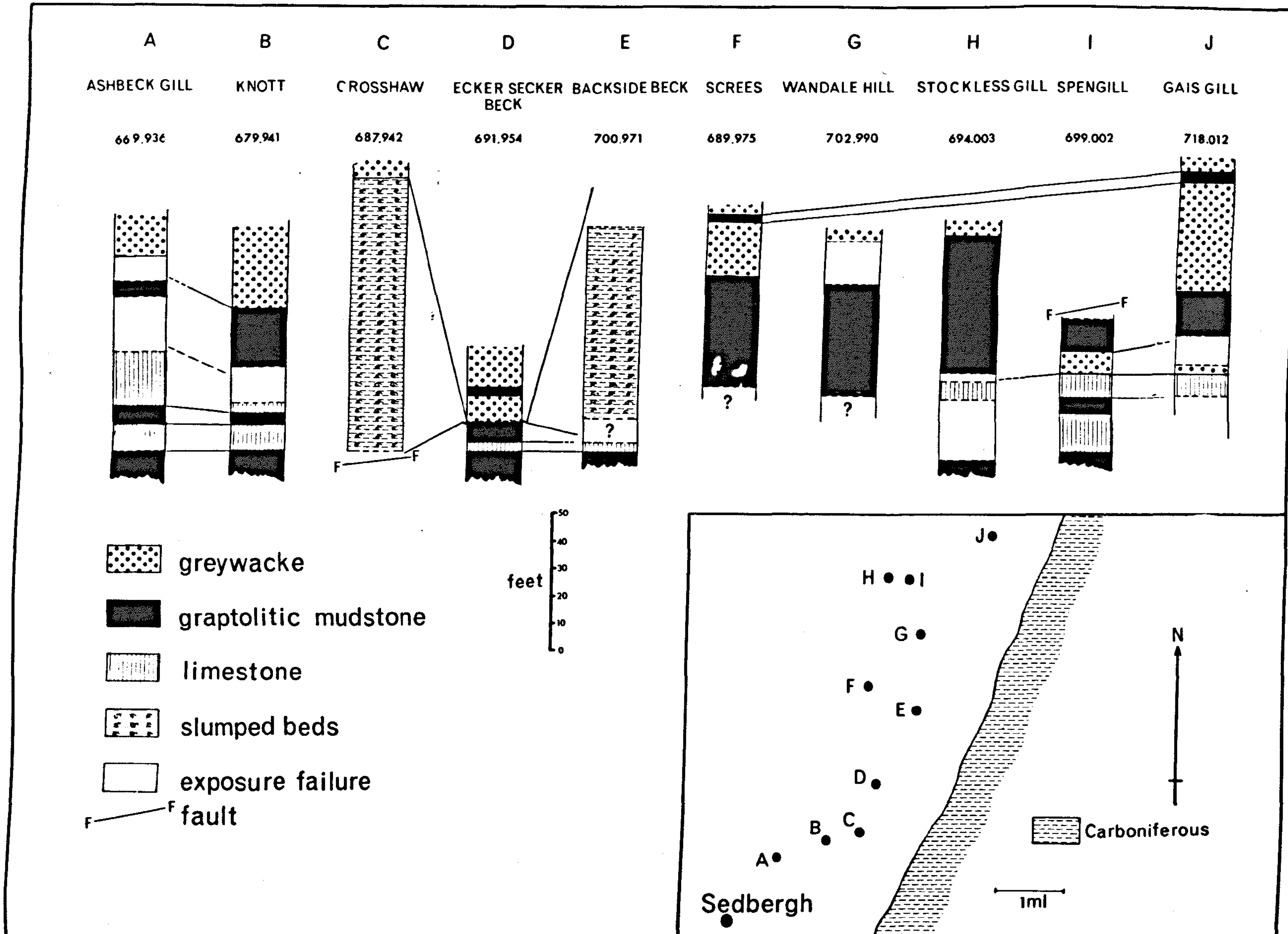
The development of the basal Ludlow limestone and its associated beds is summarized in text figs. 4a and 4b. Several conclusions may be drawn:-

a) The basal beds of the Ludlow Series are composed of a bipartite limestone in which an intercalated graptolitic mudstone yields a nilssoni-scanicus Zone fauna. The beds are underlain by the Wenlock Series.

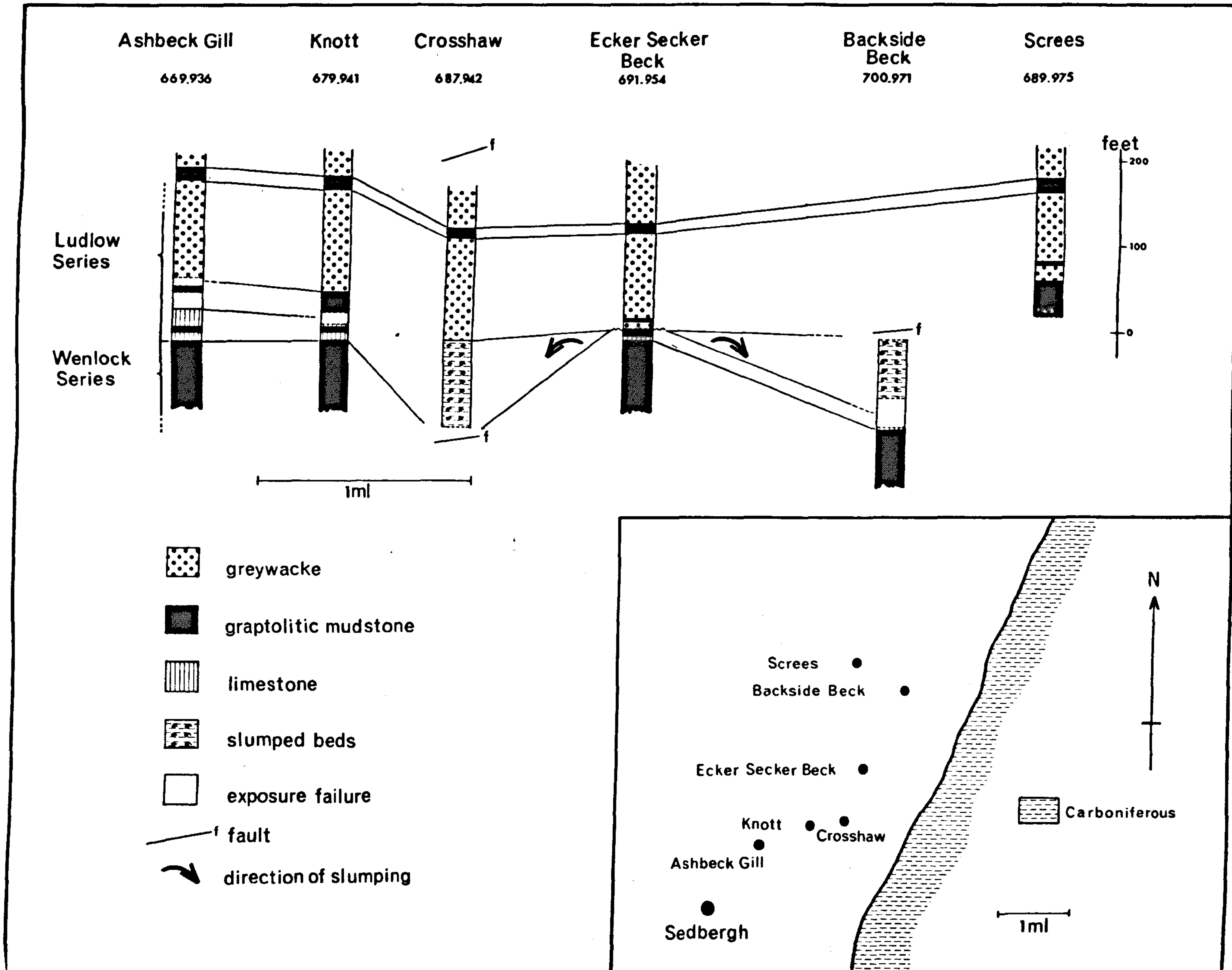
b) The lowest limestone bed is of variable thickness and is thinnest in the region of Ecker Secker Beck and increases from 4'-5' to 15' on Spengill to the north.

c) The upper limestone bed decreases in thickness to the north and in this latter area is overlain by a thin greywacke.

d) The basal limestone is overlain by the second Ludlow graptolite band which varies from about 20' in the north and south to about 50' or more in


A
B
C
D
E
F
G
H
I
J
ASHBECK GILL
KNOTT
CROSSHAW
ECKER SECKER BECK
BACKSIDE BECK
SCREES
WANDALE HILL
STOCKLESS GILL
SPENGILL
GAIS GILL
669.936
679.941
687.942
691.954
700.971
689.975
702.990
694.003
699.002
718.012
greywacke
graptolitic mudstone
limestone
slumped beds
exposure failure
fault
feet
50
40
30
20
10
0
Sedbergh
Carboniferous
N
1ml

TEXT FIG. 4a



Ashbeck Gill
669.936
Knott
679.941
Crosshaw
687.942
Ecker Secker Beck
691.954
Backside Beck
700.971
Screes
689.975
feet
200
100
0
Ludlow Series
Wenlock Series
f
1ml
greywacke
graptolitic mudstone
limestone
slumped beds
exposure failure
fault
direction of slumping
N
Screes
Backside Beck
Ecker Secker Beck
Knott
Crosshaw
Ashbeck Gill
Sedbergh
Carboniferous
1ml

TEXT FIG. 4b

the centre of the district.

e) A minor axis or upwarp existed in the Ecker Secker region from which unconsolidated sediments slumped.

The Nilssoni-scanicus to Leintwardinensis Zones

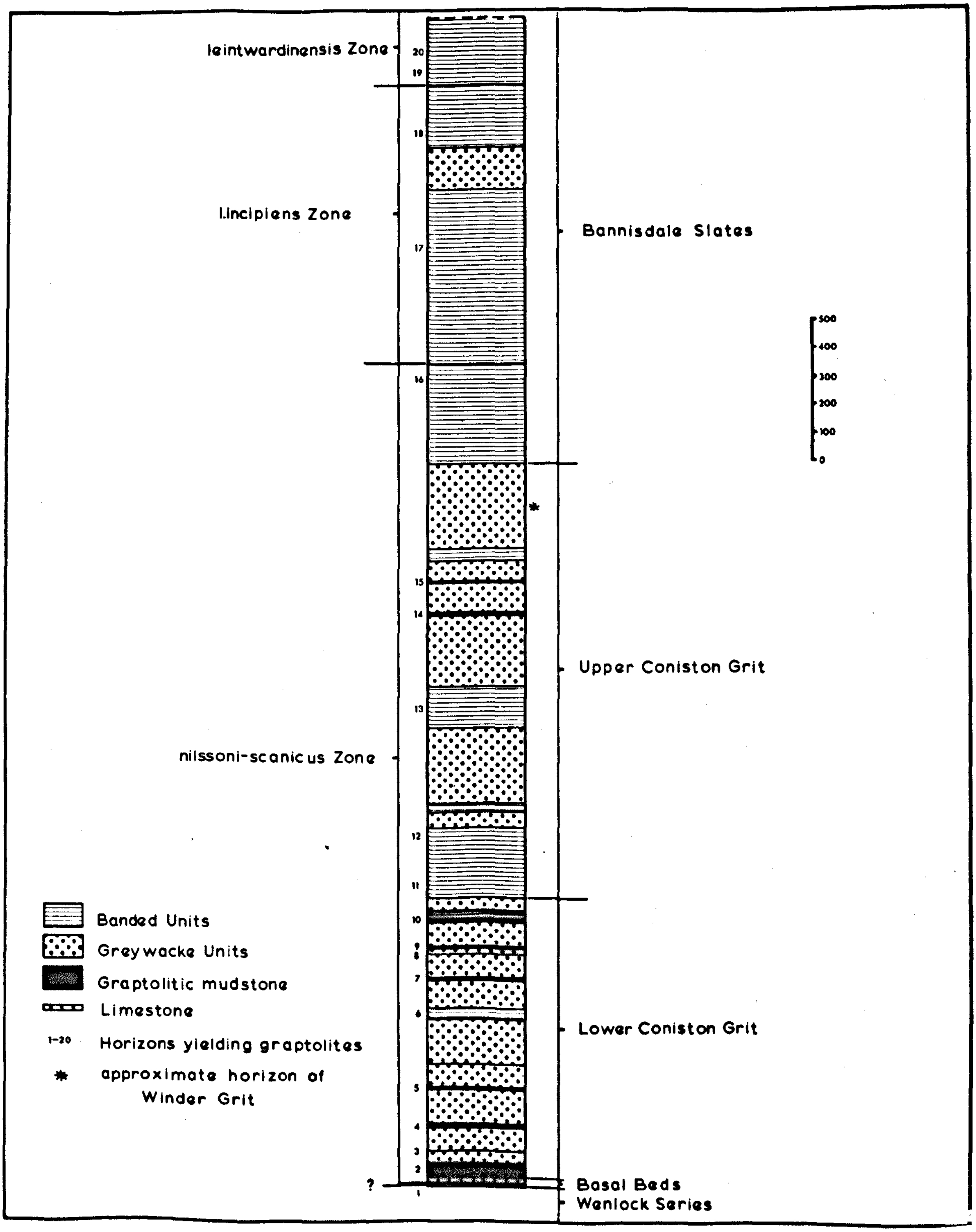
The establishment of a stratigraphical succession in the Ludlow Series has been a task of great difficulty, firstly because the fossils range through considerable thicknesses of strata and secondly because stream sections usually show only relatively small parts of the succession. Great Dummacks, Cautley Crags, The Screes and Bram Rigg Beck are the key areas for the recognition of the succession which explains why Watney and Welch (1911) were unable to describe a detailed sequence from the area they chose for study. Sedgwick (1852) clearly realized the importance of the Cautley Crags region and was able to trace the Coniston Grits for some distance. Text fig. 4c shows a generalized stratigraphical succession for the Ludlow strata.

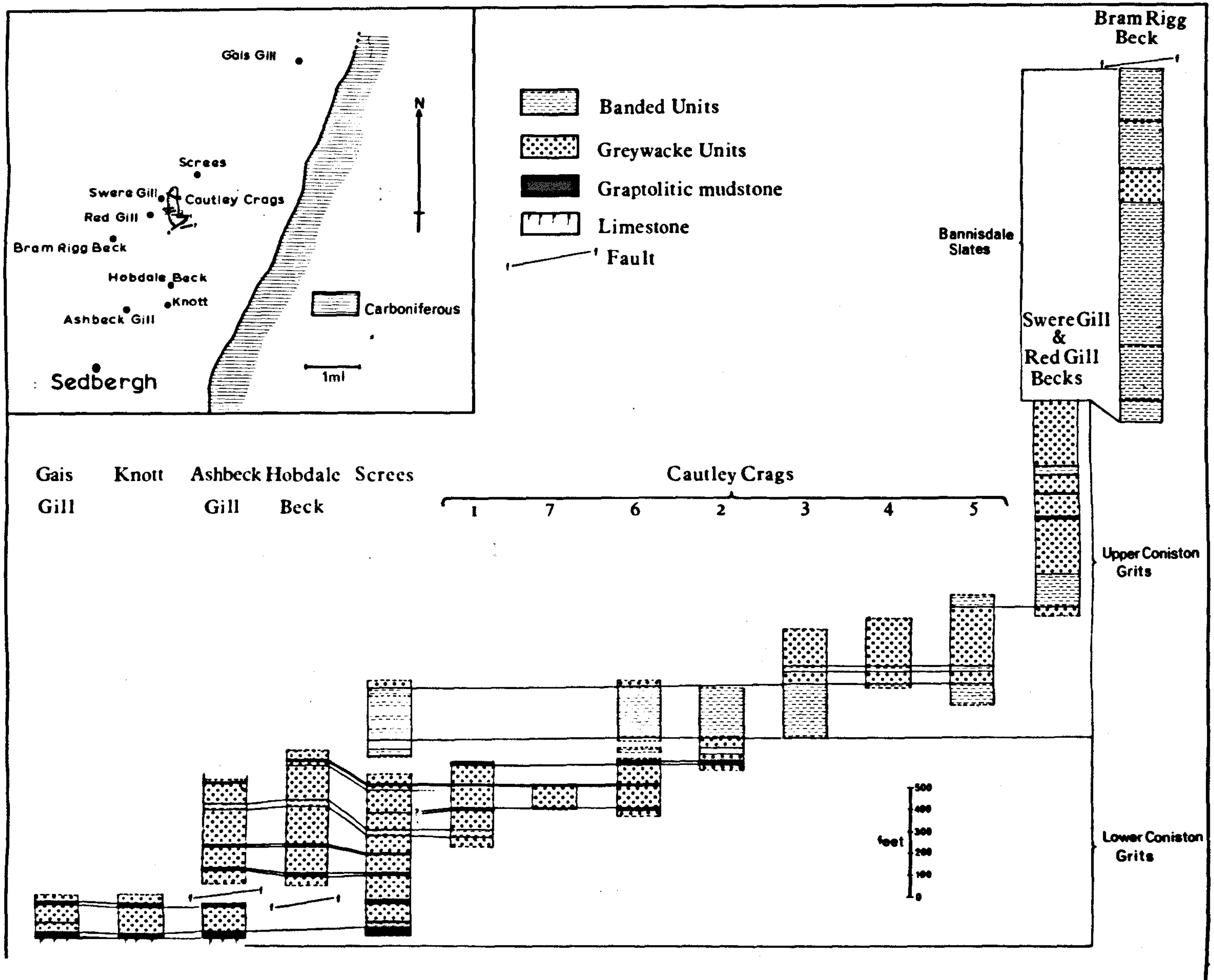
The lowest 1000' consists of alternating units of graptolitic mudstone and greywacke. The former are relatively thin and average 10'-15' in thickness, whilst the latter are each about 100'. Above this are 1500' of strata consisting of alternations of rather thicker units (each approximately 250' thick) of greywacke and the Banded Unit Facies. Finally there are at least 1500' in which the predominant rock type is the Banded Unit Facies (description see p. 99 et seq.) and in which greywacke units are subordinate. The last division is placed in the Bannisdale Slates and the lower two in the Coniston Grits.

Text fig. 4dis a correlation chart of the many relatively short sections which have been measured. It is noticeable that, considering the amount of greywacke present in the succession, the thicknesses of the various units show remarkably little lateral variation. There is a simple explanation for this fact. It is shown in chapter 7 that the greywackes are derived from the north west and that the sediments thicken in this direction. Since most of the measurements carried out have been made between Ravenstonedale in the NE and Sedbergh in the SW they clearly lie in a line at right angles to the direction of supply of sediment and hence on the line in which least variation in thickness is to be expected.

The first exposures on Screes Gill are of 15' of graptolitic mudstone

TEXT FIG. 4c


leintwardinensis Zone
l.incipiens Zone
nilssoni-scanicus Zone
Bannisdale Slates
Upper Coniston Grit
Lower Coniston Grit
Basal Beds
Wenlock Series
500
400
300
200
100
0
Banded Units
Greywacke Units
Graptolitic mudstone
Limestone
1-20 Horizons yielding graptolites
* approximate horizon of Winder Grit


Gais Gill
Screes
Swere Gill
Cautley Crags
Red Gill
Bram Rigg Beck
Hobdale Beck
Knott
Ashbeck Gill
Sedbergh
N
1ml
Carboniferous
Banded Units
Greywacke Units
Graptolitic mudstone
Limestone
Fault
Bram Rigg Beck
Bannisdale Slates
Swere Gill & Red Gill Becks
Gais Gill
Knott
Ashbeck Gill
Hobdale Beck
Screes
Cautley Crags
1
7
6
2
3
4
5
Upper Coniston Grits
Lower Coniston Grits
feet
500
400
300
200
100
0

TEXT FIG. 4d

containing very large nodules of calcareous mudstone from which only shelly fragments could be obtained. It is probably this stratum to which Marr (1913 p.12) refers and considers "... is probably, however, very low down in the Ludlow succession." This is confirmed by the present writer who considers the bed to be only a short distance above the basal Ludlow limestones. It is overlain by 23' of graptolitic mudstone (1 Sc) containing no calcareous material and which yielded the following assemblage:-

P.nilssoni (Barrande) | P.vicinus (Perner)
P.dubius (Suess) | M.scanicus Tullberg
M.varians Wood | M.roemeri Barrande
M.chimaera salweyi (Lapworth)

Above 1Sc are 107' of greywackes containing a four foot graptolitic mudstone band 20' above the base. No fossils were obtained from this band but a 4' band in the same position on Gaisgill yielded M.leintwardinensis incipiens? At the top of the 107' greywacke unit is a 15' graptolitic mudstone containing some calcareous beds (2Sc) and which yielded the following species:- P.vicinus, M.varians, M.leintwardinensis incipiens. The presence of M.l. incipiens low down in the nilssoni-scanicus Zone supports a similar record by the writer from locality 2W (700,982) on Wandale Hill. This locality yields a nilssoni-scanicus Zone fauna but contains incipiens in abundance. Its stratigraphical position cannot be proven but by the nature of the lithology and the preservation of graptolites in full relief it was thought to represent part of either the 1st or 2nd Ludlow graptolite bands. The fauna of 2W is as follows: P.bohemicus, P?.wandalensis, P.ex.gr. dubius, M.haupti, M.chimaera aff salweyi, M.varians pumilis, M.c.colonus, M.l.incipiens, Slava interrupta, crinoids, orthocone cephalopods, phyllopods, and Spirorbis sp. Watney and Welch (1911) record P.nilssoni from the same locality. M.leintwardinensis incipiens also occurs at a much higher level and will be dealt with below.

Overlying 2Sc is a 115' greywacke unit before a further graptolitic mudstone band (10', 3Sc) yields P.nilssoni. Upstream of this bed the strata continue to be well exposed in the narrow, gorge-like valley and a further 84' of greywacke were measured. The degree of exposure then becomes temporarily rather poor and there may be some graptolitic mudstone at this level. Measurement is continued by climbing out of the right bank of Screes Gill ar onto the face of The Screes itself. A further 80' of massive, generally ungraded greywacke were measured before the next fossiliferous locality, 4Sc, was reached. P.bohemicus was obtained from this locality which consists of about 30' of well bedded rock of which only a subordinate amount is graptolitic mudstone. The rest is composed of fine-grained non-graptolitic mudstone and the bed as a whole is clearly intermediate between the "pure" graptolitic mudstone facies and the Banded Unit facies. Whilst the Banded Unit Facies is typical of the Bannisdale Slates it makes its first appearance as thin beds much lower down in the succession. It is composed of thin graptolitic mudstone beds set in unbanded, fine-grained mudstones and siltstones of a darkish grey hue in which calcareous nodule bands are not infrequent and laminations of ripple drift bedding fairly common. The facies is fully described on P.99 et. seq.) Working westwards along the face of The Screes a further 75' of greywackes are seen. These contain sole markings and often have the calcareous nodules mentioned by Sedgwick which weather to a brown rottenstone. At the top of this division is a three foot bed showing slumping which is the only evidence of slumping detected by the writer except for the case already described above. The exposures are rather poor for a few yards but then a 90' greywacke unit, exceptionally massively bedded and coarse in grain, crops out along about one hundred yards of the face. Overlying this unit are 38' of greywackes containing two thin graptolitic mudstone bands (5Sc, 2'; 6Sc,6'). Both have yielded only fragments of graptolites. Examination of the Screes succession on text fig. 4d shows that above this point the beds are not well exposed, but that the greywackes contain a Banded Unit of about 30' followed by a 40' greywacke unit before the exposures become too poor for direct measurement. There is room west of this position for about 230' of beds most of which, to judge by the poor exposures, are of the Banded Unit Facies. This is the first thick bed of this facies and is equivalent to an identical bed on Cautley Crags (which can in fact be traced round Cautley Crags, through Cautley Spout to the appropriate point on the Screes. Further consideration of the succession is best taken up on Cautley Crags but it is as well to note that up to the base of the thick Banded Unit almost 1000' of strata have been measured. The typical succession of thin graptolitic mudstone units alternating with thicker greywacke units is well shown on several other sections such as :- Yarlside, Gaisgill, Knott, Ashbeck Gill etc. (v. text fig. 4d).

On Cautley Crags (Section 3) the first major Banded Unit has a thickness of 246' and contains only rare greywacke beds. About 30' from the top at locality 1Cc (6825,9630) the beds are very fossiliferous and have yielded complete specimens of Odontopleura hughesi Salter, Pterinea sp. and orthocone cephalopods. At the same level locality 8Cc on The Screes contained O.hughesi, Pterinea sp. and S.interrupta. Overlying the thick Banded Unit is a 54' greywacke unit followed by a further 27' of Banded Unit facies. No fossils have been collected from this latter horizon from any part of the district but it invariably occurs at the same point above the thick Banded Unit. This is then followed by a thick greywacke unit of which 170' are seen on Section 3 before exposmres peter out. Measurement is continued on Section 5 of Cautley Crags since Section 4 does not show the top (though 220' of greywacke are exposed). Section 5 shows 270' of greywacke overlain once again by 50' of Banded Unit facies of which the top is not seen. Locality 7Cc has yielded M.varians pumilis and Pterinea sp. in abundance. This is the highest horizon seen on Cautley Crags and further measurement must be continued on the streams which drain Great Dummacks and enter Cautley Spout (Swere Gill, Red Gill and Force Gill Beck)

The last mentioned Banded Unit is exposed on Swere Gill and measures 140'-150' in thickness. No further fossiliferous localities were found. It is overlain upstream by a 250' greywacke unit topped by 12' of graptolitic mudstone from which numerous lamellibranchs and a coral were obtained. A further 100' of greywacke separate this bed from a 6' bed of graptolitic mudstone (4Cc) which yielded:- P.nilssoni?, P.bohemicus, M.v.varians, the last two species being very common. Above 4Cc is a 75' greywacke unit followed by 40' of Banded Unit Facies. Exposures then become rather poor but are invariably of greywacke before the stream section finally becomes obscured by drift.

Until this point exposures have been fairly continuous and there has been little difficulty in tracing beds but as the watershed is approached exposures are very poor. Between here and the head of Bram Rigg Beck there is room for approximately 650' of strata of which the lowest beds are greywackes (described above from the last exposures of Swere Gill) and the highest beds of Banded Unit Facies. Locality 6Cc on Little Dummacks is in these latter beds and shows a considerable thickness of them. The following fossi[ls] were collected:-

M.varians	Calymene sp.
M.v.pumilis	orthocone cephalopods
M.aff. tumescens	lamellibranchs
M.leintwardinensis incipiens?	

The fauna, therefore, is still indicative of the nilssoni-scanicus Zone. Elles and Wood (1913) record M.v.varians from the nilssoni Zone and M.v.pumilis from both this and the scanicus Zone but not from higher levels.

From the head of Bram Rigg Beck the strata are well exposed until the junction with Rowantree Grains Gill is reached, and the beds are almost exclusively of the Banded Unit Facies. Between the stream source and the point 6645,9600 620' of beds have been measured. Fossils are not easily obtained but locality 1Br 394' above the base of this 620' division yielded numerous specimens of M.leintwardinensis incipiens but no other species. These beds are overlain by 150' of greywacke which form the highest greywacke unit in the area examined. Downstream of this unit 220' of the Banded Unit Facies are exposed by the time the junction with Rowantree Grain Gill is reached though in this section the degree of exposure begins to deteriorate. Locality 4Br yields M.leintwardinensis incipiens again to the exclusion of other species. A further thickness of approximately 240' is exposed rather sporadically between the mouths of Rowantree Grains Gill and Swarth Greaves Beck. The strata are unfolded and dip gently downstream at angles of between 30° and 12° until a fault brings in higher strata about one hundred yards downstream of the mouth of Swarth Greaves Beck. Localities 3Br and 5Br each yield M.l.leintwardinensis quite abundantly from very thin beds of graptolitic mudstone contained in a predominantly unfossiliferous succession. No specimens of M.l.incipiens were collected. The higher strata exposed downstream are of the Banded Unit Facies but no contained graptolitic mudstone was found in spite of exhaustive examination.

The succession outlined above is summarized in text fig.4c . If the Bannisdale Slates are to represent a distinct facies, and the base a facies change, then the boundary with the Coniston Grits should be drawn below locality 6Cc but above the greywackes which form the lower half of the 650' thick section. This is the procedure which the Survey workers followed but they did not clearly designate the actual beds at which the line should be drawn.

in any particular area, though deductions may be made from the published sheets (Aveline, Hughes and Tiddeman 1872; Aveline and Hughes 1872; Aveline Hughes and Strahan 1888). Marr (1892) showed that in the Lake District the Bannisdale Slates were equivalent to the leintwardinensis Zone. If the base of the division is drawn at the base of the leintwardinensis Zone in the Howgill Fells then the Bannisdale Slates would be an unnatural division and this procedure is not, therefore, adopted. The palaeontological divisions do not quite correspond with the lithological units, and all beds from locality 60c downwards should be referred to the nilssoni-scanicus Zone. The nilssoni-scanicus Zone extends, therefore, into the lowest 350' of the Bannisdale Slates as defined at Cautley. The thickness of the Coniston Grits is thus approximately 2,500 feet and the thickness of the nilssoni-scanicus Zone is 2,850'.

Above the nilssoni-scanicus Zone are 990' of strata yielding only M.l. incipiens followed by at least 240' containing only M.l.leintwardinensis. Since M.l.incipiens has been shown to occur in the nilssoni-scanicus Zone its presence cannot be taken to indicate the leintwardinensis Zone. Wood (1900) in describing the Zone of M.l.incipiens in the northern part of the Long Mountain district writes "It is probable, however, that the horizon marked by the typical form is here unfossiliferous, and that M.leintwardinensis var. incipiens occupies a lower position in the succession" The thickness of the l.incipiens Zone is given as 900'. In the same region Wood does not recognize either the scanicus or tumescens Zones, but considers that the l.incipiens Zone is probably equivalent to the tumescens Zone elsewhere.

Thus at Cautley the Ludlow Series is best divided into the following Zones:-

Zone of M.leintwardinensis	240' min.
Zone of M.leintwardinensis incipiens	990'
Zone of M.nilssoni-M.scanicus	2850'

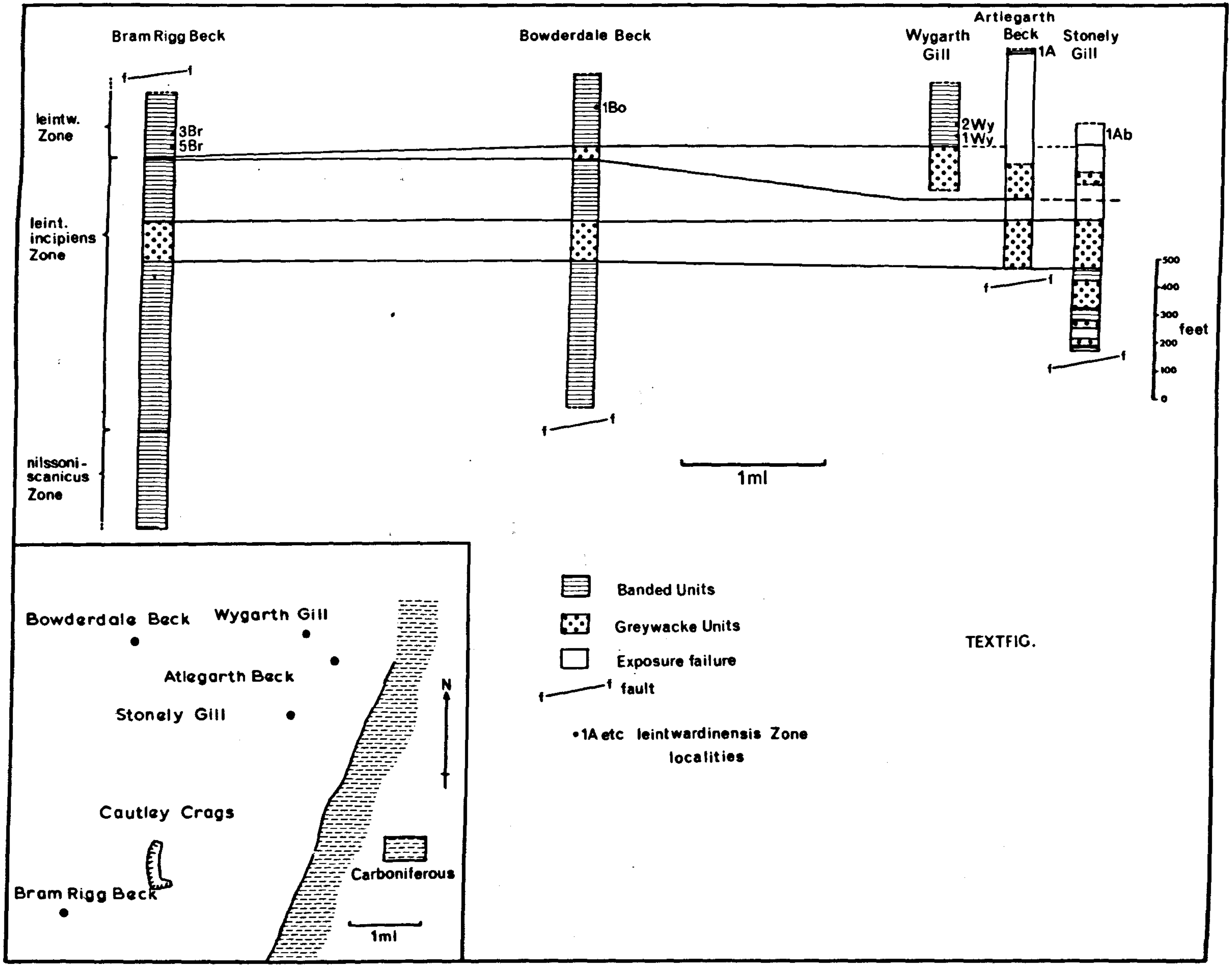
The leintwardinensis Zone, with a minimum thickness of 240' on Bramm Rigg Beck, probably reaches a maximum thickness of about 500' before the higher, unfossiliferous Bannisdale Slates are reached. Whether it recurs at a higher level cannot be determined in the region under examination.

This order of Zones is similar to that obtained by Wood in the northern part of the Long Mountain district and the leintwardinensis incipiens Zone occurs roughly in the position of the tumescens Zone of other regions. Watney and Welch (1911) thought that strata between their Zones of leintwardinensis and nilssoni might be equivalent to the scanicus and tumescens Zones of the Welsh Borders, and it is probably these which are equivalent to the Zone of M.l.incipiens described here. In the area which they examined such a Zone could not be identified because of the generally poor exposure at this level. Strata yielding M.l.leintwardinensis in other parts of the area also contain M.l.aff incipiens and P.welchi sp. nov. P.welchi occurs at a lower level in association with M.chimaera salweyi (locality 1We) whilst M.l.aff. incipiens is probably the form described by Watney and Welch as M.l.incipiens and may be a descendant of M.l.incipiens recorded from a lower level by the writer.

Several other sections in the region show the succession of the Ludlow Series to varying degrees of completion. These are summarized on text figs. 4d and e where they can be compared with the most complete successions. On Spengill the 2nd Ludlow graptolite band is exposed above the basal limestone and thin greywacke. Twelve feet of beds were measured before a fault brings down greywacke, and from this point upstream the beds are poorly exposed and quite immeasurable. The locality (3S) contains abundant graptolites and the following species were collected: P.? wandalensis?, M.roemeri, M.v. varians, M.v.pumilis, M.leintwardinensis incipiens. Stockless Gill (6940, 0025) has the strata similarly poorly exposed but above the basal limestone are at least 50' of graptolitic mudstones containing the following species: P.? wandalensis?, P.auctus sp. nov. M.chimaera salweyi, M.scanicus?, M.c. chimaera?

The similar thickness of graptolitic mudstone seen on the western slopes of Wandale Hill (localities 5W-10W, totalling at least 40') are probably of the same horizon. The following species were obtained: P.dubius, P.auctus, P.vicinus, P.bohemicus, M.colonus, M.roemeri, M.varians pumilis, G.nassa, S. spinosus, Phacops stokesi, cystids, crinoids, brachiopods, orthocone cephalopods, corals (rare).

Above the basal Ludlow limestone of Gaisgill is a thin bed of greywacke as on Spengill, and above this 16' of graptolitic mudstones are exposed though there is room for rather more. This locality (3Ga) yielded P.dubius, P.vic-



Bram Rigg Beck
Bowderdale Beck
Wygarth Gill
Artlegarth Beck
Stonely Gill
leintw. Zone
leint. incipiens Zone
nilssoni-scanicus Zone
3Br
5Br
1Bo
2Wy
1Wy
1A
1Ab
f
500
400
300
200
100
0
feet
1ml
Bowderdale Beck
Wygarth Gill
Atlegarth Beck
Stonely Gill
Cautley Crags
Bram Rigg Beck
N
Carboniferous
1ml
Banded Units
Greywacke Units
Exposure failure
fault
•1A etc leintwardinensis Zone localities
TEXTFIG.

TEXT FIG. 4e

inus and a single bedding plane with M.fritschi. A further 125' of greywacke containing a 4' band of graptolitic mudstone can be measured downstream of 3Ga firstly in the right bank and then in the left leaving the stream and measuring up to the road. The higher beds are poorly exposed but are topped by about 15' of graptolitic mudstone exposed in a small quarry by the side of the road. Further downstream the exposures fail and it is clear that a fault passes through this region since the next beds seen are of a much higher level. Locality 1A on the road south of Banks Farm yields specimens of M.leintwardinensis (v. Watney and Welch 1911, p.231). Between locality 1A and the last beds seen on Artlegarth Beck near the footbridge due south of Bank Farm there is room for at least 400' of strata. Those beds exposed upstream of the footbridge are of two greywacke units respectively 120' and 169' thick separated by a 75' Banded Unit. The greywackes may be approximately equivalent to the 150' of greywackes seen on Bramm Rigg Beck upstream of locality 4Br, but if the species recorded by Watney and Welch is in fact M.l.incipiens then the sequence seen in this region may be of a lower horizon. The writer's few specimens from locality 1A were more suggestive of aff. incipiens than the type subspecies, but were not sufficiently well preserved to allow a definite specific determination.

In the region of Adamthwaite Bank (709,005) locality 1Ab yields numerous specimens of M.leintwardinensis and M.l.aff incipiens. As in the case of the Banks Farm area just described the fossiliferous locality is surrounded by an area of no exposure but seems to be underlain on Stonely Gill by beds consisting in the main of greywackes. Two greywacke units can be recognized, a lower one of 167' and an upper one of 159' thick, separated by a Banded Unit of at least 40'. The suggested correlation of the Banks Farm-Artlegarth Beck and Adamthwaite Bank-Stonely Gill succession with that established on Bramm Rigg is summarized in text fig. 4e

In view of the degree of exposure in the Bowderdale Beck section exact measurement of the beds is not possible but the same pattern as observed on Bramm Rigg Beck can be seen here also. Thus there is an upper thick Banded Unit (400') yielding M.l.leintwardinensis and Odontopleura hughesi at locality 1Bo, underlain by a greywacke unit (150') which in turn is underlain by an appreciable thickness of the Banded Unit Facies. This last division can be seen to be underlain by greywacke at (6775,0120) before a fault cuts across the valley and brings up lower strata to the south.

The Dale Gill - Greenside Beck section is not generally well exposed but has Coniston Grits exposed sporadically at least as far downstream as locality 2Da. Downstream from the waterfall (7050,0225) is a 260' thick Banded Unit which is probably equivalent to the unit of similar thickness seen on Cautley Crags and described above. Locality 2Da is thought to be equivalent to the Winder Grit of Settlebeck Gill (6600,9315) and like this latter bed is overlain and underlain by considerable thicknesses of greywacke. Downstream from 2Da a locality 1Gr yields M.l.incipiens, Odontopleura hughesi, and Pterinea sp. but exposure is not continuous between the two localities. The horizon of 2Da is clearly near the summit of the Coniston Grits. The Winder Grit of Settlebeck Gill and the slopes of Winder cannot be accurately placed in the succession but again it seems probable that it is near the summit of the Coniston Grits.

Wygarth Gill is similar to the Dale Gill - Greenside Beck section in that exposures are not continuous and that downstream are Bannisdale Slates overlying Coniston Grits which crop out sporadically nearer the stream source. The relationships between the two cannot be adduced and no attempt can be made to estimate the thickness involved in view of the degree of exposure. Locality 1Wy has yielded numerous specimens of M.l.leintwardinensis and M.l.aff. incipiens whilst 2Wy , slightly upstream contains lamellibranchs, orthocone cephalopods and O.hughesi.

Other less complete sections are included in the correlation charts of text figs. 4d and 4e or are dealt with, where necessary, in the following chapter. The following is a complete faunal list of the graptolites found in the three zones recognized:-

Zone of M.l.leintwardinensis

M.l.leintwardinensis Lapworth

M.l.aff incipiens Wood

P.welchi sp. nov.

Zone of M.l.incipiens

M.l.incipiens Wood

Zone of nilssoni-scanicus

P.nilssoni(Barrande)

P.bohemicus (Barrande)

P.dubius (Suess)

P.vicinus (Perner)

P.auctus sp. nov.

P.welchi sp. nov.

P.? wandalensis (Watney and Welch)

P. aff tumescens (Wood)

M.haupti (Kuhne)

M.colonus colonus (Barrande)

M.c.compactus Wood

M.chimaera chimaera (Barrande)

M.c.salweyi Lapworth

M.v.varians Wood

M.v.pumilis Wood

M.roemeri (Barrande)

M.leintwardinensis inciniens Wood

M.fritschi Boucek

M.scanicus Tullberg

Conclusions

The Ludlow Series is divisible into three Zones: nilssoni-scanicus, leintwardinensis inciniens and leintwardinensis, which are respectively 2850', 990', and 240' (seen) thick. The top of the Ludlow Series is not seen and the beds above the lowest 240' of the leintwardinensis Zone have not been examined in detail. A vulgaris Zone has not been recognized and beds equivalent to this Zone as described elsewhere cannot be identified.

On a lithological basis the Series can be conveniently divided into Coniston Grits below (2,500') and Bannisdale Slates above (1,580' seen). The Coniston Grits can be broadly divided into an upper division consisting of alternations of thick greywacke units and Banded Units each approximately 250' thick and a lower division some 1000' thick composed of alternations of greywacke units (each about 100') and thin graptolitic mudstones bands.

Both graptolites and shelly fossils seem to range through appreciable thicknesses of sediment but S.interrupta has not been found above the lowest beds of the Bannisdale Slates and is restricted to the nilssoni-scanicus Zone.

O.hughesi on the other hand appears near the base of the upper division of the Coniston Grit and continues through into the Bannisdale Slates. Lamellibranchs of the Pterinea tennustriata type seem to have a similar range to O.hughesi and both are typical of the Banded Unit Facies. The lowest graptolite bands contain more graptolites and a greater variety of fossils but many of the species of graptolites range throughout the nilssoni-scanicus Zone.

Correlation with other regions is implied by the usage of the Zonal names. The l.incipiens and l.leintwardinensis Zones combined might be equivalent to the leintwardinensis Zone of the Lake District recognized by Marr and also to the Zone of the same name described by Watney and Welch from Cautley. The scanicus Zone cannot be recognized as a distinct Zone and is best included with nilssoni as the nilssoni-scanicus Zone. Beds equivalent to the tumescens Zone of the Welsh Borderland have not been identified but it is possible that the l.incipiens Zone is in this position. A similar interpretation was given by Wood (1900) for the northern part of the Long Mountain district. The same writer considered Marr's Lake District leintwardinensis Zone to be the l.incipiens Zone and to overlie the nilssoni Zone directly.

TEXT FIG. 4f

SPECIES \ HORIZON	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
P. nilssoni	—	—		?	—									?						
M. scanicus	—	—		?																
P. vicinus	—	—		—																
M. v. varians	—	—		—	—					—		—			—	—				
M. c. chimaera	—	?		—																
M. c. salweyi	—	—					—						—							
M. colonus compactus	—	—																		
M. roemeri		—																		
P. dubius		—																		
M. varians pumilis		—								—		—	—			—				
P.? wandalensis		—																		
M. leintwardinensis incipiens		—	?		—											?	—	—		
Monoclimacis haupti		—																		
P. auctus		—																		
M. c. colonus		—																		
M. fritschi		—																		
P. bohemicus		—				—				—		—		—						
S. s. spinosus		—																		
G. nassa		—																		
P. welchi													—						—	—
P. aff. tumescens																—				
M. l. leintwardinensis																			—	—
M. l. aff. incipiens																			—	—
Zone	nilssoni-scanicus Zone																l. incipiens Zone		leintwardinensis Zone	

CHAPTER 5

GENERAL DISTRIBUTION OF STRATA

One of the objectives of this work has been to produce an accurate and detailed geological map. The first Survey map to cover part of the Cautley district was Sheet 98NE (1879, drift 1887, New Series Sheet 39) on the scale 1" to 1 mile which extended as far to the east as Bowderdale, Cautley Crags, and Hobdale Beck. It did not, therefore, include the Ordovician inliers and the region of the Dent Fault. In 1889 the Survey Sheet 97NW (New Series Sheet 40) was published and extended across the Dent Fault and well into Carboniferous country. A map on the scale 3" to 1 mile accompanied the paper by Watney and Welch (1911) on the Salopian rocks of the Cautley district. This map is little different from the Survey Sheets and the authoresses themsslves write "Beds other than Salopian and Upper Stockdale, and faults traversing these, are copied from the 1" Geological Survey Map, Sheet 97NW". In view of the nature of the palaeontological study undertaken by these workers the production of only a general map is surprizing since the recognition and mapping of relatively thin faunal Zones goes hand in hand with the identification of fault patterns etc. It is the purpose of this chapter to describe some of the features of the area which have not been dealt with in previous chapters and in particular to consider the effects of faulting upon the distribution of strata.

Watney and Welch (op.cit. p.216) were correct when they described the region as one which had undergone relatively simple folding, subsequently complicated by faulting. In comparatively few parts of the area do the dips in the Lower Palaeozoic rocks approach the vertical and the folds are only rarely isoclinal. Thus the northwestern slopes of Bluecaster (7120,9685) are composed of Wenlock strata striking constantly NE-SW and dipping to the NW at angles only occasionally in excess of 50° - and this in an area within half a mile of overturned and strongly folded beds of the Carboniferous Limestone Series. It might be argued that the intrusion of the Bluecaster Diabase sill prior to the Hercynian earth movements had reinforced this particular region, but the same general rule applies to strata quite close to the Carboniferous rocks along the whole length of the district. It is clear that the effect of the Hercynian earth movements has been to superimpose a system of faulting sub-parallel to the Dent Fault upon folds of an open nature. Local instances of high dip and tight folds of small magnitude are often the result of fault dragging but the introduction of an Hercynian set of folds has not taken place.

Caledonian Folds and Faults

To the west of the Cow Pasture - High Pasture area (696,936; 699,939) the strata are prominently folded on ENE-WSW lines, whilst the fold axes show no relation to the fault pattern. The most southerly pair of the four folds form an anticlinal hill and a synclinal valley and an examination of the topography further south suggests that several more such folds may exist before Hebblethwaite Hall Gill is reached. That the folds are tightest in the region of the wood and barn (693,937) is shown by the distance apart of the fold axes as one moves away from this point, and by the time Crosshaw Beck (to the north) and Hebblethwaite Hall Gill (to the south) are reached the fold pattern, fortuitously exposed in small streamlets near the wood and barn, is lost. Localities 3Cr-6Cr yield a fauna typical of the C.rigidus mut. Zone of Stage 3 and may be considered to overlie Stages 1 and 2 of Hebblethwaite Hall Gill and to underlie Stage 4 of Crosshaw Beck.

About half a mile to the west of the High Pasture - Cow Pasture area similar tight folding is seen on the R.Rawthey at Cross Haw (687,939). Further upstream near St. Marks (691,946) and upstream on Hobdale Beck (682,942) the folding is gentle and thereplunges to the west and west-south-west. As one travels towards the junction of Hobdale Beck with the R.Rawthey at Hobdale Bridge the strata, well exposed on the Rawthey in a gorge-like section, become involved in isoclinal folds. The fold axes are horizontal and are directed ENE-WSW. Text fig.5aA is a section showing the nature of some of these folds and quite clearly illustrates that they are not simple isoclinal folds. The folding becomes very gentle again quite abruptly a few yards south of Hobdale Beck mouth. The strata involved in the folding are Ludlow greywackes and in some localities the fine grained tops of graded greywacke beds can be seen to be completely sheared out by movement parallel to the bedding plane. This is indicated by the slickensided and brecciated junctions between beds. Bounding the greywackes to the west is the Sedbergh Fault which cuts Hobdale

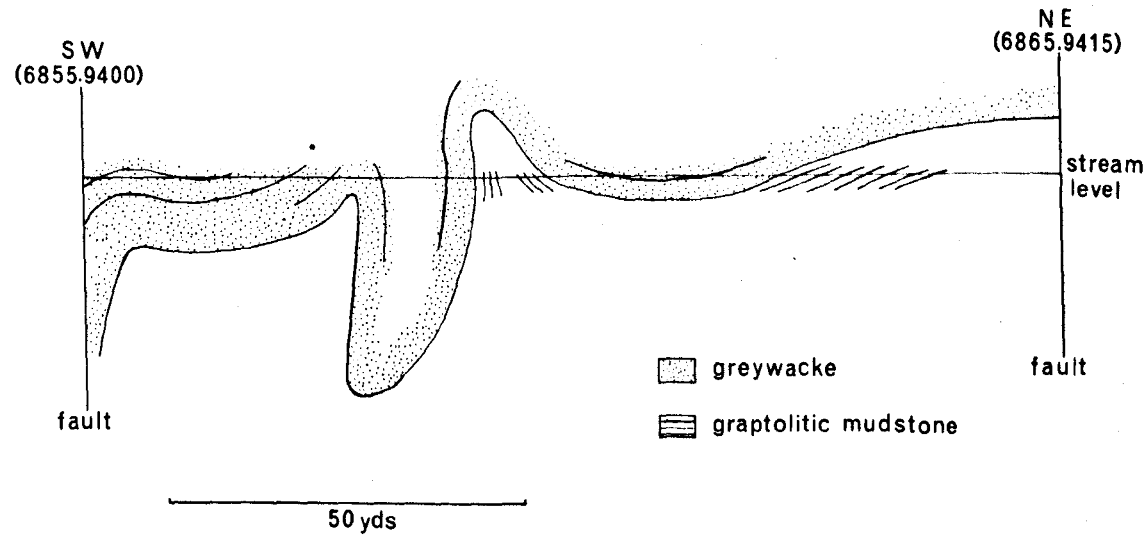
TEXT FIG. 5aA

Sketch section of the Ludlow strata exposed west of Cross Haw in the R. Rawthey.

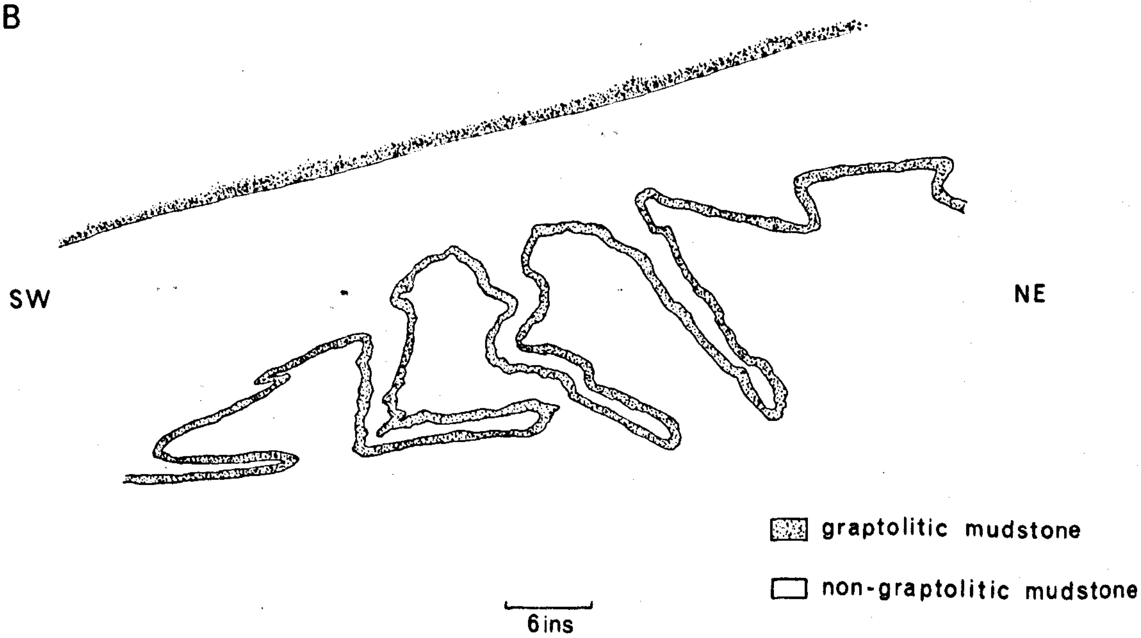
TEXT FIG. 5aB

Sketch of slumped beds seen west of Cross Haw in water-smoothed surfaces of the exposures.

A


SW
(6855.9400)
NE
(6865.9415)
stream
level
fault
fault
greywacke
graptolitic mudstone
50 yds

B


SW
NE
graptolitic mudstone
non-graptolitic mudstone
6 ins

Beck at (6825,9410) and to the east the Rawthey Fault brings up Wenlock strata. If the strike of the axial planes of the isoclinal folds is followed away from the Crosshaw region it is seen that the folded region lies in structural discontinuity with the surrounding areas. It shows, in fact, more of the characters of the Cow Pasture - High Pasture district and it appears that these rocks have been brought into their present position from further south by northward movement of a tear fault rather than by vertical displacement bringing different structure levels into juxtaposition.

Folding of the type just described is seen at no other localities in the strata which have been examined (i.e. up to the lowest beds of the leintwardinensis Zone). However, the higher Bannisdale Slates in the immediate vicinity of the Carboniferous unconformity of Ravenstonedale also appear to be strongly folded, and, in some localities at least, the folds are isoclinal. The Weasdale (691,038) and Bowderdale (675,039) areas show strongly folded beds. In the western Howgill Fells the Coniston Grits are also folded isoclinally as can be seen on Carlingill Beck (645,992). The fold axes in this region are directed E-W and the fold cores are often broken and quite commonly faulted. In these instances the E-W faults appear to be of the same age as the folds i.e. Caledonian. It will be shown later in this chapter that E-W faults closely connected with an E-W pattern of folds can still be identified in the eastern Howgill Fells despite the superimposed pattern of Dent Line dislocation.

The nature of the folding characteristic of the Ludlow Series in the eastern and south eastern parts of the Howgill Fells can best be deduced in the Bramm Rigg area west of Great Dummacks. Examination of the 6" map shows that a major anticline extends from Cautley Crags (988,660) along Bram Rigg, to as far west as Castley Knotts (645,961). To the south is a complimentary syncline of Brant Fell. The plunges of these major folds are variable in degree but invariably to the west. Generally speaking the plunge is greatest in the region of Cautley Crags, that is immediately adjacent to the westerly-throwing Hercynian N-S faults. It is possible, therefore, that the westerly plunges were increased during the Hercynian orogeny. The two major folds described above are puckered on their limbs by oblique folds of small amplitude but moderate wave length. These minor folds originate on the crests of the major folds as, for example, at Seevy Rigg (653,962) where the major Bram Rigg anticline has two diverging synclines. One of these extends W.N.W. from Seevy Rigg to Long Rigg Beck (647,964) and the other W.S.W. from Seevy Rigg to east of Ivy Crag (6450,9575). The crest of the major anticline in the Seevy Rigg area is almost flattened out (almost synclinal in fact) as is shown by the strikes of the strata on Calf Beck (655,963) and Bram Rigg Beck. If the fold axes in a system of this type are plotted indiscriminately then there will appear to be two sets of folds whose axes are slightly oblique to each other. It is, therefore, better to consider such a system as <u>one</u> set of major folds containing lesser oblique folds upon the limbs. Both types of fold must have formed simultaneously. As can be seen from the map the dips on the limbs rarely exceed 50°. The writer considers that it is this type of non-isoclinal folding which persists eastwards into the Cautley valley (its presence at Cautley Crags is undisputed). Naturally as the Dent Line is approached the number of faults increases though this may also be in part a reflection of a change to a lower, less competent, tectonic level. The Lower Llandovery dark mudstones are, for example, far more dislocated than other rock types above. The effect of increased dislocation upon the fold style described above will be to alter the angles of plunge (in this case tend to increase them to the west), to change the angle of dip upon the limbs, and make less easily recognizable the major fold trends particularly if some faults have a horizontal component. Examination of the folds along the Cautley valley shows that the axes vary between ENE-WSW and ESE-WNW. In addition a few major axes lying approximately E-W can be discerned. Thus in the NE Ordovician inlier the upper reaches of Sally Beck cut through an anticline and the lower reaches near Rawthey Bridge cut through higher strata held in a syncline.

There is yet another point of interest to be gleaned from the Bramm Rigg anticline. Cutting obliquely across the folds described above are a series of small scale plunging monoclines. These are exposed at the head of Bramm Rigg Beck (6695,9620), Rowantree Grains Gill (664,955) and Swarth Greaves Beck (6525,9550). Their magnitudes and cross cutting nature suggest that they are later than the main folds whilst their approximate parallelism to the Hercynian faults in the SE indicate that they may be of the same age as the faults - indeed that they may be the first stage of such faults.

It has been thought in the past that isoclinal folding occurred in the watershed between the Cautley valley and Ravenstonedale. Thus Watney and Welch (1911 p.231) postulated such a state of affairs on the Gais Gill section (715,010). In fact the strata can be demonstrated to young to the north down the whole of the Gais Gill section from the point where Long Gill joins it, to the part where the exposures fail on Artlegarth Beck (722,015). The change in horizon along the Gais Gill section can be explained simply and solely by the means of E-W and NNW-SSE faults. Thus at the point where the Adamthwaite road crosses Gais Gill (7170,0110) Wenlock strata are exposed yielding M.f. flemingii and ?Monoclimacis sp. at 1Ga. A short distance downstream these beds are overlain by the basal Ludlow limestone and the lowest strata of the Ludlow Series and less than 300 yards to the NE Bannisdale Slates appear.

Between the two outcrops of low and high Ludlow strata no amount of isoclinal folding could bring down such high beds (without faulting) so that a fault must pass through the region of no exposure. (In consequence, unlike most of the faults on Gais Gill, this one is not exposed). The fact that sole markings show that the beds young continuously to the north confirms this. This fault is probably the same dislocation which separates the greywackes of Three Gills (721,997) from the Wenlock Series on Five Gills (725,999).

A short distance to the south of locality 1Ga greywackes are once again exposed. The E-W fault (Gais Gill Fault) which occurs between the two localities is exposed on Gais Gill at the point (7135,0105) where it is also cut by a NNW-SSE fault with a well developed fault breccia. This latter fault brings down Ludlow greywackes to the west, whilst a NNE-SSW fault at the point (711,011) brings up Wenlock strata once again. At the junction of Long Gill and Gais Gill Wenlock beds are well exposed and both the lithological character and faunal content prove them to belong to Stage 1. The strata dip to the NNE and, therefore, whilst moving upstream one moves down the succession. A short distance upstream the same E-W Gais Gill Fault as previously noted brings in higher Wenlock strata to the south but these unfortunately are not well exposed.

At several points on the stream sections in this area "monoclinal" folding is seen, which probably represents folds of small amplitude on the limbs of major folds. An example is seen in the Bannisdale Slates just mentioned where, in less than one hundred yards, the dip increases from 26° to 76° and then abruptly back to 30 . In this northern part of the Cautley district the major folds described above have not been identified and the "monoclinal" type is most common. Faulting on the middle limb of these structures is to be expected and can be seen in several instances (e.g. Greenside Beck, 706, 024). The "monoclines" themselves are parallel to the strike which is here approximately E-W, and therefore parallel to the E-W faults of which the Gais Gill Fault is but one example. Other examples are: the Stonely Gill Fault (7115,0015); the Randy Gill Fault (6825,9950); the Bowderdale Fault (679, 998) and the Five Gills Fault (717,996). The most southerly of these are difficult to trace for long distances since the amount of cross faulting increases considerably.

As in the case of the western Howgill Fells mentioned above this E-W faulting is closely connected with the E-W Caledonian folding. Both folds and faults of this type are cut by Hercynian faults which greatly complicate the picture and make the recognition of the earlier structures very difficult in the southern and eastern parts of the Howgill Fells.

Hercynian Faulting

Having thus summarized the main Caledonain fold types and their distribution together with their associated faults, it remains to examine the complicated pattern of Hercynian fractures. These are concentrated in a belt some 6 miles long and 2 miles wide to the west of the Carboniferous strata. The general trend of the fracture belt is NNE-SSW and whilst some faults are parallel to this direction (e.g. Rawthey-Wandale Hill Fault) many others are oblique to it (e.g. the Murthwaite Fault). Broadly speaking three main directions of strike of the fault planes can be distinguished:

a) NNE-SSW e.g. Rawthey-Wandale Hill Fault
b) NE-SW e.g. Murthwaite Fault, Sedbergh Fault
c) NNW-SSE e.g. Harter Fell Fault

In addition to these main types there are numerous small faults often striking at high angles to the direction of the major faults and which are clearly accommodation features formed simultaneously with the latter.

It has been suggested at various times in the past (e.g. Marr 1916) that the dislocations in this region might be tear faults. If each of the main categories of faults (a,b,c, above) are examined it will be seen, firstly, that the NNW-SSE faults cannot be tear faults, at least not in the region of Gais Gill. In this region two such faults crop out from Harter Fell to Wygarth Gill, both cut the Caledonian Gais Gill Fault, yet neither displaces it. Nor is there any evidence further south that faults of this trend have a horizontal component.

Those in the first category (a) are parallel to the Dent Fault and have the greatest length of outcrop of the three groups. The outcrop of the Dent Fault in the region of Fell End (725,991) is flexuous and cannot, therefore, have a horizontal component unless the fault plane is corrugated and has a considerable vertical component or, alternatively, unless the "fault" is formed by a series of fault slivers. This last interpretation is a possibility and can be easily envisaged in the High Pasture -Blake Rigg (705,942) - Taythes Gill (708,953) region to the south. North of the point where the Dent Fault cuts the R.Rawthey (718,974) exposure is not sufficient to determine this degree of detail and the "fault" is merely the line separating carboniferous (vertical beds) from older strata.

It has already been suggested that the position of the Ludlow strata in the region of Crosshaw might be due to a tear fault. This would involve horizontal movement along either the Sedbergh Fault or the Rawthey Fault. The Sedbergh Fault has a very prominent curved outcrop and, as far as can be ascertained, its fault plane is vertical. It is unlikely, therefore, that this fault is a tear fault. The Rawthey-Wandale Hill Fault on the other hand has a remarkably straight outcrop for almost six miles, and conceivably has a horizontal component. This is supported by the fact that several structures to the west of the line cannot be traced to the east (e.g. the Bram Rigg - Cautley Crags anticline).

It will be appreciated that in an area of faulting of this nature some of the usual means of identification of tear faults (such as manner of displacement of outcrops) cannot be used. The later movement of fault blocks and slices quite independant of each other renders any general deductions on the manner of displacement of outcrops extremely difficult. Nevertheless in the case of the Murthwaite Fault (category "b") sinistral movement seems to have torn the Ordovician strata and associated Silurian beds to the SW. The anticline on the upper reaches of Sally Beck (mentioned above) is not represented directly to the west of the Murthwaite Fault but has been displaced to the region west of Murthwaite Park. Thus the strike seen on Three Gills (722,997) is broadly maintained until Wandale Hill Gill B (705,984) but at

Wandale Hill Gill A (705,979) it has changed to approximately 130. The anticline plunges at about 25° to the west.

If the strike of the Murthwaite Fault is followed to the SW past Handley's Bridge it would be expected to cut Backside Beck in the region of the footbridge (7000,9825), and such is the case. The fault cannot be traced any further to the SW and whether it displaces the Rawthey-Wandale Hill Fault or is displaced by it cannot be ascertained with certainty. Since it does not cut the Pickering Gill region however, it is assumed that the latter is the case.

A fault striking parallel to the Murthwaite Fault can be traced in the R.Rawthey from the point where Middle Gill enters to the mouth of Backside Beck. It is almost continuously exposed for a distance of 400 yards and is represented by a considerable fault breccia. The most interesting locality along its course is seen at the mouth of Backside Beck. Here the strata adjacent to the fault are tightly folded and have their fold axes plunging quite vertically. It is difficult to conceive any other origin for such folds than formation adjacent to the fault plane of a tear fault. The south westerly termination of this fault remains in as much doubt as the Murthwaite Fault.

It would seem, therefore, that there is evidence to suggest that some faults in categories "a" and "b" above are tear faults. Assessment of the amount of horizontal movement is, extremely difficult however, but in the case of the Murthwaite Fault it may be up to half a mile in a sinistral sense. If the folded strata of Cross Haw have been positioned by tear faulting this would probably involve dextral tear. The occurrence of sinistral and dextral tear together on a small scale can be observed at the mouth of Wandale Beck where mudstones of Wenlock Stage 1 yielded long, badly preserved specimens of <u>M.v.basilica</u> which had been displaced in both senses on the same slab.

It is inevitable that the recognition of the structural pattern outlined above, and the mapping of it in the field will result in modifications of previous concepts of stratal distribution. The fault shown by Watney and Welch (1911) and the Survey workers (1889) as cropping out from the mouth of Backside Beck to Watley Gill for example, does not exist. However at the mouth of Backside Beck there is a very small fault which can be seen striking in the direction of Ben End but it cannot have a downthrow of more than a few feet since the horizon is the same on both sides of a very small breccia. At the summit of Ben End (695,976) a fault with a similar trend may separate the Ordovician rocks of Westerdale from the Silurian to the SW. Apart from these however, the strike of faults on Ben End is NNE-SSW and not NW-SE.

Differences compared with past work

Watney and Welch show an area of "Unmapped" Wenlock bounded on the north by Stockdale rocks. In fact the whole of this area is occupied by Ludlow strata except on Watley Gill where Wenlock rocks can be proven in the position in which those workers place "Stockdale". Some of the highest Llandovery rocks are cut out on Watley Gill by a fault striking along the slopes of Yarlside and Kensgriff but to the west of the fault some grey beds are seen overlain by the lowest Wenlock. Between this point and Yarlside crags no exposures are seen but at the latter locality the Ludlow succession can be established.

The same writers show an area of "Stockdale" between the footbridge near the Cross Keys (6985,9695) and the mouth of Cautley Holme Beck (6930,9675). Strata are exposed for about one hundred yards downstream of the footbridge and consist entirely of Ludlow greywackes. Furthermore a similar exposure of greywacke is seen about one hundred yards downstream of the mouth of Cautley Holme Beck. There is, therefore, no evidence whatsoever for the presence of Llandovery rocks in this area, nor indeed for the presence of Ordovician strata bounding them immediately to the NW.

The lowest half mile or so of Backside Beck is shown as forming the boundary between Wenlock and Ludlow rocks with the Zone of C.lundgreni to the east and Zone of M.nilssoni to the west. An examination of the writer's map will show that the manner of folding of the greywackes along this stream section precludes the occurrence of Wenlock strata either in the left bank or upon the slope of Wandale Hill. This can be confirmed in the field where the stream section as far upstream as the point 6985,9780 cuts through greywackes of Ludlow age which are at least 50' above the base of the Ludlow Series. At the above grid reference a fault brings up Wenlock strata between here and the locality upstream where the Wandale Hill Fault crosses Backside Beck (6980 9805).

Text fig.5b, illustrates the Wandale Hill Fault from the above locality to the most southerly of the scree-filled gullies on Wandale Hill. The strata exposed in the small stream draining from Narthwaite quarry may be continuous with those beds on Backside Beck just described. At locality 3W they yield C.lundgreni, P.dubius, M.f.flemingii, M.f.primus, and ?C.carruthersi and dip downstream at 56°. As one approaches the Mountain View road the dip lessens to 35° but throughout this stretch younger strata are exposed downstream. Consequently as one works upstream one cannot pass normally into Ludlow rocks. Locality 19W is Wenlock in age (cf. Watney and Welch 1911, p.229) yielding M.f.flemingii, whilst locality 2W contains a large Ludlow fauna of P.bohemicus etc. The two localities must be separated by a fault, whilst in Narthwaite Quarry itself a small fault is exposed which brings greywacke against the graptolitic mudstone of 2W. Below the Mountain View road Wenlock beds are exposed for some distance before a fault brings up L. Llandovery mudstones into which is intruded a thin representative of the Bluecaster Diabase. A few yards further downstream the main Wandale Hill Fault brings up Ordovician beds.

Several further discrepencies between the present work and past work can be seen by reference to the writer's 6" map which will be discussed in due course, but requiring immediate attention is the distribution of Stage 1 of the Wenlock Series on the NW slopes of Bluecaster.

Watney and Welch (op.cit.) depict their C.murchisoni Zone as extending from the old road up to 150 yards above it in the region of Middle Gill, Far Gill and Near Gill. Their text, however, (p.218 et. seq.) describes the Zone as cropping out below the road and only occurring above it in the region of Far Gill. On Far Gill no further exposures are found after 50 yards above the road. As it is, therefore, the width of outcrop of the rocks belonging to Wenlock Stage 1 can be proved to be at least 50 yards. Since in this area the thickness which can be assigned to this stage is a little over 70', the base must be very close to the last exposures some 50 yards above the road and certainly cannot be in the region of 150 yards above the road as suggested by Watney and Welch. On Far Gill the upper boundary of Stage 1 occurs at the old road which agrees with the position mapped by Watney and Welch for the top of their C.murchisoni Zone but on Middle Gill and Near Gill the upper boundary of Stage 1 lies a considerable distance below the road which agrees with the text but not with the map of Watney and Welch.

On the Middle Gill section grey beds of the U.Llandovery are exposed a

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few yards above the road just above a felsite sill, whilst on Near Gill similar beds are seen just below the road. The whole of Stage 1 must, therefore, lie below the old road on the Middle and Near Gill sections.

Areal Distribution of the Strata

The writer would like to draw attention in this section to the general distribution of strata and particularly to mention those sections and localities which it has not been possible to discuss above, or elsewhere.

The most southerly exposures of the L.Llandovery beds are on Whinny Gill (696,941; 698,942) where a small thickness of dark grey mudstone overlies poor exposures of Basal Beds of the Silurian. Graptolites such as C.normalis, C.medius, M.atavus etc. have been obtained though the A.acuminatus Zone could not be identified. In the case of the most northerly of these two localities the exposures peter out up a small gill which enters Whinny Gill from the SE. The southerly exposure is cut off after a few feet (?15') by an E-W fault which brings down U.Llandovery beds exposed in a cliff in the left bank. The latter are faulted against a thick felsite sill near the junction with Cross Haw Beck.

Further exposures of L.Llandovery beds are found on Marsh Lane (6930, 9425) and at locality 1Ma R.longispinus was obtained. Most of the exposures are of crushed mudstone and are overlain upstream firstly by a diabase sill, presumably part of the Bluecaster sheet, and secondly by badly disturbed U.Llandovery mudstones. Into the latter beds is intruded a thick felsite sill which is almost certainly the same bed as the sill on Crosshaw Beck.

The distribution of Wenlock Stages 1,2,3, and 4 between Hebblethwaite Hall Gill and Crosshaw Beck has already been mentioned but the former section is also of importance in furnishing a superb exposure of U.Llandovery rocks which are not intruded by felsitic material. The felsite sill described above, therefore, has either thinned out or occurs at a lower level than the turriculatus Zone which comprises the lowest Llandovery beds seen on Hebblethwaite Hall Gill. To the west the U.Llandovery is faulted against the Wenlock Series. Locality 10H yields a riccartonensis Zone (Subzone C) fauna of M.riccartonensis, M.antennulatus, and P.dubius whilst 11H contains M.riccartonensis. Higher beds are exposed downstream but no fossils were obtained. The Wenlock strata are faulted in the west against the basal Carboniferous conglomerate, the boundary between the two being marked by a considerable fault breccia. It is this fault which appears to terminate the Rawthey Fault.

Upper Llandovery strata are again seen in Lat Gill (692,945) further north where they crop out high in the left and right banks. "Red" beds and grey beds are seen underlying Stage 1 of the Wenlock which is exposed in the old pine wood.

On Ecker Secker Beck rather more than half a mile to the north both L. and U.Llandovery rocks are exposed upstream of the main road in a very dislocated and intruded section. Felsites and lamprophyre dykes cut the beds every few yards so that where the rock has not been crushed by fault movements it is baked hard. Fossils have not been obtained.

Finally the Llandovery rocks are exposed, generally rather poorly, around the western and north western periphery of the northeastern Ordovician inlier. The degree of faulting dictates that the exposures are usually of little use stratigraphically whilst the beds are often so crushed that fossils are not obtained readily.

The distribution of the Wenlock Series has been largely described but a few sections of interest remain. An inlier of Wenlock rocks is seen on the R.Rawthey at Rake Wood (6850,9335) where it is almost surrounded by conglomerate and faulted against Ludlow rocks. The beds are quite well exposed but are strongly stained by iron derived from the conglomerate above. Although the bedding is usually difficult to discern the strata appear to form a gentle anticline.

Stage 4 of the Wenlock Series is exposed between the Sedbergh Fault and the basal Ludlow limestone on Ashbeck Gill. The beds are extremely cleaved and it is almost impossible to split the rock parallel to the bedding plane so that no fossils were obtained. On lithological grounds however all the rocks exposed should be assigned to the fourth stage whilst a certain amount of repetition by folding and faulting may occur.

A short distance to the north of Stage 4 of Pickering Gill the Stage is also exposed beneath poor exposures of the Ludlow Series. Unlike the Pickering Gill sections fossils could not be obtained, but both localities clearly represent the highest Wenlock beds exposed in the core of the Bram Rigg -Cautley Crags anticline.

Further north Stage 4 is again exposed underlying the basal Ludlow limestone on Bowderdale Beck and Great Randy Gill. The rocks are folded into a series of E-W folds and are so cleaved that fossils could not be obtained. At the point 679,998 the mudstones are overlain, however, by the basal limestone of the Ludlow Series and a few feet (3') of greywackes before a fault lets down higher greywackes.

On Wandale Beck Stages 1 and 2 are exposed overlying grey beds of the U.Llandovery but upstream of 7115,9980 is a region of no-exposure until the bridge over the stream at Adamthwaite Farm is reached. These beds were ascribed to the Zone of C.lundgreni by Watney and Welch but the present writer could obtain no fossils either here or in the poorer exposures west of the farm. Some distance along Stonely Gill highly disturbed Ludlow greywackes are exposed. Though not seen in juxtaposition with the Wenlock Series they are assumed to be faulted against the latter since these greywackes belong to the Bannisdale Slates (leintwardinensis incipiens Zone)and not to the nilssoni Zone as mapped by Watney and Welch.

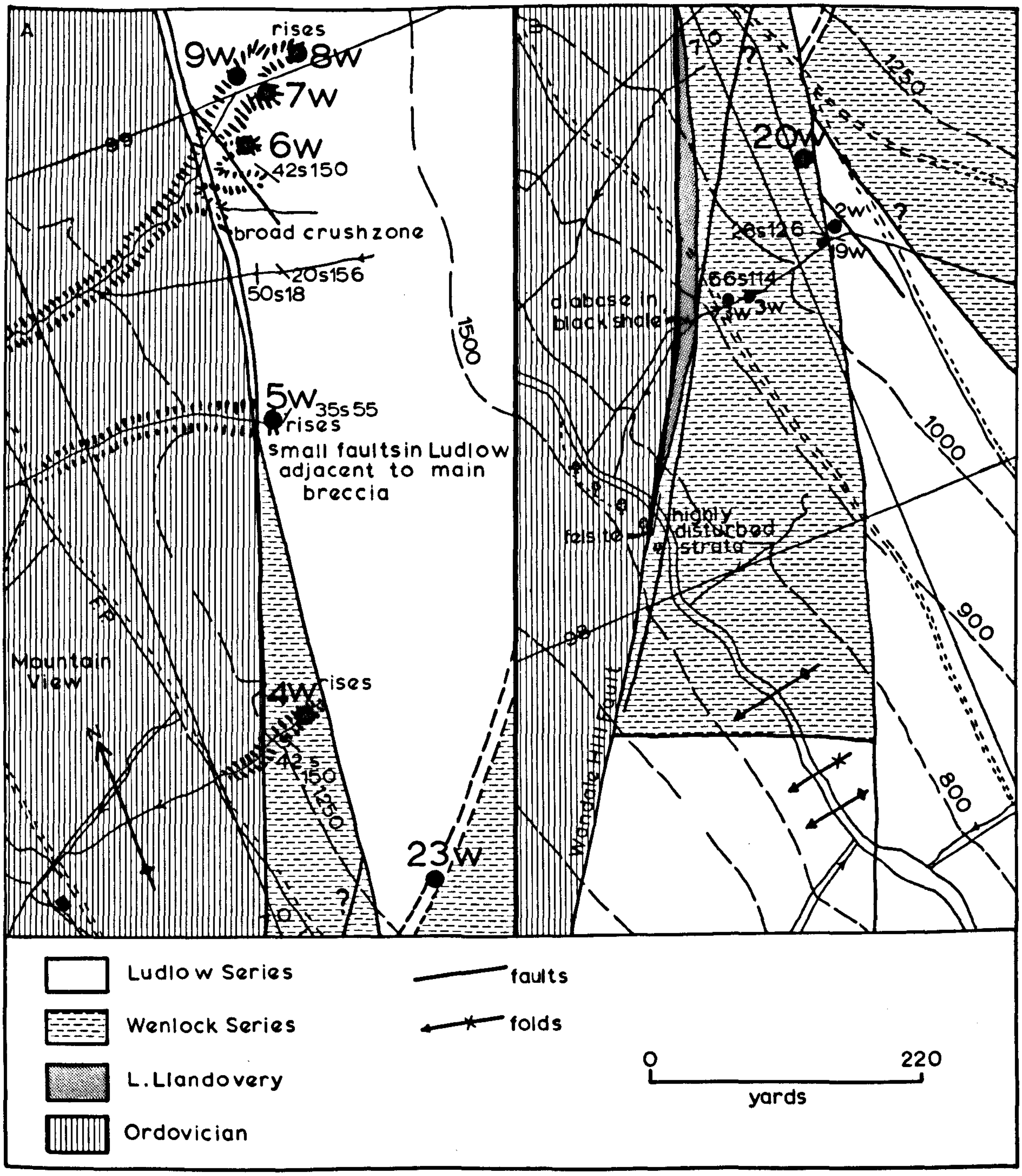
The strata between Stockless (695,005) and Bowderdale directly to the west probably all belong to the nilssoni Zone. They are clearly disturbed by several faults but within a few feet of one of these fossils were obtained (1We) indicating the nilssoni Zone: M.chimaera salweyi, P.welchi sp. nov. To the north a westerly extension of the Gais Gill Fault brings down Bannisdale Slates whilst to the south normal passage takes place into Wenlock strata (as on Stockless) or the Bowderdale Fault brings up the lower beds. Between the Stockless - Grere Fell region and Greenside Beck of Ravenstonedale a considerable amount of fault repetition must occur since the Winder Grit is not exposed until locality 2Da. Apart from one minor crumple there is no evidence of folding.

A further region of Ludlow strata is deserving of mention. Watney and Welch (1911) were the first workers to detect the presence, on Wandale Hill, of Ludlow rocks. These workers described the fossiliferous localities of the western slopes and noted a "grit" on the summit. It is also worthy of note that two localities in the basal Ludlow limestone occur at 23W (701,984) and 706,994. The former is a small sheep "scratch" of poorly calcareous beds yielding trilobite fragments whilst the latter, now almost overgrown, is of similar rock from which no fossils could be obtained. The northerly locality is the only one in a large area of course grass and it almost certainly was here that the Survey workers (1889) record a dip to the SE of 65°.

This is significant in showing the synclinal nature of the beds on Wandale Hill (whether fault formed or not) and allows the base of the Ludlow Series to be tentatively sketched in round the hill - for it is not exposed except at these two localities. Other sections of import in the Ludlow Series have been described above or are summarized in the text figs. a,b,d,e.

In view of the stratigraphical succession now known, as well as the general distribution of the strata and major faults it is clear to the writer that the region would benefit from a study directed primarily at the structural geology. Such a work could be extended to the western half of the Howgill Fells where the effect of the Dent Line Hercynian activity is less strongly felt, and where, because of this, the full effects of the Caledonian movements in the region might be deduced.

TEXT FIG. 5b



THE WANDALE HILL FAULT

CHAPTER 6

FACIES TYPES AND DISTRIBUTION

In the discussion following the valuable paper by Watney and Welch (1911, communicated by Dr.J.E.Marr) Professor T.McKenny Hughes, a very experienced worker on Lower Palaeozoic rocks in the Lake District, said "... that the parts under observation consisted of rocks differing little in detail of lithological character through great thicknesses, while fossils were scarae and badly preserved." Watney and Welch had contributed to the elucidation of the facies types as had the workers of the Geological Survey a few years earlier (Dakyns et. al. 1891), and Marr and Nicholson (1888). Later work, notably by Marr (1913, 1925, 1927A) and Wilson (1954), has made the succession of rock types still more decipherable. In the following paragraphs nine facies are distinguished. Each has its own distinctive characters which make it easily recognizable in the field and of great assistance to mapping, particularly when taken in conjunction with the vertical facies distribution pattern (v. e.g text fig. 4c) and the faunal succession. It is suggested below that several of the facies evolve with time and reflect distinct and gradually changing environments of deposition. Broadly speaking the facies of the Silurian may be regarded as the result of interplay between reducing and oxidizing conditions superimposed upon a mode of deposition of mechanical detritus which changed but slowly.

1. Conglomerates and Grits

An interesting feature of the region is the influx at long intervals of coarse sediment into environments of provable quiet deposition (v.p. 95) These coarse rocks are composed of either conglomerate and grit which probably represent a near shore environment (Group A below) or fine grained calcareous grit the origin of which is more doubtful (Group B below).

Group A: The Ashgill Shales Grit is an example of the first type. Its variations in thickness throughout the region are discussed above (pp. 9-12 text fig. 2b) where it is interpreted as a submarine distributary of a river draining a nearby landmass in the south east. The grit thins to the north west where it is only a few inches in thickness whilst in the south east it is conglomeratic and exhibits current bedding on all scales. Marine fossils such as bryozoans, brachiopods and trilobites are common. Overlying and underlying the grit are fine grained Ashgill Shales mudstones which suggest quiet conditions of deposition. The overlying mudstones are almost 40' thick so that the grit itself occurs some considerable time before the onset of the Silurian conditions of deposition.

The Winder Grit is not dissimilar to the Ashgill Shales Grit in that it is a highly calcareous fossiliferous deposit. It differs, however, in its lack of large rounded pebbles and boulders, in the predominance of angular fragments particularly of mudstone, and in its considerable areal extent. At the most northerly outcrop (Greenside Beck, 2Da) it is at least 30' thick and consists of finer parts as well as conglomeratic strata in which the most conspicuous fragments are large angular pieces of mudstone. The exact relationship between the conglomeratic and gritty portion is not certain. They may be either interbedded or mixed is a more complicated manner. The whole is calcareous and fragmentary shelly fossils including Odontopleura hughesi are abundant. The southerly outcrop on Settlebeck Gill (660,931) is rather thinner (about 20') and whilst it lacks the conglomeratic beds with large mudstone fragments, it is equally calcareous and contains numerous shelly fragments. A nearby exposure on the southern slopes of Winder (654,927) appears to be, even thinner. The underlying and overlying rocks are greywackes.

There is, therefore, a decrease in thickness of the bed and a general decrease in grain size from north to south. The presence of large angular mudstone fragments in the northerly outcrop suggests a source not far removed but there is no indication as to whether this lies to the northwest or the northeast. Perhaps the most puzzling feature is the occurrence of such a grit in a part of the succession that consists entirely of unfossiliferous greywackes. There is no suggestion, that the greywackes are shallow water deposits and yet the grit with its coarse angular grains, high lime and shell content is suggestive of shallow water. It is possible, however, that the whole bed is derived by redeposition from further afield and that the mudstone fragments represent disrupted finer beds originally interbedded with the coarse beds. Supporting this to some extent is the greywacke-like texture of the rock, the presence of grading, and the lack of large scale current bedding and rounded pebbles which are found for example in the Ashgill Shales Grit.

Group B: These are fine grained grits on a much smaller scale than those of

Group A, and the best developed (sedgwicki zone, Spengill) is only $8\frac{1}{2}$" thick. The other four beds are found in the Wenlock Series and range from three-eighths to one inch in thickness. Each is highly calcareous and usually weathers to a rottenstone on its exposed surface although the fresh surfaces have a distinctive medium grey to greenish grey colour (N5 or N6 to 5GB 5•5/1). They are composed of angular fragments of quartz, rock fragments, and rather weathered orthoclase and plagioclase. One of the thicker beds (1") is graded from coarse grit at the base to fine grit at the top. The three-eighths of an inch grit occurring in the riccartonensis Zone is extremely persistent and is constant in its thickness. Thus it is found in the northernmost point where these beds crop out (Wandale Beck, SSE of Adamthwaite Farm 711,997)and as far south as Hebblethwaite Hall Gill (691,932) over four miles away. Its base often shows small scale load moulds. It must be stressed that these five beds occur in a total of well over 1000' of fine grained mudstone and, that like the Winder Grit, they are quite atypical. Clearly they represent rare influxes of coarse material from a distant source into a quiet environment of deposition, a fact which is supported by the weathered nature of the constituent grains.

2. Ashgill Shales Mudstone Facies

The Ashgill Shales sometimes known as the Pencil Slates on account of their characteristic cleavage, constitute one of the most distinctive lithologies of the region. They overlie the alternating mudstone and nodular limestone facies of the lower beds of the Ordovician and immediately underlie the basal limestone and the graptolitic mudstone of the Silurian. The facies, however, occurs in a modified form at a higher level, particularly in the Middle Llandovery where it alternates with graptolitic mudstones. The "typical" Ashgill Shales are described first.

These consist of fine grained medium dark grey mudstone (N4) with rare calcareous nodules and occasional calcareous beds. The fauna is sparse except in the calcareous beds and consists of brachiopods, bryozoans (e.g. Phylloporina hisingeri), trilobites (e.g. Dalmanitina mucronata) and, less commonly, crinoids. None of the fossils are dwarfed and some of the brachiopods and trilobites reach a large size. Towards the top of this division, as the Ashgill Shales Grit is approached, the grain size increases locally to give thin silty lenses (v. text fig. 2a). These are also found above the grit, particularly in the lowest few feet of the 40' division.

In the Llandovery Series a very similar rock type is found firstly in the triangulatus Zone. The fine grain size and complete lack of siltstone lenses links this type with that of the lower Ashgill Shales. Calcareous nodule beds occur and it is in these that the fossils are found. Again the fauna consists of brachiopods and trilobites but other fossils are less common. The non-calcareous fractions of the facies contain only rare fossils and in some instances at least these prove to be dwarfed forms. It is certain that these beds which alternate with graptolitic mudstones, are essentially the same facies as the Ashgill Shales. They differ in being finer grained, in having a high proportion of iron carbonate compared with calcium carbonate, in their blocky cleavage as opposed to "pencil" cleavage, and in being slightly darker in colour (dark grey, N3, to medium dark grey N4). Wilson (1954) considers that the iron carbonate was precipitated directly (cf. Marr 1925) and it would certainly be difficult to envisage Marr's process of replacement in view of the fact that primary limestones exist within the iron carbonate-rich mudstones.

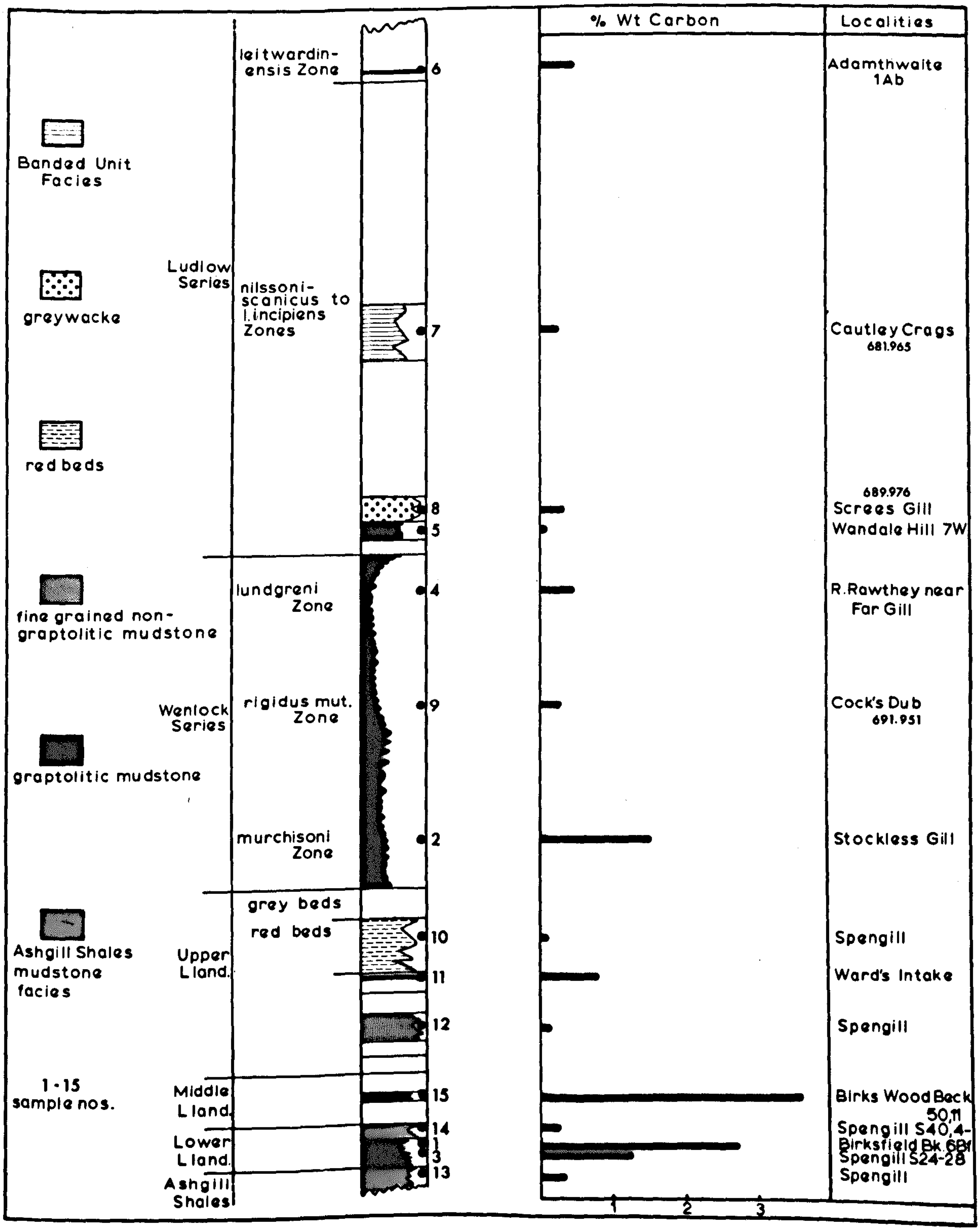
The facies is last seen in the Zone of M.sedgwicki where occasional thin beds with calcareous nodules occur. The nodules yielded shelly fossils to the Survey workers (e.g. Phacops elegans, Cheirurus bimucronatus, Illaenus bowmanni Leptaena quinquecostata, Favosites sp. , Lindstroemia sp.). In this zone the beds alternate not only with graptolitic mudstone but with the first of the fine grained, unfossiliferous mudstones (described below) and with thin calcareous grits of Group B (described above).

The conditions of deposition of these beds are difficult to envisage. Marr (1925) examined them in some detail (terming them "blue muds" since, although grey, they have a faint bluish hue) and concluded that the sparse benthonic fauna existed with some difficulty under semi-toxic conditions. He pointed out (op. cit. p.127) that the pyrite content of these rocks is far less than in the dark graptolitic mudstone and that free carbon is absent. A carbon analysis carried out for the present writer on a sample from Spengill (triangulatus Zone) showed 0·27% of free carbon which compares favourably with the figure of 0·34% obtained for the Ashgill Shales of Spengill and strongly contrasts with the much higher value (up to 3·68%) obtained for the dark graptolitic mudstone (see also text fig. 6a) with which these beds alternate. It is clear that the change from one facies to the other, whilst occurring quite suddenly, must take place without disrupting the environment of mechanical deposition, since the grain size remains unaltered and the two facies are often welded together in a manner which in itself suggests continuous deposition of the mechanical detritus across the change. Wilson (1954) reaches the important conclusion that the graptolites and carbonaceous colouring matter arrived at the sea bed from a source independent of that supplying the mechanical detritus. Thus in the Browgill Beds which he examined he proved, in effect, that if the succession of mudstone at A is twice as thick as at B, then a contained thin band of graptolitic mudstone which can be traced from A to B will also be twice as thick at A as at B. From these facts, it is tempting to conclude that the graptolite rhabdosomes and free carbon arrived at the sea bed by sinking from an algal-graptolite association at the surface which periodically drifted into an environment of quiet deposition. The bottom conditions would become anaerobic and the beuthonic fauna, already struggling for existence, would migrate or be killed off. This picture agrees with the alternation of facies and associated faunas and is basically the same conclusion arrived at by Marr (op. cit.). It does not explain, however, why the Ashgill Shale Mudstone Facies dies out in the sedgwicki Zone and is replaced by the fine grained, unfossiliferous mudstone which, in the U. Llandovery, alternates with the graptolitic mudstone. This fact is indicative of a change, perhaps a chemical change as suggested by Marr, in the depositional environment. It is at least clear that in Upper Llandovery times before the onset of red mudstone deposition, the sea was unconducive to life even when the graptolitic mudstone was not being deposited.

3. Fine Grained Unfossiliferous Mudstone

This facies is the predominent rock type between the Zones of M.sedgwicki and M.griestonensis (sensu Wilson 1954) and is equivalent to the "Green Beds" of Marr (1925). The latter author regarded them (pp.114,116) as the fine grained equivalents of the "grauwacke-grits" typical of many Lower Palaeozoic rocks, and "the normal deposits of the period in this area, owing their characters solely to the nature of the mechanical detritus which forms them...." According to Marr they differ from the dark graptolitic shales only in the absence of graptolites, free carbon, and primary iron sulphide. This paucity of free carbon is confirmed by an analysis carried out for the present writer which showed only 0·14 % compared to as much as 3·68% in the graptolitic

TEXT FIG. 6a


% Wt Carbon
Localities
Banded Unit Facies
greywacke
red beds
fine grained non-graptolitic mudstone
graptolitic mudstone
Ashgill Shales mudstone facies
1-15 sample nos.
Ludlow Series
Wenlock Series
Upper Lland.
Middle Lland.
Lower Lland.
Ashgill Shales
leitwardinensis Zone
nilssoni-scanicus to l. incipiens Zones
lundgreni Zone
rigidus mut. Zone
murchisoni Zone
grey beds
red beds
6
7
8
5
4
9
2
10
11
12
15
14
1
3
13
1
2
3
Adamthwaite 1Ab
Cautley Crags 681.965
689.976
Screes Gill
Wandale Hill 7W
R. Rawthey near Far Gill
Cock's Dub 691.951
Stockless Gill
Spengill
Ward's Intake
Spengill
Birks Wood Beck
50.11
Spengill S40,4-
Birksfield Bk.6B
Spengill S24-28
Spengill

mudstones. The lack of graptolites, and indeed all fossils, can be confirmed in the field and the small amount of pyrites can be deduced both from the hand specimen and from thin sections. The rock is composed essentially of a fine grained aggregate of quartz, altered felspar, and micaceous material together with considerable quantities of clay grade chloritic matter.

Marr (1925 p.130) records that benthonic organisms are "very rare in the green (muds)" and on p.127 writes that these consist of a few minute brachiopods. The present writer has been unable to find any fossils in the beds under discussion and neither Dakyns et al. (1891) nor Wilson (1954) record any from the Cautley district. A few small brachiopods have been obtained, however, from a 5" light olive grey band (5Y5/2)from Watley Gill (7Wa) which occurs below the convolutus Zone associated with mudstones of the Ashgill Shale type (= Marr's blue beds), and yielding Phacops glaber. Since Marr records his green muds from the Skelgill Beds it seems likely that it was from these beds just below the convolutus Zone that he obtained the brachiopods. The light olive grey mudstones are distinct from the above-described beds and moreover are not common. They differ in being softer, and more closely resemble the ashes studied by Wilson (1954) than the fine grained, unfossiliferous mudstones.

Marr used the term "green beds" and whilst when weathered the fine grained barren mudstones do have a distinct green or olive green tinge, it is interesting to note that fresh surfaces are usually various shades of grey (e.g. medium grey, N5) although the faintest of green hues is sometimes discernible.

The most puzzling feature of this facies is its barren nature and in this respect at least it resembles the greywacke facies described below. Indeed, as has already been pointed out, Marr regarded it as a fine grained variety of the latter and some modern workers consider it to be a lateral equivalent of coarse greywacke. The same author (1925, p.128) concluded that iron was present in the sea water as a hydrate but that "... as the conditions were not then favourable for its conversion into sulphide as in the case of the dark graptolitic muds, nor for its subsequent replacement in calcium carbonate by metasomatic action as in that of the blue beds, it remained in solution." Whether this explanation is correct or not the fact remains that the facies is barren of fossils. Perhaps an important point is that it differs from the Ashgill Shale Mudstone Facies mainly in the absence of iron and calcium carbonates.

The possibility that the fine grained barren mudstones may be the lateral equivalent of coarse greywackes is feasible since they differ mineralogically in having a lack of rock fragments, less felspar (which is more highly altered) and a higher proportion of clay-grade chloritic matter as a groundmass.

4. The Red and Grey Mudstone Facies

These facies occur between the griestonensis Zone (sensu Wilson, 1954) and the Wenlock Series and must be approximately equivalent to the crenulata Zone. The "red" mudstones are greyish red (10R4/2) in colour and are interbedded in places with greenish grey mudstones (5G6/1). Both are of similar grain size and differ only in their colour. Above the "red" mudstone facies are the grey mudstones (5GY5/1) discovered by Wilson (1954) and studied in detail by him.

Both Marr and Wilson (op. cit.) mentioned that a small beuthonic fauna had been obtained from the "red" mudstones and the present writer has obtained phacopid thoracic segments from beds slightly more calcareous than usual. Specimens of Phacops s.s. from the "red" mudstones of Spengill are deposited in the Sedgwick Museum, Cambridge. From the grey mudstone facies Wilson found trilobite fragments and it is from these beds that the writer has obtained the ostracod Kloedinella sp. Therefore, although fossils are rare, the rocks are not barren and none of the specimens are dwarfed. The carbon content of the rock is low (0·11%). The problems concerned with the deposition of these facies are discussed by Wilson and are not further debated here. He has shown that the "red" mudstones are not continuous throughout the Cautley area and that upon the axis where no deposition takes place the beds show no signs of oxidation, whereas away from this axis the conclusion seems inescapable that they were deposited under oxidizing conditions which resulted in the presence of red iron oxides.

The greyish red mudstones need never be confused with the red staining caused by proximity to the basal Carboniferous conglomerate. In these instances the secondary staining can always be proved as for example by the presence of Leisegang's Rings seen at Rake Wood (685,935). Other cases show a more uniform staining (e.g. the Ludlow Series on Stockless Gill and Harter Fell) but by breaking cleavage blocks to the core the original colour can be seen. Watney and Welch (1911) undoubtedly fell into error here since their "red flags and grits" (p.217 et seq.) can easily be demonstrated in the field to be the result of secondary staining.

5. Limestones

At many horizons the beds are slightly calcareous but only occasionally is the concentration of lime sufficiently great to warrant the name limestone. Three types can be distinguished:

a) thin, relatively pure unfossiliferous limestone
b) thick shelly limestones
c) highly calcareous graptolitic mudstones.

Since the last of these types c) is essentially part of the graptolitic facies it is considered under that heading. A single limestone of the first type occurs in the Zone of M.sedgwicki (see text fig.2il). It is 1'2" thick, massive, light grey to very light grey in colour (N7·5) and weathers with a pitted surface. No fossils have been obtained up to the present. The most important limestones are those of the second group which is represented by the basal Silurian limestone and the basal Ludlow limestone.

It has been shown (pp.12-14) that the basal Silurian beds are rather variable in thickness and composition but that generally they thicken to the south. Limestone is a major component and is closely associated with a hard, pale coloured, non-calcareous mudstone (see text fig.2e). The beds are underlain by Ashgill Shales and overlain by black graptolitic mudstones of the A. accuminatus Zone. Shelly fossils including brachiopods, trilobites and crinoids are abundant in the limestone but none are preserved complete. The fossils seem to occur in pockets or lenses in which the fragmentary organic remains are crowded together. This suggests rather turbulent conditions of deposition in which the shells were washed into, and held, in hollows upon the sea bed. Some parts of the limestone show banding very similar to that of the Ashgill Shales mudstones and these are usually less calcareous and less fossiliferous than the lenses mentioned above. On fresh surfaces the fossiliferous lenses show only faint traces of the contained shells and the absence of banding can be demonstrated. The occurrence of a hard non-calcareous mudstone in such intimate association with the limestone is a puzzling feature. It is possible that decalcification of some of the muds took place at an early stage and that the lime tended to become reconcentrated around the lenses of fossil fragments. This is strongly suggested by similar calcareous beds which occur 2'3" above the Ashgill Shales Grit on Spengill (see text fig. 2a).

In this case two bedding planes separated by 6" of sediment are crowded with brachiopods, trilobites and crinoids. For a thickness of five-eighths of an inch on either side of the lower of these bedding planes, and $1\frac{1}{2}$" on either side of the upper, the mudstone, in which the typical banding is clearly discernible, is highly calcareous and much harder than the surrounding uncalcified mudstone. The calcareous nodules described below (p. 99) are probably of similar origin since they often surround, for example, an orthocone cephalopod shell, or a coral growth.

The bipartite basal Ludlow Limestone is similar in many ways to the basal Silurian limestone. Thus the fossils are also preserved in lenses as aggregates of dissociated fragments. Proetid cranidia, for example, are common but complete cephala have not been found. Lateral equivalents of the limestone (which is medium grey, N4·5, in colour with a faint bluish hue) may be non-calcareous or only poorly calcareous but equally pyritous, and with only occasional fossil fragments. All the strata above, separating, and below the bipartite limestone are of graptolitic mudstone. Those beds below the limestone have calcareous nodules and in places yield gastropods, brachiopods, trilobites and cephalopods.

In view of the similarities between the basal Silurian limestone and the basal Ludlow limestone a similar mode of origin is suggested. The presence in each case of numerous shelly fossils suggests conditions more amenable to beuthonic life. Both limestones and associated non-calcareous mudstones are highly pyritous but none of this seems to be primary and it usually occurs as small cubes or large nodules. It is possible that both limestone beds would act as repositories for secondary deposition of pyrite.

Watney and Welch (1911,p.223) described this basal Ludlow limestone as "yellow and sandy when fresh". In fact it is medium grey with a bluish tinge. It seems certain that those authoresses have taken the "intermediate" rottenstone to be the fresh rock. This of course is virtually non-calcareous and quite hard in contradistinction to the final rottenstone which is very much softer and ginger in colour.

6. Graptolitic Mudstone Facies

From the stratigraphic and palaeontological point of view this facies constitutes the most important rock type. In the L.Llandovery and Wenlock Series it is also the predominent rock type but in the M. and U. Llandovery and Ludlow

Series it occurs as relatively thin bands in a generally unfossiliferous succession. The first bed of graptolitic mudstone follows immediately above the basal beds of the Silurian and is equivalent to the A.acuminatus Zone (identified by Wilson 1954) whilst the last beds occur in the leintwardinensis Zone (as seen in the Howgill Fells).

This facies occurs over a long range in time and throughout it is composed of clay to silt grade angular fragments of quartz, altered felspars, mica, iron minerals, carbonaceous material and a considerable quantity of fine grained chloritic matrix. The beds are calcareous in places. The texture is reminiscent of the greywackes (v. text fig. 6c) but the grain size less and the amount of weathered and clay grade material greater. Sedimentary structures such as current bedding, ripple drift lamination, convolute bedding etc. are absent although in thin section some small scale graded bedding has been observed in which each graded unit occupies only a few millimetres Superimposed upon this typical mudstone is a characteristic and prominent banding caused by the occurrence parallel to the bedding plane of carbonaceous matter and primary ferruginous material usually consisting of pyrite. For the sake of brevity the banding is referred to below as "carbonaceous banding."

No preference for association of the carbonaceous banding with any particular grain size has been observed and Wilson's work (v. p. 89) suggests that the carbonaceous matter came from a source independant of that of the mechanical detritus. This accords with the widely held opinion that the graptolites and the carbonaceous matter (representing decayed algae) sank from the upper layers of the ocean where they lived in symbiotic association. The banding, clear in the hand specimen, is much less distinct in thin section where the "bands" can be seen to consist of numerous very thin layers of opaque matter. In the hand specimen some bands are thicker and darker than others and these occur at fairly regular intervals. This is particularly true of the higher Wenlock and Ludlow beds but less true of lower horizons. The "bands" do not "cross cut" each other but have the appearance in thin section of lenses of opaque material wrapping round the coarser mineral grains (v. text fig. 6b no. 7). Consequently they cannot be counted with any pretence of accuracy and whilst they may represent annual deposition as some workers have claimed (Marr, 1927 & Cope 1951) this is impossible to prove. The darker bands may, in fact, represent one of several things:-

TEXT FIG. 6b1

Dark graptolitic mudstone from Lower Llandovery.

TEXT FIG. 6b2

Graptolitic mudstone from thin bed in Upper Llandovery.

TEXT FIG. 6b3

Red mudstone from Upper Llandovery.

TEXT FIG. 6b4

Graptolitic mudstone, Wenlock Stage 1, overlain by non-graptolitic mudstone.

TEXT FIG. 6b5 & 6b6

Respectively graptolitic mudstone from Stage 1 and worm tubed graptolitic mudstone from same horizon.

TEXT FIG. 6b7

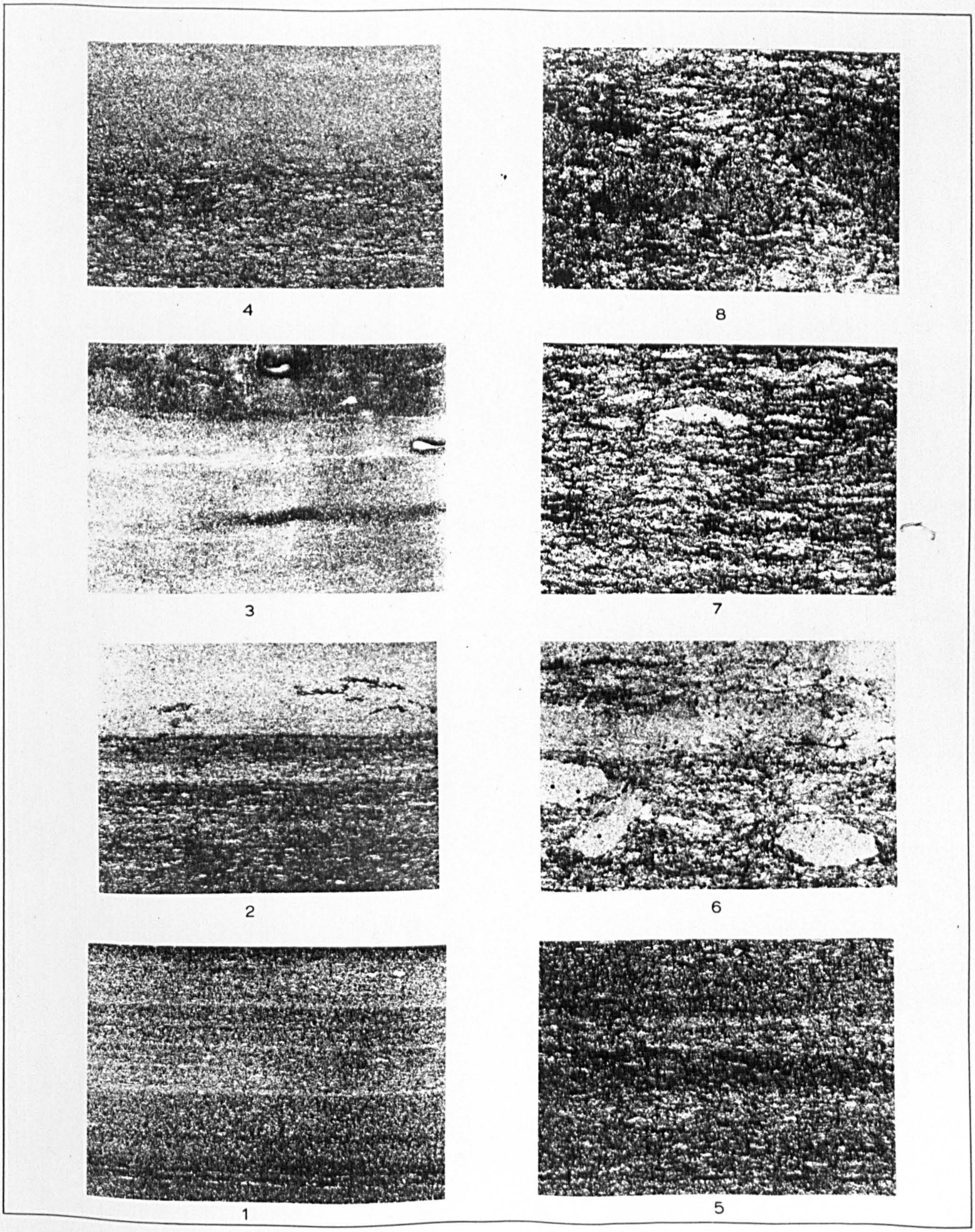
Graptolitic mudstone from the Ludlow Series, second graptolite band.

TEXT FIG. 6b8

Slide of the Banded Unit Facies from beds yielding *O. hughesi.*

all figs. x 7

TEXT FIG. 6b



a) periods when death of algal material reached a peak - possibly an annual feature.
b) periods when more algae than usual covered the area in question - not necessarily an annual feature
c) periods when decay of algae took place at a different rate than usual - possibly an annual feature but not necessarily synonymous with a) above
d) periods when the deposition of the mechanical detritus was retarded, but when deposition of carbonaceous material took place continuously.

If the last possibility was the case one would expect to find concentrations of carbonaceous matter at the top of each, or some, of the minute graded units described above. This has not been established and suggests that the last possibility is not operative. The writer feels that any one or all of the first three may be factors and that any annual feature of one might be obliterated by the operation of either of the other two factors. He envisages an almost continuous "rain" of carbonaceous matter with concentrations at particular levels as a result of any of a number of controlling factors.

Conditions of deposition of the graptolitic mudstone: The almost exclusive occurrence of fine grained muds from the base of the Silurian to the top of the Wenlock Series in itself suggests quiet conditions in the basin of deposition. The succession of over 1000' of such sediment must have been built up by almost continuous influx of fine muddy material and the presence of small scale graded bedding, as well as the general texture, suggests that this might have been achieved by the means of low density turbidity currents. These might be connected laterally with high density deposition of coarse greywackes such as those found in North Wales (e.g. the Denbigh Grits). These have been shown to flow from south to north in Wenlock times (Cummins 1957 , map p.435).

Independant evidence exists concerning the calm conditions of deposition. Text fig. 6d shows an orthocone cephalopod shell embedded in graptolitic mudstone. It depresses the carbonaceous banding along about 15 mms of its length whilst above this the bands pass almost unaltered around the shell. The specimen illustrates the following points:-

a) that the topmost 15 mms of the mud must have been quite soft to allow the penetration of the point of a relatively buoyant cephalopod shell, (not allowing for diagenetic compression which would reduce the depression of the laminae)

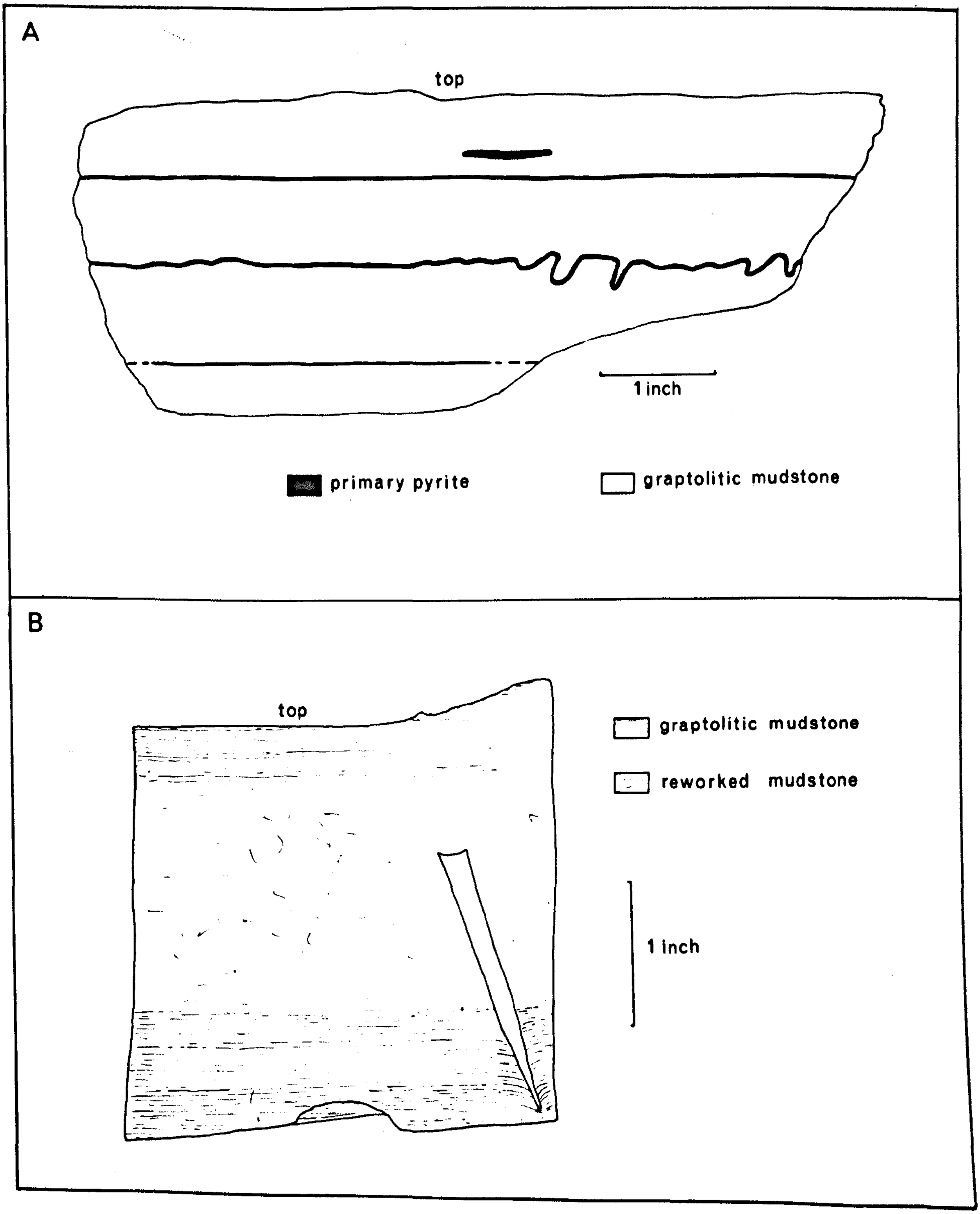
TEXT FIG. 6dA

Layers of primary pyrite showing slumping prior to deposition of later layers.

TEXT FIG. 6dB

Orthocone cephalopod seen depressing the banding of the graptolitic mudstone in which it is embedded. Full explanation in text p.95.

TEXT FIG. 6d


A
top
1 inch
primary pyrite
graptolitic mudstone
B
top
graptolitic mudstone
reworked mudstone
1 inch

b) that conditions of deposition subsequent to the penetration must have been quiet otherwise the shell would have been uprooted from its precarious position (burrowing organisms also might have acheived this end).

c) the banding is a primary depositional feature.

Some workers have discussed the possibility that the carbonaceous banding might be the result of organisms (e.g. worms) reworking the surface layers of the mud and that the lenses of coarse material surrounded by carbonaceous films might be compressed faecal pellets. A critical horizon for the discussion of this idea is at the base of the Wenlock Series where the graptolitic mudstone reappears after its absence during the Zone of M.crenulata. It alternates at first with thin bands of non-carbonaceous mudstone whose detrital components are similar to those of the graptolitic mudstone. The non-carbonaceous mudstone has a benthonic fauna of brachiopods and trilobites and in this respect resembles the underlying grey beds in which Wilson (1954) obtained trilobite fragments. Graptolites appear almost immediately in the banded mudstone but in some cases the carbonaceous banding can be seen to be obliterated by worm tubes. It is clear then that where bottom working organisms can exist they obliterate, not cause, the graptolitic banding. Indeed much of the non-carbonaceous mudstone at this horizon is the result of destruction and complete reworking of original graptolitic mudstone to form a homogeneous mass. It is also apparent that at these times conditions were not entirely adverse to benthonic life as evidenced by the diminutive brachiopods and trilobites. However, that anaerobic conditions eventually took over is illustrated by the disappearance of non-carbonaceous mudstone and its associated benthos and its eventual, almost total replacement, by conditions in which graptolite rhabdosomes were infilled with pyrite and preserved in full relief. These conditions continued until the onset of the C.murchisoni Zone.

Evolution of the Graptolitic Mudstone Facies: It will have become apparent from the above discussion that this facies is remarkably long ranging and of distinctive character. It has been observed, however, that gradual changes take place from the lowest beds to the highest beds. The most obvious of these is a gradual increase in the grain size of the mechanical detritus (see text fig.6b, 1,2,4,5,7,8). Thus fig.1 is a slide of black mudstone from the L.Llandovery. There is a very slight increase in grain size in the graptolitic mudstone of the U.Llandovery (fig.2) followed by a further increase in the Wenlock Series (figs.4,5). Throughout the Wenlock Series the increase is gradual until the rather coarse mudstone of the Ludlow Series graptolite bands is reached (fig.7). At this latter horizon the mudstone is not continuously banded and small lenses and thin bands of silt grade material begin to appear separating the more typical banded mudstone. These increase in number up the Ludlow succession until ultimately the carbonaceous banded mudstone is restricted to thin beds of $\frac{1}{4}$" to 1" in thickness in much greater thicknesses of silt and unbanded mud. It is considered that this last facies is sufficiently distinct, and so easily recognizable in the field, to warrant further description. (see below under Banded Unit Facies).

Coupled with the increase in grain size there is a concomitant decrease in the percentage weight of free carbon (see text fig. 6a). Analyses of four samples of dark carbonaceous mudstones from the L.Llandovery gave the following percentage weights: 1·28%; 2·77%; 3·62% ; 3·68% . A single analysis in one of the U.Llandovery (crispus Zone) thin graptolitic mudstones shows a rather low figure of 0·81% but examination of the rock in this section shows that pyrite is as much a cause of the distinct banding as the carbonaceous matter. This is true of many of the very thin graptolitic mudstones of the U.Llandovery Zones. In the lower Wenlock beds (murchisoni Zone) a figure of 1·55% has been obtained but thereafter a rapid decrease of carbon takes place with the increasing grain size: 0·30 % (Zone of C. rigidus mut.); 0·47% (Zone C.lundgreni); 0·09% (2nd graptolitic band in Ludlow); 0·48% (Zone M.leintwardinensis). Examination of the slide of the second Ludlow graptolite beds shows that the bands here, as in the case of the U.Llandovery, contain as much ferruginous matter as carbonaceous material and it is the combination of the two which gives the rock the distinctive banded appearance. It is interesting to note that the ferruginous matter consists of haematite and magnetite and that pyrite is rare. This point will be considered further later. (A value of 0·4% might be taken as about average for the higher Wenlock and Ludlow.)

An important change in the conditions of deposition of the graptolitic mudstones takes place with the onset of the C.murchisoni Zone. Prior to this, from the base of the Silurian upwards the graptolitic mudstones had been deposited in what was clearly an anaerobic environment devoid of benthonic life and preserving only those planktonic or pseudoplanktonic forms which sank into it. Graptolites, orthocone cephalopods, and phyllocarid crustaceans come into this category. The graptolites are often preserved in relief after being infilled with pyrites.

In the *murchisoni* Zone and above the graptolite rhabdosomes are preserved as flattened films in the rock (exceptions are described below above p. 99) and coincident with this change is the incoming of calcareous material. Some of this is resolved into bands (e.g. the 4" limestone, v.p. 33 and text fig. 3c) and some into calcareous nodules. The lime content of the rock continues to increase throughout the Wenlock Series. Small nodules are fairly common in the Zones of *murchisoni*, *riccartonensis* and *antennulatus* (Stage 2) whilst in Stage 3 the nodules are larger and thicker limestones may occur (e.g. the 2' limestone in the Zone of *C. rigidus mut.*). Nodules several feet across are found in Stage 4 in addition to very numerous small nodules, and the basal Ludlow limestone represents the culmination of the increase in lime. At this horizon conditions were very favourable to benthonic life and a large shelly fauna is found. Shelly fossils, however, first make their appearance at the same time as the calcareous material. Thus a crinoid bed with the fossils in the place of growth has been found in the *murchisoni* Zone and identical beds occur in the *riccartonensis* and *lundgreni* Zones. A bed of small brachiopods occurs in the *riccartonensis* Zone and small colonies of *Favosites* sp. are not uncommon in the calcareous nodules of the *lundgreni* Zone. Gastropods, brachiopods, orthocone cephalopods, and trilobites are found a few feet below the basal Ludlow limestone.

The graptolitic mudstone facies in the Ludlow Series contains shelly fossils far more commonly than the Brathay Flags. Crinoids, phacopid trilobites, lamellibranchs, brachiopods, cephalopods, and rare corals have all been obtained. The beds are often slightly calcareous but the lime is disseminated and only occasionally concentrated in nodules.

The paucity of primary pyrite above the *murchisoni* Zone, taken in conjunction with the factors just discussed indicates that conditions gradually became less deleterious to benthonic life. The final stage may be reached in the Kirby Moor Flags where the benthos is well established and graptolites apparently absent.

It has been pointed out that the critical point is the change in bottom conditions in the murchisoni Zone where increase in grain size, appearance of lime, decrease in primary pyrite, and appearance of shelly fossils are approximately coincident. Shortly after this (in the riccartonensis Zone) is the first evidence of stronger current activity. Thus in the lower beds orientation of graptolite rhabdosomes is not common whereas in the riccartonensis Zone and above this feature occurs sufficiently often to allow the recognition of a current running in an E-W direction though the source is not indicated. The thin calcareous grits (described above p. 86) are also a probable result of increased activity of bottom currents.

Origin of the calcareous nodules: The calcareous nodules contain gfaptolites preserved in full relief in contrast to the immediately adjacent mudstone in which the rhabdosomes are flattened. It is clear from this that deposition of the lime must have occurred almost contemporaneously with deposition since only a small thickness of sediment would be required to flatten the delicate polyparies. The common presence of shell fragments within the nodules suggests that precipitation of lime took place around them and not at random points upon the sea floor. The fact that the nodules invariably depress the bands below them yet at the same time have bands passing through them proves that deposition of the lime took place after the deposition of the surface layers of mud but before any diagenetic compaction of the sediment. It also proves beyond all doubt that the nodules are not late secondary features. Similar nodules have been described by Whitaker (1962).

Banded Unit Facies

This name is used to describe generally fine grained rocks (mud to silt grade) which in the field, and particularly in large exposures, have a characteristically banded appearance and an obvious fine grain as indicated by the closely spaced cleavage. In some cases the rock is so cleaved as to approximate to the term "slate".

The facies evolves during the U.Silurian from the graptolitic mudstone by the expansion of the thin lamellae of mud or silt which separate the carbonaceous banding in the lower beds of the Ludlow Series. Every gradation can be seen between the two facies but the typical Banded Unit, which characterizes the leintwardinensis Zone, contains only very thin (often only ¼" to 1") beds of graptolitic mudstone set amid a muddy or silty mass of much greater thickness. In the higher beds the thin beds of graptolitic mudstone dissappear.

Apart from the graptolitic mudstone the Banded Units (from tens to hundreds of feet thick) consist of a medium dark grey mudstone (N4 with a bluish hue), thin calcareous nodule beds, thin beds of often calcareous ripple drift bedding, and occasional beds of lighter or darker coloured, more homogeneous mudstone than the medium dark grey mudstone. The first mentioned is the predominant rock type but is only rarely more than a foot or two in thickness without several of the other rock types being present. It is clear from both the hand specimens and thin section that the medium dark grey mud is reworked by worms and faint tubes and contortions can often be seen It is possible that much of the graptolitic mudstone in this facies is destroyed by worms and text fig. 6b6 is a section cut at right angles to the bedding plane showing some graptolitic mudstone in the process of being contorted and obliterated. It is also likely that some of the homogeneous mudstones of lighter and darker hue represent a stage of complete destruction of the original banding. This conception of gradual destruction of original carbonaceous banding by the activity of worms is in agreement with the work of Moore and Scruton (1957) who showed that all intermediate stages existed between completely undisturbed banding and complete homogeneity. The same process has been alluded to lower down the Wenlock Series (p. 96).

An interesting feature is that the Banded Unit medium dark grey mudstone has a free carbon percentage of 0·25 (v. text fig. 6a) whilst the value of the associated graptolitic mudstone is 0·48°/o . On destruction of the carbonaceous banding there is, therefore, a probable loss of carbon though whether or not the worms themselves contribute carbon upon their death and decay is not known. This mudstone, in contrast to the graptolitic mudstone, has a rich fauna of lamellibranchs (Pterinea sp.) and trilobites (Odontopleura hughesi) with the former often crowded in their hundreds on the bedding planes. That these organisms would also help to rework the sediments and to destroy any original features is clear.

Although typical of the Bannisdale Slates (particularly the Zone of M. leintwardinensis) it is important to realize that the facies first appears low down in the nilssoni-scanicus Zone (see test fig. 4c) and that thick units occur before the Bannisdale Slates. These lower units have rather thicker beds of graptolitic mudstones from which it is necessary to obtain graptolites to determine the approximate age. The shelly fossils are of little help at present since both the lamellibranchs and trilobites seem to be long ranging. Odontopleura hughesi for example appears in one of the early, thick Banded Units and is still found apparently unchanged in the Bannisdale Slates.

8. The Greywacke Facies

Examination of text fig. 4c shows that the greywacke facies is dominant in the nilssoni-scanicus Zone but that it is not entirely replaced by the Banded Unit Facies until the leintwardinensis Zone is reached. Outside the area it recurs in higher strata but these beds have not been examined in any detail. Each greywacke unit, usually bounded by graptolitic mudstone or Banded Units, is from about 50' to 250' thick with the thinner units usually lower in the succession. Individual beds vary from a few inches to ten feet in thickness but are usually of the order of $1\frac{1}{2}$-$3\frac{1}{2}$ feet and may be either graded or ungraded. Graded beds are usually detectable in the first instance by the cleavage which is closely spaced and inclined to the bedding at a low angle in the fine grained top of a bed and more widely spaced, and at a high angle, in the coarse grained lower part of the bed. Either graded or ungraded beds may have sole markings if they follow a fine mudstone but when ungraded bed follows ungraded bed sole marks are not developed.

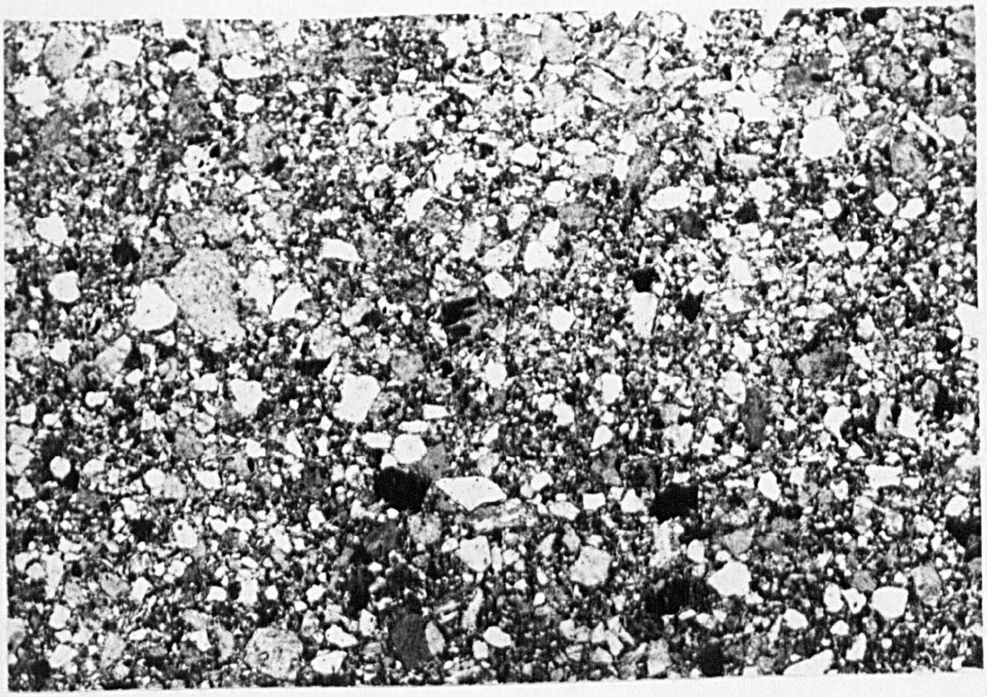
A minor greywacke development is of a rather more thinly bedded facies which often tops a whole unit for ten or twenty feet. No wholly satisfactory explanation can be offered for this type but it does seem to show current bedding rather more commonly than the thicker greywackes which only show current bedded tops occasionally. Sometimes, but not always, such a facies is followed by a graptolitic mudstone or a Banded Unit and in these cases at least may represent lower density turbidity currents heralding a temporary change in depositional environment. At no horizons have indicators of shallow water deposition been found and the writer agrees with the suggestion by Norman ( ) that deposition took place well below the wave base level.

The modal analyses (test figs. 6e,f) show that the facies falls within the usual concept of a greywacke whilst the slide (v. text fig. 6c) illustrates the typical texture of one of the coarser beds. The grain size never rises above "sandstone" grade and the term "grit" cannot be applied (except in the cases described above pp. 85 - 87), whilst to the south of the Howgill Fells the grain size of the lower greywackes seems to be even less. A thorough mineralogical study has not been undertaken.

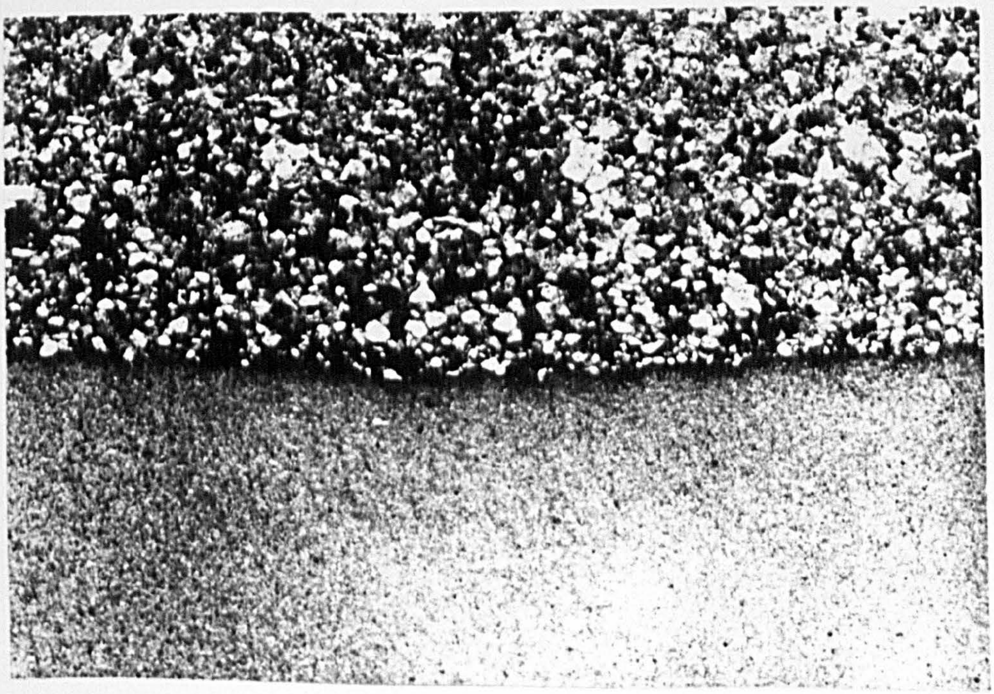
TEXT FIG. 6c1

Slide of base of thin calcareous grit from the sedgwicki Zone of Spengill. Unpolarized light. Rounded grains may be contrasted with those of typical greywacke, TEXT FIG. 6c2 of Ludlow age (locality Bowderdale Beck, Upper Coniston Grits) Both X 14

TEXT FIG. 6c



2



1

The facies types recognized and the general results given by palaeocurrent indicators agree with results obtained by other workers in the Lake District. Llewellyn*(1960) working in the Shap area observed a predominant NW source for the palaeocurrents whilst Norman**(1961) obtained both a NW and a NE source. The former worker does not seem to have obtained a NE current source and the present writer has detected currents from this direction only in one instance. It would seem likely then that throughout the Lake District outcrop a NW current source is the dominant one. In the case of such a current supplying sediment it might be expected that the beds thin from NW to SE. Norman observed this, and facies changes, in his own area and his succession prior to the Bannisdale Slates of almost 6000' (base not seen) is considerably thicker than the succession in the eastern part of the Howgill Fells (less than 3000'). If the Lake District outcrop represents a single basin of deposition of the Ludlow greywackes then one of the suggestions made by Norman that the basin might be a broad and relatively flat-bottomed trough seems to agree best with the known distribution of currents. When more is known of the palaeocurrents of other parts of the Lake District and more detail available on the thickness of sediments in these regions then a more accurate picture will be obtained of the form of the basin. The rather more variable current directions in the lower part of the succession in the Howgill Fells, namely SW and NE, prior to the establishment of a dominant NW current may simply reflect the relative instability as the basin became established.

Conclusions

1a. It is considered that Marr's "blue beds" are basically of the same facies as the Ashgill Shales mudstones but that iron carbonate has been precipitated more often than calcium carbonate. The bottom conditions were rather less tolerant of benthonic life, whilst still supporting it either in more lime-rich times or in a stunted form. The facies is replaced in the sedgwicki Zone by the fine grained barren mudstone facies.

b. The fine grained barren mudstone facies typical of the U.Llandovery may be the lateral equivalent of a coarse greywacke facies and could be deposited by low density turbidity currents.

c. The red and grey mudstones represent a return to more oxidizing conditions and contain a small benthonic fauna. They are replaced in the lowest Wenlock beds by the establishment once again of anaerobic conditions.

* Ph.D. thesis, Cambridge University.
** Ph.D. thesis, Birmingham University.

d. The limestone facies are thought to fit clearly into the pattern of alternating reducing and oxidizing conditions and that the major basal limestones each represent a local acme of oxidizing conditions when the benthos thrived in force.

e. The Graptolitic Mudstone Facies shows a gradual change during the Silurian to bottom conditions more amenable to bottom living organisms. It is not suggested, on the evidence available, that the increase in grain size, current activity, lime content etc. reflect a change to shallow water conditions.

f. The Banded Unit Facies evolves directly from the Graptolitic Mudstone Facies by increase in the amount of extraneous silt and mud which "spreads" the carbonaceous banding. The increased grain size reflects increased activity of bottom currents which probably also "freshened" the conditions thus enabling benthos to move, survive, and themselves help in the destruction of much of the carbonaceous matter which found its way to the sea bed.

g. The Greywacke Facies represents periodic influx into the area of high density turbidity currents. Although calcareous these beds are unfossiliferous and it does seem possible that any vigorous process of redeposition might comminute and dissolve the shells. The Greywacke Facies is replaced in the lower Bannisdale Slates by the Banded Unit Facies.

2. Basin of Deposition During the Silurian

There are few indications in this region of the lateral limits of the basin of deposition. The Ashgill Shales Grit suggests a land mass to the SE immediately prior to the onset of the Silurian but the System itself seems to have been marked by widespread development of the dark graptolitic shales. A local thickening of the dark shales in the L.Llandovery has been detedted (p. 23) and it is in a similar position that an axis of non-deposition was located in the U.Llandovery (Wilson 1954). In the Wenlock Series there is a slight thickening of the sediments towards the south (at least in the lowest beds) and indications of an E-W current. The outstanding feature of the Llandovery and Wenlock Series is the remarkable constancy of grain size and nature of the mechanical detritus. At the beginning of the Ludlow Series a certain amount of movement is indicated by the local unconformity and slumping off an axis in the region of Ecker Secker Beck (691,954). Higher in the Ludlow it is probable that a land mass existed far to the NW approximately in the position indicated by Wills (1952).

MODAL ANALYSES OF TWO GREYWACKES

Distance between points = 1/6 mm

Distance between traverses = 1 mm

Number of traverses = $6\frac{1}{2}$ of 25 mms

Number of grains counted = 1000

Magnification = X 300

TEXT FIG. 6e

Slide no. 8; section at right angles to bedding plane; Cautley Crags; horizon, Upper Coniston Grits, *nilssoni-scanicus* Zone, immediately above first thick (260') Banded Unit.

TEXT FIG. 6f

Slide no. 2Bo; section at right angles to bedding plane; Bowderdale Beck; horizon, Upper Coniston Grits.

TEXT FIG. 6e

MINERAL	VARIETIES		NO OF GRAINS	% OF TOTAL MINERAL	% OF THE ROCK	TOTAL NO OF GRAINS	% OF THE ROCK
QUARTZ	PLUTONIC		469		46·9	469	46·9
	VOLCANIC						
	METAMORPHIC						
	VEIN						
FELSPAR	ORTHOCLASE		206	94·4	20·6	218	21·8
	MICROCLINE						
	PLAG	ACID	12	5·6	1·2		
		BASIC					
MICA	MUSCOVITE		65	98·5	6·5	66	6·6
	BIOTITE		1	1·5	0·1		
HEAVY MINERALS	ZIRCONS AND OTHER HEAVIES		3	37·5	0·3	8	0·8
	OPAQUES		5	62·5	0·5		
ROCK FRAGMENTS			93		9·3	93	9·3
MATRIX			146		14·6	146	14·6
OTHERS							
TOTALS			1000		100%	1000	100%

TEXT FIG. 6f

MINERAL	VARIETIES	NO OF GRAINS	% OF TOTAL MINERAL	% OF THE ROCK	TOTAL NO OF GRAINS	% OF THE ROCK
QUARTZ	PLUTONIC	473		47·3	473	47·3
	VOLCANIC					
	METAMORPHIC					
	VEIN					
FELSPAR	ORTHOCLASE	165	94·8	16·5	174	17·4
	MICROCLINE					
	PLAG ACID	9	5 2	0 9		
	PLAG BASIC					
MICA	MUSCOVITE	66	100	6·6	66	6·6
	BIOTITE					
HEAVY MINERALS	ZIRCONS AND OTHER HEAVIES				21	2·1
	OPAQUES	21	100	2·1		
ROCK FRAGMENTS		15		1·5	15	1·5
MATRIX		251		25·1	251	25·1
OTHERS						
TOTALS		1000		100%	1000	100%

CHAPTER 7

SEDIMENTARY STRUCTURES

During the course of this work the writer has recorded data giving indications of current activity. A total of 691 readings have been taken of the more commonly accepted indicators such as flute and groove moulds. The nature and distribution of these is shown in fig.7a 1. Other types of sedimentary structures (e.g. L - ridge moulds) have been observed in the Ludlow Series but these have been neither studied nor utilised.

The recording method used (pp. 406-18) is that suggested by Norman * (1960). It has been realized for a considerable time (e.g. H.Cloos 1938) that folding of the strata alters the original azimuth of a linear feature. If the induced fold has no plunge then correction can be carried out by rotation to the horizontal plane about the strike as an axis. The true bearing is then given by the formula $90-\theta+\phi$ (Wood and Smith (1958 p.169)). Here, θ = angle between lineation and dip direction (measured in the bedding plane) and ϕ = strike in degrees east of north. In this method there are two theoretically possible positions but simple inspection in the field gives the correct value.

Some workers prefer to measure the azimuth of the lineation directly i.e. in a vertical plane containing the angle of plunge of the lineation as opposed to the angle of pitch in the bedding plane. (Phillips 1954 p.10). This is particularly difficult in the case of a steeply-dipping bed, or when examining the sole of a greywacke in an overhanging cornice. Some of the first recordings taken were done in this manner; but one can be converted to the other if neccessary either stereographically (e.g. Phillips 1954 pp.10-11) or geometrically:-

In fig. 7a 2 $\text{Tan } x = a/k$; $\text{Tan } y = b/k$; $\text{Tan } x / \text{Tan } y = a/b$ and $b/a = \cos z$, $\therefore$ $\text{Tan } y / \text{Tan } x = \cos z$, $\therefore$ $\text{Tan } x = \text{Tan } y / \cos z$

$$\therefore x = \text{Tan}^{-1} (\text{Tan } y/\cos z)$$

$$\therefore x = \text{Tan}^{-1} (\text{Tan } y. \text{Sec } z)$$

* Geol. Mag. v.97, pp.338-343.

TEXT FIG. 7a1

Distribution of palaeocurrent indicators.

TEXT FIG. 7a2

Full explanation in text p.104 et seq. (Alternative calculation involving u is:-

$$\frac{\sin u}{\sin z} = \frac{h/c}{h/a} = \frac{a}{c} = \sin x$$

$$x = \sin^{-1}\left(\frac{\sin u}{\sin z}\right)$$

Text Fig. 7a1

	TYPE	flute moulds	groove moulds	load moulds	current bedding	slumped beds	orientated graptolites	orientated brachiopods	orientated crinoids	others e.g. longitudinal ridges
Bannisdale Slates		r	r	c	o					
Coniston Grits		c	c	c	o					o
		c	c	c	o					o
		c	c	c	o	r				o
						r	r	r		
Wenlock Series									o	
							c			
							c		o	
				o					o	
Upper Lland.				o						
							o			
L&M Lland.							o			
Ashgill Shales					o			o		

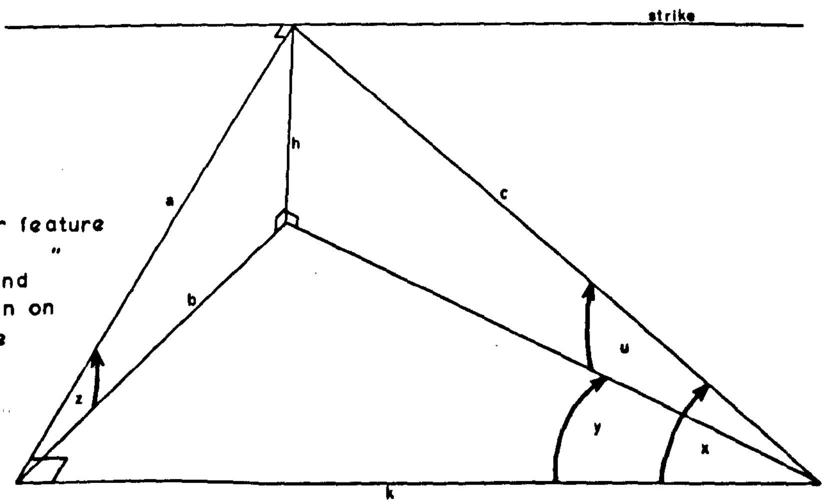
c= common

u= uncommon

o= occurs

r= rare

Text Fig. 7a2



z= angle of dip of bed

x= angle of pitch of linear feature

u= " " plunge " " "

y= " between strike and projection of lineation on the horizontal plane

c= lineation

x = pitch of lineation in bedding plane

z = angle of dip

u = angle of plunge of lineation

y = angle between strike and lineation in the horizontal plane

z and y are known directly from field observation and u is easily found by a simple alignment method (e.g. Billings 1954). It has been found that the stereographic method is quicker and quite accurate.

Norman arrives at a similar formula to that obtained by Wood and Smith but points out that such methods are only applicable to non-plunging folds. He then applies a correction factor, ω, giving the formula $\beta + \gamma - 90 \pm \omega$ β is the observed azimuth of the dip and γ the observed pitch of the linear feature, measured clockwise as seen from above. The value of ω is given by a chart which plots the degree of dip against the plunge of the fold, whilst the sign is +ve when the worker looks down the plunge of an anticline with the lineation on the left hand limb.

Norman's method is based on four assumptions:-

a) folds are geometrically perfect bodies

b) non-plunging folds attain a plunge by rotation about a horizontal axis which is at right angles to the fold axis

c) No appreciable rotation of fault blocks has taken place about vertical axes

d) No distortion within the bedding plane has occurred.

He suggests that the validity of these assumptions will depend upon individual cases and that the method, although derived for similar folding, holds equally well for concentric folds. The writer considers that assumption a) is probably basic to any method of correction used; and that in the Cautley district c) is generally valid. In the graptolitic mudstone facies crustal shortening is indicated by the distorted fossils and a compression up to 25-30 % seems not improbable in some cases. The compression has not been related to any major tectonic stress field and both the stratigraphical and geographical distribution of such compressed strata is obscure. The only point emerging at the moment is that it does not seem to affect the relatively competent greywacke beds or, as a corollary, the sole markings on them. The compression is confined, therefore, approximately to the Wenlock mudstones and "shales" of the Llandovery Series. In those cases where there has been any doubt about assumptions d) or c) no readings have been taken.

In the case of the second assumption the position is rather more difficult. Clearly, in a region where prominent phases of later folding have occurred newly formed plunging folds need not have attained their form by rotation in the manner suggested. (e.g. fig. 7b 1&2) The writer was earlier of the opinion that there were two distinct and prominent phases of folding in the area but is now inclined to the view that two sets of folds, whose axes are slightly oblique to each other, were formed simultaneously (fig. 7b. 3). Fold axes at a high angle to the general trend are uncommon and any such folds have a small amplitude (e.g. 706,984)

Ramsay (1961) suggested methods of correction for plunge bases upon a distinction between concentric folding, and similar folding caused by shearing phenomena. Flinn (1962) on the other hand discounts shear as a formative process during folding. In view of this controversy, at present in the process of being resolved, and the above discussion, it is thought that the method devised by Dr. Norman is best applicable to the Cautley area and that the results obtained support this contention.

The actual recordings and calculations are plotted in the appendix (PP. 406-418) and rose diagrams with the results plotted in 10° groupings form fig.7c. No two readings have been taken from the same bedding plane in one locality except in the following circumstances:-

a) When two possible directions of current flow occur e.g. when groove moulds, occurring with flute moulds, are slightly oblique to the axes of the latter.

b) When the bedding plane is again exposed some distance away, as, for example, further along a crag outcrop.

It is often found that at one locality yielding, say, flute moulds, bed upon bed will have sole markings with an approximate parallelism. In these cases the measurements are grouped in five degree batches and either recorded in that way on the recording sheet or alternatively the average is taken and a single figure recorded on the sheet. At some stage in the calculations the average must be taken and it is now considered that the latter method is probably more accurate.

Diagram 1 (fig.7c) consists mainly of readings taken on the foreset beds of

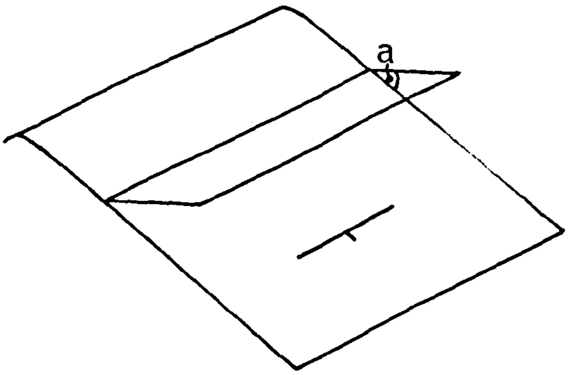
TEXT FIG. 7b1 & 2

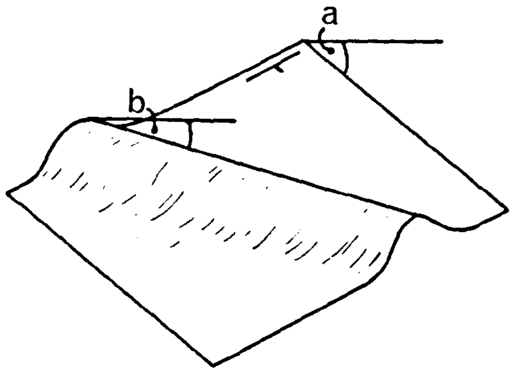
Sketch illustrating the formation of a small cross fold whose axis is oblique to that of the earlier major fold. Such a minor fold does not attain its plunge by rotation about a horizontal axis which is at right angles to the fold axis, and correction for any primary linear feature must first unfold the smaller fold and then the earlier fold.

TEXT FIG. 7b3

Sketch of the fold style in the Bram Rigg - Seevy Rigg area.

Text Fig. 7b1



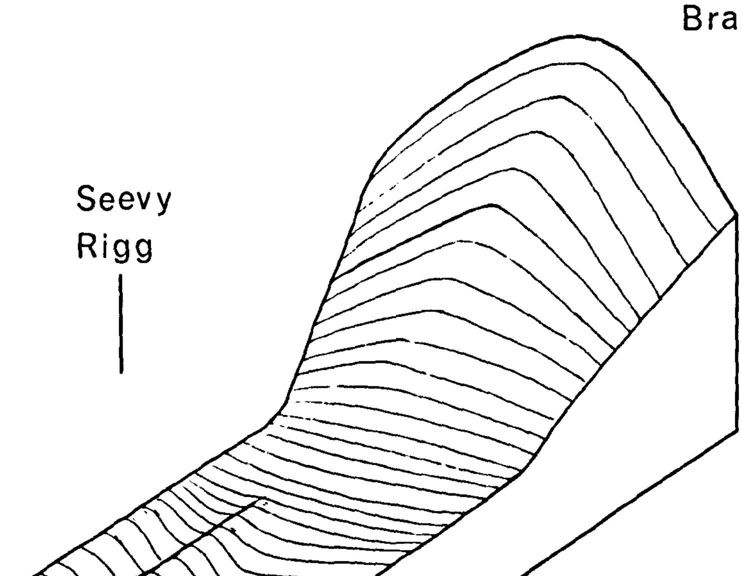


7b2

a Angle of dip on limb of large non-plunging fold

b Angle of plunge of smaller cross fold

Text Fig. 7b3 Bram Rigg



not to scale

TEXT FIG. 7c

L = load casts; each division = 2 readings.

1. 33 readings taken on the Ashgill Shales Grit: 6 orientations of brachiopod hinges; 27 current bedding readings.

2. 74 readings mainly on orientation of graptolite rhabdosomes; from the Wenlock Series.

3. 34 readings on orientation of graptolite rhabdosomes; those from bed b (Gaisgill, 2nd Ludlow graptolite band) indicate a current source in the NE.

4. 63 readings (39 flute moulds, 24 groove moulds) from the first greywacke unit, Ludlow Series; a south westerly source is indicated.

5. 82 readings (13 flute mould, 52 groove mould, 16 load moulds and 1 current bedding); a south westerly current source is indicated; horizon is lower half of the second Ludlow greywacke unit.

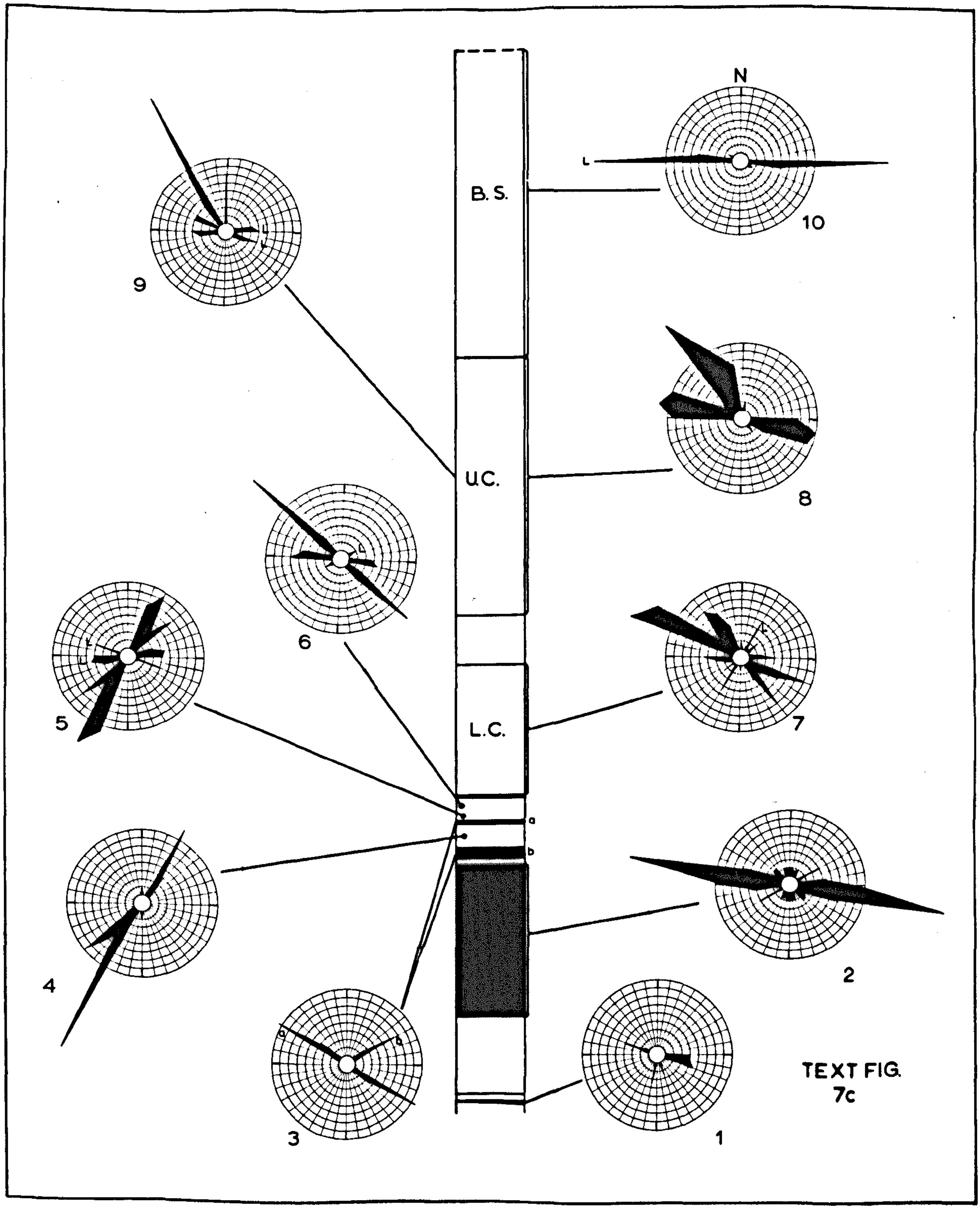
6. 53 readings (11 flute mould, 40 groove mould, 2 load mould) from upper half of Second Ludlow greywacke unit, a north westerly current source is indicated.

7. 73 readings (13 flute moulds,45 groove moulds, 15 load moulds) from Lower Coniston Grits above the first two greywacke units; a north westerly current source is indicated.

8. 120 readings (73 flute moulds, 47 groove moulds) from Upper Coniston Grits; current source lies in the north west.

9. Load moulds (18) and current bedding (56) readings from the Upper Coniston Grits. The latter agree with figure 8 in suggesting a north westerly source.

10. Load moulds (37) from the Bannisdale Slates; they show no variation from the load moulds of earlier Ludlow beds.



TEXT FIG.
7c

current bedded Ashgill Shales grit. This grit has been shown to thin to the north and west (PP. 9-12 and fig. 2b) and possibly represents the coarse infilling of a submarine channel with currents flowing from the south east quadrant. The degree of exposure and weathering does not permit many observations but it is considered that the total of 33 readings taken on foreset beds and orientation of brachiopod hinges fits in with a derivation of the sediments from the south east. A certain amount of variability is noted. The grit in Wards Intake (716,976) for example indicates the source of the current as being 185° east of north, (P.416). This variability is to be expected and there is even a slight suggestion of a "fanning out" in the area as a whole. It would, however, require many more readings to determine whether this is real or apparent.

With the exception of seven readings (see PP.408,416) those taken on orientations of graptolite rhabdosomes are confined to the Wenlock and lower part of the Ludlow Series, and are plotted on diagrams 2 & 3 (fig.7c). It has been shown that compression of the rock can exaggerate the parallel alignment of the graptolites but the writer is quite certain that his observations taken in the Cautley area represent true current sorting of the fossils particularly in view of the fact that some readings were taken on bedding planes showing no signs of compression whatsoever.

The information recorded on diagram 2 can be broken down if the recording tables (P.407) are consulted. No graptolite orientation has been detected in the Wenlock Series prior to the onset of the M. riccartonensis Zone. The majority of the readings are taken from this and the lower half of the succeeding zone. In stage 4 (approximately equivalent to the C. lundgreni Zone of Watney and Welch 1911) only six readings on the orientation of crinoid arms have been possible. This is due firstly to the fact that it is almost impossible to split the rocks along the bedding plane for more than an inch or two, and secondly to the fact that the fossils are less common and only rarely occur in groups of more than two or three.

On diagram 2 a further possible bias may exist in that 37 of the readings were taken at one locality (30-33 W 704,979) where the type of weathering and exposure facilitated both detection of orientations and measurement of them. The beds at this locality do, however, comprise 36' of strata and orientated graptolites were found not only to occur commonly throughout but to show a remarkable parallelism.

The paucity of orientation readings in Stage 4 disallows any detection of changes in current direction as the end of Wenlock times are approached but the 2nd and 3rd graptolite bands of the Ludlow Series have yielded 34 readings. Thirteen readings in the 2nd band on Gaisgill (718,012) show a pronounced derivation from the N.E. This is the very antithesis of the current source indicated by flute moulds in the 1st greywacke unit which immediately overlies the second graptolite band.(fig.7c diagram 4). Twenty-one readings from the 3rd graptolite band show but little difference from diagram 2 and the source is not indicated. Further discussion on possible interpretations of this variability in the lowest beds of the Ludlow Series appears in Chapter 5.

Eighty two readings have been obtained from the lower half of the 2nd greywacke unit and these agree well with those from the 1st showing a derivation of currents from the S.W. (diagram 5, fig.7c). The upper part of the unit, sometimes separated from the lower by a thin bed of graptolitic mudstone, shows a distinct change which is then maintained throughout the rest of the Ludlow Series (diagr. 6, fig.7c). Five flute moulds readings indicate a current source in the west and may represent a gradual swing of the current direction from S.W. through W. to N.W.

The situation obtaining in the upper part of the 2nd greywacke unit is maintained in the greywackes lying between this and the first major Banded Unit (the 260' unit). Seventy three readings have been taken; thirteen flute moulds again indicate a current source in the N.W.

Diagram 8 (fig.7c) shows flute and groove moulds only; load moulds and foreset bed readings from the same horizon are recorded on diagram 9. A total of 194 readings have been taken on beds between the 260' Banded Unit and the first beds of provable M. leintwardinensis Zone age. Thirty six of the 47 groove moulds shown on diagram 8 are recorded immediately above the 260' Banded Unit on Dalegill (706,024) and perhaps show more relation to the beds below (diagram 7, fig.7c). The current bedding foreset bed readings agree with those obtained from flute moulds and point to a north westerly current source. Load moulds are oblique to this direction and lie approximately east-west.

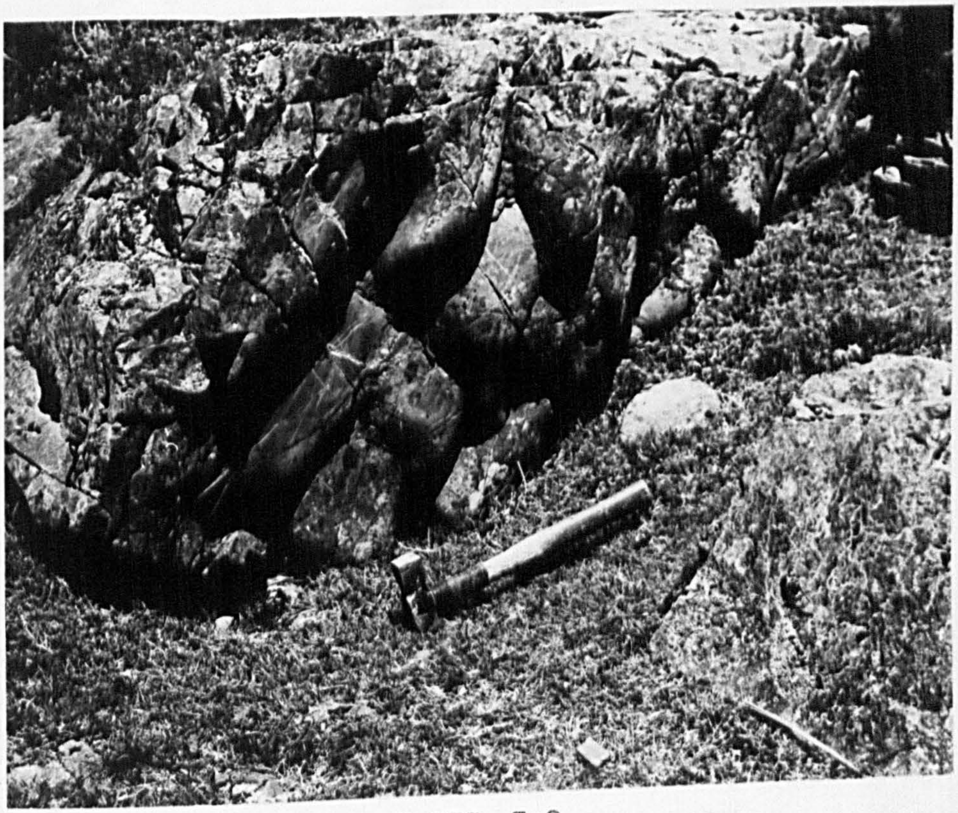
The M. leintwardinensis Zone following is composed almost wholly of the Banded Unit facies and no flute or groove moulds have been observed. Load mould[s] occur rather uncommonly and when plotted (diagram 10) show little change from those of the previous division, being aligned very prominently east-west.

It is not the writer's intention here to describe the sedimentary structures in detail but mention must be made of the main types utilized in this survey. Groove and flute moulds occasionally occur together particularly in the lower units of the Ludlow Series. The most common combination of the two takes the form of numerous, small, V-shaped flutes in association with a much smaller number of grooves. The latter may be several feet long and slightly oblique to the axes of the flutes. A second fairly common occurrence is when a sole is poor in number of moulds but has some small groove moulds and rather ill-defined, sparse flutes. Groove moulds have not been found associated with the larger type of flutes described below.

The fan-shaped, bulbous and V-shaped flute moulds described by Norman (19 61? ~~91~~) have all been found, and in addition a much larger and less-sharply defined type. These are shown on fig.7e 1 where they can be contrasted with very large fan-shaped flutes (fig.7e 2). The current source is still quite clear and the upstream end of the flute is generally bulbous and deep (up to 4") with a vortex at the bottom. The flute shallows and broadens to the downstramm end where it may be up to two feet wide. Thus far it would merely be a very large bulbous flute but very commonly a secondary, deep channel occurs almost at right angles to the main line of current movement. This is thought to represent scouring by a prominent vortex and it is considered that all parts of the flute were formed simultaneously. The fluted surface of the underlying finer grained mudstone must have been extremely irregular and it is not surprising that secondary vortices occur between the main flutes (see fig.7e 1).

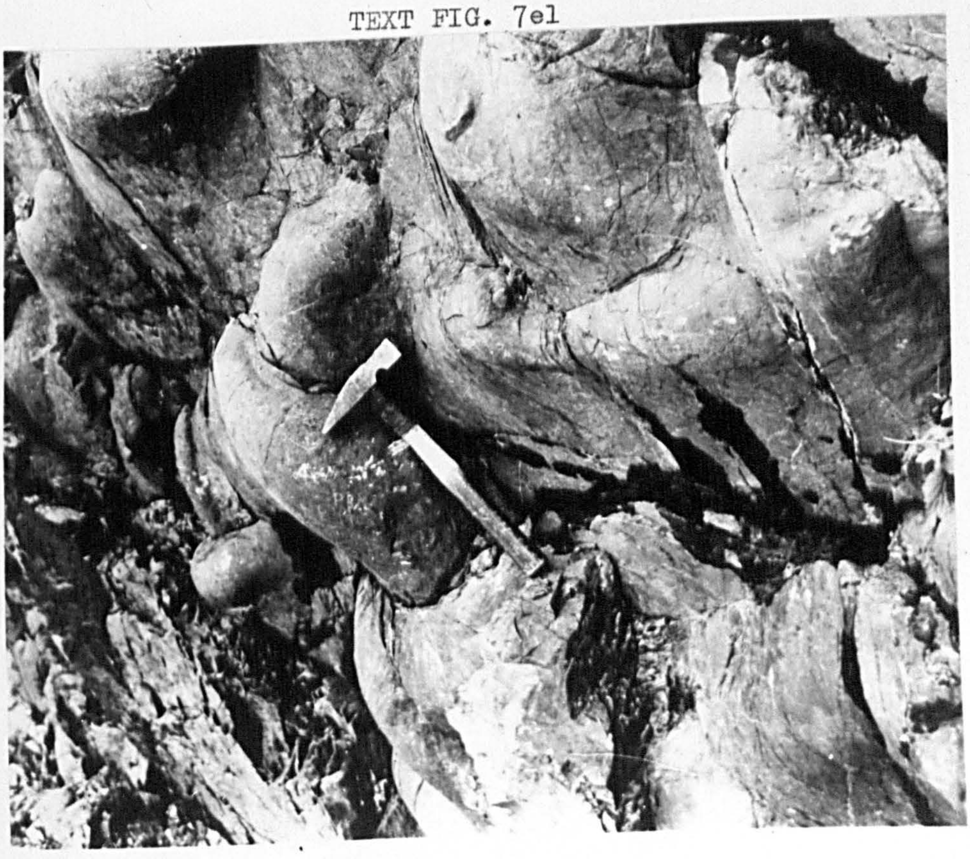
Current bedding is only common at certain horizons. Very occasionally the top of a greywacke bed may show current bedded mudstone for a thickness of some inches but more commonly it is restricted to the top twenty feet or so of a whole Greywacke Unit. At these levels the current bedding is confined to beds from a few inches in thickness up to about 18" i.e. rather more finely bedded than the greywacke beds as a whole which are roughly 2'-3' thick. In this position also they often precede the graptolitic mudstone and immediately below the junction the rock becomes more thinly bedded. This is a generalization and it is possible to find such a current bedded unit in the middle of a Greywacke Unit with no graptolitic mudstone present.

The Banded Units themselves also show current bedding on a very small



TEXT FIG. 7e2

TEXT FIG. 7e1



scale. Most of the beds showing this are lenticular and may be as thin as half an inch. No readings have been taken on this type of structure since it appears to be merely the infilling of shallow hollows and would probably give no definite indication of the general current source.

Conclusions

1. A changing pattern of current directions is discernible throughout the Silurian strata, although in some of the lower divisions (Browgill and Wenlock Stages 1 & 4) it was not possible to amass a number of readings sufficient to make a determination of current direction. Even if work were concentrated entirely on this aspect of sedimentary structures it is doubtful whether sufficient data would be forthcoming to enable current directions to be determined in the case of the Browgill Beds and Wenlock Stage 1.
2. The foreset beds of the current bedded Ashgill Shales grit agree with other evidence which suggests a derivation from the S.E. quadrant.
3. During Wenlock Stages 2 and 3 and possibly 4 the current direction was approximately W.N.W. - E.S.E. .
4. Clear evidence in the case of the first, and the lower part of the 2nd, Greywacke Unit shows the current source to lie in the S.W., whilst during the deposition of the 2nd graptolite band the current came from the N.E.
5. Above the lower part of the 2nd Greywacke Unit the current source is constantly from the N.W. the only perceptible change being a slight northerly swing higher in the succession.
6. The current directions agree in some respects with those obtained by Norman (1961) in the Blawith Area near Coniston. At Cautley however a dominant N.E. source has not been detected anywhere in the succession above the 2nd graptolite band. In the Blawith Area such a source supplies sediment at the same time as a dominant N.W. current. The possible reconciliation of this anomaly is discussed in Chapter 6 (P. 102).
7. It is considered difficult to place any interpretation on the load mould readings. During much of the Silurian they are aligned approximately east-west but in the upper part of the 2nd Greywacke Unit, and between these beds and the 260' Banded Unit, they lie in a N.E. -S.W. direction.
8. Since this is in the nature of a preliminary study it is pertinent to suggest lines of approach for further work. Firstly, during the writer's ex-

amination of the western portion of the Howgill Fells it became clear that the sediments were much thicker and the exposures of the greywacke facies rather better. (e.g. Carling Gill 645,992). It is suggested that a study of the sedimentary structures there would provide more fruitful results than in the eastern Howgill Fells where exposures are generally poorer. Secondly a mineralogical study of the type carried out by Norman in the Blawith Area and at present being done by Mr. R. Furness in the Barbon area would perhaps help to explain some of the outstanding problems, particularly those connected with provenance and depositional environments. Thirdly the Howgill Fells have, in the Ludlow Series, many other less well known types of sedimentary structures (e.g. those of Craig and Walton 1962) which would benefit from specialized study.

Further conclusions to be drawn from the results of this survey are discussed in Chapter 6 where facies types and conditions of deposition as a whole are dealt with.

SYSTEMATIC DESCRIPTIONS

INTRODUCTION

Classification of the Graptolites

At the present time there is considerable controversy over the classification of graptolites, which is not restricted to the definition of genera and subgenera alone, but affects all taxa. Obut (1957), for example, introduces new suborders, families, and subfamilies following the Treatise classification by Bulman (1955) which was deliberately intended to be simple in nature. Because of the disagreement amongst the leading workers, in dealing with supra-generic units the writer has decided to follow the classification of major taxa adopted in the Treatise. This is summarized below:-

Class Graptolithina Bronn, 1846
Order Graptoloidea Lapworth, 1875
  Family Diplograptidae Lapworth, 1873
    Subfamily Climacograptinae Frech, 1897
    Subfamily Diplograptinae Lapworth, 1873
    Subfamily Petalograptinae Bulman, 1955
  Family Retiolitidae Lapworth, 1873
    Subfamily Retiolitinae Lapworth, 1873
    Subfamily Plectograptinae Boucek & Munch, 1952
  Family Dimorphograptidae Elles & Wood, 1908
  Family Monograptidae Lapworth, 1873
    Subfamily Monograptinae Lapworth, 1873
    Subfamily Cyrtograptinae Boucek, 1933

The erection of genera and subgenera within the subfamilies listed above is equally controversial. Pribyl (1947) raised a new subgenus Paraclimacograptus within the genus Climacograptus to accommodate forms such as C.innotatus Nicholson, and in 1948 he split the genus still further by defining the subgenus Pseudoclimacograptus in which he included C.scharenbergi Lapworth, C.hughesi, (Nicholson), C.extremus H.Lapworth, etc. These two subgenera are considered synonymous with Climacograptus by Bulman (1955). Both Pribyl (1947,1948) and Bulman (op. cit.), however, recognize only one genus in the subfamily Climacograptinae. Obut (1949) on the other hand grouped his genus Hedrograptus with Climacograptus and Diplograptus in the family Diplograptidae, and then later (Obut 1957 p.29) placed it in the subfamily Climacograptinae. Subsequent workers do not seem to have recognized the genus Hedrograptus, and it receives no mention in the Treatise.

Orthograptus Lapworth, 1873 has received similar attention. Thus Hundt (1942) recognized Cystograptus as including those forms having vesicular bodies of various types as part of the rhabdosome. Pribyl (1949) raised the genus Rectograptus with O.truncatus Lapworth as its type, for those species having straight, tubular thecae unadorned by spines. Bulman (op. cit.) regarded both these genera as synonymous with Orthograptus.

The subgenera Bulmanograptus and Metadimorphograptus were named by Pribyl (1948) to include, respectively, forms such as D.confertus Nicholson and those with climacograptid thecae. The latter is synonymous with Rhaphidograptus Bulman, 1936 and the former with Dimorphograptus Lapworth (Bulman op. cit. p. V90).

In view of the difficulty often experienced in placing some species in the genera Climacograptus Hall 1865, Amplexograptus Elles and Wood, 1907, Lasiograptus Lapworth, 1873, Glyptograptus Lapworth 1873, etc. it is perhaps debateable whether further splitting of these genera should take place at present. Thus Bulman (1955 p. V 85) writes of Climacograptus Hall "Distinction from Amplexograptus and Lasiograptus not always easy, especially if apertural excavations are relatively wide or thecae less angularly sigmoidal or bear mesial spines." Similarly Packham (1962) found it difficult to decide whether to place some species in Climacograptus Hall or Glyptograptus Lapworth and eventually adopted an arbitrary rule of convenience which is also used in this work.

There are, therefore, two points of view. One is that further splitting of genera and grouping of species into subgenera based on similarities of morphology will help to unravel the evolutionary relationships. The other view is that this approach will not neccessarily improve the situation and that to refrain from subdivision at the present will mean, ultimately, a lesser amount of revision of earlier works and reduce the possibility of almost wholesale transfer and retransfer of numbers of species from one group to another. This latter view is held by the present writer and the species described here under the families Diplograptidae, Retiolitidae and Dimorphograptidae are included in the genera defined by Bulman (1955 pp. V84-91).

The Family Monograptidae

It is in the consideration of the family *Monograptidae* Lapworth that the greatest difference of opinion has arisen. Most Continental, Russian, and Chinese workers favour the recognition of numerous genera and subgenera whilst workers in Britain and the United States continue to use the simpler classification. Urbanek (1958) has summarized the main steps in the erection of these genera and subgenera up to the year 1958. The work of Urbanek (1954, 1958) has shown that if the morphological characters are worked out in detail for suitably preserved material then the separation of new genera from *Monograptus* may be justified. Thus his genera *Cucullograptus* and *Lobograptus* are well defined. It has been pointed out, however, (Bulman 1955 p. V69) with regard to similarly careful and accurate work by Eisenack (1951) that ". . the application of such improved classification may remain impracticable simply because it cannot be applied to normal imperfectly preserved specimens in shale". The erection of other genera such as *Pernerograptus* Pribyl (1941) and *Campograptus* Obut (1949) merely upon general form is less sound. The lack of knowledge for many years in the case of the genus *Demirastrites* Eisel (1912) has been amply demonstrated by Sudbury (1958), whilst the complications involved in the definition of *Spirograptus* Gurich (1908) were covered by Mu (1955) in an attempt to solve the situation. This was only partially successful since it transpires that *Oktavites* Levina (1928) has priority over *Obutograptus* Mu (1955). In this instance two new names (*Tyrsograptus* Obut and *Obutograptus* Mu) were incorrectly introduced into the nomenclature which added to the confusion. Thus Romariz, as late as 1962, includes *Monograptus spiralis* Geinitz (the type species of *Oktavites* Levina) in *Spirograptus* Gurich as *Spirograptus spiralis spiralis* (Geinitz). The type species of *Spirograptus* is *M.turriculatus* (Barrande) (subsequently designated by Bulman (1929)) - a form whose thecal characters are still not known in any detail (v. Urbanek 1958 p.11).

From the brief discussion above it can be seen that if *Monograptus* Geinitz is to be split up there are, broadly, two ways of achieving this end. Firstly species of apparently similar general form may be grouped together and described as genera or subgenera (e.g. *Campograptus* Obut). The disadvantage of this procedure is that as more information on morphological details is made available the definition of such groups requires constant revision and the species within each group needs to be perpetually reshuffled. It is inevitable that the literature becomes excessively complicated. The alternative process is that which has been followed, more or less, by Urbanek and involves splitting off from Monograptus only those groups in which the detailed morphology and perhaps evolutionary relationships are known. One disadvantage of this procedure is that the details may be so delicate as to be unrecognisable in most material (see above) but it is at the same time technically and scientifically sound. Urbanek (1958 pp.11-13) classifies the family Monograptidae Lapworth as follows:-

Subfamily Monograptinae Lapworth, 1873
- genus Monograptus (Monograptus) Geinitz, 1852
- genus Monograptus (Streptograptus) Yin, 1937

Subfamily Saetograptinae Urbanek, 1958
- genus Colonograptus Pribyl, 1942a
- genus Saetograptus Pribyl, 1942a

Subfamily Cucullograptinae Urbanek, 1958
- genus Lobograptus Urbanek, 1958
- genus Cucullograptus Urbanek, 1954

Subfamily Pristiograptinae Gurich, 1908
- genus Pristiograptus Jaekel, 1889
- genus Monoclimacis Frech, 1897

Subfamily Pernerograptinae Pribyl, 1946
- genus Pernerograptus Pribyl, 1941

Subfamily Demirastritinae Pribyl, 1946
- genus Demirastrites Eisel, 1912

Subfamily Rastritinae Pribyl, 1946
- genus Rastrites Barrande, 1850

All except the last three subfamilies were represented in the material studied by Urbanek and each genus (except the last three) was carefully defined on detailed morphological characters. The subfamilies group together forms considered to be phylogenetically related. Urbanek is unable, however to place in this classification such groups as Spirograptus, Monograptus (Globosograptus), and Monograptus (Mediograptus). In the Cautley material it has not yet been possible to recognise the details necessary for the differentiation of Colonograptus, Saetograptus, Lobograptus and Cucullograptus and the writer finds that the genera Pernerograptus and Demirastrites appear to serve no useful purpose.

In Urbanek's classification, however, the genera Pristiograptus, Monoclimacis and Rastrites can be recognised both on general form and detailed morphology, but for the reasons stated above (p.113) they are not described under his respective subfamilies and for taxa above generic rank the Treatise classification is adopted. The classification used is summarized below:-

Family Monograptidae Lapworth, 1873
Subfamily Monograptinae Lapworth, 1873
genus Pristiograptus Jaekel, 1889; (Groups A-D)
genus Monoclimacis Frech, 1897
genus Monograptus Geinitz, 1852; (Groups A-J)
genus Rastrites Barrande, 1850
Subfamily Cyrtograptinae Boucek, 1933
genus Cyrtograptus Carruthers, 1867
genus Barrandeograptus Bouček, 1933.
Incertae Sedis.
?

Discussion

1. The Genus Pristiograptus

In the author's opinion the morphology of Pristiograptus is sufficiently well defined to justify its erection as a full genus within the subfamily Monograptinae. As in the case of Monoclimacis Frech (1897) its early date of recognition supports this contention and both have been accepted perhaps more widely than any other subdivisions of Monograptus except Rastrites. Elles and Wood in their Monograph, although fully aware of Jaekel's work, did not incorporate the genus in their classification although they did include Barrande's genus Rastrites as a subgenus of Monograptus. In his original definition Jaekel considered certain species with hooked thecae (e.g. M.colonus) to belong to Pristiograptus as well as some with spinose thecae (M.testis). These are now excluded by most modern workers and Jaekel's definition is amended accordingly. In its original conception Pristiograptus was approximately equivalent to Group I of Elles and Wood, and in the present writer's concept is equivalent to the above authoress' Group 1A.

Pribyl (e.g. 1955) includes under Pristiograptus such forms as M.argutus Lapworth and M.atavus Jones and gives them the title Pristiograptus (Subgen?) in spite of the fact that in 1954 he draws attention to the great differences between the two groups. Thus he writes (op. cit. p.118) "... in the shape of the thecae, which in the species of the type of P.argutus, are of Dicellograptid type (introverted or introtorted), whereas in the species of the type of P.dubius they are entirely straight." A further major point of difference is the presence of sigmoidal curvature of the thecal tube in monograptids of the argutus type. Species closely related to M.argutus cannot, therefore, be included in Pristiograptus.

Some species of Pristiograptus (e.g. P.nudus, P.bohemicus) show a slight expansion of the free ventral margin which, if it breaks outwards upon flattening, gives the appearance of a slight excavation of the thecal margin. Such species are almost the only ones which might be confused with Monoclimacis Frech. Urbanek (1958) considers the two genera to be closely related and includes them both in the subfamily Pristiograptinae Gurich (1908).

Four groups are recognised within Pristiograptus and these are defined in the systematic descriptions below.

2. The Genus Monoclimacis

Like Pristiograptus this genus is made up of many species and its bio-characters are considered to be sufficiently well defined to justify its separation from Monograptus as a distinct genus. Monoclimacis is equivalent to to Group 3 of Elles and Wood

3. Genus Monograptus Group A

Although the characters of the apertural region are little known at present, when taken in conjunction with the flowing sigmoidal curvature of the thecal tube and the slender nature of the rhabdosome they are sufficient to distinguish the Group from any other described genera, or subgenera. The introversion of the apertural margin seems to reach a maximum in M.argutus (v. pl.26,fig.7) but in other forms usually grouped here (e.g. M.atavus) this may be completely absent in the distal thecae. When such forms are flattened they may assume a general pristiograptid appearance particularly if the degree of sigmoidal curvature is slight. Monograptus Group A is the only monograptid group in which introversion of the apertural margin takes place. The reverse is far more common (e.g. M.priodon).

4. Genus Monograptus Group B

This group is equivalent to Group 1B1 of Elles and Wood and was described as a new genus, Pernerograptus, by Pribyl (1941).

5. Genus Monograptus Group C

These forms were grouped as Pristiograptus (Colonograptus) by Pribyl (1942). Urbanek (1958) considers that Colonograptus is not only a distinct genus but that it should also be separated from the pristiograptids. He shows that the proximal thecae are relatively simple tubes with paired, lateral, ear-like processes. In the Cautley specimens such details cannot be ascertained and the proximal thecae usually appear to be slightly hooked.

This is a case where the erection of the name Colonograptus could profitably have been delayed until the details of the thecal apertures had been solved. When this was finally acheived it was realized that the forms bore little relationship to the pristiograptids but were more closely related to monograptids of the priodon type. The literature is now irretrievably burdened with numerous references to the supposed affinities of M.colonus with the pristiograptids. Examples are:-

Monograptus (Pristiograptus) colonus Obut (1949)
Pristiograptus (Colonograptus) colonus Munch (1952)
Monograptus (Pristiograptus) colonus Bodilevsky (1953)

(The confusion and diversity of opinion which invariably follows the immature splitting of groups (genera or subgenera) from Monograptus can be appreciated even from the three examples quoted in this case. A similar picture can be obtained by a study of the synonomies of many of the species described below)

6. Genus Monograptus Group D

The species grouped here have simple thecal tubes adorned with spines. Many of the remarks under Group C above also apply to this group.

7. Genus Monograptus Group E

Species in this group are those having hooked thecae throughout the rhabdosome and are referred by some authors to Monograptus (Monograptus). The type species of Monograptus Geinitz, (Lomatoceras priodon Bronn), is contained here. Most of the included species have thecae in which the dorsal margin rapidly outgrows the ventral margin to produce a hook of the priodon type whilst in a few species both margins continue to grow at more or less the same rate but the resultant tube is also hooked. The recurved portion in these latter cases may be either adpressed to the earlier part of the thecal tube as in M.knockensis or completely free as in M.gemmatus. Both these groups are dealt with by Pribyl and Boucek (1951). M.gemmatus is described as Monograptus (Subgen?) gemmatus, whilst M.knockensis is regarded as synonymous with Monograptus (Globosograptus) singularis singularis Tornquist (1892). The last species, however, seems to be much more flexuously curved than M.knockensis though the distal thecae at least are similar.

The Cautley specimens of M.barrandei show that the thecal hook is similar to that of M.gemmatus and consists of a completely free hook bent in such a manner that the apertures face the proximal end of the polypary. They are, therefore, clearly different from forms included under Monograptus (Globosograptus) as defined by Boucek and Pribyl (1951). These authors describe barrandei as Monograptus (?Globosograptus) barrandei.

8. Genus Monograptus Group F

This group includes those species with spirally coiled rhabdosomes and hooked, spinose thecae such as M.turriculatus and M.discus.

9. Genus Monograptus Group G

Monograptus minimus cautleyensis is the only form described here. The group is roughly equivalent to Monograptus (Mediograptus) Boucek and Pribyl in which the species are small and slender with stiff dorsal curvature and small thecal lobes closely adpressed to the rhabdosome. The details of the apertural lobes are not known and even the Cautley specimens, which are preserved in relief, shed no light on the matter. Boucek and Pribyl (op. cit.) include M.remotus in their subgenus Mediograptus but these forms appear to have hooked rather than lobed thecae.

10. Genus Monograptus Group H

This group is approximately equivalent to M.(Globosograptus) Boucek and Pribyl (1951) and is characterised by species in which the lobed portion of thecae is well removed from the axis of the rhabdosome and the prothecae are of axially elongated triangular shape. M.crispus a typical example, is the species described here (p.286). The details of the apertural lobes are not fully known and it is debateable whether M. (Globosograptus) should be distinguished from Streptograptus Yin. Indeed Mu (1963) figures Streptograptus nanshanensis Lee which falls within the definition of M.(Globosograptus) as envisaged by Boucek and Pribyl. Mu (op. cit. p.358) recognizes two groups within Streptograptus: " in one group the thecae are rolled for a greater part in contact with the "main axis" of the stipe (nodifer group) whereas in the other group only the apertural region is rolled (nanshanensis group)."

11. Genus Monograptus Group I

The species included here are equivalent to those usually described under Monograptus (Streptograptus) Yin and included by Elles and Wood in their Group V(a). The thecae are lobed and the lobe closely adpressed to the rhabdosome which is usually small, relatively slender and with variable curvature.

12. Genus Monograptus Group J

Sudbury (1958) dealt in considerable detail with the species described here and the sub-grouping used by her is also utilized here. The species have been variously described under Demirastrites Eisel (1912), Spirograptus Gurich (1908), Obutograptus Mu (1955), Oktavites Levina (1928) and Campograptus Obut (1949). These are not recognized by Sudbury (op. cit.) whilst Campograptus and Oktavites do not receive mention by Bulman (1955). Urbanek (1958 p.6) regards Campograptus as a very doubtful genus.

Distortion of Graptolite Rhabdosomes

That tectonic compression of the rock distorts the contained graptolite rhabdosomes has been known for many years. Tornquist (1907), however, was one of the first to indicate the direction of compression on his figures, which he did by the use of arrows. More recently Jaeger (1959) drew a line on each figure parallel to the tectonic "b" direction and a similar procedure has been adopted by the present writer. Sudbury (1958) dealt in some detail with the effects of primary and secondary compression. The former is a diagenetic flattening of the rhabdosome which takes place soon after deposition, whilst the latter is caused by crustal shortening in the tectonic "a" direction during orogenesis. (It is possible that the degree of crustal shortening might be more accurately measurable by means of distorted graptolites rather than by brachiopods, trilobites etc. whose gross morphology is more variable). Primary compression is referred to throughout the following descriptions by the word "flattening", and secondary compression simply by the word "compression".

As in the case of the Rheidol Gorge specimens (Sudbury op. cit. p.493) secondary compression can always be detected by the presence on the bedding plane of a lineation which is presumed to lie in the "b" tectonic direction. The lineation takes the form of minute ridges which are clearly small scale folds. Cleavage is developed in the rock and the cleavage planes are often seen to be approximately parallel to the lineation and subnormal to the bedding plane.

In the case of specimens which have previously suffered primary compression and are preserved as little more than films on the rock several general rules may be applied to deduce the effect of any secondary compression. On the other hand specimens preserved in full relief in pyrites seem to have more resistance to secondary compression and whilst the factors listed below may be expected to operate it is desirable to treat each case on its own merits.

A. <u>Lineation at right angles to the length of a straight, flattened polypary.</u>

The lineation on the bedding plane might be interpreted as being either parallel or at right angles to the direction of compression depending upon the structural view held by the particular worker. Therefore, whilst the phrase "direction of compression" is admittedly ambiguous the word "compression" is used in the systematic descriptions below in one sense only. A graptolite is described as having suffered "compression at right angles to the length of the polypary" only when the lineation upon the bedding plane is also at right angles to the length of the polypary. Similarly "compression parallel to the length of the polypary" is used when the lineation is parallel to the length of the polypary.

1) The width of the rhabdosome, already increased to some extent by primary compression, is further increased.

2) The thecae become more closely packed i.e. the thecal count is increased.

3) The angle of inclination of the thecal tubes seems to be increased.

4) Any slight flexuous curves are accentuated.

5) Thecal hooks tend to be flattened, whilst everted apertural margins are rotated to appear sub-horizontal.

B. <u>Lineation parallel to the length of a straight, flattened polypary.</u>

In these cases the opposite of 1) to 5) above takes place. As a rule the most noticeable effect is the decrease in width of the rhabdosome and the flattening out of any curves. Further examination shows a decrease in thecal count and an accentuation of everted and introverted apertural margins

C. Lineation oblique to the length of a straight, flattened polypary.

This seems to have little effect upon the width or thecal spacing but it does alter the shape of the thecae. Thus in the case of a biserial graptolite having horizontal apertural margins one series will become introverted and the other everted (v. pl.18, fig.11).

Good examples of A and B are illustrated on pl.20 (figs.1,2) and pl.19 (figs.7,8,9). On pl.19, fig.8 is a relatively undistorted form of intermediate proportions. Many other examples can be seen throughout plates 1-38.

The effects of primary compression are not discussed here since they have been dealt with by other workers notably by Sudbury (1958) and Packham (1962 p.499). One of the most important considerations to bear in mind is whether the ventral margin of the thecal tube breaks outwards or inwards upon flattening.

Morphological terms used

Standard descriptive terms are used throughout the systematic descriptions, and at all times the writer has tried to take into account the effects of distortion, and to record in each description the state of preservation of the material being described. When such a descriptive term as "width" is employed it is stated in some part of the description whether it applies to specimens in relief or otherwise. The term "width" also requires further explanation. It is used to describe the full extent of the rhabdosome from the dorsal margin to the most ventral extremity of hook or spine (except where it is stated to the contrary) and may be measured at any point along the polypary. The word "breadth" is occasionally used and may be regarded as synonymous with "width".

The method of thecal count adopted is that utilized by Packham (1962).

SYSTEMATIC DESCRIPTIONS

Class GRAPTOLITHINA Bronn, 1846

Order GRAPTOLOIDEA Lapworth, 1875

Family DIPLOGRAPTIDAE Lapworth, 1873

Subfamily CLIMACOGRAPTINAE Frech, 1897

(nom. transl. Pribyl, 1948 (ex Climacograptidi Frech 1897))

genus CLIMACOGRAPTUS Hall 1865

(= Paraclimacograptus Pribyl 1947; Pseudoclimacograptus Pribyl 1948)

Type Species: Graptolithus bicornis Hall, 1848

Generic diagnosis: Thecae with angular sigmoidal curvature, part of free ventral wall often parallel to axis of rhabdosome, occasionally spinose. Apertures situated in short, deep excavations, and apertural margins usually horizontal.

The " rule of convenience for present purposes." adopted by Packham (1962) is also used here and forms are retained in Climacograptus if the infragenicular wall immediately below the geniculum is inclined to the length of the rhabdosome at 45° or more.

Climacograptus normalis (Lapworth)

Plate 1, fig.3; Plate 15, fig.9; Plate 16, fig.10; Plate 19, figs.1,2

1877	Climacograptus scalaris	var. normalis Lapworth p.138,Pl.6,fig.31.
1906	" "	(Hisinger) var. normalis, Lapworth. Elles and Wood p.186,Text fig. 119a-d,Pl.26,figs.2a-g.
1924	" "	normalis Elles & Wood. Hundt Pl.1,figs.28-31.
1929	" "	var. normalis Lapw. Davies fig.29 (not described
1945	" "	" " " Waterlot Pl.4,fig.92.

Material: Over 100 specimens, mostly flattened but some in low relief.
Horizon and Localities: Zone of M. atavus - M. triangulatus; Spengill (S1-5 to S20-24, S24-28, S28-32, ?S36-39,7); Birks Beck (1Bi,2Bi); Wards Intake (15Wi,11Wi); Watley Gill (1Wa,2Wa,3Wa,4Wa).
Diagnosis: Rhabdosome long, parallel-sided for much of its length, reaching a width (flattened) of 1.5 mms fairly quickly, thecae numbering 11-7 in 10 mms, excavations deep.
Description: C. normalis is the abundant climacograptid in the L. Llandovery. It reaches a length of several centimetres and a width of 1.5 mms. The virgella may reach 10 mms long in some specimens.

At the proximal end the thecae usually number 11 in 10 mms, but this value falls rapidly to 10-9 in 10 mms a density which is maintained throughout the first few centimetres. Distal fragments commonly show 8-7 in 10 mms. A sicula has not been seen.

Thecal excavations are deep, typically climacograptid and may occupy almost one third of the width of the polypary.
Remarks: This species becomes gradually less common upwards and is rare in the lower part of the M. triangulatus Zone. No changes have been noted throughout its vertical range.
Material seen: Specimens in H.M.Geological Survey Museum (e.g. Zi 7144) and in the Sedgwick Museum, Cambridge.

Climacograptus miserabilis Elles and Wood

Plate 1, figs.1,4,5; Plate 12, fig.9; Plate 14, fig.8; Plate 15, fig.7; Plate 17, fig.1,2

1906 Climacograptus scalaris (Hisinger) var. miserabilis, var. nov. Elles & Wood pp.186-7,Text fig.120a-c,Pl.26,fig.3a-h.

?1924 Climacograptus miserabilis Elles & Wood. Hundt Pl.1,figs.20-21,26.

1929 Climacograptus scalaris var. miserabilis Elles & Wood. Davies pp.7-8 (pars) fig.27.

1945 " " " " E. & W. Waterlot Pl.4,fig.91.

Material: Over 100 specimens, all flattened.

Horizon and Localities: Zone of M. atavus - P. cyphus; Spengill (S1-5 to S17-20); Watley Gill (1Wa,2Wa,3Wa,4Wa); Birks Beck (1Bi,2Bi); Pickering Gill (P); Wards Intake (15Wi,14Wi).

Diagnosis: Rhabdosome sometimes approaching 2 cms in length, always less than 1mm width. Thecae indistinct as regards degree of sigmoidal curvature, excavations usually small but not long, thecae numbering 10-11 in 10 mms.

Description: This species differs little from the original material described by Elles and Wood (1906). Its most characteristic features are the short, small excavations and short, narrow rhabdosome. Occasional specimens from the lower beds have the virgella and nema preserved, but in the higher beds (e.g. P. cyphus Zone) most specimens have a long virgella and prominant nema (see fig.1, Pl.17) although the species is less common.

The sicula has been seen in one specimen where it is "pressed through" and it seems to be short (0·65 mm) and relatively broad. Its apex does not reach the 1st thecal pair.

In one specimen (fig.4 Pl.1) the excavations are rather less than one third the width of the polypary but generally they are about one quarter or less.

The rhabdosome width varies from 0·7 - 0·9mm.

Remarks: The Cautley specimens show more variability in rhabdosome width than is indicated in Elles and Woods original description and several specimens (e.g. Pl.1,fig.1) appear to be rather more slender. The vertical range is also greater although specimens are rare in the P. cyphus Zone, and may perhaps be regarded as representatives of a late mutation which has a prominant virgella and nema.

Material seen: Specimens in the Sedgwick Museum, Cambridge and in H.M.Geological Survey Museum (e.g. Flett Collection No.21573 from Anglesey).

Climacograptus ex. gr. scalaris (Hisinger)

Plate 1,fig.6; Plate 16,fig.8

1837 Prionotus scalaris Hisinger p.113,Pl.35,fig.4.

1906 Climacograptus scalaris (Hisinger) (Linne?). Elles and Wood pp.184-5, text fig.118a-b, Pl.36, figs.1a-c.

Material: Several fragmentary specimens in full relief from Zones of M. convolutus (Birks Beck, 5Bi) and M. sedgwicki (Spengill) and M. turriculatus (Spengill).

Description: Unfortunately no good specimens of this form have been obtained, but those fragments which do show a few well preserved thecae suggest affinities with C. scalaris scalaris. The thecae are strongly sigmoidal and have a sharp almost ridge-like geniculum. In the apertural view (v. fig.6, Pl.1) the margin is even but has a distinct lip similar to that seen in P. bohemicus (v. Pl.26, figs.1,2). A septum is present but may not be entirely complete at the extreme proximal end. The thecae are not closely spaced and range from 11 in 10 mms proximally to 9 in 10 mms distally.

Remarks: It can be seen that the distal details so far obtained agree with C. scalaris but equally clearly more material is required before a complete description can be attempted.

Material seen: Similar specimens are recorded from the Skelgill Beds, Ambleside (S.M. no. A20240-1).

Climacograptus simplex sp. nov.

Plate 16, fig.9, 11
" 17, " 6

Holotype: HUR./S75, 9·4/33.

Horizon of Holotype: Zone of M. sedgwicki.

Derivation of name: simplex, L, simple, referring to nature of thecal apertures.

Material: 3 proximal ends in full relief.

Horizon and Localities: Zone of M. sedgwicki; Spengill (S75, 9·4).

Diagnosis: Proximal end rounded in profile and cross section. Sicula free for 0·5 mm of its length. Septum complete. Thecae number 15-14 in 10 mms at extreme proximal end but only 12 in 10 mms at 6 mms. Thecal apertures with a slight lip.

Description: The longest specimen is 6 mms long and has a width of 1mm at its distal extremity. In cross section all three specimens are circular and the thecal tubes semicircular.

The sicula is exposed for 0·5 mm of its length and th.1(1) arises 0·3mm above its base. Th.1(1) then grows downwards to the base before turning upwards and opening 0·65 mm above the base of the polypary. Throughout the thecae are markedly alternate in their arrangement and at th.1(1) - 2(1) number 15 in 10 mms. At th.2(1) - 3(1) this has dropped to 14 in 10 mms and distally decreases further to 12 in 10 mms.

Thecal overlap is small and whilst the apertural margins are almost horizontal they have a slight lip in the mesial region particularly on the proximal thecae. The excavations occupy one quarter of the total rhabdosome width whether viewed from the obverse or reverse side. In the ventral view, however, they occupy well over half of the total ventral margin.

The septum is complete and begins on the obverse side at the level of the aperture of th.1(1). On the reverse side it appears about 0·4 mm above this level.

Remarks: This species is clearly close to C. scalaris but differs in the spacing of the thecae and the nature of the apertural margin. Viewed from the ventral position the excavation also occupies considerably more of the width (over one half compared with one quarter to one third in C. scalaris). The proximal end of C. simplex sp. nov. also appears to have no virgella and is rounded though it is possible that the virgella is broken off since the base of the sicula has worn appearance on the one specimen where this could be seen.

Climacograptus pseudonormalis sp. nov.

Plate 14 fig. 5; Plate 1, fig.10; Plate 12, fig.4; Plate 2, figs.1,4

Holotype: HUR./2Bi/4, flattened specimen, well preserved, distal end missing.

Horizon of Holotype: Zone of M. acinaces.

Derivation of name: "latinized" to indicate distinctness from Cl. normalis.
Material: One specimen, (the holotype) and other more doubtful material.
Description: The flattened rhabdosome is 9 mms long and distally reaches a width of 1·3 mms. The width at the level of the first thecal pair is 0·7 mm. There is a trace of a septum throughout the length of the polypary and because of this the depth of the excavations may be reduced. The latter are deep rather than semicircular, distinctly climacograptid, and remain unchanged distally. The thecal apertures are opposite.

The sicula can be faintly seen where it is "pressed through" and is approximately 1mm long, its apex almost reaching the second thecal pair. It is furnished with a short virgella. Thecal spacing is close and alters only slightly down the length from 15 in 10 mms proximally to 13½ in 10 mms distally.
Remarks: This seems a distinct species. It has a certain resemblance in size to C. normalis but the latter has more widely spaced thecae and the first few are markedly alternate, only becoming sub-opposite distally.

Climacograptus medius Toernquist

Plate 1,fig.12; Plate 12,fig.3

1870 Climacograpsus teretiusculus Nicholson (pars) p.373,figs.1a,b,f.
1872 " " " p.33,figs.8a,b,f.
1873 Climacograptus scalaris Malaise p.104,Pl.6,figs.5-6.
1897 " medius n. sp. Tornquist p.7-8,Pl.1,figs.9-15.
1906 " " " Elles & Wood pp.189-190,Pl.26, figs.4a-f,text fig.122a-c.
?1924 " " Tornq. Hundt Pl.1,figs.22-23,35,36.
1933 Climacograptus medius, Tornquist. Sun p.23,Pl.4,fig.2.
?1940 " " " . Desio p.27,Pl.1,figs.16,17.
1945 " " Tornq. Waterlot Pl.6,fig.113.
?1949 " " Tornquist. Obut p.13,Pl.1,figs.3a,b.

Material: About 30 specimens, flattened or low relief.

Horizon and Localities: Zones of M. atavus to M. triangulatus; Spengill (S1-5, S20-24,?S36-39,7); Watley Gill (1Wa-4Wa); Birks Beck (2Bi).
Diagnosis: Full grown rhabdosome very similar to C. rectangularis, attains a width of 2·5 mms (flattened), 12-10 thecae in 10 mms, proximal end rounded and very blunt, conspicuous virgella, excavations typically climacograptid.
Description: This species can only be distinguished with certainty from C. rectangularis on the characters of the proximal end. The virgella is a conspicuous feature of the polypary and is usually long and straight, whilst the initial part of the rhabdosome is broad and may measure 1mm at the level of the first pair of thecae.

Excavations are deep and in flattened material a "biscalariform" view is common suggesting that the apertural region is sufficiently thickened to be "pressed through".

Compression at right angles to the length of the polypary has the effect of closing the excavations which are then represented as a line. If compression is stronger the whole length of the polypary is marked by transverse corrugations and the thecal apertures are difficult to make out. In these cases the thecal spacing is considerably decreases and specimens having a thecal count of 20 in 10 mms have been obtained.
Material seen: Specimens in the Drew and Salter Collection, H.M.Geological Survey Museum. Sedgwick Museum, Cambridge, collection.

Climacograptus rectangularis (M'Coy)

Plate 12,fig.5; Plate 19,fig.3

1850	Diplograpsis	rectangularis,	M'Coy p.271.	
1851	"	"	"	p.8,Pl.1,B,fig.8.
1906	Climacograptus	rectangularis	(M'Coy).	Elles and Wood pp.187-8,Text fig.121a-b,Pl.26,figs.5a-e.
1924	"	"	M'Coy.	Hundt. Pl.1,figs.8-10.
?1945	"	"	"	Waterlot Pl.6,fig.111
1949	"	"	(M'Coy).	Obut p.12.Pl.1,figs.2a,b.

1955 Climacograptus rectangularis (M'Coy). Bulman fig.631c.(not described)
?1962 " " " Ross p.1386, text figs.1F,I,J,M.

Material: About 50 specimens, invariably flattened.
Horizon and Localities: Zone of M. atavus - M. triangulatus; Spengill (S1-5 to S24-28, ?S28-32 to S36-39,7); Watley Gill (3Wa); Wards Intake (?14Wi, ?11 Wi, ?13Wi); Birks Beck (1Bi,2Bi).
Diagnosis: Rhabdosome often more than 2 cms long, 2·5 mms wide, virgella conspicuous occasionally fairly long. Thecae 12-10 in 10 mms, typically climacograptid, relatively narrow proximally for a few mms after which it begins to broaden.
Description: For the first few millimetres the proximal region is relatively narrow but then broadens quickly to reach its maximum width which varies between 2 and 2·5 mms.

The virgella is usually short and conspicuous, but is occasionally rather longer (see fig.5, Pl.12), in which case the extremity is very fine.

At the proximal end the thecae number 11-12 in 10 mms decreasing distally to 10 in 10 mms. Strongly compressed specimens show higher and lower values.

The thecal excavations are deep and similar to those in C. normalis and C. medius. A septum is present - this can be ascertained even in the flattened specimens - and it may be complete.
Remarks: The only form which C. rectangularis might be confused with is C. medius. Whilst having the same thecal spacing and general size, the latter species has a blunt, rounded proximal end. The general form of specimens preserved in compressed rock may be altered to approach that of the other species. Thus specimen of C. medius compressed parallel to length of the rhabdosome would be narrower throughout and the blunt proximal end might become sharper. It is not easy therefore to distinguish the two species even on the character of the proximal end.
Material: Specimens in Drew and Salter Collection, H.M.Geological Survey Collection (Zi 7183).

Climacograptus ?tangshanensis linearis Packham

Plate 1, fig.9

1955 Climacograptus rectangularis (M'Coy). Bulman fig.631c.(not described)
?1962 " " " Ross p.1386,text figs.1F,I,J,M.

Material: About 50 specimens, invariably flattened.
Horizon and Localities: Zone of M. atavus - M. triangulatus; Spengill (S1-5 to S24-28, ?S28-32 to S36-39,7); Watley Gill (3Wa); Wards Intake (?14Wi,?11 Wi, ?13Wi); Birks Beck (1Bi,2Bi).
Diagnosis: Rhabdosome often more than 2 cms long, 2·5 mms wide, virgella conspicuous occasionally fairly long. Thecae 12-10 in 10 mms, typically climacograptid, relatively narrow proximally for a few mms after which it begins to broaden.
Description: For the first few millimetres the proximal region is relatively narrow but then broadens quickly to reach its maximum width which varies between 2 and 2·5 mms.

The virgella is usually short and conspicuous, but is occasionally rather longer (see fig.5,Pl.12), in which case the extremity is very fine.

At the proximal end the thecae number 11-12 in 10 mms decreasing distally to 10 in 10 mms. Strongly compressed specimens show higher and lower values.

The thecal excavations are deep and similar to those in C. normalis and C. medius. A septum is present - this can be ascertained even in the flattened specimens - and it may be complete.
Remarks: The only form which C. rectangularis might be confused with is C. medius. Whilst having the same thecal spacing and general size, the latter species has a blunt, rounded proximal end. The general form of specimens preserved in compressed rock may be altered to approach that of the other species. Thus specimen of C. medius compressed parallel to length of the rhabdosome would be narrower throughout and the blunt proximal end might become sharper. It is not easy therefore to distinguish the two species even on the character of the proximal end.
Material: Specimens in Drew and Salter Collection, H.M.Geological Survey Collection (Zi 7183).

Climacograptus ?tangshanensis linearis Packham

Plate 1, fig.9

Material: A single, flattened, but well preserved specimen.
Horizon: Zone of P. cyphus; Spengill (14P).
Description: The rhabdosome is incomplete and has a length of 5 mms (excluding virgella). It widens gradually throughout its length to 1mm at th.7(1) (flattened). A virgella projects 1·7 mms below the base of the sicula which is just discernable. The aperture of th.1(1) opens 0·4 mm above the base of the sicula.

Throughout the specimen the excavations are semicircular but quite deep, occupying between one quarter and one third the total width of the polypary. At the level of th.1(1) and 2(1) the thecae are closely spaced (15 in 10 mms) but distally become widely spaced (13 in 10 mms).
Remarks: The specimen is placed in the genus Climacograptus since the excavations remain deep and the geniculum more climacograptid than glyptograptid. It has a certain resemblance to Packham's subspecies C.t.linearis but has a slightly higher thecal count and a more prominant virgella, whilst the margins are tapering rather than subparallel.
Material seen: Holotype of Packham's Climacograptus tangshanensis linearis (S.M. no A51448) figured Packham 1962, text fig.3j; Pl.72 fig.3.

Climacograptus hughesi (Nicholsoh)
Plate 17, fig.5.

1853	Diplograpsus	teretiusculus	Richter	p.456,Pl.12,fig.11-13.
1869	"	Hughesi, Nich.	Nicholson	p.234.
1871	Diplograptus	teretiusculus	Richter	Pl.5,figs.5-7.
1882	Climacograptus	undulatus	Kurck	p.303,Pl.14,fig.11.
1890	"	internexus	Toernquist	p.25,Pl.2,figs.8-9.
1893	"	"	"	p.6,figs.23-27.
1897	"	undulatus	"	p.9,Pl.1,figs.22-24.
1906	"	Hughesi (Nicholson).	Elles and Wood	pp.208-210,text fig.14Ca-d,Pl.27,figs.11a-e.
?1924	"	hughesi Nicholson.	Hundt.	Pl.1,figs.8-10.

?1929 Climacograptus scalaris (Hisinger) (Linne?) var. normalis, Lapworth Glemerec p.125,Pl.5a,b.
?1934 " hughesi (Nicholson). Hsu p.67,Pl.5,figs.7a-c.
1945 " " Nich. Waterlot Pl.8,fig.130.

Material: About 30-40 specimens in relief.
Horizon and Localities: Zone of M. triangulatus, Zones of D. magnus - M. sedgwicki; Spengill (S75,9·4-80,8·4); Birks Beck(9Bi,6Bi,5Bi); Watley Gill (5Wa, 9Wa-11Wa); Spengill (S28-39,7)
Diagnosis: Rhabdosome up to 1cm long and almost 1mm broad. Proximal end round with small prominant sicula which is free for 0·65 mms of its length. Septum undulating, complete. Thecae with strong sigmoidal curvature, numbering 16-12 in 10 mms, with introverted and introtorted apertural margins.
Description: C. hughesi is superficially like C. extremus but has a considerably longer rhabdosome and the sicula is visible for some distance. In C. extremus the sicula appears to be completely enveloped.

Th.1(1) grows downwards for 0·25 - 0·3 mm before turning upwards. Its complete length is 0·9 mm. Th.1(2) grows across the back of the sicula and its aperture opens 0·13 mm above the aperture of th.1(1). The septum separates the two series throughout growth and undulates throughout.

Specimens preserved in relief show the thecal apertures to be introtorted and introverted, the former perhaps being more strongly developed than the latter. Thus a specimen in full relief showing both series of thecae will have one series displaying distinct excavations whilst the other will have the excavations filled by the most distal extremities of the introtorted thecae. (see fig.5,Pl.17), and also Elles and Wood 1906, text fig.140c.).

The specimen figured by Elles and Wood as text fig.140c seems to display sinistral torsion of the aperture whilst the Cautley specimen figured on Pl.17 (fig.5) shows dextral torsion. At present it is impossible to say whether the direction of torsion is constant.
Material Seen: Specimens in the Sedgwick Museum, Cambridge.

Climacograptus extremus H.Lapworth

Plate 1,fig.8; Plate 12,fig.6; Plate 17,fig.3

1900 Climacograptus extremus, sp. nov. H. Lapworth p.134-5,figs.22A-B.
1906 " " , H.Lapworth. Elles and Wood pp.210-11, text fig.141a-c,Pl.27,figs.13a-b.
1945 " " Lapw. Waterlot Pl.8,fig.132.

Material: Over 30 specimens, some in full relief.

Horizon and Localities: ?Zone of M. triangulatus, Zones of D. magnus to M. turriculatus; Spengill (?S36-39,7; S75,9·4-S172,0·5); Birks Beck (9Bi,5Bi); Watley Gill (9Wa-11Wa).

Diagnosis: Rhabdosome very small and narrow rarely exceeding 5 mms in length and never more than 0·5 mm in width except when flattened. Septum undulating complete. Sicula not seen. Nema long, slender. Virgella short. Thecae number 15-20 in 10 mms.

Description: The rhabdosome of this species is most distinct by virtue of its small size and slenderness. A short virgella is usually found and in one specimen an extremely fine nema has been detected (pl.17,fig.3). In flattened specimens little can be said about the nature of the thecae, but in material preserved in full relief they are seen to be very small, overlapping about one third, and have their margins certainly introverted and probably introtorted. They number 15-20 in 10 mms.

The undulating septum is a conspicuous feature of the rhabdosome as it swings with the sigmoidal curvature of the alternating thecae.

Remarks: Rather doubtful specimens have been obtained in the M. triangulatus Zone but the species is certainly present in the D. magnus Zone. Elles and Wood (1906) give its range as sedgwicki-turriculatus Zones but Sudbury (1958 p.487) also records it throughout her M. gregarius Zone of the Rheidol Gorge. This latter observation also suggests that the species comes in earlier than was supposed by Elles and Wood.

Climacograptus aff minutus Carruthers

Climacograptus aff minutus Carruthers

Plate 1,fig.11; Plate 17,fig.4; Plate 12,fig.7.

aff.

1868 Climacograptus minutus Carruthers p.132,Pl.5,figs.10a-b.

1906 " " " . Elles and Wood pp.211-2,text fig. 142,Pl.27,figs.12a-c.

Material: About 15 specimens.

Horizon and Localities: Zone of M. atavus - M. triangulatus; Spengill (S1-5 to S24-28).

Diagnosis: Rhabdosome small and slender, usually about 0·7 - 0·8 mm wide. Nema projects beyond distal extremity. Thecae with deep, narrow excavations, numbering 14-16 in 10 mms.

Description: The rhabdosome is always less than 1cm long and has a breadth (flattened) of less than 1mm. Most commonly specimens are about 5-6 mms long and 0·7 - 0·8 mm broad. The short, fine virgella and distal nema are not generally preserved.

Throughout the rhabdosome the thecae are closely spaced at 14-16 in 10 mms though lower densities are occasionally obtained.

The proximal end is rather blunt and often the base of the sicula and most proximal point of th.1(1) can be seen (v. fig.11, Pl.1). There is no trace of a septum in this flattened material.

Remarks: The species closest to these forms seems to be Cl. minutus Carruthers. It can be distinguished from C. extremus by virtue of its greater width and there is no resemblance to C. hughesi that can be detected in flattened specimens.

Material Seen: Specimens in Sedgwick Museum, Cambridge.

?Climacograptus retroversus sp. nov.

Plate 17,figs.8,8,10; Plate 18,fig.1

Holotype: HUR./S73,11·4/81, a specimen in full relief, but broken.

Horizon of Holotype: Zone of M. sedgwicki.

Derivation of Name: retroversus, L. turned backwards.

Material: 7 specimens in full relief, others flattened.

Horizon and Localities: Zone of M. sedgwicki; Spengill (S73,11·4, to S80,8·4)

Diagnosis: Rhabdosome up to 2 cms long, slender, elliptical to circular in cross section, septum undulating, complete. Thecae with retroverted apertural margins, numbering 10 in 10 mms distally, and up to 12 in 10 mms proximally.

Description: This species is superficially like C. hughesi but differs in all the measurable features as well as in the nature of the thecae. The rhabdosome in ?C. retroversus sp. nov. reaches 2 cms long in some specimens and is therefore much longer than in hughesi. The septum is complete and undulating but distally the undulation is reduced. The rhabdosome width is variable, being less than 1mm and usually about 0·8 mm. Occasionally there is a reduction in width distally.

The position of the sicula can be detected in the holotype and in obverse view it is free for 0·8 mm of its total length, of about 1·3 mms. The apex is circular in cross section whereas the rhabdosome in the same region is elliptical although this might in part be due to flattening.

The thecae are strongly sigmoidal and overlap for approximately one third their length. The supragenicular walls slope inwards towards the axis and as the thecal tube approaches the sigmoidal curve of the succeeding theca its dorsal margin begins to outgrow the ventral margin resulting in what appears to be a narrower aperture facing outwards or towards the proximal end (i.e. retroverted). In no view therefore, is there an excavation proper even though the thecae are very strongly sigmoidally curved.

Remarks: C.hughesi is the only species at all resembling ?C. retroversus sp. nov. but the two differ in the following respects:-

a) ?C. retroversus sp. nov. is much longer though about the same breadth.
b) Although both have an undulating septum, in ?C. retroversus the undulation is much less distally.
c) The thecal spacing is different (16-12 in 10 mms in C. hughesi cf.12-10 in 10 mms.
d) The characters of the thecae themselves are different.

This species is doubtfully referred to the genus Climacograptus in view of the double sigmoidal curvature exhibited by the thecal tubes.

Climacograptus innotatus innotatus Nicholson
Plate 15, fig. 8.

1869	Climacograptus	innotatus	Nich.	Nicholson p.238, Pl.11, fig.16-17.
1870	"	"	"	" p.384.
1876b	"	"	Nich.	Lapworth Pl.2, fig.54.
1877	"	"	"	" p.140, Pl.6, fig.37.
1906	"	"	Nicholson.	Elles & Wood pp.212-213, text fig. 143a(?b), Pl.27, figs.10a-e.
1924	"	"	Nicholson.	Hundt Pl.1, figs.14-15, 24-25.
1945	"	"	innotatus Nich.	Waterlot. Pl.3, fig.87.
1955	"	"	" Nicholson.	Bulman fig.63, 1d. (not described).

Material: A single specimen preserved in low relief.
Horizon and Locality: Zone of M. atavus; Watley Gill (2Wa).
Description: The rhabdosome is 2·8 mms long and 1mm broad (excluding spines) and comprises 5 thecae in each series. Thecae closely spaced numbering 19 in 10 mms.

The sicula which is completely free on one side, is 0·9 mm long and its apex reaches to the level of the aperture of th.1(2). Theca 1(1) arises 0·09 mm above its base and grows downwards for 0·26 - 0·3 mm before turning and growing upwards. Its total length is 0·8 mm. Subsequent thecae increase to a length of 1·04 mms and overlap up to a maximum of one half their length. The excavations which are deep and occupy almost one third the width of the polypary, are also rather long giving an almost semicircular profile. The apertural margins are very slightly everted. Thecal spines are not conspicuous but they arise from the geniculum. In obverse view the septum is complete and appears to be slightly flexuous.
Remarks: This specimen differs from other described material only in being rather narrower and in having a higher thecal count. It is retained in this species until the full range of intraspecific variation is known.

Material Seen: A collection from Dobb's Linn contained in the Sedgwick Museum which show the species to be much larger than *Climacograptus innotatus exquisitus* subsp. nov.

Specimens figured by Elles and Wood Pl.27,figs.10a,b,d.

Climacograptus innotatus exquisitus subsp. nov.

Plate 1,fig.7; Plate 14,fig.9

Holotype: HUR./1Bi/26, and counterpart.

Horizon of Holotype: Zone of *M. atavus*.

Derivation of name: exquisitus, L. delicate.

Material: Two specimens.

Diagnosis: Rhabdosome small and narrower than *C. i.innotatus*, virgella conspicuous, thecae spinose, numbering 15-13 in 10 mms. Nema slender projecting beyond polypary.

Description: Although the holotype is flattened it is compressed parallel to the length of the rhabdosome and the width is probably close to that of the undistorted specimen. Its length is 4.5 mms (excluding virgella and nema) and its width only 0·65 mms.

A slender virgella projects beyond the proximal end and may be bent back to lie parallel to the polypary. The nema is slender and extends for 1·7 mms beyond the distal margin of the rhabdosome.

The sicula is approximately 0·9 mm long and its apex reaches to the level of the aperture of th.1(2). At the extreme proximal end the thecae are closely spaced (15 in 10 mms) being rather less so distally (13 in 10mms). The thecal apertures are slightly everted and set in semicircular excavations which occupy one fifth of the width of the polypary. Projecting from the geniculum of each theca is a short stiff spine averaging 0·19 mm in length.

Remarks: This subspecies is very closely related to *C. i. innotatus* particularly in size and form, the presence of thecal spines, and the size and position of the sicula. It is, however much more slender being about one half of the width of Nicholson's species.

Subfamily DIPLOGRAPTINAE Lapworth 1873
(nom. transl. Pribyl 1948 (ex Diplograptidae Lapworth 1873))

genus DIPLOGRAPTUS M'Coy 1850
(=Mesograptus Elles & Wood, 1907)

Type Species: Prionotus pristis Hisinger, 1837; S.D.Gurley, 1896.
Generic diagnosis: Thecae strongly sigmoidal with apertures in broad semicircular excavations, amplexograptid at proximal end, gradually becoming more gently sigmoid (glyptograptid) and almost straight distally; periderm attenuated and with apertural lists proximally; cross section ovoid or nearly rectangular.

Diplograptus magnus H.Lapworth
Plate 1,fig.14; Plate 20,fig.10

1900 Diplograptus magnus, sp.nov. H.Lapworth p.132-4,fig.21a-d.
1907 " (Mesograptus) magnus, H.Lapworth. Elles and Wood pp.266-7, text fig.183a-b,Pl.31,figs.14a-c.
1945 Diplograptus (Mesograptus) magnus Lapw. Waterlot Pl.17,fig.216.
1961 Mesograptus magnus (Lapw.). Romariz Pl.2,fig.2, not described.

Material: Several specimens.
Horizon and Localities: Zone of M. triangulatus - D. magnus; Spengill (S32-36 Birks Beck (9Bi).
Diagnosis: Polypary robust, long, reaching a maximum width of almost 4 mms. Septum almost complete, thecae 15-12 in 10 mms, long, strongly sigmoidal proximally with conspicuous excavations more "glyptograptid" to almost straight distally.
Description: D. Magnus is not a common fossil at Cautley and the writer's distal fragments are poorly preserved. They do, however, show the usual thecal characters, and the thecae themselves number about 12 in 10 mms in this

region and are almost straight tubes. A maximum width of nearly 4 mms is reached.

The proximal thecae have strong sigmoidal curvature and the apertures are situated in deep, long excavations which occupy one quarter of the width of the polypary. In this region the thecae number 14-15 in 10 mms, are inclined to the axis at 35°, and overlap for one half their length. At a distance of 7·5 mms from the proximal end width of over 2 mms is acheived (relief). From here the polypary widens more gradually to its maximum breadth.

The sicula has not been seen. A septum is visible throughout even in the reverse aspect.

Remarks: The Cautley specimens differ in no way from other described British material. It occurs rarely in the top of the M. triangulatus zone but more commonly in the D. magnus zone following.

Material Seen: Specimens in the Elles and Wood Collection, Sedgwick Museum.

Diplograptus modestus modestus Lapworth

Plate 19,fig.6

1876	Diplograptus modestus Lapworth Pl.2,fig.33	
1877	" confertus Lapworth Pl.4,fig.8	
1897	" modestus Perner p.5,Pl.10,fig.8	
1900	" " , Lapw. H.Lapworth p.135	
1907	" (Mesograptus) modestus, Lapworth. Elles and Wood pp.263-4, text fig.180a-d,Pl.31,fig.11a-e.	
1924	" modestus Lapworth. Hundt, Pl.1,figs.46-49	
?1929	Mesograptus cf. modestus. Davies p.1-3,fig.1	
1933	Diplograptus (Mesograptus) modestus Lapworth. Sun p.30,Pl.5,figs.3a-c	
1934	Mesograptus modestus Lapworth. Hsu pp.82-3,Pl.6,figs.7a-b	
1940	Diplograptus modestus Lapw. Desio p.25,Pl.1,fig.18,Pl.2,figs.1,5,6,10, 12.	
1945	" (Mesograptus) modestus Lapw. Waterlot. Pl.17,fig.206	
1962	" modestus Lapw. Romariz P.236,Pl.22,fig.1	

Material: 6 specimens, poorly preserved.

Horizon and Localities: Zone of M. atavus; Spengill (S1-5); Watley Gill (1Wa,4Wa); Zone of A. acuminatus.

Diagnosis: Rhabdosome up to 2 cms long with a breadth of 2·5 mms distally (though this may be an increased value due to compression). Thecae almost "orthograptid" distally, 14-12 in 10 mms, but strongly sigmoidal proximally.

Description: This species is usually identified from the general form of the polypary since the thecal characters are difficult to discern. The specimen figured on Pl.19 (fig.6), however, shows the strongly sigmoidal proximal thecae and deep excavations. The excavations are here deeper than long but the rhabdosome is compressed at right angles to the line of the polypary. At the proximal end the thecae are usually closely spaced numbering up to 14 in 10 mms but this value falls quite rapidly to 12 in 10 mms distally.

Distal thecae are almost "orthograptid" in shape. The degree of overlap and angle of inclination of the thecae cannot be satisfactorily ascertained. A virgella is prominent and robust and extends for 1mm below the relatively pointed proximal region.

Remarks: D.modestus modestus is restricted to the lowest beds (M. atavus zone) and is far less common than D.m.diminutus.

Material Seen: Specimens in Sedgwick Museum, Elles and Wood Collection, together with varieties; Drew and Salter Collection (Zi 7144), H.M.Geological Survey Museum. Specimens in H.M.Geological Survey Collection (Pg607) from Nant Nod, a specimen in full relief; (3368) collected by J.E.Marr from Skelgill section (M. fimbriatus Zone), a specimen in low relief.

Diplograptus modestus diminutus Elles and Wood

Plate 2, fig.2; Plate 14, fig.2

1907 Diplograptus (Mesograptus) modestus, Lapworth, var, diminutus, var. nov Elles and Wood p.265,Text fig.182,Pl.13a-c

?1945 Diplograptus (Mesograptus) modestus var. diminutus E. & W. Waterlot Pl.17,fig.208.

Material: About 20 specimens mostly flattened.

Horizon and Localities: Zone of M. atavus; Spengill (S1-5,S5-9); Birks Beck (1Bi,2Bi); Watley Gill (3Wa); Zone of P. acinaces.

Diagnosis: Smaller in length, width, and with smaller, more closely spaced thecae than D.m.modestus. Thecae number 15-17 in 10 mms.

Description: This subspecies shows little variation from the original material described by Elles and Wood. The usual length of the polypary is about 1cm and the maximum width approximately 1·5 mms.

At the extreme proximal end the thecae number 17 in 10 mms and more distally 15 in 10 mms. The characters of the thecae are similar to those described under D.m.modestus but the distal thecae are less "orthograptid" and more "glyptograptid" in form. In short, the ontogenetic changes typified by this genus are less well shown in this particular subspecies.

A short and slender virgella projects from the proximal extremity. The sicula has not been seen.

Remarks: This subspecies is more common than D.m.modestus but is restricted also to the M. atavus zone.

Material Seen: Specimens in Elles and Wood Collection, Sedgwick Museum, Cambridge.

Diplograptus modestus tenuis subsp. nov.

Plate 1, fig.13; Plate 12, fig.1; Plate 20, fig.8

Holotype: HUR./S1-5/18, a flattened but well preserved specimen.

Horizon of Holotype: Zone of M. atavus.

Derivation of Name: tenuis, L. fine, slender.

Material: Only one definite specimen, the holotype.

Description: The rhabdosome is 1·3 cms long but incomplete at its distal extremity. Since the specimen is both flattened and compressed at right angles to the polypary the width should be exaggerated but still only reaches a maximum of 1·3 mms.

The sicula is not visible but a short, slender virgella similar to that seen in D.m.diminutus extends below the proximal end. At the level of the first thecal pair the width is 0·52 mms. The most proximal thecae show distinct, but small, excavations but at 5th - 7th thecal pairs they are already beginning to look more "glyptograptid" in form. Distally the thecae are typically those of flattened "orthograptids".

At the proximal end the thecae number 14-15 in 10 mms, decreasing distally to 11-12 in 10 mms.

Remarks: This subspecies is probably closer to D.m.modestus than D.m.diminutus in view of the similarity of the thecae and their change throughout the polypary. It differs in being far more slender.

?Diplograptus rarus sp. nov.

Plate 14,fig.4; Plate 20,fig.9

Holotype: HUR./1Bi/139, a long, complete flattened specimen.

Horizon of Holotype: Zone of M. atavus.

Derivation of name: rarus, L. thin.

Material: One complete specimen, the holotype, and other fragments of both proximal and distal regions.

Horizon and Localities: Zone of M. atavus; Birks Beck (1Bi,2Bi).

Diagnosis: Rhabdosome up to $1\frac{1}{2}$ cms long, slender, and with an attenuated periderm. Proximal thecae with relatively deep excavations, distal thecae definitely "orthograptid", alternating and with no sign of a sigmoidal curvature. Robust,distally projecting, nema and prominent, robust virgella. Thecae number 13-10 in 10 mms.

Description: The most striking feature of the rhabdosome is the attenuated periderm which, upon compression, produces the merest film in the rock. It strongly recalls Orthograptus attenuicutis (a? v) sp. nov. in this respect. The nema on the other hand is strongly chitinized for it is the most conspicuous feature of the rhabdosome, running the full length and then projecting distally. The virgella though short, is also robust and together with the first few thecae and the nema seems to be more strongly chitinized than the rest of the polypary.

A sicula has not been seen. Up to the 5th thecal pair the sigmoidal curvature is conspicuous and the excavations deep, rather than long. The thecal apertures in this region are almost opposite and approximately horizontal. The thecae number 13 in 10 mms.

Distally the thecal change is quite complete. The apertures are distinctly everted and alternating whilst the thecal tubes show no sign of sigmoidal curvature. Overlap is less than one third and the thecae number 10 in 10 mms.

Remarks: This form has been included in the genus Diplograptus on the evidence of the complete change of proximal to distal theca characters - the latter being "orthograptid". It should be pointed out, however, that the proximal excavations are similar to those borderline cases (mentioned by Packham 1962) between "climacograptid" and "diplograptid".

?D.rarus sp. nov. is quite unlike any of the described species of Diplograptus (or Glyptograptus)and is a relatively rare form. Occuring on the same slab as the holotype is a specimen of ?D.sp. A.

Diplograptus sp. A

Plate 1, fig.16; Plate 15,fig.3

Material: A few flattened specimens.

Horizon and Localities: Zone of M. atavus; Birkd Beck (1Bi,2Bi).

Description: This form appears to bear the same relationship to D. modestus diminutus as D.m.tenuis subsp. nov. does to D.m.modestus. It is more slender, reaching only fractionally over 1mm in breadth and has 15-16 thecae in 10 mms throughout its length. The thecae are also more uniform throughout as in D.m.diminutus, although there is a certain amount of doubt about their nature since it cannot be ascertained from the material whether the thecae are "climacograptid" like, or whether they are "glyptograptid" throughout with merely a slight change in sigmoidal curvature. The extreme proximal end, however, is very reminiscent of D.m.diminutus.

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genus GLYPTOGRAPTUS Lapworth, 1873

Type species: Diplograpsus tamariscus Nicholson, 1868.
Generic diagnosis: Thecae with moderate to gentle sigmoidal curvature, apertural margins commonly undulate, horizontal, or everted; supragenicular wall vertical or inclined away from the axis; infragenicular wall immediately below the geniculum is inclined at less than 45° to the axis, (this last feature is an arbitrary line drawn only for the sake of convenience); gradual change in the degree of sigmoidal curvature of the thecae may take place along the rhabdosome - becoming less sigmoidal distally - but the extremes of climacograptid and orthograptid are not seen.

Glyptograptus tamariscus tamariscus (Nicholson)
Plate 18, fig.2,6,5

1868 Diplograptus tamariscus Nicholson, p.526,(pars)Pl.19,figs.10,11,?13, (non 12).
1907 " (Glyptograptus) tamariscus, Nicholson. Elles and Wood, pp.247-248(pars) text figs.167a-c(non d), Pl.30,fig. 8a (non b-d).
?1924 " tamariscus Nicholson. Hundt. Pl.1,figs.38-40.
?1934 Glyptograptus tamariscus Nicholson. Hsu p.76,Pl.6,figs.1a-f.
?1949 Diplograptus (Glyptograptus) tamariscus (Nicholson). Obut pp.14-15, Pl.1,figs.6a-b.
1962 Glyptograptus tamariscus tamariscus (Nicholson). Packham pp.504-6, text figs. 1g-j,m-u,Pl.71,figs.1-4,11,13.

References of more doubtful synonymy can be seen in Packham, 1962, p.501, p.504.

Lectotype: Nicholson (1868) Pl.19,fig.10.
Material: About 50 specimens in varying states of preservation, either flatten.

ed or in full relief.

Horizon and Localities: Zone of P. cyphus to M. sedgwicki; Spengill (?S9-13, S24-28,S32-36,S73,11·4 - S94,7·4); Birks Beck (9Bi.6Bi); Pickering Gill (?14P); Watley Gill (5Wa,?6Wa,11Wa); Birks Beck(?2Bi).

Diagnosis: Rhabdosome "thorn-like", usually quite short, maximum width 1·3 mms in flattened specimens, or specimens in low relief compressed at right angles to the polypary. Thecae alternating, excavations both long and deep infragenicular walls typically glyptograptid, supragenicular walls inclined and the whole polypary slightly tapering. 15-9 thecae in 10 mms.

Description: The Cautley specimens differ in no way from the material described in detail by Packham (1962). Since the material is not generally well-preserved, however, his forms A,B, and C, have not been easy to recognize. The specimen figured on Pl.18 (fig.2) is close to G.t.t. form B, and has 15-14 thecae in 10 mms at the extreme proximal end decreasing to 11 in 10 mms at th.4-5. Fig.6,(Pl.18) closely resembles G.t.t. form C in having a thecal spacing of 11 in 10 mms at the proximal end and 10 in 10 mms at th.4-5, though its stratigraphic level is a little lower than recorded by Packham.

Remarks: Packham recorded G.t.t. form A from the lower beds of the total range of the species but it is in these beds at Cautley that the specimens are least well preserved and forms definitely assignable to form A have not been identified.

Material Seen: Sedgwick Museum Collection, including Packham's (1962) figured specimens.

Glyptograptus tamariscus angulatus Packham

Plate 2, fig.7

1962 Glyptograptus tamariscus angulatus subsp. nov. Packham p.510-11,text figs.3a-c,Pl.71,figs.7-8.

Holotype: Specimen figured by Packham 1962, Pl.71,fig.8,text fig.3b.

Material: One flattened specimen, almost complete.

Horizon: Zone of P. leptotheca; Birks Beck (6Bi).

Description: The polypary is 7·5 mms long and widens steadily from 0·39 mms to 0·58 mms distally, so that it is almost parallel-sided. There are 9 thecae in 10 mms throughout the rhabdosome. Thecal excavations are deep (about one half the width of the polypary) and the supragenicular walls long (average 0·78 mms), whilst the geniculum of each theca is abrupt. The interapertural distance is a little over 1mm.

Remarks: This specimen agrees very well with Packham's original description. It differs from G.t.tamariscus in being too narrow, particularly for a flattened specimen, in having deeper excavations and in its lower thecal count. From G.t.distans it can be distinguished by its more angular geniculum and its deep excavations.

Material Seen: Sedgwick Museum Collection of material figured by Packham 1962.

Glyptograptus tamariscus linearis (Perner)

Plate 15, fig.6; Plate 19, fig.4

1897 Diplograptus tamariscus Nich. var. linearis Perner, p.4,text fig.2 (?Pl.9,fig.23).

1907 " (Glyptograptus) tamariscus Nicholson. Elles and Wood pp.247-8,(pars) Pl.30,fig.8c (non text figs.167a-d,Pl.30, figs.a,b,d).

1962 Glyptograptus tamariscus linearis Perner. Packham pp.506-7,text fig. 1v,Pl.172,fig.8.

For other references of more doubtful synonymy see Packham 1962,p.506.

Lectotype: Specimen figured by Perner 1897 p.4,text fig.2.

Material: Two specimens in relief, but weathered.

Horizon and Localities: Zone of M. convolutus; Watley Gill (9Wa).

Diagnosis: Rhabdosome long, parallel-sided, tapering quickly at the extreme proximal end. Maximum breadth 1·56 mms. Thecal spacing 13-9 in 10 mms.

Description: The rhabdosome is long and parallel-sided. One distal fragment has a length of nearly 4 cms whilst the proximal end (fig.6,Pl.15) widens to 1·3 mms within 6 mms of the base of the polypary.

The sicula is not seen. The reverse aspect of the proximal end has a complete septum which suggests that it will probably be complete for the rhabdosome as a whole. The first few thecae number 13 in 10 mms but this falls to 10 in 10 mms by th.6-7 and distally is about 9-9½ in 10 mms.

The thecal excavations are characteristically deep (over one third the rhabdosome width) and long. The apertural margins are horizontal. Overlap is very small.

Th.1(1) opens 0·65 mms above the base of the polypary and th.1(2) at 0·91 mms above the same point. The full length of th.1(1) cannot be determined since the sicula and downward-growing portion of the first thecae are not seen.

Remarks: This subspecies was recorded by Packham (1962) from the Zone of P. cyphus whereas Perner's original specimen is from M. convolutus Zone. The only difference between Packham's specimen and the Cautley specimens is that the latter have an initial thecal spacing of 13 in 10 mms.

Material seen: Specimens in Sedgwick Museum figured by Packham(1962).

Glyptograptus tamariscus aff varians Packham

Plate 18, fig.9

1962 Glyptograptus tamariscus varians subsp. nov. Packham pp.509-10, text figs.1a-f, Pl.71, figs.14-17.

Holotype: Specimen figured by Packham 1962, Pl.71, fig.5, text fig.1d.

Material: One specimen flattened.

Horizon and Locality: Zone of P. leptotheca; Birks Beck (6Bi).

Description: This specimen is a fragment 5·85 mms long with a maximum breadth of 0·78 mms (flattened). The periderm is very thin and the nema prominent. The thecae number 10 in 10 mms. and the thecal excavations are deep and long; the geniculum is flowing rather than angular.

Remarks: The specimen is very close to G.t.varians Packham, and resembles his text fig.1f especially in the nature of the thecae and the general dimensions.

Material seen: Specimen figured by Packham 1962, text fig.1f and others.

Glyptograptus packhami sp. nov.

Plate 2,figs.5,6; Plate 16,fig.6

Holotype: HUR./S73,11·4/6, a proximal end in full relief, obverse view.
Horizon of Holotype: Zone of M. sedgwicki.
Derivation of name: After G.H.Packham author of "Some Diplograptids from the British Silurian".
Material: Two specimens in full relief; the holotype and a more distal fragment.
Horizon and Localities: Zone of M. sedgwicki; Spengill (S73,11·4 and S80,8·4).
Diagnosis: Rhabdosome slender, probably over 1cm long and reaching a width of 0·78 mms. Thecae with gentle sigmoidal curvature, glyptograptid, numbering 10-9 in 10 mms and inclined to the axis at a very low angle. Sicula free for almost the whole of its length (about 1·5 mms). Septum present.
Description: The form and size of the rhabdosome is highly characteristic. It has an inferred length of a little more than 1cm and a width (relief) of only 0·78 mms (At the level of the aperture of th.1(1) the width is 0·32 mms.)

The sicula appears to be almost entirely free and is approximately 1·5 mms long. Its apex reaches to the level of the top of th.1(2). Th.1(1) is 1·04 mms long and its aperture opens 0·4 mms below the apex of the sicula. The thecae are, therefore, alternating and continue to be so throughout the polypary.

The thecal spacing increases distally to 9 in 10 mms from 10 in 10 mms proximally. Thecal overlap is fractionally over one quarter in both proximal and distal thecae. The geniculum is flowing, and the supragenicular wall parallel to the axis and approximately 0·65-0·70 mms long in both proximal and distal thecae.

The apertural margins are everted and in profile view sometimes appear very slightly concave. There is a slight narrowing of the thecal tube toward the aperture.

The excavation is long and shallow. It occupies one third of the rhabdosome width in the proximal thecae but only one quarter distally.

A septum is visible on the whole of the obverse side but it is not present at th.8(1) on the reverse side. In cross section the rhabdosome is elliptical (seen at th.7(1) with the short axis of the ellipse in the plane of the median septum.

Remarks: In general appearance G. packhami resembles G. tamariscus distans Packham but it differs in the following points:-

a) In the presence of a median septum throughout the obverse side.
b) In its closer spaced proximal thecae (10 cf 8-9 in 10 mms).
c) In having a less angular geniculum to its thecae.
d) In being more slender at the extreme proximal end.
e) In the shorter supragenicular wall (0·7 max. cf 0·8 mms).

The two forms must be closely related however, since both the thecal and rhabdosome forms agree very closely.

Packham (1962) records G.t.distans from the Zone of M. cyphus (Dobb's Linn) and M. gregarius (Rheidol Gorge)whilst the Cautley species occurs in the Zone of M. sedgwicki. If G. packhami is developed from G.t.distans then the change would involve the growth of a median septum. Davies (1929) showed that in some climacograptids loss or reduction of the median septum occurred in later representatives.

From G.t.angulatus Packham, G. packhami differs mainly in being broader, in its less abrupt geniculum, and in the narrower proximal end. G.t.acutus Packham and G.t.tamariscus (Nich.) have much more closely spaced thecae.

Glyptograptus aff incertus Elles and Wood
Plate 18, fig.3

aff

1907 Diplograptus (Glyptograptus) tamariscus var. incertus var. nov. Elles and Wood, p.249,text fig.168a-b,Pl.30,figs.9a-d.

1922 " tamariscus incertus Elles and Wood. Gortani p.104,Pl.17, fig.24.

?1962 Glyptograptus tamariscus incertus (Elles and Wood). Romariz p.236,Pl. 22,fig.5.

1962 Glyptograptus incertus Elles and Wood. Packham pp.518-9,text figs.4a-d,Pl.72,figs.6-7.

Lectotype: The specimen figured by Elles and Wood 1907, Pl.30,fig.9c. refigured by Packham 1962, text fig.4a, Pl.72,fig.6.

Material: A single well preserved proximal end, together with others which are less well preserved.

Horizon and Localities: Zone of D. magnus; Birks Beck (7Bi,8Bi).

Description: This specimen has the general form and appearance of a proximal end of G. incertus but is rather better preserved than the material described by the above authors.

The sicula appears to be almost completely free and is 1·3 mms long, its apex extending fractionally above th.2(1). Th.1(1) emerges from the sicula only 0.13 mms above its base and grows downwards for a distance of 0.26 mms before turning upwards and opening 0·68 mms above the base of the polypary. The apertural margins in this region are very slightly everted, and are set in deep excavations. The thecae number 15 in 10 mms.

At the aperture of th.2(1) the rhabdosome width is 0·7 mms. This increases to 1mm by the level of th.5(1). A septum is present in the obverse but not in the reverse view.

Remarks: Whilst the specimen agrees with G. incertus in the characters of the thecae, as well as in the general proportions and degree of sigmoidal curvature, it has a slightly higher thecal count. More specimens showing the distal end are required before a definite comparison can be made.

Material seen: Specimens in Sedgwick Museum, Cambridge.

Glyptograptus ?enodis latus Packham

Plate 16, fig.4

1962 Glyptograptus enodis latus subsp. nov. Packham p.518,text fig.4e,fig. 20,Pl.71.

Holotype: The specimen figured by Packham 1962 as text fig.4e,Pl.71,fig.20, the only specimen known.

Material: One specimen in full relief without proximal end, from Zone of D. magnus; Birks Beck.

Description: This specimen is 7 mms long but has the proximal end missing. There are 10 thecae in 10 mms and at its distal extremity (about the 11th thecal pair), it is 1·3 mms broad. In the distal region the common canal occupies one half of the total width of the rhabdosome but proximally the proportion is much less.

The degree of sigmoidal curvature is considerable but not climacograptid and the depth of the excavations is rather less than one third of the rhabdosome width.

Remarks: This form resembles G. enodis latus Packham in the rhabdosome width, thecal count, and nature of common canal but differs in having rather more sigmoidal curvature of the thecae, and a roughly circular cross section. Furthermore there is a septum which may be complete in one view - presumed to be the obverse view.

Glyptograptus cuneatus sp. nov.

Plate 3, fig.1

Holotype: HUR./14P/20, the only specimen, complete and well preserved, but flattened.

Horizon: Zone of P. cyphus, Pickering Gill (14P).

Derivation of name: cuneatus, L. wedge-shaped.

Description: The rhabdosome is flattened and slightly compressed at right angles to its length, with consequent increase in thickness. The length is 6·25 mms and the thickness, distally, 1mm. At the level of the aperture of th.1(1) the width is 0·5 mms and the maximum width is achieved in such a manner that the whole polypary is wedge-shaped. The sicula has not been detected with certainty. A short, fine virgella projects from the proximal extremity.

The thecal spacing is constant at 15 in 10 mms. The geniculum is probably not as angular as it appears in the speeimen since it will have been accentuated by compression. Nevertheless it does not approach the climacograptid degree of angularity. The supragenicular wall is inclined away from the axis and averages 0·52 mms in length. The excavation is only 0·2 mms deep throughout the specimen and consequently only occupies a small proportion of the width of the distal part of the rhabdosome.

Remarks: In this last respect, as well as in general form, this species is similar to G. tamariscus mut. fastigans Haberfelner, and Packham's G.sp.cf

G.t. fastigans. On the other hand the thecae are closely spaced and the rhabdosome is less tapering than both forms. G. cuneatus sp. nov. has a less robust polypary than Packham's specimen.

Glyptograptus sinuatus sinuatus (Nicholson)

Plate 16, fig.5

1869 Diplograptus sinuatus, Nich. Nicholson p.235,Pl.11,fig.11.
1897 " (Glyptograptus) sinuatus, Nich. Perner p.5,Pl.9,figs.9-12, text fig.3.
1907 " " " , Nicholson. Elles and Wood pp.255-7,text fig.175a-b,Pl.31,figs.6a-c.
1924 " sinuatus Nicholson. Hundt, Pl.2,figs.2,3.
1945 " (Glyptograptus) sinuatus Nich. Waterlot. Pl.16,fig.199,Pl.9, fig.140.
1962 Glyptograptus sinuatus (Nicholson). Romariz p.236,Pl.22,fig.4.

Material: Many specimens, mostly in full relief.
Horizon and Localities: Zone of M. triangulatus to P. leptotheca; Spengill (S24-28 to S36-39,7); Watley Gill (5Wa); Birks Beck (9Bi,6Bi).
Diagnosis: Rhabdosome between 1 and 2 cms long, initially relatively narrow, then widening to 2 mms (relief). Virgella and nema conspicuous when preserved. Thecae 15-10 in 10 mms, alternate with strong sigmoidal curvature, supragenicular walls inclined, geniculum flowing, thecae inclined at 30°..
Description: The form of the polypary is very distinctive in being broad, short, and with an initial portion of relatively narrow width which flares after th.4(1) to 1·43 mms and ultimately, more gradually, to 2mms. At the level of the aperture of th.1(1) the width is 0·52 mms. Both a virgella and nema are often present and each may measure more than 10 mms. Both are very slender.

At the extreme proximal end the thecae number 15 in 10 mms, and 14 in 10 mms at th.4(1). Immediately after this narrow portion there is an increase in the size of the thecae, in their angle of inclination to the axis, and in the thecal spacing itself which falls to 13-10 in 10 mms. After th.

9(1) or thereabouts the thecae are spaced constantly at 10 in 10 mms. It is interesting to note that the septum begins on the reverse side after the initial narrow portion, and not immediately as it does on the obverse side.

The distal thecae are distinctly sigmoidal but are inclined to the axis at approximately 30°, whilst the initial thecae, by contrast, are inclined at a low angle and show a certain resemblance to those of G.tamariscus tamariscus. They differ, however, in having shorter, narrower excavations.

The distal thecae expand as the aperture is approached giving the supragenicular wall a slightly rounded appearance. The actual thecal margin has a distinct lip caused by slight outward growth at this point. Overlap is pronounced distally (one half) having increased from one third in the proximal region. The thecae seem to show torsion of the thecal axis but the actual amount and kind cannot be estimated in the writer's material.

Remarks: G.s.sinuatus is a very distinctive fossil and can only be confused with G.s.crateriformis subsp. nov. (described below) from which it differs in the points enumerated on p.

Glyptograptus sinuatus crateriformis subsp. nov.

Plate 16, fig.3

Holotype: HUR./S75,9·4/74, a specimen in full relief; somewhat pyritised so that the proximal extremity is destroyed.

Horizon of Holotype: Zone of M. sedgwicki.

Derivation of name: crateriformis, L. cup-shaped.

Material: 3 specimens in full relief, but incomplete.

Horizon and Localities: Zone of M. sedgwicki; Spengill (S75,9·4).

Diagnosis: General form and size very similar to G.s.sinuatus but thecae inclined at a lower angle even in the distal parts and the thecae more widely spaced (10-8 in 10 mms). Maximum breadth 2 mms. Thecae strongly sigmoidal, alternate, apertural margins slightly everted and expanded into a lip or flange.

Description: The proximal end of this subspecies is not known. The distal fragments in all their general characters as well as thecal form agree with Nicholson's species but the two can be distinguished on the following grounds:

a) The thecae of G. sinuatus crateriformis are widely spaced distally (8 in10 mms) and even near the proximal end number 10 in 10 mms.

b) The thecae are inclined to the axis at only 20°.

c) The amount of overlap is less and the thecal tubes appear altogether more robust.

d) The degree of expansion approaching the aperture, and particularly the apertural lip or flange, is much greater.

Remarks: Only a few specimens have been obtained but they are sufficiently distinct to warrant description as a new subspecies. Elles and Wood (p.257 and p.520) restrict G.s.sinuatus to their zone of M.gregarius and in view of its obvious affinities it is probable that G.s.crateriformis subsp. nov. has developed from the earlier form.

Material seen: Specimens in the Sedgwick Museum labelled Glyptograptus cf sinuatus (A23692 a and b, A23691) seem to be synonymous with G.s.crateriformis subsp. nov. They are recorded from the "M. cyphus Zone, Great Rundale Beck Cross Fell Inlier".

Glyptograptus sp.1

Plate 18, fig.8

Material: A single flattened specimen, HUR./1Wa/37 and counterpart HUR/1Wa/22.

Horizon: Zone of A.acuminatus; Watley Gill (1Wa).

Description: The rhabdosome of this specimen is nearly 6 mms long and 1mm wide, though this latter figure is increased by flattening and stfong compression. The periderm is very thin but a conspicuous feature is the presence of a strongly chitinized nema which swells distally and projects beyond the end of the rhabdosome.

The thecae are distinctly glyptograptid and number 14-12 in 10 mms. A short virgella can be seen.

Remarks: The specimen is imperfectly preserved and no comparison with other described species is made at the moment.

Glyptograptus sp.2

Plate 18, fig.4

Material: A single specimen almost flattened.

Horizon and Locality: Zone of M.sedgwicki; Spengill (S80,8·4).

Description: This specimen is a glyptograptid of tamariscus - like appearance which differs from those described above in having its thecae very closely spaced and in the presence of a very stout virgella. The thecae number over 20 in 10 mms and the virgella actually swells slightly in the part most removed from the proximal end.

The specimen is almost flattened and is compressed obliquely to the length of the rhabdosome. The latter has accentuated the angularity of the geniculum in the thecae of the first series, but does not seem to have greatly increases the thecal count.

In spite of the distortion of this specimen it resembles G. serratus Elles and Wood and may represent a proximal end of this species. The distal parts are not seen but after 4 mms a thickness of 1mm is reached.

Glyptograptus sp.3

Plate 16, fig.7

Material: A single specimen in full relief but with the proximal end missing. HUR./S75,9·4/153.

Horizon and Locality: Zone of M. sedgwicki; Spengill (S75,9·4).

Description: The rhabdosome is small and reaches a width of 0·82 mms. When complete its length is probably 5-6 mms. The thecae show typical glyptograptid sigmoidal curvature with the infragenicular wall inclined to the axis at about 40°. The distal extremity of the supragenicular wall is inclined away from the axis and measures approximately 0·78 - 0·90 mms in length. The geniculum is angular.

Each theca has a maximum length of 1·5 mms and a slightly everted apertural margin. The thecae which number 9 in 10 mms are strongly alternate in their arrangement and the common canal extremely narrow.

Remarks: The strongly alternate arrangement of the thecae suggests affinities with G.tamariscus tamariscus but the wide spacing of the thecae so close to the proximal end differentiates this specimen from that subspecies.

From G. t.distans, G.t.angulatus, G.t.acutus and G.t.varians it differs in having an inclined supragenicular wall.

Glyptograptus sp.3 is almost certainly a new form but more material is required before a diagnosis and detailed description can be given.

?Glyptograptus sp.A

Plate 2, fig. 8; Plate 16, fig.2

Material: Several specimens in full relief, but fragmentary.

Horizon and Localities: Zone of M. triangulatus; Watley Gill (6Wa).

Description: This form is retained, doubtfully, in the genus Glyptograptus on the grounds that the geniculum, though angular, is not quite climacograptid in form and that the supragenicular wall is unusually bent.

This latter phenomenon is the most characteristic feature of the thecae. The supragenicular wall continues to grow upward from the geniculum but it is inclined slightly inwards towards the axis so that the thecal tube becomes constricted as the aperture is approached. Immediately beyond this constriction, however, there is a sudden expansion of the tube producing a broad aperture which is also strongly everted.

The rhabdosome reaches a width (in relief) of 1·7 mms and even proximally is quite robust (0·8 - 0·9 mms at level of th.1(1)). Proximally the thecae are spaced at 9½ in 10 mms and distally at 8½ in 10 mms. The degree of overlap is approximately one half the length of the thecae.

Remarks: The characters of the thecal tubes appear to be unique; the only species possibly having similar thecae being ?Climacograptus retroversus sp. nov. (see p.). The two are possibly related.

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genus ORTHOGRAPTUS Lapworth, 1873
(= Cystograptus, Hundt 1942; Glossograptus Ruedemann, 1947 partim (non Emmons, 1855); Rectograptus Pribyl, 1949)

Type species: Graptolithus quadrimucronatus Hall, 1865
Generic diagnosis: Thecae straight throughout the length of the rhabdosome though occasionally very slight sigmoid curvature; paired apertural spines in one group, large basal spines not uncommon.

Orthograptus vesiculosus (Nicholson)
Plate 3,fig.3; Plate 15,figs.1,2,3

1868 Diplograpsus vesiculosus Nicholson pl.3,fig.11
1869 " " " p.237,Pl.11,figs.14-15.
1874 " " Dairon p.183,Pl.1,figs.20
1876 Diplograptus " Nich. Lapworth Pl.2,fig.41.
1877 " " " " Pl.6,fig.19.
1907 " (Orthograptus) vesiculosus, Nich. Elles and Wood pp.229-231, text fig.151a-f,Pl.28,figs.8a-d.
1933 Diplograptus (Orthograptus) vesiculosus Nicholson. Sun p.25,Pl.4,figs. 4a-b.
1945 " " " " Waterlot Pl.11,fig.153

Material: Over 30 specimens, all flattened, all growth stages represented.
Horizon and Localities: Zones of M. atavus to P. cyphus; Spengill (S1-5 to S13-17, ?S17-20); Birks Beck (1Bi); Watley Gill (1Wa,3Wa); Pickering Gill (14P).
Diagnosis: Rhabdosome long, broad with a prominant virgella and a characteristic vesicle. Sicula large, thecae about 10 in 10 mms.
Description: All the diagnostic characters of this form are greatly altered by compression (see Pl.15,figs.1-3) but the rhabdosome is usually broad and over 2 cms long.

The orthograptid thecae in flattened specimens are best seen in the young stages of growth. Th.1 grows downwards to the base of the sicula, or beyond before growing upwards (Pl.3,fig.3). The sicula in the Cautley specimens is at least 6·5 mms long and th.1, which originates 2 mms above the base of the sicula, is fully 2·5 mms in length.

Distal thecae usually have their characters obscured in flattened material and the pseudo-"biscalariform" views mentioned by Elles and Wood are common.

The virgella is long and usually about 5 mms. A vesicle is developed and in the Cautley specimens this usually begins within the rhabdosome. It is clearly visible for example in fig.1 (Pl.15), but distal extremities which show it extending beyond the rhabdosome have not been observed with certainty.

Remarks: This species was first reported from Cautley by members of H.M. Geological Survey (Dakyns et.al. 1891). Elles and Wood on p.230 state that the Lake District specimens are usually poorly preserved but the specimens figured here are in good condition. (cf. Pl.15,figs.1-3, with Elles and Wood 1907, text figs.1a-f).

To judge by the figures of Elles and Wood (Pl.28,figs.a-d) there is a certain amount of variability in the breadth of the rhabdosome. The Cautley specimens approach the narrower variants but are distinct from O.v.penna Elles and Wood.

Material seen: Specimens in Sedgwick Museum Collection, Cambridge.

Orthograptus cyperoides (Tornquist)

Plate 20,fig.6

1897 Diplograptus cyperoides Tornquist p.16,Pl.2,figs.30-32.

1907 " (Orthograptus) cyperoides, Tornquist. Elles and Wood, pp.238-9,text fig.158a-b,Pl.29,figs.8a-c.

1924 " cyperoides Tornquist. Hundt, Pl.1,fig.50.

1945 " (Orthograptus) cyperoides Tornq. Waterlot Pl.11,fig.160.

Material: Several specimens in relief.

Horizon and Localities: Zone of M. triangulatus, ?Zone of M. convolutus;

Spengill (S36-39,7); Watley Gill (5Wa,?9Wa).

Diagnosis: Rhabdosome short and narrow with a characteristic proximal region and a relatively long sicula.

Description: The maximum length noted for the polypary of this species is about 6 mms, and the maximum breadth (low relief) is 1·3 mms.

A remarkable feature of O. cyperoides is its sicula of 2·3 mms length, which reaches to the level of the 3rd thecal pair. At its base the sicula is 0·15 mms broad and is, therefore, almost 15 times longer than it is broad.

The thecae are simple overlapping tubes, reaching a maximum length of 1·3 mms distally and overlapping from one third to one half their length. Throughout the rhabdosome the thecae are slightly alternating. In the obverse view a septum extends the whole length of the polypary but it has not yet been determined whether it is equally developed upon the reverse side.

Remarks: The Cautley specimens agree in most respects with other described British material (Elles and Wood 1907) but have the thecae rather more closely spaced at 14 in 10 mms (cf.12 in 10 mms for the Scottish and Welsh material) and ma breadth slightly in excess of 1mm. Like this material the writer's specimens have a septum which may be complete and are therefore a little different from Tornquist's Swedish specimens. The form briefly described below as aff. cyperoides however has no septum at all.

Material seen: Specimens in Elles and Wood Collection, Sedgwick Museum, Cambridge.

Orthograptus aff cyperoides (Tornquist)

Plate 20,fig.5

aff.

1897 Diplograptus cyperoides Toernquist p.16,Pl.2,figs.30-32.

Material: A single specimen (HUR./S36-39,7/30) preserved in relief in pyrites but weathered out leaving a mould.

Horizon: Zone of M. triangulatus; Spengill (S36-39,7).

Description: This specimen has the proximal end obliterated but must be less than 1cm long. It is almost parallel-sided with a maximum width (full relief) of 1mm.

The thecae are simple, straight tubes about 1mm long which overlap for one third of their length. The thecal count shows 13 in 10 mms. There is no trace of a septum.

Remarks: This form is very close to the previous species and may be an extreme variant of it.

Orthograptus bellulus (Toernquist)

Plate 15, fig.4

1890 Diplograptus bellulus Toernquist p.28,Pl.1,figs.25-29.
1893 " " " p.10,figs.42-44.
1897 " " " p.17,Pl.2,figs.20-25.
1907 " (Orthograptus) bellulus, Tornquist. Elles and Wood pp.231-2, text fig.152a-c,Pl.29,fig.2a-e.
1924 Diplograptus bellulus Tornquist. Hundt Pl.2,figs.14-16.
1945 " (Orthograptus) bellulus Tornq. Waterlot Pl.11,fig.158.

Material: A single flattened specimen with proximal end missing, together with other more doubtful specimens.

Horizon and Locality: Zone of M. convolutus and P. leptotheca; Watley Gill (11Wa); Birks Beck (5Bi,6Bi).

Description: This specimen has the typical rhabdosome and thecal form of Toernquist's species. The rhabdosome is flattened and compressed at right angles to its length thereby increasing its width to 2·5 mms. At the same time the density of the thecae has been increased to 15-16 in 10 mms. The total length of the rhabdosome is probably about 1cm, and the thecae, despite compression are distinctly orthograptid.

Material seen: Specimens in Sedgwick Museum Collection, Cambridge.

Orthograptus attenuatus sp. nov.

Plate 3,fig.2; Plate 20,fig.7

Holotype: HUR./14P/7, the only specimen, preserved as a film in dark grey shale, complete and well preserved.

Horizon of Holotype: Zone of P. cyphus; Pickering Gill (14P).
Derivation of name: attenuatus, L. attenuated refers to nature of periderm.
Description: The rhabdosome has a length of 5·46 mms and widens steadily from 0·5 mms at the level of the first thecal pair to 1·17 mms distally. It is, therefore, wedge shaped. Eight thecae are developed in each series and these are distinctly orthograptid in form.

A sicula can be detected, and though not accurately measurable, it is certainly less than 1mm long and probably reaches to about the level of the distal extremities of the first thecal pair.

Throughout the rhabdosome the thecae number 15 in 10 mms and overlap for approximately half their length. The apertural margins are more or less horizontal.

A nema projects beyong the distal extremity and can be traced down to the sicula as a thickening chitinous thread. No septum is apparent though in such a flattened specimen it could have been obliterated.

By comparison with other fossils on the same slab it can be seen that the chitinous test is extremely thin.

Remarks: The tiny wedge-shaped polypary and attenuated periderm serve to distinguish this form from other orthograptids. The close thecal spacing is also a distinctive feature.

Orthograptus cf. insectiformis (Nicholson)

Plate 18, figs.10,11.

1869	Diplograpsus insectiformis Nicholson p.237, Pl.11, fig.13.	
1876	Diplograptus " Lapworth Pl.2, fig.40.	
1877	" " " Pl.6, fig.15.	
1907	" (Orthograptus) insectiformis, Nicholson. Elles and Wood pp.228-229, text fig.150a-c, Pl.28, figs.7a-c.	
1924	" insectiformis Nicholson. Hundt Pl.2, figs.20,21.	
1945	" (Orthograptus) insectiformis Nich. Waterlot Pl.10, fig.150.	

Material: 3 specimens, flattened.
Horizon and Locality: Zone of M. convolutus; Watley Gill (11Wa).

Diagnosis: Rhabdosome short, relatively broad, with a prominent and robust virgella, and spinose thecae numbering 20-15 in 10 mms (compressed).

Description: This species is almost certainly the same as Nicholson's but the state of preservation does not permit a full assessment of the biocharacters.

The length of the rhabdosome, excluding the virgella, is about 1cm though the specimens may be incomplete. A width of 1·5 mms is acheived but is probably accentuated by a combination of flattening and compression. (value exclusive of spines).

The sicula cannot be detected but a robust virgella extends for 5 mms below the proximal end. Thecal spacing is clearly reduced by strong compression and at the extreme proximal end the thecae number about 20 in 10 mms. Distally this value falls to 15 in 10 mms. Each theca throughout the rhabdosome is provided with a spine. The mode of origin of the spines cannot be determined and it is unfortunate that the lineation in the rock is parallel to them. This has the effect of obscuring both the detail and length.

From the size of the polypary, the shape and spinose nature of the thecae the Cautley specimens seem closest to O. insectiformis (Nich.)

Material seen: Specimens in H.M. Geological Survey Collection.

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subfamily PETALOGRAPTINAE Bulman 1955

genus PETALOGRAPTUS Suess 1851

(pro Diprion Barrande 1850 and Petalolithus Suess, 1851)

Type Species: Prionotus folium Hisinger, 1837; SD Lapworth 1873.

Generic diagnosis: Rhabdosome foliate, thecae at a considerable angle to axis of rhabdosome. Thecae long, nearly straight or with gentle ventral curvature, with large overlap; th.1(1) and 1(2) with pronounced upward direction of growth, leaving sicula much exposed; in cross section rhabdosome is exaggeratedly rectangular; septum partial or absent.

<u>Petalograptus ovatoelongatus</u> (Kurck)

Plate 3, fig.5

1850 Graptolithus palmeus Barrande Pl.3,fig.7.
1851 Petalolithus palmeus Suess Pl.8,fig.1.
1868 Diplograptus palmeus Nicholson p.523,Pl.19,fig.2-3.
1876 " " Lapworth Pl.1,fig.27.
1882 Cephalograptus ovato-elongatus n.sp. Kurck p.303,Pl.14,fig.10.
1890 Diplograptus " " Kurck. Geinitz Pl.A,fig.40.
1897 Petalograptus palmeus var. ovato-elongatus Kurck. Elles p.197,Pl.14, figs.11-14.
1908 " " " " " " Elles and Wood pp.277-8,text fig.191a-c,Pl.32,fig.4a,?4b (non 4c-d).
?1908 " " var. latus, Barrande. Elles and Wood pp.275-6 (pars) text fig.189a-c,Pl.32,fig.2c-f (nona-b).
?1919 Diplograptus (Petalograptus) folium var. ovato-elongatus Kurck. Kirste p.130,Pl.1,figs.30a-c.
?1920 " " var. latus Gortani p.23,Pl.1,fig.36.
?1941 Petalolithus ovato-elongatus (Kurck). Boucek and Pribyl pp.2-5,text fig.1a-e,Pl.1,figs.1-2.
1945 Petalograptus palmeus var. ovato-elongatus Kurck. Waterlot Pl.19,fig. 231.

non.
1897 Diplograptus palmeus var. ovato-elongatus Perner p.6,Pl.9,fig.6,8.

<u>Material</u>: 2 good specimens in full relief, preserved in pyrites. One showing the sicula.

<u>Horizon and Locality</u>: Zone of <u>M. triangulatus</u>; Birks Beck (9Bi).

<u>Description</u>: The rhabdosome is robust and distinctly ovato-elongate in form. A maximum breadth of 4·3 mms is reached in the ovate portion of the polypary and the species narrows to 3·25 mms in the elongate portion. The length is 1cm.

The sicula is 2 mms long and its apex reaches the level of the apertures of the first thecal pair. Th.1 is 2·5 mms long and subsequent thecae, though about the same length, grow out at a high angle to the axis thus increasing the width since th.1 is pressed to the sicula for 0.8 mms of its length.

All the thecae show a mean apertural expansion to 0·6 mms. The apertural margin itself is concave in profile view and the ventral margins of the thecae are also concave. In cross section the thecae are rectangular. Thecal spacing is close (13-15 in 10 mms) at the proximal end, but decreases to 12 in 10 mms distally. The angle of inclination also changes from approximately 45° proximally to about 30° distally (see fig.5,Pl.3). All the thecae have growth segments which are rather broader in the distal than the proximal thecae, and also in the apertural rather than the axial region. They number approximately 35 to each theca.

The septum in one specimen is complete and in the other (obverse view) can only be partial or may be absent entirely.

Remarks: The specimens described here agree with Kurck's original specimen in having an ovato-elongate outline. Elles and Wood (1908) also took this as a character of specific importance. Other forms, however, have been described by Boucek and Přibyl (1941) which, though having the general dimensions do not show the above feature. These authors extend the specific definition to include the more parallel-sided forms, and consider synonymous many forms previously described under a variety of names.

The writer refers the Cautley species only to those forms having an ovato-elongate profile.

Material:seen: Specimens in H.M.Geological Survey Collection.

Petalograptus minor minor Elles

Plate 3, fig.6

1893 Diplograptus palmeus Toernquist Pl.1,figs.29-31.

1897 Petalograptus minor Elles p.201,Pl.14,figs.17-21.

1908 " " Elles. Elles and Wood pp.279-281,text fig.193a-b, Pl.32,figs.5a-e.

1920 Diplograptus (Petalograptus) minor Gortani p.23,Pl.1,fig.37.

1933 Petalograptus minor Elles. Sun p.33,Pl.5,figs.5a-b.

?1934 " patulus Schwarzbach, p.4-6,fig.3.

1941 Petalolithus minor (Elles 1897). Boucek and Pribyl pp.5-6,text fig. 1f,g, Pl.1,fig.3.

1945 Petalograptus minor Elles. Waterlot Pl.19,fig.234.

1949 Diplograptus (Petalograptus) minor Elles. Obut p.15,Pl.1,figs.9a-b.

non.

1923 Petalograptus minor Gortani Pl.4,Pl.1,fig.5.

Material: Several specimens in full relief.

Horizon and Localities: Zone of M. triangulatus; Birks Beck (7Bi); Spengill (S24-28, S32-36, S36-39,7).

Diagnosis: Rhabdosome short, about 7·5 mms, relatively broad (3 mms) and oblong in outline. Thecae reaching a maximum of a little over 2 mms and numbering 12-15 in 10 mms.

Description: The rhabdosome is very distinctive in size and outline. A sicula has not been observed.

The thecae are long tubes averaging approximately 2 mm in length and overlapping for more than three quarters of this. They have concave apertural margins in profile view and the ventral margin of each theca is also concave. Proximally the thecae are inclined to the axis at 45° but more distally this value lessens. Throughout the length the thecal spacing is close and they number 12-15 in 10 mms; 13-14 in 10 mms is the usual figure.

The specimen figured on Pl.3 (fig.6) is a mould of a reverse view and it shows a septum extending some way down the polypary.

Remarks: P.minor at Cautley is identical with the material described fully by Elles (1897) and Elles and Wood (1908) except that at least in some specimens the septum is partially developed on the reverse side.

The apparantly high thecal count is not unusual since the figures of Elles and Wood (Pl.32) show considerably more than the 12 in 10 mms given in their diagnosis. A figure of 13-14 in 10 mms seems more usual in their figs. 5a,5c,5d, and 5e. Boucek and Pribyl (1941) record 12-14 in 10 mms (i.e. 6-7 in 5mms see p.5).

Material seen: Specimens in Sedgwick Museum, Cambridge.

Petalograptus minor finitimus subsp. nov.

Plate 3, fig.4; Plate 14, figs.6,7.

Holotype: HUR/6Bi/41, complete specimen in full relief, preserved in pyrites, reverse view.

Horizon of Holotype: Zone of P. leptotheca.

Derivation of name: finitimus L. 'near'.

Material: 6 specimens, four of which are complete and preserved in full relief

Horizon and Localities: Zone of D. magnus; Birks Beck (6Bi).

Diagnosis: Rhabdosome small, oval, reaching 6 mms. in length and almost 4mms in width. Proximal end pointed. Thecae number 14-15 in 10 mms, inclined to the axis at 40°, 2mms long (maximum). No septum. Sicula immeasurable

Description: The rhabdosome is characteristically small and oval in outline, except for the proximal end which is bluntly pointed. A maximum length of 6 mms. and width of almost 4 mms is reached in the largest specimen, but the others are all rather shorter and narrower than this.

Because of the mode of preservation the sicula cannot be seen in the one specimen exhibiting the obverse side of the rhabdosome. On the reverse side no specimens show a septum, whilst one (Pl.3,fig.4) partially broken specimen suggests that there is no septum on the obverse side. This same specimen also shows that the sicula cannot be longer than 1mm.

The thecae are closely spaced (14-15 in 10 mms) and reach a maximum length of almost 2 mms. Each has its ventral margin concave in profile view and its apertural region expanded. The apertural margin is even, to slightly concave.

Remarks: The only described British species with which P.minor finitimus can be compared is P.minor minor. It is clearly close to this subspecies but is distinctly smaller, has no septum, and probably has a much smaller and less conspicuous sicula. P.m.finitimus also differs from P. praecursor Boucek and Pribyl in being broader and in having its thecae inclined at a higher angle to the axis. The thecal count, however, is the same and the sicula must be of a similar size. All three species occur at the same horizon.

Petalograptus kurcki sp. nov.

Plate 20, figs.1,2,3.

Holotype: HUR./S73,11·4/40, a specimen in full relief but compressed, obverse view.

Horizon of Holotype: Zone of M. sedgwicki; Spengill (S73,11·4).

Derivation of name: "Latinised" after C.Kurck.

Material: Six specimens preserved in full relief.

Horizon and Localities: Zone of M. sedgwicki; Spengill (73,11·4).

Diagnosis: Rhabdosome small, short, and narrow; more or less parallel-sided. Sicula long and free for a considerable distance in the obverse view. Thecae small, numbering 18 in 10 mms (allowing for compression).

Description: The rhabdosome is very short and in all cases is less than 6 mms. A maximum width of 1·4 mms is reached almost immediately.

The sicula is free for almost the whole of its length when viewed from the obverse side. It is at least 1·7 mms long having an apex well above the level of the apertures of the second pair of thecae. The base is 0·2 mms in diameter.

The thecae themselves are small with a maximum length of 1mm and overlap for one half of their length. They are closely spaced numbering 16-20 in 10 mms. The highest of these figures (20) was obtained from specimens compressed at right angles to the length of the polypary and the smallest (16) for those affected in the opposite way. A thecal count of 18 in 10 mms will be near the true figure for uncompressed specimens. The thecal tubes do not expand in the region of the aperture. Growth segments, number approximately 25 per theca and show an increased width towards the distal end of each theca and towards the distal end of the rhabdosome.

No septum is present.

Remarks: The specific characters of this species are sufficient to distinguish it from other forms. Particularly striking is the small size of the rhabdosome, small and closely spaced thecae and the complete lack of a septum. The six specimens occur on a single slab in association with a pyritous globule showing concentric rings.

genus CEPHALOGRAPTUS Hopkinson, 1869

Type species: Diplograpsus cometa Geinitz, 1852
Generic diagnosis: An extreme development of Petalograptus; rhabdosome more or less triangular, composed of a few elongate thecae.

Cephalograptus aff cometa extrema Boucek & Pribyl

Plate 20, fig.4

aff.
1941 Cephalograptus cometa extrema n. subspec. Boucek & Pribyl pp.14-15, Pl.1,fig.10,text fig.21-m.

Holotype: The specimen figured in text fig.2 1.
Material: A single distal fragment in low relief. (HUR./S75,9·4/32).
Horizon and Locality: Zone of M. sedgwicki; Spengill (S94,7·4).
Description: This small fragment is easily placed in the genus Cephalograptus by the presence of long thecae and a rapidly-narrowing proximal part. The relative narrowness of the polypary (0·78 mms) and the small number of thecae (3-4 on each side of axis) suggests affinities with C.c.extrema rather than with C.c.cometa (Geinitz). The rhabdosome may not, however, be fully developed and more material is required before a diagnosis and full description can be given.

A nema projects 2 mms beyond the distal extremity of the polypary.

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subfamily RETIOLITINAE Lapworth, 1873

(nom.transl. Boucek & Munch, 1952 (ex Retiolitidae Lapworth 1873)) genus RETIOLITES Barrande, 1850

(nom. conserv. (ICZN Opinion 199)) (= Gladiolites Barrande, 1850; Gladiograptus Lapworth, 1875; Dimykterograptus Haberfelner 1936; Pseudoretiolites Boucek & Munch, 1944).

Type Species: Gladiolites geinitzianus Barrande, 1850

Generic diagnosis: Reticula on strongly developed clathria of parietal, pleural, apertural, and aboral lists, with virgula rapidly incorporated on one side and dorsal list ("zigzag virgula") on other.

Retiolites geinitzianus geinitzianus Barrande

Plate 16, fig.1

1850 (Gladiolites) Retiolites Geinitzianus Barrande p.69,Pl.4,figs.16-33

1851 Retiolites Geinitzianus Barrande. Suess p.95,Pl.7,figs.1d-e.

1852 " " " Geinitz p.52,Pl.6,figs.1-8.

1868 " " " Nicholson p.530,Pl.19,figs.19-20.

1882 " " " Tullberg p.41,Pl.1,figs.10-17.

1890 " " " Holm p.18,Pl.2,figs.2-5.

1908 " (Gladiograptus) Geinitzianus, Barrande. Elles and Wood pp.336 - 8,text figs.220a-f,Pl.34,figs.8a-d.

1929 " " geinitzianus Barrande. Glemerec pp.134-7,Pl.3, figs.9a-e.

1944 " (Retiolites) geinitzianus geinitzianus Barrande 1850. Boucek and Munch pp.566-9,Pl.3,figs.2-5,text figs.13c-h & 14c-d.

1945 " (Gladiograptus) Geinitzianus Barr. Waterlot Pl.20,fig.237.

?1947 " geinitzianus Barrande. Ruedemann pp.466-7,Plate 83,figs.1-2.

?1953 " geinitzianus Barr. Kuhne p.444,fig. in text.

Lectotype: Specimen figured by Barrande Pl.4,figs.17-19.

Material: Many specimens with some well preserved proximal ends, mostly in relief.

Horizon and Localities: "R.geinitzianus and vars" recorded by Wilson (1953) from his M.greistonensis Zone but these have not been examined by the writer; Zone of C.centrifugus - C.insectus: Bluecaster Gills, Near Gill (8N); Middle Gill (1M,4M); Wandale Hill (47W,37W,25W,26W,28W,29W); Pickering Gill (5P,6P, 10P,8P); Hebblethwaite Hall Gill (5H).

Diagnosis: Rhabdosome long, broad, sword-shaped, blunt proximally. Well developed and striking reticula, thecae at a high angle to the axis numbering 19-10 in 10 mms. Clathria well developed. Thecae inclined at 60°.

Description: Although specimens from 1-2 cms are the commonest, fragments up to 5 cms long have been obtained. The maximum breadth is about 4-5 mms. A breadth (relief)of 4 mms is reached 1½ cms from the proximal extremity and thereafter the rhabdosome is more or less parallel-sided. Some idea of the rapid increase in width can be obtained from the widths measured at the levels of the 1st, 2nd, and 3rd thecal pairs. They are, respectively:- 0·78 mms, 1·17 mms, 1·43mms.

At the proximal extremity the thecae are closely spaced and may number 19 in 10 mms. Away from this point the thecal tubes, though maintaining approximately the same angle to the axis, increase in length and width so that at 1½ cms they number 15 in 10 mms at the most. Distally a further reduction in density takes place down to 10 in 10 mms.

The clathria is well developed, each of the strands and lists being about 0·05 - 0·06 mms thick. Various clathrial elements can be identified in relief specimens, particularly those which are split into two halves.

The reticula is very striking consisting of a chitinous network whose threads are about half the width of the clathrial elements. There are 9-11 "meshes" along the length of each thecal tube and 3-4 across the width.

Remarks: R.g.geinitzianus is a very characteristic fossil of the lowest zone of the Wenlock Series. It has not been found in the Zone of C.murchisoni (as here defined) although it was recorded in 1911 by Watney and Welch from their murchisoni zone.

Retiolites geinitzianus augustidens Elles and Wood

Plate 22, fig.4

?1852 Graptolithus venosus Hall p.40, Pl.17A, figs.2a-c.
1908 Retiolites (Gladiograptus) geinitzianus, Barrande. var. augustidens sp. nov. Elles and Wood p.338, Pl.34, figs.9a-c.
1936 Dimykterograptus bončevi Haberfelner p.92, fig.5.
?1944 Retiolites (Retiolites) geinitzianus augustidens Elles and Wood 1908 Bouček and Munch pp.563-6, Pl.2, figs.1-4, text figs. 11a-e, and 12b-e.
?1945 " (Glad.)Geinitzianus var. Venosus Hall. Waterlot Pl.20, fig. 238.
?1947 " geinitzianus Barrande var. venosus (Hall). Ruedemann p.467-8, Pl.83, figs.4-9.
?1949 " " Barrande var. augustidens Elles. Obut p.16, Pl.2, figs.2a-b.

Material: Less common than R.g.geinitzianus but about 20 specimens in relief.
Horizon and Localities: Zone of C.centrifugus - C.insectus; Wenlock Series; Bluecaster Gills, Near Gill (8N); Middle Gill (2M,4M); Wandale Hill (51W, 37W,25W,26W,29W); Pickering Gill (5P,8P,9P); Birksfield Beck (7Bf).
Diagnosis: Rhabdosome up to 3 cms long, parallel-sided or slowly widening. Proximal end rounded. Clathria and reticulum prominent. Thecae inclined at 40° - 50°, numbering 15-10 in 10 mms.
Description: Occuring at the same horizon as R.g.geinitzianus is a narrow form which does not exceed 3 cms in length and which has a maximum width of 2·5 mms. These characters themselves are sufficient to distinguish it from R.g.geinitzianus.

The thecae throughout are inclined to the axis at 40° - 50° and at the proximal end usually number 15 in 10 mms. Their density falls rapidly to 10 in 10 mms at a little over one centimetre from the proximal extremity. The "mesh" of the reticulum is very similar to R.g.geinitzianus and the clathrial elements are equally distinct.
Remarks: This subspecies is also restricted to the lowest zone of the Wenlock (Stage 1) and is common enough to be regarded as a characteristic fossil of it

The Cautley specimens are identical with the described British specimens of the subspecies and are clearly close to those described by Bouček and Münch (1943). The only noticeable difference from the latter material is in breadt and thecal spacing (2·5 mms cf. 3·4 mms, and 15 in 10 mms cf 11-12)

A narrow form of R.geinitzianus was not detected by Watney and Welch (1911).

In view of the fact that R.g.augustidens occurs at the same horizon and the same geographical locality as R.g.geinitzianus (though not on the same bedding plane) there may be a case for raising the former to specific status.

Material seen: Specimens collected by Professor Shotton from Swindale Beck Nr. Knock. Some of these (e.g. S.M. no. A23714 a-b) are R.g.augustidens whilst others are R.g.geinitzianus.

Specimen no. A35825 (Sedgwick Museum) labelled R.g. ?var. augustidens is R.g.augustidens (Locality, Whinny Gill, Cautley below High Pasture Wood, probably 1-5 Wh. collector unknown.).

Other specimens in Sedgwick Museum.

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genus PSEUDOPLEGMATOGRAPTUS Pribyl 1948

Type species: Retiolites perlatus obesus Lapworth, 1877

Generic diagnosis: Like Retiolites but with somewhat ill-defined clathria and well developed lacinia.

Pseudoplegmatograptus obesus obesus (Lapworth)

Plate 19,fig.10

1876 Retiolites perlatus Lapworth Pl.3,fig.61.

1877 " " var. obesus Lapworth p.137,Pl.6,fig.26.

1890 " obesus Lapworth. Toernquist p.10,Pl.2,fig.24-5.

1908 " (Plegmatograptus) obesus (Lapworth). Elles and Wood pp.342-3 text fig.223a-c,Pl.34,figs.12a-c.

?1924 Retiolites obesus Lapworth. Hundt p.80,Pl.11,figs.28-31.
?1939 " " " Münch p.23,fig.38.
?1944 Plegmatograptus obesus obesus (Lapworth). Bouček and Münch pp.532-535, text fig.1a-g,2a-b,Pl.1,figs.1-2.
1945 Retiolites (Plegmatograptus) obesus Lapw. Waterlot Pl.20,fig.242.
1949 Plegmatograptus obesus (Lapworth). Obut pp.17,Pl.2,figs.5a,b.

Material: About 7 specimens, one complete, one in relief.
Horizon and Localities: ?Zone of M. sedgwicki, Zone of Monograptus turriculatus; Spengill (?S94,7·4; S124,10·25; S140,11; S166,8·5; S196,9·25; S197, 5·5).
Diagnosis: Rhabdosome about 2 cms long, overall width of the order of 6 mms. Thecae fairly distinct numbering 13 in 10 mms at the proximal end. Clathria probably poorly developed if at all, lacinia present.
Description: This species fits the diagnostic features enumerated by Elles and Wood (1908) in their detailed description of the British specimens rather more closely than it does those listed by Bouček and Münch (1943) for the Central European material. The reticulate pattern of the flattened rhabdosome is, however, similar in all cases.

The Cautley specimens are at least 2 cms long and possibly more, having an average (adult) width of 6 mms. At the proximal end thecal counts of 13 in 10 mms are common but at 1cm this has fallen to 9 in 10 mms which is then maintained.

The reticulate pattern is very similar to that figured in text fig.233a by Elles and Wood and text fig.2b by Bouček and Münch. Whilst the various elements of the rhabdosome are not easily identified a clathria does not appear to be developed.
Remarks: The thecal spacing (13-9) compares well with the figures given by Elles and Wood (12-9) and rather less well with the 11-12 in 10 mms given by Bouček and Münch. The breadth of the polypary (6mms) is intermediate to those quoted by the above authors (8mms and 4-5 mms respectively.)

The nature of the reticulum seems sufficient to distinguish this subspecies from the subspecies of Bouček and Münch P.o.reticulatus, P.o.hexagonalis and P.o.relictus.
Material seen: Specimens in Elles and Wood Collection, Sedgwick Museum.

subfamily PLECTOGRAPTINAE Boucek & Munch, 1952

genus GOTHOGRAPTUS Frech, 1897

Type species: Retiolites nassa Holm 1890

Generic diagnosis: More or less circular in cross section, thecal apertures connected by ventral instead of pleural lists, reticula fairly well developed; rhabdosome tapering distally and terminating in a tubular appendix; virgula central in the corona, later incorporated in lateral wall.

Gothograptus nassa (Holm)

Plate 3, fig.7

1890	Retiolites nassa Holm p.25, Pl.2, figs.12-14.
1895	Gothograptus nassa Frech p.670.
1897	Retiolites nassa Holm. Perner p.36, Pl.17, figs.20-21, text fig.32a,b.
1900	" (Gothograptus) nassa Wood p.486, Pl.25, fig.30, text fig.27.
1908	" " " (Holm). Elles and Wood text fig.225, Pl.34, figs.15a-d.
?1909	" " Holm. Moberg and Tornquist p.19, Pl.1, fig.14.
1938	Gothograptus nassa (Holm). Bulman P.D.80, fig.40d, (non 40e)
1945	Retiolites (Gothograptus) nassa Holm. Waterlot p.65, Pl.20, no244.
?1948	Gothograptus nassa (Holm). Pribyl p.21, (not figured)
1952	Gothograptus nassa (Holm, 1890). Boucek and Munch pp.11-15, Pl.1, figs. 9-11, text figs.2a-i, 3a-d.

Material: A few specimens, flattened and not well preserved.

Horizon and Localities: top of Stage 4, Wenlock Series, P.nilssoni Zone Ludlow Series; Wandale Hill (4W, 8W).

Diagnosis: Polypary small, narrow. Sicula not seen; thecae 14-15 in 10 mms, nature obscure. Nema present. Conspicuous reticulum, clathria not well developed.

Description: The rhabdosome is less than 1cm long and almost parallel-sided A maximum width of 0·78 mms is reached almost immediately and the thecae are uniformly spaced at 14-15 in 10 mms. Details of the thecal tubes cannot be made out but the apertures are represented by tiny excavations of the margins Thickenings near the aperture probably represent those described by Elles and Wood (1908, p.344). The reticulum is formed of a tiny mesh-work which is rectangular in outline in these compressed specimens.

Remarks: This is a rare form in the Wenlock Series at Cautley but it has been found at locality 4W (Wandale Hill) in association with M. flemingii and P. dubius. The former fossil has not been found above the Brathay Flags. Further discussion on the stratigraphic position of this fossil takes place on p.

Material seen: Specimens figured by Elles and Wood Pl.34, figs.15 b,d, in the M. vulgaris Zone exhibit, Sedgwick Museum (S.M. nos. A22489-90)

genus SPINOGRAPTUS Boucek & Munch, 1952

Type Species: Retiolites spinosus Wood, 1900

Generic diagnosis: Like Plectograptus but with better developed reticula and paired apertural spines.

Spinograptus spinosus spinosus (Wood)

non. figured

1900 Retiolites spinosus, sp. nov. Wood pp.485-6, fig.26, Pl.25, figs.29A-B.

1908 " (Gothograptus) spinosus (Wood). Elles and Wood pp.345 and 347, text fig.226a-c, Pl.34, figs.16a-c.

non d (= Pl. maculata)

Material: A few flattened specimens, fairly well preserved.
Horizon and Localities: Zone of P. nilssoni, Ludlow Series; Wandale Hill (8W)
Diagnosis: Rhabdosome short, spinose, and relatively broad. Clathria conspicuous, reticula coarse and apparently irregular in flattened specimens.
Description: These specimens occur fairly commonly, but not abundantly, in the second graptolite band of the Ludlow Series. They differ in no way from the material described by Wood (1900) and Elles and Wood (1908) but they are usually less well preserved.

The rhabdosome is about 1 cm long, has a width of nearly 2 mms (exclusive of spines) and thecae spaced at 10-11 in 10 mms.

The clathrial elements are not easily identified but can be seen, to be made up of slender threads. A reticulum is developed but is coarse and irregular. Flattening of all the specimens has obscured the pattern of the reticulum.
Material seen: Elles and Wood Collection, Sedgwick Museum.

Spinograptus spinosus praespinosus subsp. nov.
Plate 19, fig.11

?1911 Retiolites spinosus Wood. Watney and Welch text and tables, non fig.

Holotype: HUR/20N/40, distal fragment showing spines, among a cluster of proximal fragments (Pl.19,fig.11)
Horizon of Holotype: Zone of C. rigidus mut.
Material: 30-40 specimens, all flattened, some showing clathria only.
Horizon and Localities: Zone of M. riccartonensis to Zone of C. rigidus mut. Wenlock Series; Near Gill (17N,16N,19N,20N).
Diagnosis: Rhabdosome longer than 2 cms, width at least 2 mms, thecae with short stiff spines, numbering $8\frac{1}{2}$-9 in 10 mms.
Description: This form from the Wenlock Series is very close to Wood's species particularly in the nature of the clathria and reticulum which are indistinguishable from those of the type species.

The detailed measurements, however, show that S. s. praespinosus subsp. nov. is quite distinct. A rhabdosome length of at least 2 cms is commonly achieved although young specimens are not uncommon. The width is very often over 2 mms and the general form is parallel-sided. Projecting from the margins of the rhabdosome, and invariably at right angles to it, are short stiff spines. These reach a maximum length of 0·5 mms.

The thecal spacing is constant at $8\frac{1}{2}$-9 in 10 mms which is rather less than in Wood's species.

As in the case of the previously described species the clathrial and reticulate elements cannot be easily pictured. The reticulum however, seems to become less prominent in the distal part of the polypary and is completely absent on some specimens. One specimen over 2·6 mms broad had only clathrial elements and was without spines.

Remarks: In is certain that the Wenlock form is distinct from the Ludlow species but it seems likely that the latter evolved from the former. Only fragments of retiolitids have been obtained from Stage 4 and S.s.spinosus Wood has not been obtained above the lowest beds in the Ludlow Series. The time gap, therefore, is not as great as might at first be supposed. Certainly it is no greater than that between Wenlock and Ludlow representatives of P. dubius s.l.

Family DIMORPHOGRAPTIDAE Elles and Wood, 1908

genus DIMORPHOGRAPTUS Lapworth, 1876
(= Bulmanograptus Pribyl, 1948)

Type Species: D.elongatus Lapworth 1876; SD Bassler, 1915

Generic diagnosis: Proximal portion of rhabdosome uniserial with loss of th.1 (2) and generally further thecae of the secondary series, becoming biserial distally; biserial portion usually with partial septum; development more or less of monograptid type; thecae orthograptid or glyptograptid with a tendency in some species toward isolation of the apertural region; uniserial portion of varying length; initial bud upwardly-directed at origin.

Dimorphograptus confertus confertus (Nicholson)

Plate 4, fig.1

1868 Diplograpsus confertus Nicholson p.526, Pl.19, figs.14-15.
1888 Dimorphograptus confertus Marr and Nicholson p.707.
1897 " Swanstoni, var. Kurcki. Toernquist p.19, Pl.2, figs.34-33
1908 " confertus (Nicholson). Elles and Wood pp.349-350, text fig.227a-b, Pl.35, figs.3a-d.
1945 " " Nich. Waterlot Pl.21, fig.247.

Material: About 12 specimens, all flattened, most showing the proximal end.
Horizon and Localities: Zones of M.atavus to P. cyphus; Spengill (S1-5 to S20-24).
Diagnosis: Rhabdosome short, straight, relatively broad. Uniserial portion short, stiff, with three thecae and a prominent sicula. Thecae in biserial portion number 14 in 10 mms, overlap two-thirds.
Description: The biserial portion of the rhabdosome may reach 2 cms in length but most specimens are shorter. Thecal spacing in this region is rather closer than proximally and they number approximately 14 in 10 mms. Most of the specimens are compressed and readings from 11-16 in 10 mms are not uncommon. The compression however does not radically alter the typical appearance of the flattened thecae. They are relatively simple tubes with the ventral margin perhaps concave, or at least with apertural expansion. Overlap is always of the order two-thirds and the margins of the apertures vary between even and slightly everted. It is difficult, however, to asses the effect of flattening upon the apertural characters.

The uniserial portion is short and stiff and has a prominent sicula. This is at least 1·7 mms long and 0·5 mms wide, (at the base) though this latter feature is probably increased by flattening and compression. Its apex reaches almost to the level of the aperture of th.2. There are three thecae in the uniserial portion which differ from those of the biserial part only in being inclined to the axis at a lower angle. Overlap is considerable. At the level of the aperture of th.2 a width of 0·6 mms is usual.
Remarks: D.confertus is not as common as one is led to suppose by the account

of the Geological Survey workers (Dakyns et al. 1891).

It is however, restricted to the D.confertus Zone of Marr and Nicholson (1888) and in this sense is a useful stratigraphic indicator. D.confertus swanstoni (Lapw.) has not been found.

Material seen: Specimen figured by Elles and Wood Pl.35,fig.3a (S.M. no A20699) - a specimen which is compressed at right angles to the length of the polypary. Other specimens in the Sedgwick Museum Cambridge.

Specimen 3363a from Hatch Collection (H.M.Geological Survey, collected by Marr) D.confertus Zone, Skelgill.

Specimens of D.c.swanstoni in Sedgwick Museum, Cambridge.

Dimorphograptus epilongissimus sp. nov.

Plate 22,fig.1, 2, 2b.

?1882 Dimorphograptus cfr. Swanstoni Lapw. Kurck p.300,Pl.14,figs.5-7.

Holotype: HUR./S20-24/ , long, flattened specimen complete except for sicula

Horizon of Holotype: Zone of P.cyphus.

Derivation of name: epi, close upon, prefixed to "longissimus".

Material: About 7 specimens, proximal ends.

Horizon and Localities: Zone of M.atavus to P.cyphus, Spengill (S5-9,S13-17, S20-24).

Diagnosis: Rhabdosome long, robust with a relatively slender proximal end. Uniserial portion 4 thecae, sicula of diminutive width. Thecae, distally number 11-9 in 10 mms, and proximally less than 8 in 10 mms.

Description: The distal part of the rhabdosome may be up to 3 cms in length and is parallel-sided. Depending upon the compressional direction the thecae number 12-8 in 10 mms but in undistorted specimens there are about 11 in 10 mms in the early part and 9 in 10 mms in the most distal. The slender and gracefully curved uniserial portion has less than 8 in 10 mms.

The sicula is small and barely reaches the aperture of th.1. At the level of th.2 the width of the rhabdosome is 0·52 mms and the thecae in this region are relatively simple tubes of the orthograptid type. Distal thecae, which show overlap up to one half of their length, are also of orthograptid appearance but like D.c.confertus appear to have an apertural expansion.

In this case however, the apertural features might also be explained by the presence of a thickened lip which on flattening produced a definite "list" or denticle. The apertural margins are probably horizontal to slightly everted.

Remarks: D.epilongissimus sp. nov. is easily distinguished from D.cfr.longissimus Elles and Wood by its longer, more slender, uniserial portion which has 4 thecae instead of 2-3. The size and position of the sicula is, however very similar.

Kurck in his original description of Diplograptus (?) longissimus did not figure a proximal end but the similarity of the distal thecae led Elles and Wood to the conclusion that it was in fact synonymous with their Dimorphograptus.

It is possible that a similar relationship exists between D.cfr. longissimus and D.epilongissimus sp. nov. as has been observed between D.e.nicholsoni subsp. nov. and D.e.erectus Elles and Wood.

Material seen: Specimens of D.cfr. longissimus in Elles and Wood Collection, Sedgwick Museum, Cambridge. (figured Elles and Wood Pl.35,fig.8d).

Specimens in Sedgwick Museum labelled as D.erectus Elles and Wood (S20, 795-8) are synonymous with the form described here as D.epilongissimus sp. nov and are quite distinct from D.erectus.

Dimorphograptus erectus nicholsoni subsp. nov.

Plate 4,fig.2; Plate 21,figs.1,2; Plate 22,fig.3a

Holotype: HUR./1Bi/64, flattened specimen preserved as a silvery film in dark grey shale, proximal end and sicula intact.

Horizon of Holotype: Zone of M.atavus; Birks Beck.

Derivation of name: After H.A.Nicholson, one of the foremost of early workers on Lower Palaeozoic rocks.

Material: About twenty specimens, all flattened.

Horizon and Localities: Zones of M.atavus, P.acinaces, and P.cyphus; Spengill (S5-9, S13-17, S20-24); Birks Beck (1Bi,2Bi).

Diagnosis: Polypary small and narrow with a short, slender, and slightly curved uniserial portion comprising either 2 or 3 thecae.

Description: The rhabdosome is typically short and slender though occasional specimens up to nearly 2 cms long have been obtained. A maximum width of 1·43 - 1·5 mms is reached distally. In this region the thecae are closely spaced at 12-14 thecae in 10 mms. They show slight sigmoidal curvature and the degree of overlap is not great. This latter feature is difficult to assess accurately for in specimens compressed at right angles to the polypary it appears greater. It is probably about one third. The thecal tubes in this region are almost 1·3 mms. long.

The uniserial portion, though short, is gently curved and about 0·54 -·05 mms broad at the level of th.2, The sicula is fully 1·7 - 1·8 mms long and its apex reaches almost to the level of th.2. This is significant since it almost reaches the biserial portion and thus makes an otherwise slender uniserial part quite robust.

In the lower beds (M.atavus Zone) this subspecies invariably has only 2 thecae in the uniserial part but in slightly higher beds (P.acinaces Zone) it has either 2 or 3 thecae, more commonly the latter. The thecae number 11 in 10 mms in this region.

Remarks: D.e.nicholsoni closely resembles D.e.erectus in general form, size, and thecal characters. Those fossils from the M.atavus Zone are distinct in their closer thecal spacing and by having only two thecae in the uniserial part. However in the P.acinaces Zone specimens having 3 thecae in the uniserial part of the rhabdosome are more common. This form is clearly intermediate between the two subspecies and is only kept in D.e.nicholsoni on the grounds that it occasionally has 2 such thecae and never 4.

A single specimen from the P.cyphus zone (HUR./S20-24/ Pl.22,fig.3a) of Spengill (S20-24) is quite indistinguishable from D.e.erectus. It has 3 thecae in the uniserial part, is over 1cm long, and has a distal width of 2mms. This width of 2 mms does not seem to be unusual for D.e.erectus (see Elles and Wood Pl.35,fig.9a).

It is almost certain therefore that within the limits of the Dimorphograptus confertus Zone there is an evolutionary line; D.e.nicholsoni - D.e.nicholsoni mut. - D.e.erectus.

Material seen: Specimens figured by Elles and Wood Pl35 ,fig.9a,text fig.233b

(S.M. no.A20,779); Pl.35,9d (S.M. no.A20,783) and specimens figured Pl.35 figs.9b,c, and text fig.233a. These specimens are described by Elles and Wood (pp.355-356) and have three thecae in the uniserial portion. None of the specimens in the Sedgwick Museum collection has four thecae in the uniserial portion (cf. Elles and Wood p.355 and Bulman 1960,p.69) and this fact has since been confirmed for the writer by Professor Bulman (personnel communication). One specimen has only two thecae in this position (S.M. no A20,785, figured Bulman 1960,p.69 text fig.2d as D.erectus). Another specimen (A20 802 a & b) also has two thecae in the uniserial portion but unfortunately is from a loose block.

Specimens A20,795-8 (collected by J.E.Marr from the D.confertus Zone, Spengill Head) have four thecae in the uniserial portion but these are distinct from D.eredtus Elles and Wood and are synonymous with the species here described as D.epilongissimus sp. nov.

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genus AKIDOGRAPTUS Davies, 1929

Type Species: A.ascensus Davies 1929.
Generic diagnosis: Thecae climacograptid or orthograptid; proximal end characterized by loss or reduction of th.1(2); but owing to shortening of th.2(2) there is no apparent uniserial portion; initial bud downwardly directed at origin.

Adidograptus acuminatus acuminatus (Nicholson)
Plate 21,fig.3.

1867 Diplograptus acuminatus Nicholson p.109,Pl.7,figs.16-17.
1897 " " Toernquist p.14,Pl.2,figs.5-7.
1908 Cephalograptus (?) " (Nicholson). Elles and Wood pp.289 and 295, text fig. 199,Pl.32,figs.11a-d

1924 Diplograptus acuminatus Nicholson. Hundt Pl.2,figs.9,10,17.
1929 Akidograptus acuminatus (Nicholson). Davies p.9,fig.32, (no.10 schematic).

Material: A few well preserved specimens, several fragments.
Horizon and Localities: Zone of A. acuminatus; Watley Gill (1Wa); Spengill (4" band at base of dark grey shales).
Diagnosis: Rhabdosome short, wedge-shaped, with a very prominent sicula and long "orthograptid" thecae, numbering 7 in 10 mms.
Description: The rhabdosome rarely reaches 1cm in length, and most commonly is 5-6 mms long with a breadth of 1mm. A few fragments, however, suggest, that a greater length and width (up to 1·5 mms) may be reached.

The sicula is long (at least 2 mms) and completely free on one side. Th.1 originates 0·71 mms above its base and the base of the polypary is typified by the projecting lower portion of the sicula. Th.1(1) is 2 mms long and gives rise to th.2(2) almost immediately. At a distance of 2·5 mms above the base of the sicula th.2(1) is already developed as a bud and the septum is formed. Th.2(1) appears to grow from th.2(2) as does th.3(2).

Th.2(1) and 3(2) are therefore adjacent at their proximal ends but immediately separated by the septum.

The thecae in the proximal region number approximately 7 in 10 mms but more distally where the thecal tubes are shorter a higher count is obtained.
Remarks: The thecal tubes are orthograptid rather than diplograptid but any such comparison with thecae of other genera can only be approximate.

The species was first recorded from the Cautley district by Wilson (1953) who identified and delimited the A. acuminatus Zone.
Material seen: Specimens in Sedgwick Museum, Cambridge.

Akidograptus acuminatus praematurus Davies

Plate 21, fig.4

1929 Akidograptus acuminatus mut. praematurus nov. Davies p.10, fig.25

Material: A single proximal end and other more doubtful fragments.
Horizon and Localities: Zone of A.acuminatus; Spengill (4" band at base of dark grey shales).
Diagnosis: Rhabdosome short, straight, with a similar, but blunter, proximal end to A.a.acuminatus. Thecae of "orthograptid" type numbering 11½-14 in 10 mms.
Description: The best specimen is preserved as a mould in such a manner that the length of the sicula cannot be determined. Compression can be observed in this specimen and the lineation is at right angles to the polypary; but whilst this may have accentuated other features it cannot be the cause of the blunt proximal end.

Th.1(1) is only 0·8 mms long and th.2(2) 1·3 mms. They are more closely spaced (11½-14 in 10 mms) in this region than in specimens of A.a.acuminatus (7 in 10 mms) and the thecal tubes are much shorter. In all its characters the Cautley subspecies resembles fig.25 (Davies 1929) except in having a slightly higher thecal count (11½-14 in 10 mms cf.11 in 10 mms)
Remarks: This subspecies was recorded by Davies as an early form of A.a.acuminatus but at Cautley it occurs in the same 4" band and may represent a late survival. It is, however, rarer than the typical form.

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genus RHAPHIDOGRAPTUS Bulman, 1936
(= Metadimorphograptus Pribyl, 1948)

Type Species: Climacograptus tornquist Elles and Wood, 1906.
Generic diagnosis: Like Dimorphograptus but with thecae of climacograptid type; initial bud downwardly or upwardly directed at origin.

Rhaphidograptus toernquisti (Elles & Wood)

Plate 19, figs.7,8,9

1876 Climacograptus rectangularis Lapworth Pl.2,fig.50.
1877 " scalaris var. rectangularis Lapworth p.138,Pl.4,fig.32.
1897 " rectangularis Toernquist p.8,Pl.1,fig.16-21.
1906 " Tornquisti, sp. nov. Elles and Wood pp.190-191,text fig. 123a-b,Pl.26,figs.6a-f.
1924 " " Elles and Wood. Hundt Pl.1,figs.32-34.
1936 Rhaphidograptus tornquisti (Elles and Wood). Bulman text p.19 et seq. and text fig.1a-e, schematic text fig.2a.
1945 Climacograptus Tornquisti Elles and Wood. Waterlot Pl.6,fig.112.
?1949 " tornquisti Elles and Wood. Obut p.13,Pl.1,figs.4a-b.

Material: Several hundred specimens, many flattened, some preserved in full relief, many specimens showing sicula.
Horizon and Localities: Zones of M.atavus to M.sedgwicki; Spengill (S1-5 to S73,11·4); Birks Beck (1Bi,7Bi,9Bi); Pickering Gill (14P,1P); Wards Intake (13Wi); Watley Gill (4Wa,5-6Wa).
Diagnosis: Rhabdosome up to 4 cms long, maximum breadth in relief, about 2 mms. Sicula long and prominent, uncovered along almost the whole of one side. Virgella long, swelling away from the sicula to become more robust. Thecae of climacograptid type with deep excavations, numbering 12-10 in 10 mms.
Description: The Cautley representatives of this species from the zones of M.atavus to M.triangulatus differ in no way from previously described material. Compression, however, has a considerable effect on flattened specimens which take on either a very broad or a very narrow appearance (see Pl.19,figs.7 & 9). Thecal counts of up to 20 in 10 mms may be observed in material compressed at right angles to the polypary, whilst the breadth is greatly increased. Specimens in relief which are affected by this compression often show a crumpling of the proximal end similar to the specimen figured by Bulman (1936,text fig.1d)

On the other hand compression parallel to the length of the rhabdosome produces a narrow form with a reduced thecal count. This might be mistaken for a new species were it not for the fact that it is always possible to detect the lineation upon the bedding plane.

R. tornquisti is not so well represented above the zone of M. triangulatus but forms again occur in some abundance in the lowest bed of the M. sedgwicki Zone. More material will have to be examined before it can be decided whether these are identical with earlier forms or whether there have been changes. The septum may not develop until further along the rhabdosome but the general size and proportions of the polypary appear to be very similar.
Material seen: Specimens in Sedgwick Museum, Cambridge.

Family MONOGRAPTIDAE Lapworth, 1873
Subfamily MONOGRAPTINAE Lapworth, 1873
(nom. transl. Yin, 1937 (ex Monograptidae Lapworth 1873))

genus MONOCLIMACIS Frech 1897

Type Species: Graptolites vomerinus Nicholson, 1872
Generic diagnosis: Rhabdosome often long and more or less straight though slight curvature is common proximally and rarer distally; ventral wall of each theca subsequent to th.1 has a distinct excavation which contains the apertural region of the preceding theca; apertural region often appears to be "hooked" but in some Ludlow representatives it has been shown that a "hook" effect can be caused by an independant monofusellar structure which grows from the geniculum of the suceeding theca; the amount of ventral excavation in these later forms may be less than in the earlier ones.

Monoclimacis vomerina basilica (Lapworth)

Plate 4, figs.3-6; Plate 13, fig.1; Plate 22, fig.12; Plate 23, figs.1,2; Plate 24, figs.6,7

1880 Monograptus galaensis var. basilicus nov. Lapworth p.152,Pl.4,fig.6a-b.
1910 " vomerinus (Nicholson) var. basilicus Lapworth. Elles and Wood text fig.276b (?276a), Pl.41,figs.2b-c, (? 2a and 2d).
?1911 " " Nich. var.β Elles. Watney and Welch (pars) in text. non fig.

Holotype: Specimen figured by Lapworth (1880) Pl.4, figs.6a-b, now in Lapworth collection at Birmingham University (B.U.1548). Figd. here on Pl.22, fig.12 and Pl.4,fig.3.

Material: Over 100 specimens usually in full relief.

Horizon and Localities: Zones of C.centrifugus - C.insectus to Zone of M.f. belophorus, ?Zone of C.rigidus mut.; Bluecaster Gill, Middle Gill (1M,4M,?6M, 14M,15M,? above this); Near Gill (8N,10N,11N,16N,17N); Whinny Gill (6Wh); Hebblethwaite Hall Gill (5H,9H); Birksfield Beck (6Bf); Hobdale Beck (1Bd); Wandale Hill, Gill A (25W,26W,28W,29W,30W,34W), Gill B (47W,46W,37W); R.Rawthey (8Ra,9Ra); Pickering Gill (3P,4P,5P,?6P,7P,8P); R.Rawthey, Mouth of Wandale Beck (49W,51W,50W,53W,54W).

Diagnosis: Rhabdosome very long and almost straight attaining a breadth of 3 mms distally. Proximal end slender; thecae number 10-7½ in 10 mms. Sicula small.

Description: Lapworth in his original description figured only a distal fragment (B.U.1548) but the thecal characters were so distinct as to make them unmistakeable. He mentioned that the proximal end was more slender than in M.vomerinus Nicholson. Elles and Wood (1910) also figure a distal fragment (text fig.276b and Pl.41, fig.2c, actually from Lapworth's type specimen). They also figure (text fig.276a) a poorly preserved proximal end from Lapworth's collection but do not described it adequately.

Distal fragments are up to 3mms broad (relief) and are invariably straight The thecae are long, overlapping tubes in which the sigmoidal curvature is not always clear. The degree of overlap is at least two-thirds.

Associated with these distal fragments of M.v.basilica are forms referable to M.v.vomerina, and in addition proximal ends which are straight and more slender than those of the latter species. They are also quite distinct from M.v.gracilis and are thought to be the proximal ends of M.v.basilica.

The sicula is 1·3 - 1·5 mms long and its apex reaches to just below the level of the aperture of th.1. Occasional specimens occur in which the apex of the sicula ends about 0·06 mms above the distal extremity of th.1.

Theca 1 originates 0·3 mms above the base of the sicula and is approximately 1·17 mms long. The proximal end involving about 5 thecae has a characteristic "thorn-like" appearance (see Pl.4,fig.4) and widens steadily from 0·32-0·39 mms at th.1 to 0·65 mms at th.5. Thereafter the rhabdosome widens more gradually to 1·1 - 1·2 mms at th.16. Th.16 is the last measurable theca seen on these proximal ends.

Thecal spacing is fairly constant at 9½-10 in 10 mms over the first 1cm but by th.16 (1½ cms from the sicula) it has dropped to 8½ in 10 mms.

Remarks: M.v.basilica differs from M.v.vomerina in the characters of both its proximal and distal regions. The sicula is slimmer, and extends less far along the polypary, whilst the whole "thorn-like" nature of the proximal end is thinner.

Watney and Welch (1911) do not record M.v.basilica (nor M.hemipristis (Meneghini)) but they may have mistaken the proximal ends here described for M.v.var. β which appears in their text and tables. Elles and Wood(p.411) include M.v.var. β in their synonymy of var. gracilis but the proximal end of basilica is distinct from this.

The specimen of M.v.var.gracilis figured by Elles and Wood as fig.3a (Pl.41) is now contained in the Birmingham University Collection as B.U.1549. This occurs on a slab with many other specimens all apparently identical. In spite of the fact that they are flattened they appear more robust than M.v. basilica but agree in thecal count (10 in 10 mms). The graceful recurvature of the proximal end mentioned by Elles and Wood (p.41) does not seem to be a constant feature and many of the specimens on the same slab as B.U.1549 are quite straight. Furthermore the sicula on these specimens is 2 mms long and the author has been quite unable to differentiate these and the probable lectotype of M.v.vomerina (B.U.1542) which is identical in size, appearance of thecae, and size and position of the sicula (see discussion under M.v.aff vomerina).

Thus M.vomerina basilica (Lapworth) as redefined here is quite distinct from other described species in Britain.

Pribyl (1940) includes M.v.basilica in his synonomy of M.hemipristis (Meneghini) but does not figure or describe this latter fossil. The writer cannot be certain from the published figures of M.hemipristis that it is synonymous with Lapworth's basilica and the latter is retained here as a separate species.

M.v.basilica is the common monoclinacid of the zones C.centrifugus - C.insectus to C.murchisoni but is less common above.

Material seen: Specimens from Pencerrig. Distal fragments from this locality approximate closely to Lapworth's type specimen of M.v.basilica whilst the associated proximal ends are very similar to M.v.basilica as described from Cautley, being rather slender and either straight or with slight dorsal curvature. Examples:-

proximal end - S.M. no A22,125, Hopkinson Collection, Pencerrig
distal fragment S.M. no. A22,123 " " "

Specimens from "West of Wharfe" (e.g. S.M. no. A22,095) are distal fragments probably referable to M.v.basilica though labelled M.vomerinus.

Specimens from Trecoed (Zone of C.murchisoni). These are identical to those from Pencerrig (S.M. A22,129-30 listed as M.vomerinus var. by Elles 1900 p.375). M.basilicus is in fact listed from Builth (Elles 1900 p.384, locality 14, S.M. no. A22141 a-b) but from the Zone of C.rigidus.

Two good specimens (the best preserved of those in the Sedgwick Museum Collection) occur on a slab labelled C.murchisoni (S.M. no. A23571) from the Salopian of the Cwm Cignant stream ESE. of Llanidloes. (The cyrtograptids were listed by Jones 1945, p.328). Both these vomerine monograptids have the sicula and proximal end preserved and are identical with the species here defined as M.v.basilica Lapworth.

Specimens of M.v.gracilis. Five syntypes occur on slab S.M. no. A51065 one specimen of which is figured by Elles and Wood as text fig.277. These specimens are almost straight and are close to M.v.basilica being perhaps fractionally more slender.

Monoclimacis vomerina aff vomerina (Nicholson)

Plate 13, fig.3; Plate 23, fig.3; Plate 24, fig.8,5; (Plate 13, fig.2 = Elles & Wood 1910, Pl.41,fig.3a; Plate 4, fig.7 = Elles & Wood 1910, Plate 41, fig.1b; fig.3, Plate 24 = Elles & Wood 1910 Pl.41, fig.1a, the probable lectotype)

aff.

1872 Graptolites vomerinus Nicholson p.53,fig.21.
1876 Monograptus " , Nich. Lapworth p.353,Pl.12,figs.6a-e.
1900 " " (Nich) var.α Elles pp.403 & 405,fig.15.
1910 " " (Nicholson). Elles and Wood pp.409-411,text fig. 275 a-f,Pl.41,figs.1a-e.

Lectotype: Not yet designated but Dr.I.Strachan, Birmingham University is considering designating the specimen figured by Elles and Wood (1910) Pl.41, fig.1a, a flattened but complete specimen, described by Elles and Wood as "Typical specimen impression, (?) figured Lapworth, Geol. Mag., 1876, Pl.Xii, fig.6a". This is refered to, hereafter, as the "probable lectotype".

Material: Several specimens in full relief, and other more doubtful fragments.

Horizon and Localities: Zones of C.centrifugus - C.insectus to M.riccartonensis; Bluecaster Gills, Middle Gill (6M,4M,11M); Near Gill (12N,8N,10N,11N); Hebblethwaite Hall Gill (5H); Wandale Hill Gill A (26W,28W,29W); R.Rawthey (?8Ra), Mouth of Wandale Beck (49W,51W,?53W,?54W).

Diagnosis: Rhabdosome long, more or less straight, reaching about 2 mms in width distally. Proximal end usually straight and robust. Sicula up to 1·5 mms long. Thecae number 11-7 in 10 mms.

Description: The rhabdosome is long, straight and stiff though the proximal end may be straight or show slight dorsal curvature.

The sicula is about the same length as in M.v.basilica but is more robust and its apex usually reaches above the aperture of th.1. At the extreme proximal end the thecae usually number 11 in 10 mms, although readings up to 13 in 10 mms are not uncommon. The specimen figured by Elles and Wood (Pl.41 fig.1b) has 12½ in 10 mms, whilst one on the same slab has 13 in 10 mms. Distally counts down to 7 in 10 mms are fairly common.

The whole proximal end is robust and widens rapidly from 0·52 mms to 1mm after 1cm and 1·5 mms after 2 cms.

Remarks: M.v.aff vomerina is not a common fossil at Cautley.

The probable lectotype (B.U.1542) is a flattened specimen about $6\frac{1}{2}$ cms long. At its distal extremity it has a breadth of only 1·69 mms and a thecal spacing of $8\frac{1}{2}$ in 10 mms. The sicula may be fully 2 mms long with its apex reaching to the level of th.1 which is rather long. In this region the thecae number 11-10 in 10 mms.

Elles (1900) in her description of M.vomerinus (Nich.)var.α gives the sicula as nearly 2·1 mms long and shows it reaching to about, or just above the aperture of th.1 which again is rather long (fig.15,p.405).

It is clear that the description of Elles and Wood (1910) is not fully diagnostic of the specimens which they figure. A thecal count of 11-10 in 10 mms is given in the diagnosis yet all their figured specimens on Pl.41 show less than this. The specimen figured as fig.1c on Pl.41, for example has $7\frac{1}{2}$ in 10 mms (Birmingham University Specimen No.B.U.1544). Figures 275a and b(p.410) on the other hand are two specimens which fit very well into the description. It is specimens such as these to which the Cautley material is referred, and in fact to which the oft-described M.vomerinus of other workers seems to be referred.

As has been mentioned above the probable lectotype of M.v.vomerina appears to the writer to be synonymous with the type specimen of M.v.gracilis (B.U. 1549).

In view of the facts described above it appears that a revision of the species group with a redefinition of its members must be undertaken before any further progress can be made.

Material seen: Specimens figured by Elles and Wood as text fig.275a (S.M. no. A22,094). This is very close to M.v.aff vomerina.

Specimens from Corwen (Denbigh Flags) are also close to M.v.aff vomerina (e.g. S.M. no.A22,107).

Specimens from Crummack Beck. These are vomeriniform distal fragments possibly referable to M.v.aff vomerina.

Monoclimacis shottoni sp. nov.

Plate 23, fig.5

Holotype: HUR./28W/76 a complete specimen in full relief.
Horizon of Holotype: Zone of C.centrifugus - C.insectus.
Derivation of name: After Professor Shotton.
Material: Numerous specimens in full relief, all proximal ends.
Horizon and Localities: Zone of C.centrifugus - C.insectus; Wandale Hill Gill A, (28W), Mouth of Wandale Beck (49W,51W); Pickering Gill (3P,5P,6P,10P); R.Rawthey (?8Ra).
Diagnosis: Rhabdosome short (?), with slight ventral curvature,narrowing distally. Sicula prominent. Thecae with distinct sigmoidal curvature numbering 12-13 in 10 mms.
Description: No specimens over 7 mms long have been obtained and since these narrow towards their distal extremities it is thought that they are probably full grown. The maximum width is reached at th.4 and rarely exceeds 0·71 mm. At th.7 the width has decreased to 0·58 mm and the distal narrowing is very conspicuous.

The sicula is 2 mms long and its apex invariably reaches the level of the second thecal aperture. It is 0·29 mm wide at the base and shows a faint ventral curvature. Th.1 arises 0·20 mm above the aperture of the sicula. Thecal lengths are as follows:- th.1, 0·9 mm; th.2, 0·9 mm; th.3, 1·17mms; th14, 1·23 mms; th.5, 1·3 mms.

Growth segments are usually visible on the thecae but not on the sicula. As in the case of M.haupti (Kuhne) there is an increase in thickness of these segments from the proximal to the distal thecae. In M. shottoni sp. nov. there are over 20 growth segments in th.1 (7-8 in the metatheca) but each theca beyond only has 14-15 such segments (6-7 in the metatheca). There is no diminution in width of the rings in the region where the rhabdosome begins to narrow (th.5-7).

The thecal margins are not "hooked" but appear to be slightly everted.
Remarks: M.shottoni sp. nov. closely resembles those specimens figured by Elles (1900) as M.vomerinus var and included by Elles and Wood (1910) in their synonomy of M.crenulatus Tornq. These, which are figured natural size, are rather broader than the Cautley specimens, however, but have the same

sized sicula (2mms) and the same thecal count (12-13 in 10 mms), similar general size, and are recorded from the murchisoni Zone. (Reference to their table X, p.406, suggests that the figures may be more than natural size.)

No other figured proximal ends of M.crenulata resemble the Cautley species. Dr. Hede informs the writer that Tornquist's original material may have been lost since he has found no trace of it in the Lund Palaeontological Museum and it does not appear to be in the Museum of the Geological Survey (Stockholm).

The specimen figured by Elles and Wood (1910, text fig.278a now in the Dept. of Geology, Birmingham, spec. no. B.U.1555) appears to be little different from their M.cfr. greistonensis (text fig.280a, Pl.41, fig.6a-b). This latter species has been more fully described by Wilson (1953) from material obtained from his M.greistonensis Zone in the Cautley district (cf. their fig. 280a with Wilson's fig.26). The diagnostic characters are:- a) sicula 1·5mms apex midway between th.1 and th.2; b) thecae numbering 12-9 in 10 mms; c) th. 1 and th.2 "hooked". Specimen B.U.1555 has a 1·5 mms long sicula whose apex reaches midway between th.1 and th.2 but the thecal count of 14-13 in 10 mms proximally is rather higher. The rhabdosome widths are very similar with the Cautley specimens perhaps a fraction narrower.

Pribyl (1940) includes M.cfr.greistonensis Elles and Wood in his synonomy of M.linnarssoni Tullberg, but this in the author's opinion this is a more doubtful step since the thecal spacing is distinctly less (Tullberg 1883 gives 8-9 in 10 mms, Pribyl 10-8 in 10 mms).

M.crenulatus (Elles and Wood fig.278a only), M.cfr.greistonensis (Elles and Wood 1910, fig.280a), and Monoclimacis sp. (Wilson 1953, figs.25-26), are therefore considered to be ~~synonymous~~ conspecific, and quite distinct from M.crenulata, M.greistonensis and M.linnarssoni.

Material seen: M.shottoni sp. nov. was first recorded by Professor Shotton (1935 from his locality "g" Swindale Beck as M.vomerinus var. crenulatus (Tornquist). Some of these specimens are now contained in the Sedgwick Museum, Cambridge and are identical with the Cautley species. The associated assemblage is also the same (for further discussion see p. 53).

Specimens of M.crenulata from Llanidloes, Montgomeryshire, listed Jones 1945 p.327 (S.M. no A23574, and A23573). The former has a more slender proximal end than M.v.basilica and has a sicula whose apex extends to midway between the apertures of th.1 and 2. The specimen listed by Jones 1945 p.325

(S.M. no. A23568) is recorded from 40' above the base of the Salopian. It differs little, if at all, from the form here described as M.v.basilica.

Specimens of M.crenulata from the Zone of M.crenulata, Denbigh Shales, Penarth Uchaf (N.W. of Pen-y-glog). These are median fragments labelled M. crenulatus Tqt. (S.M. nos. A22023-4).

Monoclimacis linnarssoni (Tullberg)

Plate 24, figs.1,2

1883 Monograptus Linnarssoni n.sp. Tullberg p.20,Pl.2,figs.5-9.

Material: A single distal fragment, low relief, 5½ cms long, one proximal end in full relief, other more doubtful fragments.

Horizon and Localities: Zone of C.centrifugus - C.insectus; Middle Gill (4M).

Description: The distal fragment of the rhabdosome is quite straight and fully 5½ cms long. At the most proximal point seen, the width is 0·91 mm. The rhabdosome is almost parallel-sided since at the distal extremity it is still only 1·17 mms wide.

The thecae are sigmoidally curved tubes, inclined at a low angle to the axis (approximately 20°) and numbering 9 in 10 mms throughout the whole length. Excavations of the ventral margin are conspicuous and deep, occupying almost half the width of the polypary. The length of the excavations is 0·4 mms.

The proximal end has thecae which are identical in their general characters to those of the distal fragment. They number 10 in 10 mms. The sicula is long and slender measuring slightly over 2 mms and reaching midway between th.1 and 2. In this respect it is very similar to Tullberg's original figure of the proximal end.

Remarks: The thecal characters distinguish this rare species from all others occurring at Cautley. It closely resembles Tullberg's original figures, the only difference being that the Cautley specimen has a slightly longer excavation. Tullberg (p.20) gives a thecal count of 7-8 in 10 mms but Pribyl (1940) gives a range of 10-8 in 10 mms.

Material seen: Specimen from Grieston Quarry (S.M. no. A22017) labelled M.linnarssoni. This, however, seems indistinguishable from M.griestonensis which occurs in abundance at the same locality.

Monoclimacis griestonensis nicoli subsp. nov.

Plate 21, figs.7,8. (Pl.21, figs.9,10 = Elles and Wood 1910, text fig.279a, and Pl.41, fig.6a)

Holotype: HUR./8P/19, a proximal end in full relief with sicula preserved.
Horizon of Holotype: Zone of C.centrifugus - C.insectus.
Derivation of name: "Latinised", after Nicol author of M.griestonensis.
Material: About 5 specimens in full relief.
Horizon and Localities: Zone of C.centrifugus - C.insectus.
Diagnosis: Rhabdosome probably quite short, slender and fragile. Maximum breadth seen 0·3 mm. Thecae long, narrow tubes closely adpressed to the axis numbering $9\frac{1}{2}$-9 in 10 mms.
Description: The only parts known of this subspecies are proximal ends and fragments of proximal parts. The maximum observed width is 0·3 mm which is achieved 5 mms from the base of the sicula.

The sicula is prominent, 1·5 mms long, and its apex reaches almost to the level of the aperture of th.1. It is furnished with a short slim, virgella at the aperture which measures 0·2 mm across. Th.1 arises 0·4 mm above the base of the sicula and is 1·17 mms long. Thecal overlap is slight (one quarter).

Each thecal tube grows parallel to the axis for a distance of 0·5 mm and then takes a small but slight bend towards the ventral surface resulting in a shallow excavation. Thereafter the thecae grow inclined to the axis at a very low angle indeed.
Remarks: In general form this subspecies is closely related to fossils of the M.griestonensis Group. The diagnostic features outlined above fall within the range of those in the detailed description by Elles and Wood (1910), However, fig.279a of these authoresses has 13 thecae in 10 mms in both the figure and the specimens (B.U.1556). The specimen figured on their Pl.41 (fig.5a), which occurs on Nicol's type slab, has 14-12 thedae in 10 mms. (Occurring on the same slab are two specimens of M.spiralis s.l. and one badly preserved specimen which might be M.griestonensis).

It is clear from these specimens that M.griestonensis nicoli subsp. nov. is more robust at the proximal end and has a much larger sicula. (The sicula on their fig.279a is 0·7 mm long). The degree of sigmoidal curvature of the thecae is also slightly less in the Cautley subspecies and the excavation smaller.

Pribyl (1940) describes a new subspecies M.g.minuta and redescribes Boucek's M.g.kettneri. M.g.nicoli subsp. nov. seems to be quite distinct from these forms though it resembles M.g.minuta in the narrow width of the rhabdosome.

Material seen: Specimens of M.g.griestonensis recorded Elles and Wood p.414 from the Talerddig Grits (A21673-6, Sedgwick Museum). Specimen listed Jones 1945 p.327 (S.M. no. A23576).

Specimens of M.g.griestonensis in H.M. Geological Survey Museum.

Specimens figured Elles and Wood Pl.41, fig.6a and text fig.279a (Birmingham University Collection nos. 1559 and 1556 respectively) The former occurs on the same slab as a specimen of M.spiralis s.l.

Monoclimacis kingi sp. nov.

Plate 22, figs.5-10; Plate 11, fig.1

Holotype: HUR./19N/70, a flattened proximal end 3 cms long, with sicula intact

Horizon of Holotype: Zone of M.flexilis belophorus Near Gill (19N).

Derivation of name: In honour of the late Professor W.B.R.King contributor for many years to the problems of Lower Palaeozoic stratigraphy.

Material: Several hundred specimens, all flattened, many well preserved.

Horizon and Localities: Zones of M.riccartonensis (Stage 2) to C.lundgreni (Stage 4); Bluecaster Gills, Middle Gill (16M,19M,20M,?21M,23M,25-30M); Near Gill (14N,18N,19N,16N,17N,20-23N,25-29N); Wandale Hill Gill B (43W,44W, 45-46W); R.Rawthey (11 Ra,10Ra,9Ra); Mouth Wandale Beck (67-69W).

Diagnosis: Full length unknown but probably more than 30 cms. Distally reaches 2 mms (flattened) from 0·3 to 0·5 mm proximally (flattened). Dorso-ventral curvature. Thecae number 10-8 in 10 mms.

Description: The rhabdosome has a very characteristic appearance widening from a slender and graceful proximal end, which almost invariably shows distinct dorsal curvature, to a long and variously curved distal region. Whilst many are almost straight, equally as many show slight ventral or dorsal curvature and the complete rhabdosome would probably show variable curvature.

For the first 3-5 mms, the proximal end is sharply recurved and the sicula prominent. In relief it must be extremely slender.

The sicula is 2 mms long and its apex is above the level of the aperture of th.1. Occasional specimens show a slightly shorter sicula but this reaches only just to the level of the aperture of th.1 and its true apex may be hidden

Th.1 originates fully 0.4 mm above the base of the sicula which is therefore conspicuous with its short virgella. The sicula is rarely curved. At the proximal end the thecal spacing is most constant at 10 in 10 mms. The change distally is very gradual and even the most distal fragments do not show less than 8 thecae in 10 mms.

The excavation is well marked throughout the polypary but distally it often increases in length. As a rule it occupies about one-third of the width of the polypary.

Remarks: M.v.basilica is the only form with which M.kingi sp. nov. might be confused in the proximal region. In reality however the latter species is distinct in being far more slender, in lacking the "thorn-like" appearance, in having a longer sicula, and in being recurved proximally. The distal thecae are quite different.

It is this subspecies which Watney and Welch probably mistook (in part) for their higher recordings of M.v.var.β (In the lowest beds they probably confused M.v.basilica for their M.v.var β).

The presence of a pristioform view of M.kingi sp. nov. possibly explains their high recording of M.Hisingeri Carr. var. (= P.watneyi sp. nov.).

Specimens of M.kingi sp. nov. obtained from the Zone of C.lundgreni (Stage 4) are even more slender than those from Stages 2-3. The thecae are more closely spaced and often number 11 in 10 mms at the proximal end. Thecal counts of 10 in 10 mms often extend for several cms.along the rhabdosome. Thus whilst the species has a long range, the latest representatives are of stratigraphic importance. Since they are easily separable from those below, they might perhaps, merit description as a new subspecies.

Monoclimacis haupti (Kuhne)

Plate 23, fig.4

1955 Monograptus haupti n. sp. Kuhne pp.365-8, Figs. 3A-F.
1958 Monoclimacis haupti (Kuhne). Urbanek pp.88-92, Text figs.59-65,Pl. lV, fig.5.

Holotype: Specimen figured by Kuhne (1955) fig.3A-F.
Material: A single specimen preserved in full relief, proximal end.
Horizon and Localities: Ludlow Series; Zone of P.nilssoni, ?1st graptolite band; Wandale Hill (2W).
Diagnosis: Rhabdosome short, probably almost straight, sicula conspicuous and ventrally curved. Thecae with distinct sigmoidal curvature numbering 12-14 in 10 mms.
Description: The sicula has a minimum length of 1·43 mms. Its apex is hidden but probably extends to the level of the second thecal aperture. In spite of the fact that the specimen has been displaced at the level of th.3 (giving an apparent dorsal curvature) the sicula is clearly curved ventrally. Three distinct rings are present on the upper half of the sicula which are thought to be equivalent to the "peridermal rings" described by Urbanek (1958 p.58). At the base the sicula is 0·32 mm across and between this point and the lowest peridermal ring there are about 35 growth segments. This figure agrees very closely with fig.61c (Urbanek 1958, p.90). The middle peridermal ring is 0·26 mm above the lower, and the top one 0·13 mm above the middle.

Theca 1 originates 0·1 mm above the base of the sicula and has a length of 0·7 mm. Succeeding thecae increase slowly in length up to th.5 (the last measurable thecae) which is 1·3 mms long. At this point the width of the rhabdosome is 0·71 mm.

Each protheca has approximately 14-15 growth segments (counted in profile view) and the metathecae 8-9 segments. There is a distinct and gradual increase in the width of the growth segments (measured in the same plane as the length of the rhabdosome) from the sicula, where they are very closely spaced, to th.5 where they measure 0·05 mm accross.
Remarks: Urbanek (1958) showed that Kuhne's species was in fact a Monoclimacis in view of the strong sigmoidal curvature of the thecae. Furthermore he sug-

gests (p.90) that M.haupti may be conspecific with Monograptus praeultimus Munch. M. praeultimus has thecae of the "ultimus" type, attains a length of 4·5 - 7·5 mms long and has a thecal spacing of 12-14 in 10 mms. Its maximum breadth is 1.1 mms. M.ultimus Perner is also considered by Urbanek to be referable to Monoclimacis Frech.

The specimens described by Kuhne (1955) and Urbanek (1958) were obtained from erratic boulders.

? Monoclimacis sp. A

Plate 21, figs.5,6.

Material: 2 flattened proximal ends, both obliquely compressed.

Horizon and Localities: S233,3 M.crispus Zone, Spengill.

Description: This rare form has a distinct appearance of the thecal aperture (fig.6 Pl.21) which is seen as a small semicircular excavation beneath a "flange" on the geniculum of the succeeding theca. The "flange" is thought to be the compressed appearance presented by a monofusellar structure of the type described by Urbanek (1958). All the thecae on both specimens show this feature.

The sicula may reach 1·82 mms in one specimen and is 1·7 mms in the other. In both cases the apex of the sicula reaches the level of the aperture of th.2. Proximally the thecae number 12-13 per cm. By the time th.6 and th.7 are reached the thecal count has dropped to 11 per cm.

The width of this form may be increased by the flattening and compression which it has undergone but ranges from 0·32 mm at the proximal end, to 0·52 mm at a distance of 6-9 mms from the base of the sicula. These figures exclude the"monofusellar" structure which at th.7 (the most distal theca seen) is 0·19 wide. A slight dorsal curvature is seen at the extreme proximal end of the rhabdosome but this is effected purely by the addition of the sicula to a perfectly straight dorsal margin.

Remarks: The thecal count is similar to that found in M.cfr.greistonensis Elles and Wood (1910) and Monoclimacis sp. Wilson (1953) but it differs from these in having a longer sicula reaching further along the rhabdosome, and in having more "hooked" thecae. The general dimensions, however, are very similar and it is possible that this form, occurring as it does at a lower horizon, may be a forerunner of Monograptus cfr. griestonensis Elles and Wood.

There is little doubt that Monoclimacis sp. Wilson is synonymous with Monograptus cfr. griestonensis Elles and Wood. Furthermore Pribyl (1940) includes the latter in his synonomy of Monoclimacis linnarsoni (Tullberg). The validity of this last step is more doubtful since Pribyl gives a thecal count for M.linnarsoni of 10-8 per cm. whilst Tullberg 1883 gives 7-8 thecae per cm. Monoclimacis linnarsoni (Tullberg) may occur at a slightly higher horizon than Monoclimacis sp. Wilson and M.cfr. griestonensis Elles and Wood.

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genus PRISTIOGRAPTUS Jaekel, 1889

Type Species: P. frequens Jaekel, 1889

Generic diagnosis: Rhabdosome of very variable length and curvature but commonly almost straight; thecae are straight, simple tubes throughout the length of the rhabdosome, and have varying degrees of overlap, and inclination; siculae from small to very large; flattened specimens may occasionally be confused with Monoclimacis Frech.

genus PRISTIOGRAPTUS, GROUP A

Diagnosis: Rhabdosome usually with strong dorsal curvature proximally and, perhaps related to this, a tendency of the thecal apertures to expand; distal parts more or less straight and in this region thecae are long, narrow tubes often with great overlap; angle of inclination generally low; siculae very long.

Horizon: typically the Lower Llandovery.

Pristiograptus gregarius (Lapworth)

Plate 23, fig.8; Plate 24, fig.10

1851	Graptolites Nilssoni, Barr.	Harkness p.61, Pl.1, figs.7a-d.
1868	" " "	Nicholson p.537 (pars) Pl.20, fig.19.
1876a	Monograptus gregarius, sp. nov.	Lapworth p.317, Pl.10, figs.12a-c.
1876b	" "	Lapworth Pl.1, fig.7.
1877	" "	Lapworth p.131, Pl.5, fig.4.
1892	" " Lapworth.	Toernquist p.8.
1897	Pristiograptus "	Frech p.660, fig.215, Pl.1, fig.3-5.
1899	Monograptus " Lapworth.	Toernquist p.4-5, Pl.1, figs.1-6.
1910	" " "	Elles and Wood pp.365-6, Pl.36, figs. 3a-d, text fig.238a-b.
?1924	" " "	Hundt Pl.5, fig.4.
?1931	" " "	Haberfelner Pl.1, fig.1.
1940	" " "	Desio p.31, Pl.2, figs.16, 17.
?1945	" " "	Waterlot Pl.23, fig.260.
1947	" cf. gregarius "	Ruedemann p.481, Pl.84, fig.1.
?1962	Pristiograptus gregarius (Lapworth).	Romariz p.282 (not figured)

Material: Many specimens usually in low relief preserved in pyrites, occasionally in full relief.

Horizon and Localities: Zones of P.cyphus, M.triangulatus, D.magnus, P.leptotheca up to M.sedgwicki; Spengill (S9-13 (?), S13-17, S24-28, S28-32, S36-39, S75,9·4 (?)); Birks Beck (7Bi, 8Bi, 9Bi, 6Bi); Pickering Gill (14P); Watley Gill (6Wa).

Diagnosis: Rhabdosome dorsally curved throughout, usually only a centimetre or two long, Sicula extremely long and prominent. Thecae simple tubes of very characteristic appearance.

Description: The most characteristic feature of this species is a long sicula. In most of the Cautley specimens this is about 5 mms long and its apex reaches to at least the level of the aperture of th.3, and usually to that of th.5. This latter feature, besides showing considerable variation, is also often difficult to determine since the apex often passes quite imperceptably into the dorsal margin. The base of the sicula (relief) is 0·19 mm across and it maintains this width until th.1 originates 1·3 mms above its base. At the point of origin of th.1 the rhabdosome is 0·36 - 0·27 mm broad, but at the aperture of th.1 this has increased to 0·58 mm. Th.2 arises only a short distance above the base of th.1 so that there is considerable overlap even at this stage (two-thirds). The thecal length remains constant at least up to th.7 (2·2 mms) but the overlap begins to decrease slightly.

Distally the thecae are little different and the rhabdosome does not exceed about 0·7 mm (in relief) whilst some specimens show a slight decrease in width immediately the sicula is passed. Throughout the rhabdosome the thecae number 9½-10½ in 10 mms and the apertural margin is at right angles to the axis.

Specimens recorded from higher levels do show some differences. Those from the P.leptotheca Zone (e.g. 6Bi, Birks Beck), whilst having a typical proximal end, are associated with long distal fragments which may be conspecific. These show typical thecae with up to about two-thirds overlap. The common canal is very wide in proportion and the thecae show a distinct sigmoidal curvature not disimilar to that seen in Monoclimacis. A slight sigmoidal curvature is sometimes seen in the proximal thecae.

Material from the Zone of M.sedgwicki, whilst similar to P.gregarius in most characters, seems to have a high thecal count of 14-15 in 10 mms. The apertures in these specimens have an appearance of introversion but this almost certainly is due to crushing.

Further material may show that there are several varieties of this species perhaps with stratigraphic importance, and perhaps also showing some link with P.cyphus.

Material seen: Specimen thought to have been figured by Harkness (1851) on Pl.1 fig.7a (H.M. Geological Survey Collection).
Specimen in Sedgwick Museum, Cambridge.

Pristiograptus cyphus (Lapworth)

Plate 4, figs.10,12,13.

1876	Monograptus cyphus, sp. nov.			Lapworth p.352,Pl.12,figs.3a and 3c, (non 3b and d).
1910	"	"	Lapworth.	Elles and Wood pp.362-4,text figs.236a-d,Pl.36,figs.1a-c.
1924	"	"	"	Hundt Pl.4,figs.24,30-33.
1945	"	"	"	Waterlot Pl.22,fig.258.

Material: At least 20 specimens, usually fragmentary, none in relief.

Horizon and Localities: Zone of P.cyphus, ?Zone of M.triangulatus Spengill (S9-13, S13-17 (common), S17-20 (common), S20-24); acinaces Zone;(12Wi)

Diagnosis: Rhabdosome with conspicuous dorsal curvature throughout. Proximal end slender with long sicula. Thecae long, simple, overlapping tubes numbering approximately 10 in 10 mms.

Description: Because of its considerable length the rhabdosome is invariably fragmentary in the Cautley specimens. Nevertheless, these usually show the dorsal curvature and the characteristics of the thecae.

The proximal end is slender and has a width of 0·39 mm at the level of th.1 (in flattened material). The apex of the long sicula extends almost to the level of the aperture of th.2. Theca 1 is almost 2 mms long and overlaps th.2 for about one quarter of its length. Compression distorts the characters of most specimens to a certain extent but the thecal apertures seem to be very slightly everted. Naturally oblique compression at one angle will accentuate this, whilst at another it will subdue it, and the thecae may appear to have horizontal apertures.

More distally the thecae increase in length, overlap, and angle of inclination to the axis. Here they measure about 2·5 mms long, occasionally more, and are relatively narrow (0·4 - 0·5 mm). The angle of inclination is 10°-20° and they overlap for two thirds of their length.

Remarks: P.cyphus is common in its own zone but may extend a little above into the Zone of M.triangulatus. It is distinguished from most forms by its proximal end. From P.gregarius it differs in having a shorter sicula which only extends to midway between th.1 and 2.

The distal thecae could be confused with other types having long, simple overlapping tubes, but from P.leptotheca, and P.acinaces it is fairly distinct

Material seen: Specimens in Sedgwick Museum, Cambridge.

Pristiograptus aff. acinaces (Tornquist)

Plate 4, fig.11; Plate 24, fig.11

aff.

1899 Monograptus acinaces n. sp. Tornquist p.5,Pl.1,figs.7-8.

1909 " rheidolensis sp. nov. Jones p.535,figs.19a-c.

1910 " acinaces, Tornquist. Elles and Wood pp.364-5,text fig. 237a-d,Pl.36,figs.2a-e.

Material: About 50 specimens, always flattened.

Horizon and Localities: Zones of P.acinaces - P.cyphus; Spengill (S13-17, S17-20., S9-13); Pickering Gill(14P).

Description: This species has resemblences to both P. acinaces and M.incommodus Toernquist. The reason for this is partly a matter of preservation since only the outline of the fossil can be determined. It differs from M. incommodus in the apparent lack of sigmoidal curvature of the thecae, the everted apertural margins, the greater thickness, the greater range of thecal spacing, and an apparent increase in thecal overlap distally.

No extreme proximal ends have been found but several slender and slowly widening specimens occur. The most slender of these has a width of 0.5 mm, whilst the distal fragments are 1·3 mms wide. The thecal spacing varies from 5-7 in 10 mms proximally, to 12 in 10 mms distally. Coincident with this increase in thecal count is a slight increase in angle of inclination coupled with an apparent increase in overlap of the thecal tubes.

These specimens seem to show neither the width of rhabdosome (though distal fragments may be lacking) nor the apertural expansion of P.acinaces. This latter feature may possibly be obliterated by flattening although the opposite would be expected.

The exact length and overlap of the thecae cannot be determined but both values appear to be less if the angle of inclination is any guide.

A further point is that the proximal regions of all these specimens are gently curved dorsally, not moderately recurved as figured by Jones (1909) and Elles and Wood (1910) for the Rheidol Gorge specimens.

On general form and outline P. aff. acinaces bears a superficial resemblance to other forms. From P.concinnus and M.sandersoni it differs in its invariable dorsal curvature. Another species of similar dimensions is M. atavus Jones and it is possible that the form here called P. aff. acinaces is in reality a variant of the former but lacking the sigmoidal curvature (it might be obliterated upon compression), and with a low angle of thecal inclination.

Remarks: M. aff. acinaces occurs in S13-17 in what appear to be loose (or collapsed) "colonies" of rhabdosomes.

Material seen: In H.M.Geological Survey Museum, specimen figured Elles and Wood Pl.36,fig.2b, cited p.364-5; specimen figured Jones 1909 fig.19c and again by Elles and Wood Pl.36,fig.2d; specimen figured Jones 1909 fig.19a and again by Elles and Wood Pl.36, fig.2a and text fig.237b; specimen figured Jones 1909 fig.19d and again by Elles and Wood as text fig.237d.

Pristiograptus leptotheca (Lapworth)

Plate 4,fig.8,9; Plate 13,fig.10; Plate 23,fig.6,7; Plate 24,fig.12.

1876a	Monograptus	leptotheca, sp. nov.	Lapworth	pp.352-3,Pl.12,fig.4a-e,
1876b	"	"	"	Pl.1, fig.14.
1877	"	"	"	p.130,Pl.5,fig.22.
1882	"	"		Tullberg p.12,Pl.2,figs.8-12.
1897	Pristiograptus	"		Frech p.657,fig.212.
1899	Monograptus	"	Lapworth.	Toernquist p.5-6.
1910	"	"	"	Elles and Wood pp.371-2,text fig. 242a-c,Pl.37,figs.2a-d.
?1924	"	"	"	Hundt Pl.6,fig.1-4.
1945	"	"	Lapw.	Waterlot Pl.24,fig.267.
1949	"	(Pristiograptus) leptotheca Lapworth.		Obut p.21,Pl.4,figs. 1a-b.
?1961	Pristiograptus	leptotheca (Lapworth).		Romariz in text, not figured or described.

?1962 Monograptus leptotheca Lapworth. Romariz p.283, not figured.

Material: Many specimens, always fragmentary, but preserved in full relief in pyrites.

Horizon and Localities: Zones of M.triangulatus, D.magnus, P.leptotheca and M.sedgwicki; Birks Beck (9Bi,6Bi,5Bi); Spengill (S75,9·4, S80,8·4); Watley Gill (11Wa,9Wa).

Diagnosis: Proximal end unknown, but specimens close to it have been obtained. Rhabdosome more or less straight throughout. Thecae characteristically of extreme length and tenuity (in profile). Maximum width over 2 mms. Thecae number 8-10 in 10 mms.

Description: Usually only short fragments of the rhabdosome are obtained but the thecal characters are so distinct that confusion with other forms is not likely. The rhabdosome is more or less straight and distally reaches a thickness of over 2 mms and perhaps nearer 2·5 mms. The thecae are so long and thin in profile, however, that they easily slide over one another on compression to produce a displaced, or a sinuous dorsal margin (see fig.8, Pl.4).

At a width of 2 mms (on the rhabdosome) the thecae have a length of up to 6 mms and more distally may be even longer. In these areas the overlap is often more than three-quarters of their length. There is often a pronounced expansion in the region of the aperture. The apertural margins appear to be quite even and at right angles to the length of the thecae. Because the thecae are inclined at a low angle to the axis (10°) the apertural margin appears to be approximately horizontal.

A proximal end with sicula attached has not been found, but specimens showing the typical thecae down to a breadth of less than 0·5 mm have been obtained. On these the thecae are over 3·25 mms long and still overlap for more than half their length.

Remarks: Elles and Wood (1910) place this species in their Gp.1A 2. along with M.regularis, M.jaculum etc. In view of the continued elongation of the proximal thecae the writer takes the view that it may have more affinities with forms like M.acinaces Toern. which Elles and Wood place in Gp. 1Ai (a). The whole form of the thecae is close to M.acinaces and the proximal end may well turn out to be of that type rather than the stiff "nudus" type with its short thecae and small sicula. P.leptotheca is here, therefore, included in Pristiograptus Group A.

Material seen: Specimens in H.M.Geological Survey Museum, figured Elles and Wood Pl.37,figs.2d,e.

Specimens in Sedgwick Museum, Cambridge.

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genus PRISTIOGRAPTUS, GROUP B

Diagnosis: Proximal end usually straight, slender, with short thecae of small overlap; sicula small its apex not extending to the level of the aperture of th.2; distal thecae variable, either long tubes with considerable overlap or short, broad tubes with much less overlap.

Horizon: Typically Middle and Upper Llandovery.

Pristiograptus nudus (Lapworth)

Plate 5,fig.2.

1852 Monograpsus sagittarius Hisinger p.33,Pl.2,figs.2a-b,3a-b,4.
1853 " " " . Richter Pl.12,fig.19.
1876 Monograptus Hisingeri, Carr. sp. Lapworth pp.350-1,Pl.12,figs.1a,1b,1d, 1e,?1f.
1880 " " " var. nudus var. nov. Lapworth. p.156,Pl.4, figs.7a-c.
1883 " Hisingeri Carr. Tullberg p.18,Pl.2,figs.45-48.
1890 " " " Geinitz Pl.A,fig.3.
?1897 " " Carruth. Perner p.11-12,Pl.13,figs.2-4,6,(non 5)
1899 " nudus Lapworth. Toernquist pp.8-9,Pl.1,fig.18-20.
1908 " Hisingeri Carruthers. Allachverdjiew pp.338-9,Pl.4,fig.6

1910 Monograptus nudus (Lapworth). Elles and Wood pp.375-6, text fig.246a-d, Pl.37, figs.6a-e.

?1931 " cf. nudus Lapworth. Aigner fig.4.

1940 " nudus Lapw. Laursen p.22, Pl.1, fig.3, text fig.8.

1945 " " " Waterlot Pl.25, fig.276.

1948 Pristiograptus (Pristiograptus) nudus (Lapworth 1880). Pribyl p.74, non fig.

1949 Monograptus " " (Lapworth). Obut p.21, Pl.3, fig. 8a-c.

1950 " " " " Obut p.21, Pl.3, figs. 8a-c.

1952 Pristiograptus (Pristiograptus) nudus (Lapworth). Munch p.92, Pl.21, figs.1a-1b.

1954 Monograptus nudus (Lapworth). Wilson, in text and tables.

1955 Pristiograptus (Pristiograptus) nudus (Lapworth 1880). Pribyl and Spasov. p.193, non fig.

1962 Pristiograptus nudus nudus (Lapworth). Romariz p.284, ?Pl.13, figs.4,5, Pl.16, fig.1.

Lectotype: Specimen figured by Lapworth (1876) Pl.12, fig.1a.

Material: Over 100 specimens, invariably flattened but some well preserved.

Horizon and Localities: ? Zone of M.sedgwicki, Zone of M.turriculatus, M. crispus and M.griestonensis (in the sense of Wilson 1953); Spengill (?S73, 11·4 - S80,8·4, S197,5·5 - S259,1·25, S264,5); Wards Intake (5Wi).

Diagnosis: Rhabdosome straight, with slight ventral curvature at the proximal end in some specimens. Thecal tubes characteristically inclined up to 40°, and numbering 12-8 in 10 mms.

Description: The rhabdosome usually reaches a length of 3-4 cms but may be longer. Typically it is stiff but material from the higher zones often shows a slight ventral curvature at the proximal end.

The sicula is small and its apex only reaches to the level of the aperture of th.1. Proximally the thecae are closely spaced, particularly over the first few mms where they number 12 in 10 mms. Their density rapidly falls to 9-10 in 10 mms, which is maintained throughout much of the length, although occasional distal readings of 8 in 10 mms are obtained.

At 3 cms from the sicula a width of 1·43 - 1·5 mms is reached. From this point the increase in width is slow but the final width may approach 1·7 mms.

The thecae in the adult portions are almost 2 mms long and overlap approximately for one half of their length. A characteristic feature of this species is an expansion in the free ventral margin which, on compression, may give rise to a slight excavation. The angle of inclination is about 30-40° and only rarely exceeds this value.

Remarks: The Cautley specimens do not differ appreciably from other described material.

Material seen: Specimens in H.M.Geological Survey Collection and the Sedgwick Museum, Cambridge.

Pristiograptus watneyi sp. nov.

Plate 13, figs.7,8.

?1900 Monograptus Hisingeri Carr. var. Elles in tables and text, non fig.

?1911 " hisingeri " " Watney and Welch in text and tables, non fig.

Holotype: HUR./37W/19 and counterpart /17, specimen in full relief with a total length of about 14 cms.

Horizon of Holotype Zone of C.centrifugus - C.insectus.

Derivation of name: After G.R.Watney joint authoress of "The Zonal Classification of the Salopian Rocks of Cautley and Ravenstonedale" 1911.

Material: One well preserved specimen (the holotype), and another fragmentary but well preserved specimen. Other doubtful specimens.

Horizon and Localities: Zones of C.centrifugus - C.insectus to Zone of M.riccartonensis; doubtful above this latter zone; Wandale Hill Gill B (37W); Hobdale Beck (1Hd); Bluecaster Gills (?Middle Gill and Near Gill).

Diagnosis: Rhabdosome long and quite straight, reaching a distal breadth of 2·3 mms. Thecae simple overlapping tubes numbering 13-7 in 10 mms. Angle of inclination up to 40°.

Description: (Drawn mainly from the holotype). The rhabdosome is long and straight with perhaps a very gentle dorsal curvature at the proximal end, the whole being similar to P.regularis.

The sicula has a length of 1·43 mms and is quite inconspicuous. Its apex reaches 0·15 mm above the level of the aperture of th.1. Th.1-3 number 13 in 10 mms and are inclined to the axis at a very low angle (5-10°). Both the thecal spacing and angle of inclination increase rapidly so that they number 9 in 10 mms inclined at 20°, only 1cm from the sicula. The overlap at this point is rather less than one half.

There is no change in the thecal characters distally but they are less closely spaced (7 in 10 mms) whilst the angle of inclination increases to 30-40°. The thecal overlap is rather more than one half and the tubes themselves have a length of 2·5 mms.

Remarks: The species recorded as M.hisingeri Carr. var. by Watney and Welch (1911) was probably in part P.watneyi for the latter certainly belongs to P.nudus Group. On the other hand Watney and Welch record their variety throughout the Wenlock Series but state that it is rare in their lowest and topmost zones. The writer feels that they may have confused pristioform views of M.kingi sp. nov. with P.watneyi. M.kingi is common in their zones of M.riccartonensis and C.rigidus and rare in their highest zone of C.lundgreni (as they record for M.h.Carr. var.). It is absent in their C.murchisoni Zone where P.watneyi occurs rarely.

The two species, P.watneyi and M.kingi, though superficially resembling each other in size, are quite distinct. The latter, quite apart from the ventral excavation of the thecal margin, has a distinct dorsal curvature at the extreme proximal end, a prominent sicula, is more slender, and the rhabdosome as a whole often shows dorso-ventral curvature.

From members of Pristiograptus Group C, P.watneyi differs in the slender and slowly widening proximal region. The closest species is probably P.nudus. From this it differs in the following points:-

a) The distal thecae are long rather than broad, but there is an almost imperceptible expansion in the region of the aperture.
b) The rhabdosome is broader distally and more slender proximally.
c) Thecal spacing both proximally and distally is different.
d) The sicula is longer and its apex extends further.
e) The angle of inclination distally (30-40) is less than in P.nudus.

Pristiograptus regularis regularis (Tornquist)

Plate 5, fig. 1; Plate 24, figs. 13, 14.

1899 Monograptus regularis n.sp. Tornquist p.7, Pl.1, figs.9-14.
1910 " " , Tornquist. Elles and Wood pp.372-3, text fig.243 a-c, Pl.37, figs.3a-d.
1919 " (Pristiograptus) regularis Kirste p.191.
1929 " cf. regularis Haberfelner p.114.
?1931 " regularis mut. α nov. mut. Haberfelner Pl.1, fig.2.
1933 " regularis Tornquist. Sun p.41, Pl.6, fig.7.
1945 " " Tornq. Waterlot p.71, Pl.26, fig.281.
1947 " " Tornquist. Ruedemann pp.486-7, Pl.84, figs.15-18.
1951 Pristiograptus regularis Munch p.73, fig.14.
1952 " (Pristiograptus) regularis regularis Munch p.93, Pl.21, figs.6a-b.
1955 " " " " Tornquist 1899. Pribyl and Spasov p.194.
?1960 Pristiograptus regularis regularis (Tornq.) Romariz Pl.1, fig.7 not described.
?1961 " " " " Romariz Pl.1 fig.2 not described.
?1962 " " " (Tornquist). Romariz Pl.15, fig.10.

Lectotype: Specimen figured by Tornquist (1899) Pl.1, fig.9.
Material: Over 200 specimens invariably flattened.
Horizon and Localities: ?Zone of M. sedgwicki, Zone of M. turriculatus to M. griestonensis (in the sense of Wilson 1953); Spengill (?S75, 9·4; ?S124, 10·25 to S131, 10·25; S136, 1·25 to S264, 5 except S145, 0·75; S210, 8; S217, 6·25; S252, 3·5 to S254, 7·25; S258, 9 to S260, 5·5).
Diagnosis: Rhabdosome straight, long, and more slender proximally than P. nudus. Thecal tubes simple, long, quite slender and inclined to the axis at a low angle. 7½-9 in 10 mms distally.
Description: The rhabdosome is stiff and straight throughout. Distal fragments over 7 cms long are commonly found which show no diminution in breadth and suggest that the complete rhabdosome was very long indeed.

The proximal end is slender and bears an inconspicuous sicula which has a maximum length of 1mm. Its apex reaches to the level of the aperture of th.1. At the aperture of th.1 the rhabdosome width is 0·39 mms (flattened) and must be even more slender in specimens preserved in relief. Over the first cm the thecae are closely spaced and number 13-10 in 10 mms. Thereafter this value falls very quickly to 9 in 10 mms. Distally the thecae become even more widely spaced and the count is often as low as 7½ in 10 mms.

The maximum breadth of the rhabdosome (flattened) is 1·5 mms.

The thecal tubes show a slight expansion of the free ventral margin, as in the case of P.nudus, and upon flattening this is reflected in a slight excavation. Overlap of the thecae increases distally to a maximum of two-thirds.

Remarks: Specimens occurring rarely in the zone of M.sedgwicki are similar but smaller and have the thecae more closely spaced,(15 in 10 mms). The width at the level of th.1 is 0·26 mm. These forms may bear some relation to P.regularis solidus Pribyl.

Material seen: Specimens in H.M.Geological Survey Museum and the specimen figured by Elles and Wood as text fig.242c (Sedgwick Museum, Cambridge.

Pristiograptus aff. variabilis (Perner)

non fig.

aff.

1897 Monograptus jaculum, Lapw. var. variabilis mihi.Perner p.12,Pl.13,figs. 10-15.

Material: 44 badly preserved, flattened specimens from Zones of M.turriculatus and M.crispus; Spengill.

Description: These rather badly preserved specimens are referred to P.variabilis on general grounds only. The rhabdosome is straight and about 1mm broad (flattened).

The thecae have little overlap throughout, whilst the apertural margins vary between horizontal and slightly introverted. These characters are similar to the proximal regions of P.jaculum (Lapw.) but in all the Cautley specimens there is a lack of width and thecal overlap. It is this which distinguishes Lapworth's from Perner's species, and suggests that the Cautley specimens have more affinities with the latter rather than the former.

Material seen: Specimens in the Sedgwick Museum figured by Elles and Wood Pl. 37, fig.5a, text fig.245a,b.

Pristiograptus concinnus (Lapworth)

Plate 5, fig.3.

1876	Monograptus concinnus, sp. nov.	Lapworth pp.20-21, Pl.11, figs.1a-e.
1910	" " , Lapworth.	Elles and Wood pp.368-9, text figs. 240a-d, Pl.36, figs.5a-f.
1934	" concinus Lapworth.	Hsu p.91, Pl.7, figs.2a-b.
1945	" " "	Waterlot pl.23, fig.264.
1949	" (Pristiograptus) concinnus Lapworth.	Obut p.21, figs.7a,b.
?1962	Pristiograptus concinnus Lapworth.	Romariz p.279, Pl.3, fig.4.

Material: A few specimens in full relief, others flattened.

Horizon and Localities: ?Zone of P.cyphus, Zone of M.sedgwicki; Spengill (?S 13-17, S75, 9 4).

Diagnosis: Ventrally curved rhabdosome, but short fragments appear almost straight. Width (in relief) about 1mm. Thecae simple tubes with a slight expansion of the free ventral margin, numbering about 8 in 10 mms.

Description: The specimen figured on Pl.5 (fig.3) is almost identical with the specimen figured by Elles and Wood (p.369, text fig.240d). Both have the same thecal length and count and both are preserved in full relief. The Cautley specimen is fractionally narrower, and the thecae are inclined to the axis at a smaller angle.

Specimen HUR./S75,9·4/123 also shows the expansion of the free ventral margin which, unlike the interthecal septum, is convex. The interthecal septum is flat except for a shallow groove running obliquely across it. This does not seem to be a feature caused by flattening or compression since the graptolite is not distorted in any way, and the groove does not lie parallel to the bedding plane but in a plane very slightly oblique to it.

The fact that the interthecal septum is essentially flat, and the free ventral margin convex gives the appearance of a slight excavation of the ventral margin. Upon being flattened this will be accentuated and is well seen in the specimens figured by Lapworth and Elles and Wood (both in specimens in relief and in flattened material).

Other more doubtful specimens (S13-17) seem to show these characters but are too badly preserved to make a definite identification and M. concinnus can only be recorded with certainty from the zone of M.sedgwicki.

Material seen: Specimens figured by Elles and Wood Pl.36,figs.5d and f. and text fig.240d. (H.M.Geological Survey Museum).

Specimens in the Sedgwick Museum, Cambridge.

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genus PRISTIOGRAPTUS GROUP C

Diagnosis: Proximal regions relatively robust and commonly with a distinct ventral curvature over the first few thecae; sicula prominent often extending to the second thecal aperture; rhabdosome usually straight or with very gentle flexures.

Horizon: Typically Wenlock and Lower Ludlow.

Pristiograptus dubius dubius (Suess)

Plate 5,fig.4,5; Plate 25,fig.1,5,7.

1850 Graptolithus colonus Barrande p.43,Pl.2,fig.5.

1851 " dubius Suess p.115,Pl.9,figs.5a-b.

1876 Monograptus colonus, Barrande var. dubius, Suess. Lapworth p.506,Pl.20, fig.10.

1880 " serra Hopkinson MS.Lapworth Pl.4,figs.6c-d.

1883 " dubius Tullberg p.29,Pl.1,figs.28-29,Pl.2,figs.20-21.

1890 " " Holm p.16,Pl.1,fig.18-26.

1893 Monograptus dubius Wiman p.2,Pl.7.
1899 " " Suess. Perner p.9,Pl.14,figs.8,9a-b,Pl.17,figs. 17a-b.
1900 " " (Suess). Wood p.454,Pl.25,fig.1A-B,text fig.9.
1908 " " " Allahverdjiew p.357,Pl.4,fig.3.
1910 " " " Elles and Wood pp.376-8,text figs.247a-b, Pl.37,figs.7a-d.
1924 " " " Hundt Pl.6,figs.8-11.
1929 " " " Haberfelner pp.106-7,135.
1934 " " " Cox p.421.
?1940 Monograptus cfr, dubius (Suess). Desio p.32,Pl.2,fig.15.
1944 Pristiograptus dubius dubius (Suess 1851). Pribyl p.3,Pl.1,figs.4-6.
1945 Monograptus dubius Suess. Waterlot p.70,Pl.25,fig.277.
?1947 " " (Suess). Ruedemann p.479,Pl.84,figs.19-21.
1948 Pristiograptus (Pristiograptus) dubius dubius (Suess). Pribyl p.69, non fig.
1952 Pristiograptus (Pristiograptus) dubius dubius (Suess). Munch p.85,Pl. 18,fig.1.
1953 Monograptus dubius (Suess). Walker pp.365-70,text figs.2-3.
1953 Pristiograptus (Pristiograptus) dubius cf.dubius (Suess). Urbanek p. 285,fig.8.
1955 " " " dubius (Suess). Pribyl and Spasov pp.191-192,non fig.
1955 Monograptus dubius (Suess). Kuhne pp.360-5,fig.2.
1958 Pristiograptus dubius (Suess). 1851 Urbanek p.83.
1958 " (Pristiograptus) dubius dubius (Suess 1851). Pribyl p. 117,Pl.1,fig.1
1960 Monograptus dubius (Suess). Berry p.1160,Text figs.2A,2E.
1962 " " " Ross pp.67-8,text figs.4D,G,H,I,K;5K,L.
?1962 " cf. " " Ross pp.69,text figs.3A,F, 5C (non 5D).
?1962 Pristiograptus dubius dubius (Suess). Romariz p.281,Pl.14,fig.1,Pl.16, figs.4,6, (non 5); Pl.17,fig.3; Pl.21, fig.1.

Holotype: Specimen figured by Suess (1851) Pl.9,fig.5a.

Material: Several hundred specimens all preserved as films.

Horizon and Localities: Wenlock Series, Zones of M.antennulatus , to C.lundgreni; Bluecaster Middle Gill (11M,12-20M,?27-29M), Near Gill (13N,14-21N); Birksfield Beck (8Bf); Whinny Gill (7Wh,9Wh); Ecker Secker Beck (9Ra,12Ra, 13Ra); Hobdale Beck (1Bd); Hebblethwaite Hall Gill (7H,10H); Wandale Hill (3W,4W,6W), Gill A (34W), Gill B(41W,42W,44W,48W), R.Rawthey, Mouth of Wandale Beck (65W,66-67W,69W). Ludlow Series, Zone of P.nilssoni; (2W,7W,8W).

Diagnosis: Rhabdosome of variable length, conspicuous ventral curvature at proximal end, and delicate dorsal curvature throughout the mesial regions.

Maximum breadth 1·9 - 2·0 mms (flattened). Thecae simple tubes, numbering 10-8 in 10 mms inclined at 30-35°.

Description: The most typical shape of the polypary is seen in fig.1 (Pl.25). At the proximal end there is almost invariably a slight ventral curvature involving 4-5 thecae. Mesial fragments often show a gentle dorsal curvature whilst distal portions may be quite straight. The maximum width of the rhabdosome (flattened) which is 1·9-2·0 mms is achieved within 3 cms of the proximal end. The width at the level of th.1 is 0·6 - 0·65 mm.

The thecal spacing in this species is one of the most constant of all the species examined. Proximally there are 10 in 10 mms and distally this falls to 8 in 10 mms. Adult thecae are 2·5 mms long and overlap here is rather more than half.

Remarks: P.d.dubius differs in no way from other British material dexcribed most fully by Elles and Wood (1910). Specimens from the Ludlow Series are, however, a little longer and more slender and may have some affinities with P.d.ludlowensis(Bouc.).

In contradistinction to the situation in the Wenlock, P.d.dubius is not particularly common in the Ludlow Series but of those specimens examined there is no difference in thecal spacing or angle of inclination to distinguish them from P.d.dubius and they are here retained in this subspecies. The only detectable difference is a slight shortening of the thecal tube resulting in a more slender rhabdosome.

Material seen: Specimens in Sedgwick Museum, Cambridge.

Pristiograptus dubius pseudolatus subsp. nov.

Plate 25, fig. 2.

Holotype: HUR./18N/53a, specimen well preserved as an impression, complete proximal region but short, about 4 cms.

Horizon of Holotype: Zone of M.flexilis belophorus.

Derivation of name: "Latinised" to indicate that it is distinct from P.d.latus (Bouc.).

Material: 31 specimens, proximal and distal fragments, all flattened.

Horizon and Localities: Zones of M.flexilis belophorus - C.rigidus mut.(rare at base) Near Gill (18N,19N,16N).

Diagnosis: Rhabdosome several cms long, proximally with dubius-like ventral curvature, but distally quite straight. Maximum width 2·7 mms. Thecal tubes simple, inclined to the axis at 20-30^{o} and numbering 10-7 in 10 mms.

Description: This subspecies is superficially very similar to P.d.dubius but the rhabdosome, whilst showing the same ventral curvature at the proximal end, is distally straight and broader. A width of 2 mms is reached at only 1·5 cms from the proximal end, which, at the level of th.1 is 0·75 mms broad. At $3\frac{1}{2}$ cms the width has increased to 2·34 - 2·47 mms and in the most distal fragments seen reaches 2·7 mms.

Initially P.d.pseudolatus has the same thecal spacing as P.d.dubius (10 in 10 mms) but at $1\frac{1}{2}$ cms the count has already fallen to 7 in 10 mms. This is then maintained to the distal extremity.

The angle of inclination of the thecae is considerably less than in P.d. dubius and ranges between 20-30^{o} being usually nearer 20^{o}.

The sicula is over 2 mms long, usually 2·3 mms and its apex reaches to the level of the second thecal aperture.

Remarks: Many of the bedding planes at the locality of the holotype show no signs of compressional activity and this subspecies is clearly not the result of compression. If compression at right angles to the polypary had taken place (neccessary to increase the rhabdosome width) then the angle of inclination would have been increased (whereas in fact it is less) and the thecae would be more closely packed (in fact they are less closely spaced). At the same time any curvature would be accentuated and the sicula reduced in length; the opposite is true in both cases.

P.d.pseudolatus bears some general resemblance to P.d.latus Bouc. In this latter species however the angle of inclination appears to be higher even than in P.d.dubius (see e.g.Pribyl 1943 Pl.1,fig.7).

From P.meneghini giganteus (Gortani) the Cautley subspecies differs in having a higher thecal count, and from P.sardous sardous (Gortani) in being rather more slender and in having a lower angle of inclination.

Pristiograptus meneghini meneghini (Gortani)

Plate 25,figs.5,6.

1857 Graptolithus (Monograpsus) colonus (non. Barrande) Meneghini (pars) p. 164.

1922 Monograptus meneghini Gort. Gortani p.47,Pl.8(1),figs.3-8,Pl.12(5),fig. 6d,Pl.13(6),figs.2c,4a.

1922 " " " " p.99,Pl.17,(3),fig.10.

1936 " paradubius Haberfelner pp.89-90,figs.2a-b.

1943 Pristiograptus meneghini meneghini (Gortani 1922). Pribyl pp.11-13,text fig.2,figs.E1-3,Pl.1,figs.1-2.

1952 " (Pristiograptus) meneghini meneghini (Gortani). Munch p. 86,Pl.18,fig.9.

1952 " " meneghini meneghini (Gortain). Pribyl pp.26-27,Pl.1,figs.4,15.

1955 " " meneghini meneghini (Gortani,1922). Pribyl p.193,non fig.

?1958 " " cf. meneghini meneghini (Gortani,1922). Pribyl pp.117-8,Pl.1,fig.9.

?1962 " meneghini meneghini (Gortani). Romariz p.283,Pl.13,figs. 13,16,17.

Lectotype: Specimen figured by Gortani (1922) Pl.8(1),fig.4.

Material: About 50 specimens, all flattened, several proximal ends, but distal fragments are more common.

Horizon and Localities: Stages 2 and 3 (Wenlock Series); Bluecaster Near Gill (16N,17N,20N,21N,22N,23N), Middle Gill (16M), Wandale Hill (68W).

Diagnosis: Rhabdosome similar in appearance to but broader than P.pseudodubius (Bouc.). The proximal region shows distinct ventral curvature but distal fragments are straight. A maximum width of 1·6-1·7 mms is attained. Thecal count 9-7 in 10 mms.

Description: The rhabdosome is rather longer than that of P.pseudodubius and may reach 5 cms whilst a breadth of 1·6-1·7 mms is reached in some specimens.

The sicula is full 2 mms long and its apex extends to about the level of the second thecal aperture. At the level of th.1 the rhabdosome has a breadth of 0·65 mm (flattened) which increases distally to 1·43-1·5 mms in most specimens. Some specimens, however, from the top of Stage 2 (Zone of M. antennulatus) are rather broader, 1·6-1·7 mms and in this respect agree with the Bohemian forms described by Pribyl (1943). Specimens in Stage 3 (Zones of M.flexilis belophorus - C.rigidus mut.) have a maximum width of 1·43-1·5 mms.

There is a difference also in the thecal spacing between specimens from the two horizons. Those from the lower horizon (Stage 2) have thecal counts 9-7 in 10 mms - again agreeing with Bohemian material - with occasional readings of 10 in 10 mms at the proximal end. In Stage 3 readings of 10 in 10 mms are more common and the full range is 10-8 in 10 mms. The most usual value obtained is 9.

The angle of inclination in most specimens is 30° or rather less.

Remarks: The slight shift in diagnostic characters from Stage 2 to Stage 3 of this species is regarded as a gradual change which would, if continued, give rise to P.pseudodubius. Thus those specimens from Stage 2 are identical with P.m.meneghini whereas specimens from Stage 3 are narrower and have a slightly increased thecal count.

Pristiograptus pseudodubius (Boucek)

Plate 25, figs.8,9

1932 Monograptus pseudodubius Boucek pp.1-2, Pl.2e-f.

1944 Pristiograptus pseudodubius(Boucek 1932). Pribyl pp.8-9, Pl.1, fig.8, text fig.I,3.

1945 Monograptus pseudodubius Boucek. Waterlot pl.26, fig.288.

?1962 Pristiograptus pseudodubius (Boucek). Romariz Pl.16, fig.3.

Lectotype: Specimen figured by Boucek in fig.2e, and refigured by Pribyl, text fig.I,3.
Material: About 30 specimens, invariably flattened, usually poorly preserved.
Horizon and Localities: Stage 4, Zone of C.lundgreni; Near Gill (25N-28N); Hobdale Beck (3Bd.); R.Rawthey (2Ra).
Diagnosis: Rhabdosome short, narrow, with gentle ventral curvature throughout. Maximum width 1mm, thecae number 10 in 10 mms.
Description: The rhabdosome is typically short and slender, appearing gently arched with the thecae on the concave side. Specimens over 2 cms long have not been observed. Flattened specimens, compressed at right angles to the polypary, show thicknesses up to 1·17 mms.

The conspicuous sicula is 1·5 mms long, with its apex reaching almost to the level of th.2. A short, stout virgella is present.

Proximally the thecal spacing is rather closer (11-10 in 10 mms) falling to 10-9½ in 10 mms mesially and distally. The thecal tubes have a maximum length of 2 mms and overlap throughout the rhabdosome for one half of their length. They are inclined to the axis at 20-30°.
Remarks: In all their diagnostic features the Cautley specimens agree with P.pseudodubius (Bouc.). The Cautley material is however, closer in general appearance to other material figured by Pribyl (1943, Pl.1, fig.8) than to the original figured by Boucek (1932, fig.2e) and Pribyl (1943, text fig.I3) which appears to be a rather broad variant. Pribyl (p.9) does mention that rather broad forms can occur.

P.pseudodubius has a superficial resemblance to P.m.meneghini (Gortani). It differs from the latter in being even narrower (1mm cf.1·5-1·7 mms) and in having a higher thecal count. P.m.meneghini has been found at Cautley in Stage 3 and it may have given rise to P.pseudodubius which is typical of Stage 4, since both forms are obviously closely related.

The same order of appearance is maintained in Bohemia (Pribyl 1943, p.44).
Material seen: A specimen labelled M.dubius from C.lundgreni Zone in Sedgwick Museum (S22,008). This specimen is close to the form here described as P. pseudodubius.

Pristiograptus vicinus (Perner)

Plate 25, fig. 3; Plate 23, fig. 11.

1899 Monograptus vicinus n.sp. Perner p.22, Pl.14, figs.25a-b.
1900 " comis, sp. nov. Wood p.459, Pl.25, figs.8a-b, text fig.12.
1910 " " , Wood. Elles and Wood p.381-2, Pl.37, fig.9, text fig. 251.
1936 " vicinus Perner. Boucek p.7, non fig.
1936 " compressus Boucek p.7-8, Pl.1, figs.11-12.
1943 Pristiograptus vicinus (Perner 1899). Pribyl pp.15-18, Pl.1, fig.10-11, text figs.12, and II, N, O, P.
1945 Monograptus vicinus Perner. Waterlot Pl.23, fig.263.
1945 " comis Wood. Waterlot Pl.26, fig.283.

Holotype: Specimen figured by Perner Pl.14, figs.25a-b.
Material: About 30 specimens, all flattened.
Horizon and Localities: Ludlow Series, Zone of P.nilssoni; Wandale Hill (7W, 8W).
Diagnosis: Polypary slender, almost straight to slightly curved (ventral), short, maximum breadth 1·3 mms. Thecae simple, overlapping tubes numbering about 10 or 11 in 10 mms, 2 mms long (max.), overlap about one half.
Description: The rhabdosome varies from almost straight to specimens which, commonly show a ventral curvature of the proximal end. Only rarely does this species exceed 2 cms in length. The maximum breadth of flattened specimens occurs at the distal extremity, and is 1·3 mms. This is achieved by slow and steady widening from a breadth of 0·5 mms at the level of th.1.

The sicula merges inconspicuously into the polypary and its apex can only be detected by the presence of a slight indentation in the dorsal margin of the rhabdodome. Its length is 1·5 mms and it extends above the level of the aperture of th.1. The sicula aperture has a short prominent virgella.

The thecae are not uniformly spaced throughout the rhabdosome. They number 11 or 12 in 10 mms proximally, 11 in 10 mms mesially, and 10 in 10 mms distally. The angle of inclination increases to 25°- 30° distally.
Remarks: Perner's original specimen shows considerable ventral curvature of the type shown by P.bohemicus, and it is not surprising that Wood (1900) gave

the British form a new name (M.comis). Pribyl (1943) however, redescribes and figures Bohemian material and considers that M.comis Wood and P.vicinus Perner are synonymous.

Material seen: Specimens in Wood Collection, Sedgwick Museum, labelled M.comis.

Pristiograptus auctus sp. nov.

Plate 5,figs.6-9; Plate 25,fig.4.

Holotype: HUR./7W/62 almost complete, flattened impression.

Horizon of Holotype: Ludlow Series, Zone of P.nilssoni, 2nd graptolite band; Wandale Hill (7W,8W).

Derivation of name: auctus, L. 'increase','growth'.

Material: About 40 specimens, all flattened.

Horizon and Localities: Zone of P.nilssoni, 2nd graptolite band; Wandale Hill (7W,8W).

Diagnosis: Rhabdosome long, broad, and stiff. Proximal end invariably with slight ventral curvature, distal parts usually straight. Thecae long, simple overlapping tubes numbering 18-11 in 10 mms. Sicula long, virgella short and transversely (?) expanded into a disc.

Description: The rhabdosome is about 4 cms long and usually straight distally though some specimens show a gentle dorsal curvature. The proximal end is invariably ventrally curved to the extent that 6 thecae are involved. A maximum width (flattened) of rather less than 2 mms is achieved within 2 cms of the sicula but specimens compressed at right angles to the line of the polypary show values of slightly over 2 mms. At the level of th.1 the rhabdosome width is 0·7 - 0·75 mm.

The sicula is not always conspicuous but has a length of 2·3 mms. Its apex reaches to the level of the aperture of th.3. Thecal spacing over the first few mms of the polypary is very close and varies from 17-20 in 10 mms. depending upon the direction of compression. A value of 18 in 10 mms is the most constant. At a distance of 4-7 mms from the base of the sicula the thecal count has fallen to 13-18 in 10 mms, 15 in 10 mms being the usual figure, whilst distally 10-14 is the total range encountered.

The thecae are simple tubes which reach a maximum length of 2·5 mms in the distal region. Here the overlap has increased to three-quarters from two-thirds proximally, and the thecal tubes are inclined to the axis at up to 45°.

One of the most striking features of the specimens is the presence of a short virgella (0·6mm) which swells out into a bulb-like shape and has the appearance of a globule hanging from the proximal end of the rhabdosome. This is approximately 0·4-0·5mm in diameter. Thickening of the virgella in this manner is invariably present but one specimen, less expanded than the others suggests the possibility that the virgella is transversely expanded, and that only upon compression does it rotate to the bedding plane. If this is the case specimens with the swelling half buried are to be expected.

It is not possible to decide whether this feature is one of specific importance or whether it is a parasitic phenomenon. In support of the former interpretation are the facts that it is invariably present in P.auctus and that it does not appear on other species from the same horizon.

Remarks: P.auctus is clearly close to such species as P.vulgaris (Wood) and P.tumescens(Wood). The degree of curvature of the proximal end is intermediate between these two species, whilst the width of the rhabdosome is nearer P.tumescens. The combination of characters described above serves to distinguish P.auctus from both these species.

Elles and Wood (1910,p.380) describe forms of P.tumescens from the Lake District which are shorter, broader, and have a higher thecal count (13-12 in 10 mms) than those from the type area. It is possible that these are related to the species here described although P.auctus is longer than P.tumescens.

Pristiograptus welchi sp. nov.

Plate 23, fig.10; Plate 25,fig.11

Holotype: Specimen HUR./1Ab/22 and counterpart 22a.

Horizon of Holotype: Zone of M.leintwardinensis, in association with M.l.aff. leintwardinensis Hopk. M.S. and M.l.aff. incipiens Wood.

Locality of Holotype: 1Ab,Adamthwaite Bank, Ravenstonedale, Westmorland.

Material: A few more fragmentary and less well-preserved specimens. The holotype is flattened but not unduly compressed being perhaps slightly reduced in *in width.

Derivation of name: After E.G.Welch who, in conjunction with Watney, produced a valuable paper (1911) on the Salopian fauna of the Cautley area.

Diagnosis: Very small, narrow rhabdosome with only a few thecae. Length about 5 mms, width (flattened) 0.65 mm to 0·7 mm. Proximal end with slight ventral curvature. Sicula about 1·2 mms long; thecal count 14 in 10 mms.

Description: The tiny polypary is most characteristic and specimens preserved in relief must be very narrow, possibly of the order of 0·5 mm. Some specimens slightly exceed 5 mms in length and the holotype is 5·33 mms. The maximum breadth in flattened specimens is about 0·7 mms and this is achieved by the fourth or fifth theca.

The sicula is not prominent but has a length of 1·2 mms. Its apex reaches to the level of the aperture of th.1. About 6-8 thecae may be present on the rhabdosome and these are all of simple pristiograptid type with a maximum length of 1·3-1·4 mms, and a width of 0·2 to 0·22 mm (flattened specimens). Distally the thecae overlap for one half their length, but rather less than this proximally.

The thecae number 14 in 10 mms, throughout the rhabdosome and are inclined at a low angle to the axis of the rhabdosome - about 20° distally and less at th.1 and th.2.

Remarks: The only form approaching this species in dimensions is P.praeultimus Münch from the nilssoni-scanicus Zone of Thuringia. This is of similar length but rather broader (1·0-1·1 mms compared with 0·7mm). The thecal count is similar (12-14 in 10 mms compared with 14 in 10 mms). However the thecae are of P.ultimus (Perner) type and in flattened specimens a slight excavation of the ventral margin is seen suggesting that the thecae are not of simple pristiograptid form.

This is a rare species at Cautley and it was not recorded by Watney and Welch (1911) in their work on the Salopian rocks.

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* Other material from locality 1We, nilssoni-scanicus Zones.

?Pristiograptus wandalensis (Watney & Welch)

Plate 26, fig.4; Plate 25, fig.10; Text fig.8

1911 Monograptus wandalensis sp. nov. Watney & Welch pp.235-6, fig.4A-C.
?1924 " " Watney & Welch. McLearn pp.35-6, Pl.1, fig.7.
?1947 " " " " . Ruedemann p.491, Pl.85, figs.15-16.

Material: Several specimens preserved in full relief, none as flattened impressions.

Horizon and Localities: Ludlow Series; Zone of P. nilssoni, ?1st graptolite band; Wandale Hill (2W).

Diagnosis: Rhabdosome short, less than 2 cms long, straight, to dorsally curved. Maximum width (relief) 1·43-1·5 mms. Thecae number 19-13 in 10 mms. Sicula 1·43 mms. Angle of inclination decreasing distally to 35° .

Description: Watney and Welch in their original description give the curvature as dorsal. The author's material shows that the curvature varies between straight and dorsal and one specimen even shows ventral curvature.

The sicula is very prominent, 1·43 mms long and with its apex reaching well above the level of th.2. Th.1 and 2 are very short (0·6mms) and are inclined to the axis at 50°, whilst the apertures of both thecae narrow considerably. Later thecae become inclined at a lower angle and eventually remain constant at 35°. Here the thecal tubes are almost 2 mms long and overlap for two-thirds their length.

In profile view the thecal apertures appear to be slightly concave, though this feature is not obvious in all specimens. The tendency to narrow aperturally, described by Watney and Welch, is not a prominent feature and seems restricted to the proximal thecae. The appearance of isolation of the apertural region, coupled with narrowing of the aperture, figured by these authors (fig.4C) is a common feature caused by obscuring of the aperture by chloritic material. Fig.4A gives a more accurate picture of the thecae.

Remarks: The exact character of the first theca of the rhabdosome is still not known with any certainty. It narrows to 0·13 mms and is rounded in profile, whereas th.2 is 0·3 mms across the aperture and is similar to succeeding thecae. Th.1 may not in fact, be pristiograptid at all.

TEXT FIG. 8a1-8

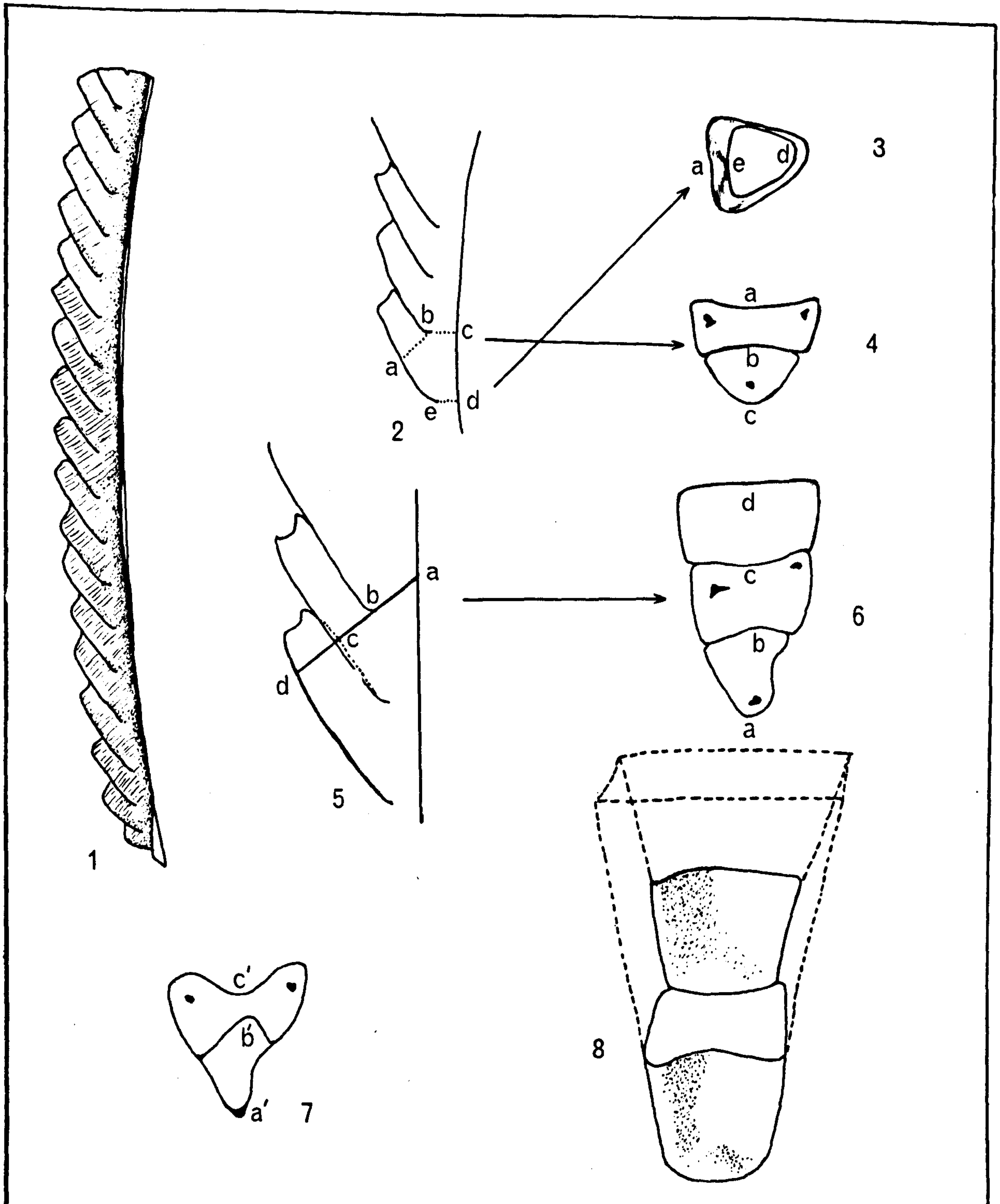
1. Pristiograptus? wandalensis (Watney & Welch), HUR/2W/7; partially destroyed or being taken apart.

3 & 4. Sections across the rhabdosome as shown in fig.2.

6. Section along the line abcd shown on fig.5.

7. Similar section to line abc of figure 5 but at a more distal part of the rhabdosome.

8. Dorsal view of proximal thecae with metatheca removed (shown by dotted lines).



1
2
a
b
c
d
e
3
a
e
d
4
a
b
c
5
a
b
c
d
6
d
c
b
a
7
c′
b′
a′
8

TEXT FIG. 8b1-8

(specimen HUR/2W/7)

1. Key to figs. 2-7.

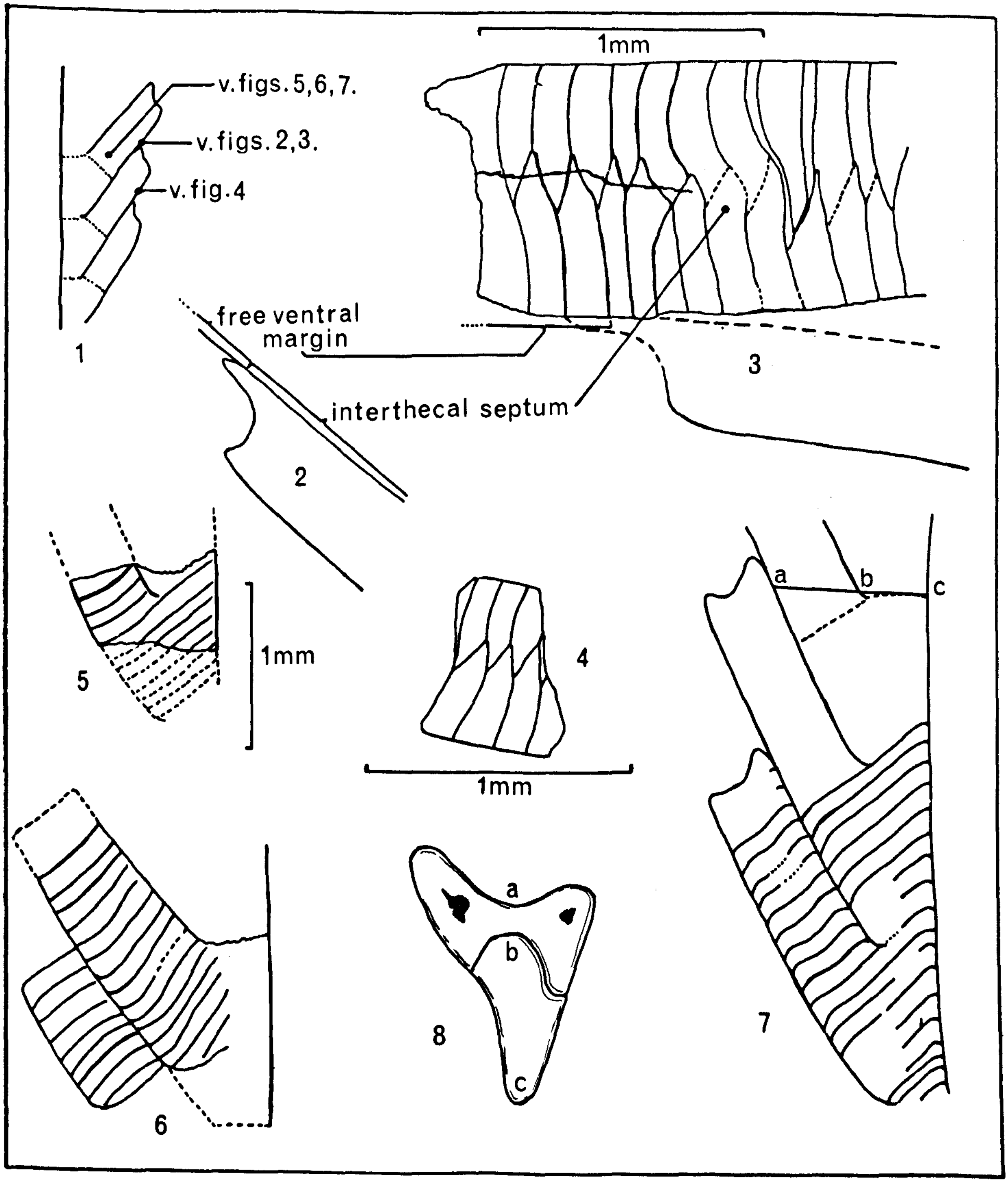
3. Sketch showing growth rings of interthecal septum.

4. Sketch showing growth rings of free ventral wall.

5,6. Sketch showing growth rings on part of protheca and metatheca.

7. As figs. 5,6 but with key to fig.8.

8. Section along the line abc of fig.7, distal part of rhabdosome.



v.figs.5,6,7.
v.figs.2,3.
v.fig.4
1
1mm
free ventral margin
interthecal septum
2
3
5
1mm
4
1mm
a
b
c
6
a
b
8
c
7

genus PRISTIOGRAPTUS GROUP D

Diagnosis: Rhabdosome with strong ventral curvature becoming straighter distally; thecal tubes with small amount of overlap, and slight expansion in region of free ventral margin; aperture may have a "lip".

Horizon: Lower Ludlow.

Pristiograptus bohemicus (Barrande)

Plate 26, figs.1-3; Plate 28, fig.13.

1850	Graptolithus bohemicus		Barrande p.40,Pl.1,figs.15-18.
1851	"	"	Suess pp.110-111,Pl.8,figs.6a-e.
1851 ?	"	Barrandei	Scharenberg p.15,Pl.1,figs.5-5a.
1852	Monograpsus bohemicus		Barrande. Geinitz p.36,Pl.2,fig.41.
1869	Graptolithus	"	Heidenhain p.149,Pl.1,figs.4a-c.
?1878	Monograptus	"	Haupt p.19.
1881	Graptolithus scalaris		Quenstedt Pl.c 1,fig.44.
1883	Monograptus	bohemicus	Barr. Tullberg Pl.3,figs.3-5.
1884	"	"	La Touche p.77,Pl.18,fig.573.
1889	Pristiograptus	"	Barr.sp. Jaekel pp.672-3,Pl.28,figs.3-6.
1890	Monograptus	"	Geinitz p.14,Pl.A,fig.10.
?1892	"	"	Barrois p.99.
1897	Pristiograptus	"	Frech, p.644.
1899	Monograptus	"	Perner pp.25-26,Pl.14,figs.15-16,Pl.17,figs. 3,8,9,11,text figs.17-18.
1899	"	"	rarus Perner p.26,Pl.17,fig.10.
1900	"	"	(Barr.) Wood p.483,text fig.25,Pl.25,figs.27A & B.
1908	"	"	Barr. Allahverdjiew p.338,Pl.4,fig.5.
1911	"	"	(Barrande). Elles and Wood p.367-8,Pl.36,figs. 4a-d,text figs.239a-c.

1920 Monograptus bohemicus (Barrande). Gortani p.26, Pl.2, figs.9-10.
?1924 " " " Hundt p.72, Pl.3, fig.6.
1928 " falciformis Shrock pp.2?4-6, figs.7-8.
1929 " bohemicus Barrande. Haberfelner pp.126-127.
1931 " " " Boncev pp.55, 59.
1933 " " " Thomas & Keble p.76.
1935 " " " Decker p.438, figs.20-24.
1936 " zarizelliensis Haberfelner pp.87-88, text fig.1.
1936 " bohemicus (Barrande). Boucek p.3, Pl.1, figs.1-3.
1937 " " " Harris & Thomas p.70, Pl.1, figs.4-6.
1939 " " " Keble & Benson p.84.
1939 " " " Hundt pp.87, 126.
1942 Pristiograptus " " Munch p.246, Pl.1, fig.1.
1945 Monograptus " Barr. Waterlot p.62, Pl.23, fig.261.
1947 " " (Barrande). Ruedemann p.474, Pl.84, figs.2-5.
1947 " falciformis Shrock Ruedemann p.480, Pl.92, fig.15.
1948 Pristiograptus (Pristiograptus) bohemicus bohemicus (Barrande). Pribyl p.68.
1949 Monograptus " " (Barrande). Obut p.20, Pl.3, figs.4a-b.
1951 " bohemicus (Barrande). Sherrard p.130, Pl.8, fig.d,e; text fig.2d.
1952 Pristiograptus (Pristiograptus) bohemicus bohemicus (Barrande, 1850). Pribyl pp.23-26, Pl.2, figs.5-6.
1955 " " " bohemicus (Barrande, 1850). Pribyl and Spasov p.191.
1955 Monograptus bohemicus Barrande. Kuhne pp.382-4, text fig.9, A-I.
1958 Pristiograptus bohemicus (Barrande), 1850. Urbanek pp.77-80, pl.4, figs. 1-3, text figs.46-51
1962 Monograptus bohemicus (Barrande). Ross p.64-65, text figs.5G,H,J.

Material: Many specimens preserved in relief and as flattened impressions the latter as a rule being more complete.

Horizon and Localities: Ludlow Series, Zone of *P.nilssoni*.

Diagnosis: Rhabdosome with characteristic ventral curvature, almost straight distally, and up to 3-4 cms in length. Maximum width approximately 1·5 mms. Thecae number 12-8 in 10 mms and are simple tubes.

Description: The actual form of the rhabdosome with its constant and conspicuous ventral curvature is highly characteristic and it may be immediately distinguished from P.nilssoni by its complete lack of dorsal curvature and the more robust nature of the polypary.

The sicula is approximately 1·17 mms long and its apex extends almost to the level of thecae 1. At the base it is 0·4 mms across (flattened) and is provided with a short virgella.

Closer packing of the thecae is seen at the extreme proximal end where they usually number 10 or 11 in 10 mms, but some readings of 12 in 10 mms have been noted. The width of the rhabdosome at the aperture of th.1 (flattened) is 0·52-0·55 mms. The early thecae increase quickly in length and overlap: th.1,1mm long; th.2,1·3 mms long; th.3,1·43 -1·5 mms long. Overlap at this position on the rhabdosome is from almost nil at th.1-2 to one quarter of the thecal length at th.3-4.

The most distal fragments obtained attain a breadth of 1·5 mms (relief) and the thecae overlap for about half their length. They are inclined to the axis at 25° and are over 2 mms long. The thecal count regularly drops to 8 in 10 mms.

There is a slight change in the nature of the thecal tube from the proximal to the distal region. Distally, where the rhabdosome is straight the tube appears to be quite simple and the apertural margins everted. At the proximal end however, where the thecae invariably occur on a ventral curve, the apertural margins are at right angles to the line of the polypary and the free ventral margin shows an expansion immediately on becoming free. This continues almost to the aperture where there is a sudden, slight, and temporary contraction resulting in a distinct "lip".

This feature of expansion of the thecal tube is clearly not a result of breaking outwards of the free ventral margin upon compression since it is equally prominent in specimens preserved in relief. Upon compression the "lip" may appear as a short denticle on the ventral extremity of the aperture.

Remarks: The Cautley specimens have a slightly greater range of thecal count than is usually given for British specimens (see Elles and Wood 1910,p.367; Wood 1900,p.483) and no specimens have been found whose thickness reaches 2 mms

Material seen: Specimens in Sedgwick Museum, Cambridge.

Specimens from Hassi Bedda - 1A well, Algeria (provided by W.A.Knaap, Compagnie des Petroles D'Algerie).

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genus MONOGRAPTUS Geinitz, 1852 emend.

(pro Lomatoceras Bronn, 1835; Monoprion Barrande, 1850; ICZN Opinion 198)

(= Pomatograptus Jaekel, 1899; Spirograptus Gurich, 1908; Demirastrites Eisel, 1912; Oktavites Levina, 1928; Streptograptus Yin, 1937; Pernerograptus Pribyl, 1941; Colonograptus, Pribyl, 1942; Saetograptus Pribyl, 1942; Globosograptus Boucek & Pribyl, 1948; Mediograptus Boucek & Pribyl, 1948; Campograptus Obut, 1949; Tyrsograptus Obut, 1949 (= Spirograptus); Cucullograptus Urbanek, 1954; Obutograptus Mu, 1955 (= Oktavites); Lobograptus Urbanek, 1958).

Type Species: Lomatoceras priodon Bronn, 1835; subsequently designated Bassler, 1915.

Generic diagnosis: emended only to exclude Rastrites Barrande 1850 (as was also done, for example, by Bulman, 1955), Pristiograptus Jaekel 1889, and Monoclimacis Frech, 1897; thecal tubes highly variable; in many species two thecal types in the same rhabdosome, one proximally and the other distally; curvature of rhabdosome highly variable.

genus MONOGRAPTUS GROUP A

Group diagnosis: Rhabdosome slender, variously curved but usually dorsally; proximal end often very fine; thecal tubes long in proportion to width, closely adpressed to the axis, showing varying degrees of sigmoidal curvature; apertural margins everted to introverted most commonly the latter.

These forms do not fit conveniently into any of the above groups considered synonymous with Monograptus Geinitz.

Monograptus atavus Jones

Plate 5, figs.10,11; Plate 26, figs.5,6; Plate 28, figs.2,3

1909	Monograptus atavus sp. nov.	Jones	p.531, figs.18a-d.
1910	" "	Jones.	Elles & Wood pp.403-4, text figs. 270a-e, Pl.39, figs.1a-d.
?1931	" "		Haberfelner Pl.1, fig.8.
?1934	" "	Jones.	Hsu p.96, Pl.7, fig.7a-b.
1945	" " "		Waterlot Pl.30, fig.316.
?1955	Pristiograptus (Subgen?) atavus Jones, 1909.		Pribyl. p.195 listed.

Material: Several hundred specimens, usually flattened or in low relief, but some in full relief. Always fragmentary; polypary of great length.

Horizon and Localities: Extremely common from a few feet above the base of the Silurian to the base of the M.triangulatus zone. Rare in this latter zone and does not occur above; Spengill (S1-5 to S24-28); Birks Beck (1Bi, 2Bi); Pickering Gill [illegible]

Diagnosis: Curvature variable but usually with slight dorsal curvature proximally, stiff and straight distally. Maximum breadth 1·1-1·2 mms. Apertures may be slightly everted distally but usually show slight introvertion. Thecae with flowing sigmoidal curvature. Overlap up to one half.

Description: The polypary is of great length and distinctly more robust than in M.sandersoni and M.incommodus. At the proximal end the curvature is almost always gently dorsal whilst distally it is more variable and may be ventral, straight or dorsal. Dorsal curvature is more usual however.

The number of thecae in a given unit of length varies between 5-7 in 10 mms in specimens compressed parallel to the length of the polypary, and 12-14 in 10 mms in those compressed at right angles to the length. In the uncompressed state they usually number 7-11 in 10 mms. The chart (text fig. 8c) shows the range of thecal count obtained for specimens suffering varying degrees of compression. The tables for horizons S1-5, and S5-9 show that in specimens relatively unaffected by compression (i.e. those which have suffer-

TEXT FIG. 8c

A = Measurements taken on specimens having lineation parallel to the length of the rhabdosome.

B = Measurements taken on specimens having lineation oblique to length of rhabdosome.

C = Measurements taken on specimens having lineation at right angles to length of rhabdosome.

VARIATIONS OF THECAL SPACING IN M. ATAVUS JONES.

(no. of thecae per cm.)

Locality S1-5			Locality S5-9		
A	B	C	A	B	C
6-7	8-9	12	6-7	8	13
6-7	7·5	11	6-7	9	9-9·5
6-7	7·5-8		6-7	8	13
6-7	10		6	9	13
6			6	8	13
6			5	7·5	13
7·5			7·5	8	10-11
9·5			6-7	8	10-11
			5	9·5	10-11
			5		10-11
			6-7		
			5		
Locality S9-13			**Locality S13-17**		
6	5	10-11	5	6	
6-7	8-9	10-11	5-6	6	
	8-9	10-11		8-9	
	8-9	13-12		8-9	
	8	13-12		8	
		10-11		7-8	

ed oblique compression) the usual thecal count is $7\frac{1}{2}$-9 with occasional variants showing 10. (The very high thecal counts of 13 in 10 mms may have resulted from compression of these extreme variants at right angles to the length of the polypary). The tables for horizons S9-13 and S13-17 show a slight shift in values and lower counts of 5 and 6 are seen. These figures agree with those given by Jones (1909) and Elles and Wood (1910) but suggest a greater range of variation.

The thecae show a variable amount of sigmoidal curvature but this is usually less than in M.argutus Lapw. Proximal thecae show the greatest sigmoidal curvature and also the greatest amount of introversion of the apertural margin. This latter feature becomes less distally where slight evertion can often be seen. Naturally certain directions of compression will accentuate both evertion and introversion of the margin.

The angle of inclination of the thecae to the axis is greater in M.atavus than in M.sandersoni and M.incommodus but in the Cautley specimens this angle is less than for the figured Welsh specimens (Jones 1909), Elles and Wood (1910) suggesting a tendency towards M.incommodus. Overlap increases distally to a maximum value of about one half the length of the thecae.

Remarks: M.atavus Jones is the first monograptid to appear in the Silurian strata. It may give rise to M.incommodus Toern. which first appears in the zone of M.cyphus (S13-17). This would involve the loss of the everted apertural margins seen in M.atavus, a decrease in the angle of inclination, and a lessening of the overlap; in short, loss of the characters typical of the distal parts of M.atavus. The same tendencies carried to a greater degree would result in M.sandersoni Lapw.

Material seen: Specimens of M.tenuis (Portlock) (=atavus) from Spengill (S.M. nos. A21069-71).

Specimens in H.M.Geological Survey Museum.

Specimens figured Jones 1907 fig.18a (syntype) and 18b. Figure 18a is very similar to the specimen in relief figured here on Pl.26 (fig.5).

Specimens figured Elles and Wood Pl.39,figs.1a,b,d and text fig.270c-d.

Monograptus argutus argutus Lapworth

Plate 26, fig.7

1876	Monograptus argutus, sp.nov. Lapworth	pp.318-319, Pl.10, figs.13a-c.
1910	" " Lapworth.	Elles and Wood pp.408-9, text figs.274 a-f, Pl.40, figs.3a-c.
?1924	" argatus Lapworth.	Hundt Pl.4, figs.18,19,33,34; Pl.6, figs7
?1933	" Argutus Lapworth.	Sun p.44, Pl.7, fig.4.
?1934	" argutus Lapworth.	Hsu p.97, Pl.7, figs.8a-e.
?1945	" " Lapw.	Waterlot Pl.30, fig.315.
?1948	Pristiograptus (Subgen?) argutus Lapworth.	Pribyl.listed pp.78-79.
?1955	" " " " " "	p.195.

Holotype: Specimen partly figured by Lapworth Pl.10, fig.13b and refigured completely by Elles and Wood Pl.40, fig.3a.

Material, Horizon and Localities: Not a common fossil but several specimens were obtained, preserved in relief from (9Bi) Birks Beck section. This horizon is in the D.magnus Zone. Other specimens probably referable to this species have been found in the M.triangulatus zone, Spengill, and M.convolutus Zone (9Wa).

Diagnosis: Rhabdosome arcuately curved with thecae on convex side, reaching a breadth of over 1mm. Proximal end strongly recurved and thecae closely set (12 in 10 mms) in this region. Distal fragments are straighter and thecal count lower (down to 8 in 10 mms).

Description: The thecae are highly characteristic having introverted and introtorted apertural regions. The aperture is twisted more towards the obverse side and the apertural region, in the obverse view, appears as a tiny lobe which slightly impresses the ventral margin of the succeeding theca.

The angle of inclination is approximately 20° throughout the rhabdosome and the thecal tubes overlap for one half their length.

The degree of sigmoidal curvature in the Cautley specimens is slightly less than is suggested by the description of Elles and Wood but the material compares well with the specimens figured in their text figure 274.

Remarks: M.argutus argutus is a typical, if uncommon fossil of the M.triangulatus to M.convolutus Zones.

Material seen: Specimens in Sedgwick Museum, Cambridge.

Specimens figured Elles and Wood Pl.40, figs.3b, d, and text figs.274a.

Monograptus argutus sequens subsp. nov.

Plate 27, fig.4.

Holotype: HUR./S73,11·4/73.

Horizon of Holotype: Zone of M.sedgwicki.

Material: Rare, one well preserved specimen as a mould and other fragmentary specimens from the same horizon; (S73,11·4), Spengill.

Derivation of name: sequens, Latin, meaning "following".

Description: This subspecies is very close indeed to M.argutus argutus Lapw. but is distinctly narrower and more stiffly curved whilst the thecae are more closely set.

In most characters the thecae agree with those of M.a.argutus but they are shorter (maximum 1·1-1·2 mms) and number 13-15 in 10 mms compared with 12-8 in 10 mms in the case of M.a.argutus.

The thickness of the rhabdosome reaches a uniform thickness of about 0·5 mms and is distinctly narrower than M.a.argutus.

Remarks: M.a.argutus Lapw. is recorded by Elles and Wood (p.522) from the zones of M.gregarius and M.convolutus. It seems likely that M.a.sequens subsp. nov. is a direct successor of the earlier form.

Monograptus jonesi sp. nov.

Plate 27, fig.1

Holotype: HUR./6Bi/76.

Horizon of Holotype: P.leptotheca Zone.

Material; Horizon and Localities: Rare, one specimen 2 cms long, well preserved, other fragments from same horizon and locality. Birks Beck (6Bi) zone of P.leptotheca.

Derivation of name: After Jones, author of M.atavus.

Description: The rhabdosome is slender, fragile and shows dorsal curvature in all the fragments seen. The thickness of the polypary does not exceed 0·3 mms and the minimum value observed is 0·25 mms. A uniform thickness, therefore, prevails throughout the length.

In the most proximal portion the thecae number 11 in 10 mms. Distally this falls to about 10 in 10 mms although the thickness of the rhabdosome has increased but slightly.

The thecae are long, narrow tubes closely adpressed to the axis and showing distinct sigmoidal curvature a short distance above their origin. Overlap is small and always less than one quarter of the thecal length. Apertural details cannot be ascertained but they appear to be of the M.argutus Lapw. type.

Remarks: The species with the closest affinities to M.jonesi sp. nov. are undoubtedly M.atavus Jones and M.argutus Lapw. From these forms it differs in being more uniformly slender, in having its thecae inclined to the axis at a very low angle, and in the number of thecae in a given unit of length. In M.sandersoni Lapw. the thecae are different and the curvature usually ventral, though the width of the proximal region is similar. The slender polypary of M.incommodus is also comparable but the "argutus"-like thecae and degree of overlap distinguish it from this species.

Monograptus sandersoni Lapworth

Plate 27,fig.2

1876	Monograptus Sandersoni, sp. nov.	Lapworth p.320,Pl.11,figs.2a-e.
1910	" " Lapworth.	Elles and Wood pp.404-5,text figs. 271a-d,Pl.39,figs.10a-e.
?1931	" cf."	Haberfelner Pl.1,fig.9.
?1933	" sandersoni Lapworth.	Sun p.43,Pl.7,fig.3
1945	" " "	Waterlot Pl.30,fig.319.

Material: Poorly preserved fragments.

Horizon and Localities: M.triang. Zone, Spengill.

Description: Only a few fragments which are referable to this species have been found. These show slight sigmoidal curvature of the thecae, which are

adpressed to the rhabdosome, and whose apertures are introverted. The specimen figured on Pl.27,(fig.2) has a thecal count of approximately 6 in 10 mms whilst a thickness of 0·52 mms is attained. All the fragments are of insufficient length to determine the overall degree of curvature of the polypary.
Remarks: M.Sandersoni Lapw. is recorded from Spengill section by the workers of H.M.Geological Survey (Dakyns et al. 1891) but it is possible that some of their specimens were Tornquist's species M.incommodus.
Material seen: Specimens figured Elles and Wood Pl.39 fig.10d and text fig. 217c (H.M.Geological Survey Museum). Specimens in Sedgwick Museum, Cambridge.

Monograptus incommodus Toernquist

Plate 27,fig.3; Plate 28,fig.1

1899	Monograptus incommodus	n. sp. Toernquist	p.11,Pl.2,figs.1-5.
1910	" "	, Toernquist.	Elles and Wood p.406,text fig.272a-e,Pl.40,figs.1a-e.
?1924	" "	Hundt	Pl.6,fig.18.
?1931	" "	Haberfelner	Pl.1,fig.10.
1933	" "	Tornquist.	Sun p.38,Pl.6,fig.3.
?1945	" "	Tornq.	Waterlot Pl.30,fig.320.
?1947	" "	Tornquist.	Ruedemann p.481,Pl.85,fig.26.

Material: Many specimens, preserved as impressions, fragments of varying lengths.
Horizon and Localities: Very common in the zone of P.cyphus: Spengill (S13-17, S17-20,S20-24). Pickering Gill (12P).
Diagnosis: Long, very slender and fragile, often with dorsal curvature: maximum breadth about 0·7 mm. Thecae number down to 7 in 10 mms.
Description: The rhabdosome is extremely long, slender and fragile. Complete specimens have not been obtained. The proximal end is so slender that details cannot usually be determined, though in suitable specimens the thecae are seen to be identical with those of the distal portion, whilst the overlap is rather less. Overlap reaches one half in the distal thecae.

Throughout the polypary the ventral margins of the thecae are almost parallel to the dorsal margin so that in poorly preserved material it may be impossible to see the thecae at all. This is particularly true when the fossil is compressed parallel to the length of the polyrary. Compression in the opposite direction increases the width of the rhabdosome and at the same time makes the thecal aperture more visible.

Allowing for compressional effects the thecal count falls within the range given by Tornquist (7 in 10 mms) and Elles and Wood (8 to 7 in 10 mms).

The thecal apertures are at right angles to the dorsal margin of the rhabdosome and are quite even. There seems to be no evertion, introvertion, or torsion.

Whilst sigmoidal curvature of the thecae may be discerned it is less well developed than in any other species of this group.

Remarks: M.incommodus is very distinctive and can be distinguished from M. sandersoni Lapw. by its dorsal curvature and lack of introversion of the thecal aperture. In the Cautley specimens, however, the proximal end may be just as slender as in M.sandersoni.

Material seen: Specimens figured Elles and Wood Pl.40,fig.1a (S.M. no S21026-7); fig.1c and text fig.272e (A21029); specimen S.M. A21051 from Spengill. Specimens figured Elles and Wood Pl.40, fig.1d (H.M.Geological Survey Collection)

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genus MONOGRAPTUS GROUP B

Group diagnosis: Rhabdosome with dorsal curvature proximally and more or less straight distally; proximal end usually slender and sicula very small; biform, with hooked thecae proximally and straight, simple thecal tubes distally.

M.argenteus aff argenteus (Nicholson)

Plate 28, fig.6

1869	Graptolites argenteus,	Nicholson p.239, Pl.Xl, fig.19.
1910	Monograptus "	(Nicholson). Elles and Wood pp.388-389, text fig. 257a-d, Pl.38, figs.5a-d.
?1931	" "	Haberfelner Pl.1, fig.5.
1945	" "	Nicholson. Waterlot Pl.27, fig.293.

non.

1924	Monograptus argenteus	Hundt Pl.3, fig.13.

Material: One fairly well preserved specimen in low relief and other more doubtful fragments.

Horizon and Localities: P.leptotheca zone, (6Bi) Birks Beck.

Diagnosis: Curvature typical; rhabdosome widens abruptly to over 1·5 mms immediately after the sharp dorsal bend, widening more gradually distally from this point. Thecae number 12 in 10 mms and become less prominently hooked in the distal region and finally becoming simple tubes.

Description: These forms agree in general form and dimensions with M.argenteus described by Nicholson (1869) and Elles and Wood (1910) except that the angle of inclination of the thecae and mode of overlap is more akin to M.cygneus Toernquist (here described as M.argenteus cygneus).It is not impossible that such specimens represent material compressed at right angles to the distal part of the polypary (parallel to the proximal part). This would increase the thecal count, and would also increase the thickness of the rhabdosome and angle of inclination of the thecae. On the other hand the rock containing the figured specimen (Pl.28, fig.6) only shows evidence of a small amount of compression in the diredtion requisite for the above interpretation. Roughly parallel distal fragments on the same slab show a maximum thickness of only 1·69 mms which compares rather better with M.cygneus Toernquist.

Remarks: Whilst this form agrees in dimensions with M.argenteus (Nicholson) it may prove to be synonymous with M.a.cygneus (Toernquist).

The latter fossil occurs at the same locality and horizon, whilst the rest of the assemblage is indicative of the P.leptotheca Zone.

Material seen: Specimen A20953-4 (Sedgwick Museum) seems rather slender and cygneus-like; specimen figured by Elles and Wood fig.257a (S.M. no.A20941) from Llanystwmdwy, near Criccieth; specimens in H.M.Geological Survey.

Monograptus argenteus cygneus (Toernquist)

Plate 27, fig.5; Plate 28, figs.5,7; Plate 29, fig.6

1892 Monograptus cygneus n. sp. Toernquist p.16, Pl.1, figs.28-31.
1910 " argenteus var. cygneus (Toernquist). Elles and Wood pp.389-390, text fig.258a-b, Pl.38, figs.6a-d.
?1931 " cygneus Haberfelner Pl.1, fig.6.
1945 " " Tornq. Waterlot Pl.27, fig.294.

Material: Many good polyparies in low relief, and fragments of both proximal and distal parts. One well preserved distal fragment in full relief.
Horizon and Localities: P.leptotheca zone (6Bi) Birks Beck and M.sedgwicki zone (S75,9·4) Spengill.
Diagnosis: Rhabdosome long, distally straight but with characteristic dorsal proximal curvature with hooked thecae in this region. Thecae number 10-12 in 10 mms. Maximum thickness of rhabdosome is 1·2-1·3 mms.
Description: Typically the rhabdosome has a long, straight distal portion with simple tubular thecae, and a dorsally curved proximal end with hooked thecae.

A maximum width of 1·2-1·3 mms is achieved distally where the thecae number 10 in 10 mms. The single specimen from the M.sedgwicki Zone has 9 thecae in 10 mms. At the proximal end the thecae are more closely spaced and number 12 in 10 mms.

Distally from the abrupt bend the length of theca involved in the hook becomes less and less until the thecae are quite simple and tubular. In some specimens this occurs after only a few mms.

The maximum overlap of one half is reached just prior to the bend and is maintained to the distal extremity. Throughout the rhabdosome the angle of inclination is low and distally it is approximately 20-25°.

Fragments showing the sicula have been found and show it to be 1mm.long reaching to just above the level of the aperture of th.1.

Remarks: This species at Cautley differs in one of its diagnostic dimensions from the forms described by Elles and Wood from other British localities. The thecal count is higher (12-10 in 10 mms as compared with 8 in 10 mms) whilst the thickness is rather less than that given on their p.389. In general form and size, however, the Cautley specimens are so close to those figured by Elles and Wood that they must be conspecific.

Monograptus limatulus Toernquist

Plate 28, fig.4; Plate 29, fig.7

1892	Monograptus limatulus n.sp.	Toernquist p.9, Pl.1, figs.6-8.
?1897	" "	Tornquist, Perner p.10, Pl.13, fig.9
1899	" " "	. Tornquist p.14, Pl.2, figs.18-20.
1910	" " "	Elles and Wood pp.390-391, text-fig. 259a-c, Pl.38, figs.7a-d.
1924	" "	Hundt Pl.5, fig.16.
?1931	" "	Haberfelner Pl.1, fig.7.
1945	" "	Tornquist. Waterlot Pl.27, fig.296.
1948	Pernerograptus limatulus (Tornquist).	Pribyl p.65, listed.
1952	" " "	Munch p.99, Pl.25, fig.4.
?1955	" cf. " (Tornquist, 1892).	Pribyl and Spasov p.190, listed.

Material: No specimens have been found which show both distal extremities and proximal portions, but many characteristic proximal ends, and fragments occur.

Horizon and Localities: M.convolutus zone, 9Wa Watley Gill,

Diagnosis: Very characteristic curvature where the species broadens suddenly from a proximal end no wider than 0·26 mms to a distal width of 1mm. Thecae number 11 in 10 mms (distally). Sicula not seen.

Description: Rhabdosome with a highly characteristic curvature from a long slender proximal region to a distal region of the order of 1mm wide. Most specimens are small, showing at the most 1cm of the distal portion.

The sicula has not been seen and the characters of the proximal thecae cannot be ascertained. These early thecae are long slender tubes, seemingly without overlap, and perhaps with "hooked" apertural regions. The apertures are more distant from each other than in the distal part of the rhabdosome, where they number 11 in 10 mms.

Distally the thecae show overlap of up to nearly one half the thecal length. Here they are relatively simple tubes showing no apertural adornments but there may be slight sigmoidal curvature. One of Toernquist's (1899) figures also suggests this (Pl.2,fig.20).

Remarks: The degree of comparity between the Cautley material and that described by Toernquist (1892,1899) is very remarkable. Elles and Wood (1910, p.390) record thecal counts of 12 in 10 mms suggesting slightly smaller thecae and variation from Toernquist's original material; but this is not found in the writer's material.

Material seen: Specimen figured Elles and Wood Pl.38,fig.7b,text fig.259b (Sedgwick Museum) and specimen figured Elles and Wood text fig.259c (H.M. Geological Survey); others from Pary's Mountain, Anglesey (H.M.G.S.Museum).

Monograptus difformis ?subsp.
Plate 34,fig.8

Material: Single specimen with sicula, showing proximal curvature and proximal thecae.

Horizon and Locality: *M.sedgwicki* Zone; (S80,8·4) Spengill.

Description: The rhabdosome is curved in the manner typical of the species, *M.difformis* Tornquist, and in this feature only it closely resembles the specimen figured by Elles and Wood (Pl.38,fig.46). It differs in being smaller whilst the "fish-hook" is only 2·5 mms across the gape.

The sicula is 0·78 mm long (lengthened by compression) and its apex reaches to the level of the top of th.1. At the level of th.1 the thickness of the rhabdosome, again reduced by compression, is 0·4 mms and it is, therefore, rather more robust than *M.difformis* Tornquist. Furthermore only four thecae are found proximal to the point of maximum curvature.

Distally a thickness (reduced) of 0·52 mm shows that the rhabdosome does not greatly increase in width in this direction. All the thecae on the specimen are hooked, but the distal ones less prominently so.Allowing for compression the thecal count is approximately 15-16 in 10 mms.

Overlap of the thecal tubes in the Cautley specimen is only slight.

Remarks: This fossil occurs at a higher level than that from which it was recorded by Elles and Wood(p.387,p.523) and though possessing the general form of the M.difformis polypary it is distinct in most of its characters:-

a) The sicula is smaller (0·78 compared to 1mm.)

b) the recurved proximal portion is shorter and smaller

c) the proximal end is more robust

d) the thecal count is distinctly higher.

Other fossils with a similarly shaped rhabdosome are M.clingani (Carr.) and M.millepeda (M'Coy) but the thecae of these forms are different.

Material seen: Specimen of M.difformis figured Elles and Wood Pl.38,fig.4b. Sedgwick Museum; specimen of M.clingani and M.millepeda in H.M.Geological Survey Museum.

Monograptus revolutus Kurck sensu lato

not figured

Specimens of M.revolutus undoubtedly occur in abundance at some horizons at Cautley but so far the writer has obtained only short fragments. None of the forms distinguished by Kurck, Elles and Wood, and Sudbury, can therefore be recognised. Fragments have been found from the following localities and horizons:- S13-17,; S24-28; 6Bi; Spengill etc.

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genus MONOGRAPTUS GROUP C

Group diagnosis: Rhabdosome robust, more or less straight; thecae are simple overlapping tubes distally but the first few thecae are hooked; hooks have been shown to consist of lateral, paired, ear-like processes projecting from the aperture though this cannot be determined on the Cautley material.

<u>Monograptus colonus colonus</u> (Barrande)

Plate 28, fig.8; Plate 29, fig.5

1850 Graptolithus colonus, Barrande p.42, Pl.2, figs.2,3 (non figs.1,4,5)
?1852 " " Barr. Geinitz p.38, Pl.2, figs.33-36.
1880 Monograptus roemeri Barr. Lapworth p.151, Pl.4, figs.5a-e (non figs.3a-d).
?1883 " colonus Barr. Tullberg pp.29-30, Pl.1, figs.21-23.
?1890 " " " Geinitz pp.15-16, Pl.A, fig.14.
1897 " " " Frech pp.655-656, fig.209.
1899 " " " emend. Perner. Perner p.9-10, text fig.12, Pl.14, figs.3,12,17.
1900 " " (Barrande). Wood p.463, pl.25, figs.10A-D, text fig. 14.
1908 " " Barr. Allahverdjiew pp.337-8, pl.4, fig.4.
1910 " " (Barrande). Elles and Wood pp.391-393, text figs. 260a-c, Pl.38, figs.8a-d.
1920 " " " Gortani pp.33-34, Pl.2, figs.28-29.
1924 " " Barrande, Hundt. Pl.6, figs.21,22; Pl.7, figs.1,2.
1936 " " " 1850). Boucek p.144-5, text figs.2a-e.
1942 Pristiograptus (Colonograptus) colonus colonus (Barrande 1850). Pribyl pp.4-5, text fig.2, figs.1-3.
1945 Monograptus colonus Barr. Waterlot Pl.28, fig.298.
1949 " (Pristiograptus) colonus (Barrande). Obut p.22, Pl.4, fig. 2a-b.
1952 Pristiograptus (Colonograptus) colonus (Barrande). Munch p.96, Pl.23, figs.1a-b.
1955 Monograptus colonus (Barrande). Kuhne pp.370-2, text fig.5A-B.
1958 Colonograptus colonus (Barr.)1850. Urbanek pp.5 -53, Pl.1, figs.4-5; text figs.23-25.
1960 Monograptus colonus (Barrande). Berry p.1160, text fig.2f.
?1962 " " " Ross p.71, text figs.3C.H,J; 5A,B,F.
?1962 Colonograptus colonus colonus (Barrande). Romariz p.289, Pl.13, fig.9.

non.
1876 Monograptus colonus, Barrande. Lapworth pp.505-6, Pl.20, figs.9a-d.

Lectotype: fig.2, Pl.2, of Barrande's originals, refigured and described by Perner 1899.

Material: Several flattened specimens and two well preserved specimens (in relief). M.colonus colonus is not a common fossil.

Horizon and Localities: 1st and 2nd graptolite bands of the Ludlow Series, zone of M.nilssoni, Wandale Hill, Hobdale Beck.

Diagnosis: The first three or four thecae appear to be hooked whilst distal thecae seem to be simple tubes of the pristiograptid type. Sicula at least 1·3 mms long, extending to the level of the second thecal aperture. More or less uniform width with a maximum of 2 mms (relief). Thecae number 15-16 in 10 mms at the extreme proximal end and 10 in 10 mms distally. Angle of inclination about 40°.

Description: The Cautley forms of this species are not large and rarely attain a length of more than 2 cms.. Otherwise their general form is typical and shows a slight, but characteristic, amount of ventral curvature at the proximal end. Distally the rhabdosome is more or less straight but often shows slight dorsal curvature.

Thickness of the rhabdosome, angle of inclination of the thecae to the axis, and thecal count each vary with the disposition of the fossil to the direction of compression in the rock. This description is drawn, however, from material preserved in relief which does not seem to have been distorted in any way.

The thecal count over the first four or five thecae varies between 15 thecae in 10 mms and 13 in 10 mms but hereafter falls rapidly so that at 1·5 cms from the sicula 10 in 10 mms is the usual figure. At 2 cms the rhabdosome thickness is about 2 mms and the thecae are inclined at about 40°.

The first four proximal thecae appear to be slightly hooked, though th.3 and 4 are distinctly less so than th.1 and 2. The distal thecae are about four or five times as long as broad and reach a maximum length of 2·5 mms. Overlap, distally is about three quarters of the thecal length.

Remarks: The Cautley specimens differ slightly from Barrande's original Bohemian material (redescribed by Perner 1899 pp.9-10) in being rather shorter and narrower. Perner gives a thecal count of 10 in 10 mms which may be for the "mature" thecae. If this is so, the forms from both areas agree in this respect.

Elles and Wood (1910) give a thecal count of 12-10 in 10 mms which also agrees with the specimens in the writer's collection except that at the extreme proximal end 15 in 10 mms is commonly recorded. If figs.8a-d (Pl.38) of Elles and Wood are natural size (see note on plate descriptions of Pl.36) then they show a thecal count over the first few thecae of more than 15 in 10 mms. On p.392 these writers point out that a certain amount of variation exists in the British material. The Cautley specimens are shorter and narrower than the forms described by them in their general diagnosis.

Urbanek (1958) has described the apertural processes of M.colonus from material extracted from calcareous erratic boulders. The "hook" described here is actually composed of paired, lateral ear-like processes composed of a monofusellar structure. Distally these processes are gradually lost. Such detail cannot be ascertained on the writer's material. In specimens preserved in relief in mudstones it is conceivable that these processes could either be broken off or bent out of sight. In such cases the "hooked" apertures of the proximal thecae would be missing and it would be difficult to distinguish this species from some pristiograptid species.

Urbanek's material shows a straight proximal end (p.50) with a thecal count of 15 in 10 mms proximally. He points out that the first 5 mms contain 8-9 thecae. This, on the writer's method of measurement, would be given as 16-18 th. in 10 mms proximally which agrees closely with Elles and Woods figs.8a-d. Urbanek's figs. 4,5b (Pl.1) do seem to show a slight ventral curvature.

Material seen: Specimens in Sedgwick Museum, Cambridge.

Monograptus roemeri (Barrande)

Plate 28,fig.9

1850 Graptolithus Roemeri Barrande p.41,Pl.2,figs.9-11.

1897 Pristiograptus " " . Frech p.656,fig.210.

1899 Monograptus " " Perner pp.16-17,Pl.14,figs.1,10,18,24, (non 7); text fig.11.

1900 " " (Barr.). Wood pp.470-1,text fig.17,Pl.25,figs. 13A-B

1910 Monograptus Roemeri (Barrande). Elles and Wood pp.397-398, text fig. 265a-b, Pl.39, figs.2a-d.

1929 " " var. Haberfelner pp.111-112, Pl.2, figs.5a-b.

1929 " sp. " pp.109-110, Pl.2, figs.2,3.

1936 Monograptus roemeri (Barrande 1850). Boucek Pl.2, figs.4-6, figs.2; k in text.

1942 " " " Munch p.252, Pl.3, fig.7-9, Pl.7, fig. 7.

1942 Pristiograptus (Colonograptus) roemeri (Barrande 1850). Pribyl p.8,10, text fig.2, fig.12; text fig.1, fig.2.

1945 Monograptus Roemeri Barr. Waterlot Pl.28, fig.305.

?1951 " roemeri (Barrande). Brown and Sherrard p.133, Pl.8, fig.9. text fig.2, fig.f.

1952 Pristiograptus (Colonograptus) roemeri (Barrande). Munch p.96, Pl.23, fig.4.

Material: Several fragmentary and flattened specimens with any specimens, particularly of distal thecae, preserved in relief.

Horizon and Localities: 2nd graptolite band, Ludlow Series, zone of M.nilssoni Wandale Hill, Yarlside. possibly 1st graptolite band and higher beds.

Diagnosis: At least 4 cms long and 3 mms wide (relief). Thecae number 10 in 10 mms distally and up to 16 in 10 mms at the proximal end. Sicula about 1·8 mms long reaching about the level of aperture of thecae 2. Th.1 and th. 2 are hooked.

Description: The polypary shows slight ventral curvature at the proximal end and fairly strong dorsal curvature distally. The first two thecae seem to be recurved into a hook whilst distally the thecae are relatively simple tubes. The angle of inclination of the thecae to the axis is always high and even distally is about 50° . In the Cautley specimens the degree of overlap slightly exceeds three quarters in the distal thecae, which as a general rule do not reach a length of 3 mms. At the same point on the rhabdosome they are five times as long as wide.

Distal thecae isolated from the matrix can be seen to be transversely expanded throughout their length (Pl.28, fig.9). When the common canal is reached the polypary narrows quickly to the dorsal margin. Thecae having a length of 2·6 mms and a thickness, in profile, of 0·52 mm are transversely expanded to 1·43 mms. At the juncture with the common canal this value has fallen slightly to 1·17 mms. The apertures which are simple and rectangular in outline, face in the direction of the length of the tube. The common canal has a breadth, in profile view, of 0·78mm. An interthecal groove has been observed but this may be a feature of compression, or flattening.

Remarks: The Cautley specimens differ from those described by Elles and Wood only in having shorter thecae inclined at a higher angle to the dorsal margin thus maintaining the same overall breadth. The material also shows that a thecal count of 10 in 10 mms, is achieved distally but otherwise they closely resemble figs.2a-d (Pl.39) of the above authors.

In his redescription of Barrande's original specimens (1899) Perner gives a thecal count, mesially and distally, of 11-12 in 10 mms and a thickness of of 3·2 mms. Apart from these small differences the forms are very similar.

Material seen: Specimens in Sedgwick Museum, Cambridge.

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genus MONOGRAPTUS GROUP D

Group diagnosis: Rhabdosome usually small, stiff; thecae relatively simple overlapping tubes but spinose either throughout rhabdosome, or proximally; in some species spines have been shown to be tubes formed by enrolling of ear-like lateral processes, but this cannot be determined in Cautley material.

Monograptus chimaera chimaera (Barrande)

Plate 28, fig.10.

1850 Graptolithus chimaera, Barrande p.52, pl.1V, figs.34,35.
?1889 Pristiograptus colonus Barr. sp. Jaekel p.674, pl.28, fig.8.
1899 Monograptus Chimaera, Barr. Perner p.14, pl.17, fig.18a-b.

1900 Monograptus chimaera, (Barr.). Wood p.471,pl.25,figs.18A-D.
1910 " " (Barrande). Elles and Wood p.398-400,text figs. 266a-b,pl.39,figs.3a-d.
1929 " " " Haberfelner pp.125-126,pl.2,figs. 15a-c,?d.
1936 " " (" 1850). Boucek p.146,text fig.3a-c.
1942 Pristiograptus (Saetograptus) chimaera chimaera (Barrande 1850). Pribyl pp.13-14,text fig.3,nos.1-3.
1945 Monograptus chimaera Barr. Waterlot pl.29,fig.307.
1949 " (Pristiograptus) chimaera (Barrande). Obut p.22,pl.4,figs. 3a,b; pl.7.
1952 Pristiograptus (Saetograptus) chimaera chimaera (Barrande). Munch p.97,pl.24,figs.1a-b.
1953 Monograptus chimaera (Barrande). Walker pp.370-373,figs.4-6.
1955 " " " Kuhne pp.372-379,text figs.6A-H.
1958 Saetograptus chimaera " Urbanek pp.53-62,text figs.26-31,pl. 2,figs.1-4; pl.3,figs.1-3; text plates 2,3.

Material: One complete, fairly well preserved specimen and other more fragmentary specimens.

Horizon and Localities: 1st graptolite band, Ludlow Series, zone of M.nilssoni 6 Bd. Knott near Sedbergh.

Diagnosis: Rhabdosome probably up to 2 cms long, with slight ventral curvature proximally, otherwise stiff and broad. Sicula prominent. Thecae throughout the rhabdosome have spines developed from the lateral margins of the thecae.

Description: The Cautley specimens are preserved in low relief but are compressed at right angles to the length of the rhabdosomes. This has caused distortion of several measurable biocharacters but the general form of the polypary and details of the thecae can still be made out.

Thecal counts, increased by compression, of 20 in 10 mms have been observed. The thickness of the rhabdosome, 2 mms must also be increased. The sicula is 2mms long and reaches to the level of the aperture of th.3.

Spines can be detected throughout the length of the fossil but distally they are shorter and blunter. Invariably they arise from the lateral margins of the thecal apertures, and, in these forms which are preserved in low relief, only one set can be seen in each specimen.

Remarks: Urbanek (1953 and 1958) has described the detailed structures of the spines from material etched out of limestone erratics. There is no possibility of recognizing such structures in the Cautley specimens so far obtained.

Material seen: Specimens in Wood Collection, Sedgwick Museum (including *M.c. semispinosus*.)

Monograptus chimaera salweyi (Lapworth)

Plate 29, fig.1

1880 Monograptus Salweyi, Hopkinson MS. Lapworth p.150, Pl.4, figs.2a-b.
1884 " chimaera LaTouche p.77, Pl.18, fig.571.
1900 " " var. Salweyi (Hopkinson ms.) Wood p.472, text fig. 18, Pl.25, figs.19A, B.
1910 " " var. Salweyi (Hopkinson M.S.) Elles and Wood p.400, text figs.267 a-b, Pl.39, figs.5a-d.
1938 " cf. uncinatus var. orbatus. Munch pp.60-61, Pl.5, figs.1-2.
1942 Pristiograptus (Saetograptus) chimaera salweyi (Lapworth 1880. Hopkinson MS.) Pribyl pp.14,16, text fig.1, no.1; text fig.3, nos.4-8.
1945 Monograptus chimaera var. Salweyi Hopk. Waterlot Pl.29, fig.308.
?1951 " salweyi (Hopkinson). Brown and Sherrard p.132, Pl.8, figs. a,b, text figs.2b,c.
1958 Saetograptus chimaera salweyi (Barr.). Urbanek p.56, Pl.2, figs.3a,b.

Material: One good specimen in relief but with the spines only poorly preserved, other fragmentary specimens.

Horizon and Localities: 2nd graptolite band, Ludlow Series, *M.nilssoni* zone 2W, Wandale Hill; 1We, West Grain.

Diagnosis: Like *M.c.chimaera* this form has spinose thecae throughout, the spines arising from the lateral margins of the thecae. Polypary short, usually less than 1cm, and narrow, in relief often less than 1mm.

Description: The rhabdosome is short and narrow, with a stiff proximal end. At the level of the aperture of th.2 the thickness is 0·78 mm. This gradually increases to about 1mm at the distal extremity so that the polypary is more parallel-sided than wedge-shaped.

The thecae number 19-20 in 10 mms over the first three or four thecae but then the count falls rapidly to 15 in 10 mms after about 5 mms. At the proximal end the thecae are short - about 0·52 mm long but increase in length to 1·4 mms distally (exclusive of spines).

The sicula is 1·9 mms long and reaches well above the aperture of th.3, and almost to that of th.4.

Spines are not well seen on the specimens in relief but they can be detected throughout the polypary. The length assigned to the spines of this species by Elles and Wood has not been observed but this may be a reflection of the mode of preservation.

Thecal overlap is fairly constant at about half the thecal length even in the proximal portions where very slight excavation of the ventral margin can be detected.

Remarks: This subspecies is distinct from M.c.chimaera (Barrande) but in general size it approaches M.leintwardinensis Hopkinson M.S. It differs, however, in the stiffer proximal end, parallel-sided nature of the rhabdosome and position of origin of the spines.

Material: Specimen in Wood Collection, Sedgwick Museum.

Monograptus leintwardinensis leintwardinensis Lapworth

Plate 30, figs.1,2

1880 Monograptus leintwardinensis, Hopkinson (MS) Lapworth p.149,fig.1,Pl.IV

1884 " " J.D. LaTouche p.77,Pl.28,fig.574.

1897 Pristiograptus uncinatus, Frech p.658,fig.213.

1900 Monograptus leintwardinensis, Hopk. MS. Wood p.474,text fig.19,Pl.25, figs.21A-B.

1910 " " Hopkinson MS. pp.401-402,text fig.268a-c, Pl.39,figs.8a-f.

1942 Pristiograptus (Saetograptus) leintwardinensis leintwardinensis (Lap-

worth 1880 Hopkinson MS.). Pribyl p.18, text fig.3, nos.11-12.
?1945 Monograptus leintwardinensis Hopk. Waterlot Pl.28, fig.311.

Material: About fifty specimens in varying states of preservation, but usually flattened and distorted.

Horizon and Localities: Zone of M.leintwardinensis associated with M.l.aff. inciriens and P.welchi sp. nov. in the lower part and on its own in the higher beds; Adamthwaite Bank, Bram Rigg Beck, Wygarth Beck, Artlegarth Beck, Bowderdale.

Diagnosis: Polypary short and stiff, about 5 mms long but occasionally longer. Thickness uniform, about 1mm with a maximum of a little more than this. Sicula prominent, 1·3 mms long reaching to the level of the second thecal aperture. Thecal count 15 in 10 mms except at the extreme proximal end where it rises above this figure.

Description: These forms are smaller in all dimensions than those described by the above authors but otherwise resemble them closely. The same relationship is also seen in the case of M.l.aff. inciriens (p.254) and the writer believes that the dwarf size may be a reflection of environmental conditions.

The comparison of dimensions is best made in tabular form:-

	Cautley	Welsh Borderlands
length	_ 5mms	max. 1·3 cms
breadth	1·1mm	max. 1·6 mms
length of sicula	1·3 mms	2·1 mms
thecal count	15 in 10 mms	14-15 in 10 mms

Remarks: This form could possibly be described as a separate subspecies since it shows constant and strong differences from the type material obtained in the Welsh Borderlands.

Material seen: Specimen no A23991 (Sedgwick Museum) is a slab from Aberedw, Nr Builth (presented by Wood) with many specimens very close, if not identical, to the Cautley species; specimens from Tebay Gill (Westmorland) (e.g. S.M. no A24035) are all semispinose.

Monograptus leintwardinensis incipiens Wood

Plate 28, figs. 11, 12 ? new.
30 figs 3, 4.

1900 Monograptus leintwardinensis var. incipiens, nov. Wood p.475, Pl.25, figs.22A-B.

1910 " " " incipiens, Wood. Elles and Wood p. 402, text fig.269, Pl.39, figs.9a-d.

1942 Pristiograptus (Saetograptus) leintwardinensis incipiens (Wood 1900). Pribyl p.19, text fig.3, no. 13.

Lectotype: Specimen figd. by Wood fig.22A and again by Elles and Wood fig. 9a.

Material: Several hundred specimens, mostly well preserved but flattened, occuring densely upon the bedding planes.

Horizon and Localities: P.nilssoni zone, exact level of some not known but probably quite low down. 2W (Wandale Hill). In addition 1Br, 4Br, (Bramm Rigg) immediately below zone of M.leintwardinensis.

Diagnosis: First 3-5 proximal thecae spinose. The extremities of the long spines are usually directed towards the proximal end and apparently originate near or at the dorsal margin of the aperture. Distal thecae non-spinose, simple tubes with overlap up to and over two-thirds. Sicula prominent reaching to the level of aperture of th.3.

Description: The polypary has the typical appearance described and figured by Wood (1900) and Elles and Wood (1900 and 1910). The maximum width is about 1·8 mms to 1·9 mms, i.e. fractionally narrower than the diagnosis given by Elles and Wood. The type specimen, however, only reaches a width of 1·95mms distally and 2 mms (e.g. the specimens figured 9b-d) seems a more usual thickness.

As a rule four proximal thecae are spinose but specimens with three and five are not uncommon. The thecae number 15 in 10 mms and this figure is often maintained throughout the short polypary.

The type specimens in both figures have 15 in 10 mms proximally falling to 14 in 10 mms distally; but other figured specimens have as few as 11 in 10 mms.

The sicula is prominent and gives the proximal end a stiff appearance not unlike that of *M.c.salweyi*, but unlike that form the distal thecae are free of spines. A maximum length of 1·8 mms has been measured, and the apex extends to the level of the aperture of th.3. The base of the sicula is 0·44 mm broad and possesses a short virgella and a dorsal flange or spine.

Remarks: *M.l.incipiens* Wood differs from *M.c.semispinosus* Elles and Wood not only in the point of origin of the spines which ally it with the *M.leintwardinensis* species group - but in the general dimensions. *M.l.incipiens* is much narrower and shorter. From *M.l.primus* (Boucek) it differs in having a longer and more prominent sicula and in its lack of dorsal curvature at the proximal end. The thickness is very similar, but *M.l.primus* seems to have far more spinose thecae (e.g. Pribyl 1942 obr. 3 figs.19-21). From *M.l. leintwardinensis* Lapworth it differs in the manner described by Wood (1900 p. 475).

This subspecies was probably mistaken for *Monograptus chimaera s.l.* by Watney and Welch (1911) who may have been misled by its occurrence at a low horizon. The subspecies listed by those writers as *M.l.incipiens* Wood and occurring at roughly the same level as *M.l.leintwardinensis* is here described as *M.l.aff. incipiens* Wood (see pp. 254). Wood (1900 p.476 and facing p.450) and Elles and Wood (1910 p.402) mention the occurrence of *M.l.incipiens* in Tebay Gill Westmorland. This may be *M.l.aff incipiens*.

Wood (1900 p.476) also points out that *M.l.incipiens* occurs at a lower horizon than *M.l.leintwardinensis* and that it may have given rise to the latter. This is a very feasible interpretation and the appearance of *M.l.incipiens* at Cautley at an even lower level does not preclude this. In the Welsh Borderland this subspecies occurs with *M.ultimus* Perner, whilst at Cautley it occurs with *P.bohemicus*, *P.nilssoni*, and other forms indicative of a lower horizon.

Material seen: A specimen presented by Wood to the Sedgwick Museum (A24046-7) is identical to the Cautley specimens recorded from the *P.nilssoni* Zone; specimen figured Elles and Wood Pl.39,fig.9c (S.M. no. A24412) is also identical to the Cautley specimens.

Monograptus leintwardinensis aff. inciniens Wood

Plate 30, figs.3,4.

Material: Fairly common in the zone of M.leintwardinensis with P.welchi sp. nov. Usually badly preserved in low relief. M.l.leintwardinensis occurs at the same localities if not on the same bedding planes.

Description: This form does not exceed a thickness of about 1·2 mms nor a length of 1cm. The proximal end is stiff or even with a very slight dorsal curvature whilst the proximal thecae are spinose. Distally the thecae have no spines and are simple tubes. Four or five proximal thecae bear spines. The sicula may reach 1·3 mms in length and its apex reaches the level of the aperture of th.3. Thecal counts can only be approximate because of the compression generally undergone by the rock but values of under 15 in 10 mms have not been obtained. At the extreme proximal end 20 thecae in 10 mms is more common.

Remarks: In general form the species is very close to M.l.inciniens Wood and was termed such by Watney and Welch (1911) and probably also by Wood (1900 p.476, and facing p.450). It differs however, in being both narrower and shorter and in actual size comes within the range of M.l.leintwardinensis Lapworth. From this latter species it is distinct in having only the proximal thecae spinose.

The writer has hesitated to suggest a subspecific name for this fossil since it may be merely a dwarf form of M.l.inciniens Wood whose size is dictated by the onset of unfavourable environmental conditions (though this in itself could constitute grounds for erection of a subspecies). (see also p.252). This is also suggested by the forms here described as M.l.leintwardinensis and P.welchi sp. nov.

Monograptus varians pumilis Wood

Plate 29, fig.3,4; Plate 30, fig.5

1900 Monograptus varians var. pumilis mov. Wood p.469, text fig.16, Pl.XXV, figs.17A,17B.

1910 " " ". " Wood. Elles and Wood pp.396-7, text fig.264a-c,Pl.39,figs.7a-c.

1942 Pristiograptus (Colonograptus) varians pumilis (Wood 1900). Pribyl p.7; text fig.2,no. 9.

?1947 Monograptus varians var. pumilis Wood. Ruedemann p.489,Pl.85,figs.11-14.

?1962 " " " " ? " Ross p.67,text figs.3D,E.

Material: Several specimens in low relief and flattened, usually poorly preserved, an exception being HUR./ 3S/ 6.

Horizon and Localities graptolite bands 1,2,10,12,13,15 and 16, Ludlow Series M.nilssoni zone. Spengill, Wandale Hill; 2W,3S; Cautley Crags (Cc)

Diagnosis: A little over 1cm long with a maximum breadth of 1·9-2·0 mms. in flattened specimens and about 1.4 mms in those preserved in relief. Two to three "hooked" thecae occur at the proximal end where the thecal count is 19 in 10 mms. Distal thecae simple tubes, thecal count 15 in 10 mms. Sicula about 1·7 mms long, apex reaching to level of aperture of th.3. Overlap reaches a maximum in the distal thecae where it is about two-thirds of the thecal length.

Description: In forms preserved in relief M.v.pumilis is typically very short and narrow. At th.7 for example the thickness is only rarely more than 1mm. About 6-7 mms from the proximal end there may be a rather rapid expansion of the rhabdosome (fig. 3 Pl. 29) but specimens lacking this are more common and in them the maximum known breadth is not attained.

The proximal end is straight and the sicula prominent. A length of 1·7 mms has been noted in some specimens of the sicula and the apex is invariably about the level of the aperture of th.3. Usually th.1 and 2 show the "hooked" form of the aperture but occasionally th.3 does also.

The actual nature of the "hook" is not clear.but in one specimen (HUR./ 2W/134 figured Pl. 29fig. 3 the "hook" seems to form from the lateral wall of the theca, as in the cases of M.chimaera and M.colonus and it seems to be more spine-like than would be the case were it merely due to retroversion of the thecal aperture. The specimen on Plate30(fig. 5 , HUR./3S/6) also shows this on th.1, but in the case of th.2 the spine seems to have its origin on the dorsal margin of the theca. The four thecae subsequent to these all show what is either a slight growth on the lateral margins of the thecae or a constriction of the aperture.

Remarks: *M.varians pumilis* itself is not a common fossil, though the specimens obtained agree closely with the descriptions and figures of Wood (1900) and Elles and Wood (1910).

Material seen: Specimens of *M.varians pumilis* and *M.v.varians* in Sedgwick Museum.

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genus MONOGRAPTUS GROUP E

Group diagnosis: Contains the forms attributed by some authors to *Monograptus (Monograptus)*; rhabdosome small to large, usually more or less straight, but often with a gentle flexuous curvature; thecae distinctly hooked, occasionally spinose; hook either free (as in *gemmatus*) or adpressed to metatheca (as in *knockensis*) or with excessive growth of dorsal margin compared to ventral (as in *priodon*).

Monograptus priodon (Bronn) s.l.

Plate 6,figs.3,4,5; Plate 8,figs.1,2; Plate 11,fig.2; Plate 31,fig.5; Plate 32,fig.4.

1835 Lomatoceras priodon Bronn p.56,Pl.1,fig.13.

1912 Monograptus priodon (Bronn). Elles and Wood pp.418-420,text figs.282a-b,282c-d,Pl.42,figs.2a-e.

(A more complete synonomy of this species up to 1912 can be found in Elles and Wood 1912).

Material:Over 100 specimens preserved in full relief, low relief or flattened.

Horizon and Localities: Fairly common in zones *C.centrifugus* - *C.insectus* to

C.murchisoni. Not known with certainty above the latter zone. Pickering Gill (5P,10P,8P); R.Rawthey, Mouth of Wandale Beck (50W,52W,?53W); Wandale Hill (46W,37W,25W,26W,28W,29W); R.Rawthey (8Ra,68f); Hebblethwaite Hall Gill (9H); Bluecaster, Middle and Near Gills (12N,8N,2N,3M,1M,4M).

Diagnosis: Rhabdosome very long, approximately straight, with a maximum breadth of 3 mms. Thecal count 11-13 in 10 mms proximally, falling to 9-11 in 10 mms distally. Angle of inclination proximally low, about 20° , increasing distally. Overlap also increases distally to about two-thirds. Thecal tubes hooked.

Description: The Cautley specimens differ considerably from the material described, for example, by Elles and Wood (1912). A combination of flattening and compression has profound effects upon such measurements as thecal count, width etc. and the description below (and diagnosis above) is drawn from material preserved in full relief in which there is little sign of distortion.

Tullberg (1883 Pl.2,figs.23 and 25) figures two proximal ends of M. priodon Bronn; and these seem to bear the same relationship to each other that the undistorted specimens at Cautley bear to the flattened and compressed specimens. His fig.25 is probably a flattened specimen whilst fig.23 is shaded in the manner of a specimen in relief.

The rhabdodome is approximately straight but does show slight dorso-ventral curvature, which can be exaggerated by compression at right angles to the line of the polypary. At the level of the hook of th.1 the width of the rhabdosome is 0·52 mm. From this point it widens gradually so that at 2½ cms from the sicula a width of 1·8 mms is reached. Distally a maximum of about 3 mms is attained.

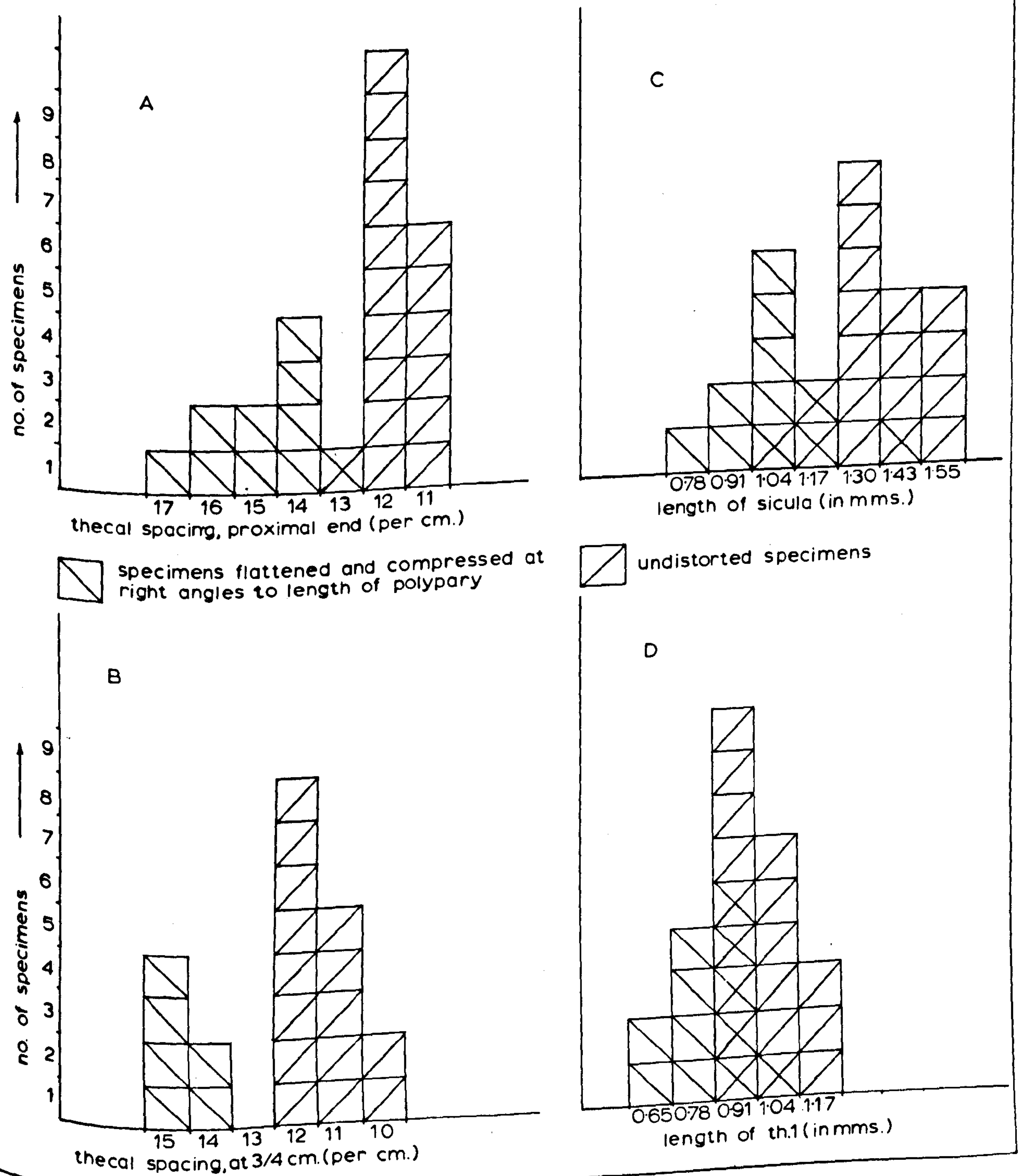
The sicula is rather small measuring from 0·78 mm to 1·55mms. These two figures are extremes caused by varying compression and the undistorted siculae are usually from 1·04 mms to 1·3 mms long. The apex barely passes the level of the hook of th.1.

The length of th.1 (exclusive of the extroverted portion) likewise varies from 0·65 mm to 1·17 mms but the undistorted specimens have a length of 0·9 mms. Th.1 buds from near the base of the sicula.

In the first few mms the thecae number 11-12 in 10 mms with one recorded instance of 13 in 10 mms. At 7·5 mms from the sicula this has fallen slight-

TEXT FIG. 8d

Histograms illustrating the effect of flattening and compression upon some measurable biocharacters of Monograptus priodon (Bronn).



ly to 10-12 in 10 mms. Distally counts ranging from 9-11 in 10 mms are obtained.

Specimens which are flattened and compressed at right angles to the polypary give much increased values: 13-17 in 10 mms proximally, 14-15 mesially and rather less distally (see text fig.8d).

A change in the angle of inclination of the thecae to the axis of the rhabdosome also takes place distally. The change is very gradual from 20° or less at th.1-th.5, to 40° at th.23-27. The angle continues to increase throughout the rhabdosome (see Pl.6,figs.3,4).

Overlap of the thecal tubes is almost nil at th.1-th.3 (see Pl.6,fig.3) but slowly increases in amount to about two-thirds in the distal region.

More than one-half of the thecal tube is involved in the hook at the proximal end and this figure is maintained distally. In this part of the rhabdosome the hook is much less prominent and is enrolled to a smaller degree. Whereas at the proximal end the aperture may face the dorsal margin of the polypary, in the distal region it is merely turned back to face the proximal end.

Remarks: Whilst the Cautley specimens agree in general form with M.priodon (Bronn) they differ considerably in detail. The main points of difference are summarized as follows:-

1. The sicula is smaller and its apex barely surpasses th.1.
2. The proximal end is narrower.
3. The early thecae are inclined at a lower angle to the dorsal margin.
4. The degree of overlap is less in the early thecae.
5. The hook is more prominent proximally and the aperture enrolled further.

The degree of difference between the proximal ends can best be appreciated by comparing Pl.6,figs.3,4 with text fig.282a-b of Elles and Wood p.419.

The writer has been unable to place the Cautley form in any of the described subspecies of M.priodon. It is quite distinct from M.p.var. rimatus Perner and M.p.var. validus Perner.

Material seen: Specimens in Sedgwick Museum, Cambridge, and H.M.Geological Survey Museum.

Monograptus riccartonensis Lapworth

Plate 6,fig.7; Plate 10,fig.3.

1876 Monograptus Riccartonensis, sp. nov. Lapworth pp.355-6,Pl.13,figs.2a-e.
1877 " " Lapw. Lapworth Pl.5,fig.23.
1880 " riccartonensis Lapworth. Lapworth p.155,Pl.4,fig.8c.
1883 " Riccartonensis Lapw. Tullberg pp.23-24,Pl.2,fig.26-27.
1912 " riccartonensis Lapworth. Elles and Wood pp.424-425,text figs.286a-c,Pl.42,figs.8a-c.
?1924 " " Lapworth. Hundt Pl.5,figs.8,9.
1934 " " " 1876. Peltzmann p.204,Pl.1,fig.6.
1945 " " Lapw. Waterlot Pl.34,fig.345.
1958 " " Lapworth. Obut p.62,Pl.4,fig.12; Pl.5, figs.1,2; text fig.11.

Material: Over 100 specimens all preserved as films on the bedding plane.
Horizon and Localities: Restricted to the M.riccartonensis Zone (as defined at Cautley) i.e. lower part of M.riccartonensis Zone as recognised elsewhere; R.Rawthey, Mouth of Wandale Beck (53W,54W,55W,56W,57W,59W,60-63W); Wandale Hill Gill B (38W-40W); Gill A (30W-34W); Wandale Beck (70W); Whinny Gill (6Wh-7Wh,1Wh); Hebblethwaite Hall Gill (6H-8H); R.Rawthey (5Bf,8Bf-9Bf); Bluecaster, Near Gill (10N,11N,13N?); Middle Gill (6M,11M,12M,13M).
Diagnosis: Rhabdosome characteristically stiff with uniform width of 1·5 mms and very slight dorsal curvature at the proximal end. Thecae 10-8 in 10 mms. Hooked thecae with typical bead-like shape in flattened material. Sicula prominent. Overlap one-third to one half.
Description: The Cautley specimens do not differ in any way from previously described material. It is extremely abundant on some bedding planes and often shows parallel orientation of the rhabdosome due to sorting by currents.

The maximum breadth of the rhabdosome is achieved very quickly (see fig. 7, Pl.6) and is then maintained. The thecae seem to be uniform throughout the rhabdosome and no change in the nature of the hook has been detected. Theca 1 is apparently rather shorter than those immediately following it. It arises near the base of the sicula.
Remarks: The significance of the vertical distribution of this form is dis-

cussed in detail (pp.38-41). It suffices to mention here that it does not occur in the C.murchisoni Zone at Cautley and it is restricted to the lower part of the Monograptus riccartonensis Zone recognized by Watney and Welch.
Material seen: Specimens in Sedgwick Museum, Cambridge.

Monograptus irfonensis inclinatus subsp. nov.
Plate 31,fig.12; Plate 10,fig.1

Holotype: HUR./39W/3 a flattened proximal end and unaxial thecae.
Horizon: Zone of M.riccartonensis, top. (39W) Wandale Hill.
Material: Six specimens, including holotype, on a single slab. All flattened specimens but quite well preserved.
Derivation of name: inclinatus, L. inclined towards.
Diagnosis: Distal part of polypary similar to M.riccartonensis, but much more slender. Proximal part showing initial dorsal curvature followed by ventral curvature. Thecae in this region like those of M.irfonensis. Maximum thickness 1·2-1·3mms. Thecae number 9½-11 in 10 mms.
Description: The rhabdodome shows dorsal curvature proximally (over the first 2 cms) followed by ventral curvature for a similar length. Distal fragments seem to be more or less straight. The degree of curvature has probably been slightly lessened by compression. All the specimens are current sorted and lie parallel to the direction of elongation of the rock. However, since the specimens are flattened (tending to increase the width) and at the same time compressed parallel to their lengths (tending to decrease the width) the two effects probably cancel out leaving a rhabdosome similar in width to the original. Under such circumstances distortion of the thecal characters is to be expected but in fact their appearance suggests that this has not occured to any great extent. The thecal hooks, for example, are not noticeably adpressed to the rhabdosome.

The sicula is nearly 1·7 mms long and 0·3 mm across the base. Its apex reaches to the level of the hook of th.1. The early thecae number 11 in 10 mms and are very similar to the thecae of M.irfonensis Elles (figured by Elles 1900 fig.19 and Elles and Wood 1912 text fig.292). They are approximately 1·5 mms long with a small hook in the apertural region, and have slight sigmoidal curvature very close to that on fig.292 of Elles and Wood. Overlap of the thecal tubes is rather less than half.

The distal thecae are rather more distant ($9\frac{1}{2}$ in 10 mms) and the overlap is about half. There is also a slight change in the angle of inclination from 10°-15° in the proximal region to 20° distally. The characters of the thecal hook do not change.

Remarks: On almost all counts this subspecies is intermediate between M.riccartonensis Lapw. and M.irfonensis Elles. The shape of the thecae is, however closer to the latter and it is here included as a subspecies of that form. It differs from M.irfonensis in being rather broader distally and in having more closely set thecae. The flexuous curvature of the rhabdosome is very similar.

From M.riccartonensis Lapw. which it resembles in general form of the thecae, nature of the hook, and the uniformity of the thecae throughout the rhabdosome, it differs in the following aspects:-

1. The sicula is shorter, and reaches less far along the polypary.
2. The rhabdosome is flexuous and the proximal end has prominent dorsal curvature.
3. The rhabdosome is narrower; the thecae are inclined to it at a smaller angle and they are more closely spaced.

M.irfonensis inclinatus subsp. nov. separated from M.riccartonensis before the top of the M.riccartonensis Zone (as here defined) and probably gave rise to M.irfonensis irfonensis Elles which appears in both Cautley and Shropshire in the C.lundgreni Zone (see Elles 1900, and Watney and Welch 1911) Both forms are rare and at Cautley the writer has found only a single undoubted specimen of M.i.irfonensis. (This was found in the Harter Fell area during undergraduate mapping and has since been misplaced). Its horizon was, as noted by Watney and Welch, the zone of C.lundgreni.

Material seen: Specimen of M.irfonensis figured Elles and Wood Pl.43,fig.3 (S.M. no. A22303 a and b).

<u>Monograptus flemingii flemingii</u> (Salter)

Plate 32, fig. 8; Plate 13, fig. 5

1852	Graptolites Flemingii, n. sp.	Salter p.390, Pl.21, figs.5a-b, 6, 7a-b.
1876	Monograptus "	Salter, sp. Lapworth pp.504-5, Pl.20, fig.8a-d.
1883	" "	Salt. Tullberg p.23, Pl.2, fig.25.
1900	" "	(Salt.) var. β & δ Elles pp.402-3, figs.12 and 14.
1912	" "	(Salter). Elles and Wood pp.425-6, text fig.287 a-d, Pl.42, figs.5a-d.
?1911	"	flemingii Salt. var. β δ Watney and Welch text and tables.
?1924	"	Flemmingi. Hundt Pl.5, fig.22.
?1940	"	Flemmingii Salter. Laursen p.26, text fig.17.
1945	"	flemingii Salter. Waterlot Pl.34, fig.347.
1952	"	(Monograptus) flemingi flemingi (Salter 1852). Pribyl pp. 5-7, Pl.1, fig.6.
1962	"	flemingi flemingi (Salter). Romariz p.247-8, Pl.11, fig.5; Pl.15, fig.3.

<u>Lectotype</u>: Specimen figured Salter 1852, Pl.21, fig.5a.

<u>Material</u>: Many specimens, some in relief but mainly in low relief or flattened.

<u>Horizon and Localities</u>: Stages 3 and 4, zones <u>belophorus - lundgreni</u>. Bluecaster Middle Gill (?21M, 22M, 29M, 30M); Near Gill (19N, 16N, 21N, 22N, 23N, 24N, 25N-26N, 29N); Wandale Hill (3W, 4W, 72W, 24W); Pickering Gill (11P); Hobdale Beck (2Bd); R.Rawthey (12Ra); Birksfield Beck (?11Bf); Two Gills, Harter Fell (1Tw); Near Gill (19N).

<u>Diagnosis</u>: Rhabdosome slightly flexed, very long, slight dorsal curvature at extreme proximal end. Maximum width 2·5 mms. Thecae hooked, numbering 16-19 in 10 mms.

<u>Description</u>: The polypary is very long and robust but slightly flexuous. Dorsal curvature is almost always present at the proximal end but distal fragments, whilst often showing slight ventral curvature, are usually straight. As has been noted with other species from Cautley the degree of curvature varies considerably with the direction of compression.

The sicula is approximately 1·5 mms long and is very prominent. Its apex reaches to about the level of thecae two, whilst the base has a short virgella.

Close spacing of the proximal thecae is typical. The usual thecal count is 16 in 10 mms though occasionally more are noted in the same length. This falls distally to a minimum of around 9 in 10 mms.

In the Cautley specimens the hook occupies one quarter of the width of the polypary in the proximal region and rather more distally. As in the case of *M.priodon* Bronn the distal hooks are less recurved than the proximal end.

The angle of inclination is about 30° throughout the polypary.

Remarks: The Cautley specimens show no variations from earlier described material. The apparently high thecal count at the proximal end (16 in 10 mms) is also shown by the figures of Elles and Wood (1912 Pl.42,figs.5a-d) and Lapworth (1876 Pl.20,fig.8a).

Salter (1852) called this species *Graptolites Flemingii* not, as recorded, by Pribyl (1948, 1952) *Graptolitus flemingi*.

The writer has examined the localities from which Watney and Welch (1911) obtained *M.flemingii var γ* and has obtained many specimens. Although these resemble in general form those figured by Elles and Wood (Pl.42,figs.7b and 7d) they are indistinguishable from proximal ends of *M.f.flemingii* being equal in all dimensions. Furthermore adult rhabdosomes at the same localities also belong to the latter. No specimens have been obtained which could definitely be assigned to *M.flemingii compactus* Elles and Wood.

Material seen: Specimens from Moughton Whetstones (S.M. nos. A51198-511203) labelled "M.vulgaris Zone"; specimens from Dooree Common Tipperary (S.M.nos. A51183,2 presented by Sir R.Griffiths to the Sedgwick Museum).

Monograptus flemingii primus Elles and Wood

Plate 31,fig.9

1900 Monograptus Flemingii (Salt.) var. α Elles p.402,text fig.11.

?1911 " flemingii Salt. var. α Watney and Welch, in text & tables

1912 " " (Salter) var. primus, nom. nov. Elles and Wood, pp.426-437,text fig.288,Pl.42,figs.6a-d.

1945 Monograptus flemingii var. primus E & W. Waterlot Pl.34,fig.348.
1952 " (Monograptus) flemingi primus Elles and Wood 1913. Pribyl pp.7-8,Pl.1,fig.7.
?1962 " flemingi primus Elles and Wood. Romariz p.248,Pl.7,fig.9; Pl.11,fig.11.

Holotype: Elles and Wood (1912) Pl.42,fig.6a.
Material: Only a few specimens definitely assignable to this species.
Horizon and Localities: Zone of C.lundgreni, Stage 4, (rare) Wandale Hill (3W.); Near Gill, Bluecaster (26N); R.Rawthey (12Ra); Stage 3.
Diagnosis: Shorter and stiffer than M.f.flemingii, flares more rapidly to a maximum breadth of 2·5 mms. Thecal count 14-8 in 10 mms.
Description: This species is very similar to M.f.flemingii (Salter) but has a broader and stiffer proximal end with the thecae more spaced. Specimen HUR./3W/34 is compressed at right angles to the polypary yet the thecae at the proximal end number only 14 in 10 mms. These proximal characters are critical in identification and distal fragments may be indistinguishable from Salter's species.
Remarks: This is a rare fossil at Cautley though Watney and Welch (1911) record it as common in their C.rigidus Zone. It is possible that some of the fossils described below as M.flemingii-priodon are referable to this species.
Material seen: Specimens of M.f.primus figured Elles and Wood Pl.42,figs.6c-d (S.M. nos. A22,289-90); specimens of M.f.compactus figured Elles and Wood Pl.42,figs.7c-d (Elles Collection S.M.nos. A22,299-300).

"Monograptus flemingii-priodon"

Plate 31,fig.2

Material, Horizon and Localities: Very badly preserved, flattened rhabdosomes, from zone of M.flexilis belophorus (i.e. Watney and Welch Zone M.riccartonensis) Bluecaster Middle Gill (13M,14M).
Description: These are distal fragments, flattened, and having appearances intermediate between M.priodon Bronn and M.flemingii (Salt.). The thecae usually number about 10 in 10 mms and are inclined at rather a high angle to the

the axis as in distal thecae of M.priodon. The apertural hooks, on the other hand, are very reminescent of M.flemingii and the specimens may represent early forms of this species. The rather high thecal count may be a compressional feature. More material is required before definite conclusions can be drawn but the writer feels that this material may turn out to be synonymous with M.flemingii primus Elles and Wood.

Monograptus sedberghensis sp. nov.

Plate 31, fig.10

Holotype: HUR./40W/1 complete but flattened specimen.
Horizon of Holotype: Top of the M.riccartonensis Zone.
Material and Locality: Single but complete specimen, preserved as a flattened impression; Wandale Hill Gill B (40W).
Derivation of name: After the nearby town of Sedbergh.
Diagnosis: Rhabdosome with gentle dorso-ventral curvature, widening from 0·6 mms to 2 mms at 4 cms from the sicula. Thecae with small hooks numbering 14-15 in 10 mms over first few mms and 12 in 10 mms distally. Overlap about one-half, increasing distally.
Description: The rhabdosome is not robust but reaches a maximum width (flattened) of 2 mms at a distance of 4 cms from the sicula. The proximal end shows ventral curvature for a length of about 1cm when a change to gentle dorsal curvature occurs and is maintained throughout the remainder of the polypary.

The sicula is small and not prominent. Its length is 1·2 mms and the apex barely reaches the level of the hook of th.1. The dorsal margin of the sicula is continuous with the dorsal margin of the polypary. This arrangement is the primary reason for the slight proximal ventral curvature.

The proximal thecae are closely spaced numbering 14-15 in 10 mms but this figure falls rapidly to 12 in 10 mms after 1cm. No further change in spacing takes place and at the distal extremity the thecae also number 12 in 10 mms.

Thecal overlap increases slightly to rather more than half in the distal portion but the thecae themselves are uniform throughout. There is no apparent change in the nature of the hook which always involves only the top of the thecal tube and closely resembles that of M.riccartonensis Lapw. A maximum length of approximately 2·5 mms is reached in the distal thecae. Throughout the rhabdosome the thecae are inclined to the axis at 30°.

Remarks: M.sedberghensis sp. nov. is extremely rare and a most puzzling fossil. The thecal hooks (and general thecal form as far as this can be ascertained in flattened specimens) resemble those of M.riccartonensis Lapw. and M.irfonensis inclinatus subsp. nov. but the slight ventral curvature of the proximal end and dorsal curvature of the mesial parts distinguishes it from these species. If the proximal end were straight there would be a certain resemblance to M.flemingii (Salter) but the rhabdosome is altogether too slender for any of the described forms of that species.

M.sedberghensis also resembles, at least in general form, M.uncinatus uncinatus Tullberg and M.uncinatus orbatus Wood. Both these forms are from the Lower Ludlow. The Cautley specimen is particularly close to the original specimen figured by Tullberg (1882 Pl.1,fig.24). This specimen shows the slight dorso-ventral curvature of the rhabdosome, and although slightly over natural size, seems to have the same dimensions and thecal count (although in his description p.30-31 he gives a figure of only 9 in 10 mms; presumably for the distal region). Tullberg's species, however, has a more prominent and recurved hook and the thecal tubes are broader and inclined to the axis at a higher angle (Pl.1,fig.25).

The general form is also close to the subspecies M.u.orbatus Wood particularly the specimen figured by Wood (1900 Pl.25,fig.23B). This specimen has similar curvature, and dimensions (even to thecal count and thickness). Again however, as with M.uncinatus Tullberg, the hook is very different and its resemblance to these forms is probably a case of convergence.

M.tariccoi Gortani is probably the species closest to M.sedberghensis sp. nov. The Cautley species agrees with Gortani's in the size and position of the sicula, the nature of the proximal end and spacing there of the thecae, and the actual nature of the hook. From M.tariccoi it differs in being shorter, more flexed, rather more slender, and in having a closer spacing of the thecae distally. Gortani's species is a Wenlock form but seems to occur at a slightly higher horizon with C.rigidus Tullberg (Gortani 1922,1934).

M.sedberghensis sp. nov. does suggest some connection between M.riccartonensis Lapworth and M.tariccoi Gortani.

Monograptus flexilis flexilis Elles

Plate 6, figs. 8, 9; Plate 9, fig. 5.

1900 Monograptus flexilis, sp. nov. Elles pp.405 & 7, text fig.18.

1912 " " Elles. Elles and Wood pp.430-1, text fig.293, Pl. 43, figs.4a-e.

1942 " flexilis flexilis Elles 1900. Pribyl pp.486, text fig.1, 1-5, Pl.1, figs.1-3, Pl.2, figs.2-3.

1945 " flexilis Elles. Waterlot Pl.35, fig.360.

1962 " " " Romariz p.249; Pl.8, fig.8; ?Pl.15, fig.7

Holotype: Specimen figd. Elles 1900 p.417, fig.18 and refigured Elles and Wood (1912) Pl.43, fig.4a.

Material: Several hundred specimens, all flattened.

Horizon and Localities: Zones of C.rigidus mut. to ? C.ellesi; Near Gill (19N, 16N, 17N); Middle Gill (19M, 20M, 21M, 22M, 26M, 27M); R.Rawthey (?11Bf); Ecker Secker Beck (9Ra); Wandale Hill Gill B (45W); R.Rawthey, Mouth of Wandale Beck (67W, 68W); Crosshow (5Cr).

Diagnosis: Characteristic curvature, and hooked thecae upon dorsal surface. Virgella and nema usually well seen. Sicula prominent. Maximum breadth 2 mms. Thecae number 12-9 in 10 mms. Thecal hooks typical and usually distinct from those of M.flemingii and M.priodon.

Description: The Cautley specimens are quite typical; no variations with time have been noted.

The rhabdosome is of considerable length and distal fragments several inches long have been found. These usually show ventral curvature at some stage though the proximal regions are invariably dorsally curved. It is clear that in adult rhabdosomes an S-shape is the usual form. The actual degree of curvature varies with the compression which the fossil has undergone but at the proximal end the first few thecae are often in a line at right angles to that taken by the distal part of the polypary.

The sicula is prominent measures approximately 2 mms in length and its apex is usually almost at the level of th.2. Very occasionally it extends beyond this. Most specimens have a long and exceptionally robust virgella. Rare specimens at Cautley have two spines in the position of the virgella.

TEXT FIG. 8ea

Histogram of rhabdosome width of the species M. flexilis measured at the level of the aperture of th.1.

+ = specimens figured by Elles & Wood from Welsh Borderland.

x = specimens figured by Elles & Wood from Cautley.

TEXT FIG. 8eb

Histogram of rhabodosme width of the species M. flexilis measured at 2 cms from the proximal end.

+ = specimens figured by Elles & Wood from Welsh Borderland.

x = specimens figured by Elles & Wood from Cautley.

TEXT FIG. 8ec

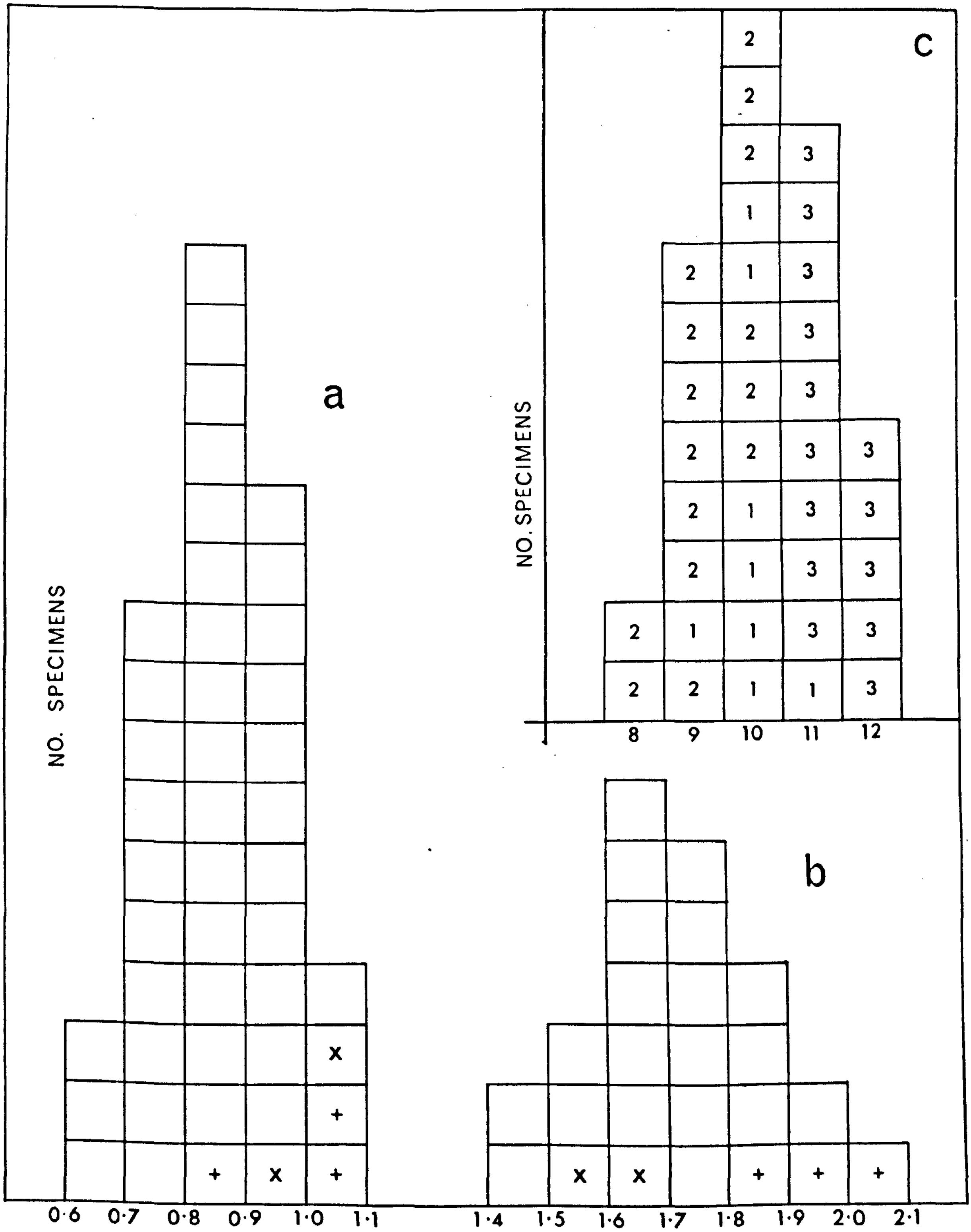
Histogram of thecal spacing of the species C. rigidus mut.

1 = thecal count immediately prior to cladium.

2 = thecal count distally.

3 = thecal count over first few thecae.

TEXT FIG. 8e


a
NO. SPECIMENS
0·6
0·7
0·8
0·9
1·0
1·1
x
+
+
x
+
b
1·4
1·5
1·6
1·7
1·8
1·9
2·0
2·1
x
x
+
+
+
c
NO. SPECIMENS
8
9
10
11
12
2
1
3

Both certainly originate from the ventral side of the sicula aperture and in one specimen (HUR./16N/386) the virgella actually appears to bifurcate.

Remarks: This is a common fossil on some bedding planes throughout the zone designated as C.rigidus by Watney and Welch (1911).

Monograptus flexilis belophorus (Meneghini)
Plate 31,figs.3,8

1857 Graptolithus (Monograpsus) belophorus Meneghini (Pars) p.166,tab. B, fig.46,11,4,4a.

1857 " " Gonii Meneghini (pars) p.172,tab.B,Pl.11, 6a.

1857 " " priodon Meneghini (pars) p.178,tab.B,Pl.11, 9,9a.

1922 Monograptus belophorus Mgh. em. Gortani p.17(57),Pl.10,(3),figs.9-15, Pl.12(5),figs.3b,14,Pl.13(6),fig.1.

1922 " " var. laxus Gort. p.10,(94),Pl.16(2),figs.7-8,Pl. 18(4),?figs.12A,Pl.19(5),fig.4.

1922 " ballaesus Gort. p.10-11(94-95),Pl.16(2),figs.12-18,Pl.18(4) figs.11A,Pl.19(5),figs.2A,3,6C.

1942 " flexilis belophorus (Meneghini 1857, em. Gortani 1922). Pribyl pp.6-7,text fig.1,figs.6-7,Pl.2,fig.1.

1945 " belophorus Meneghini. Waterlot Pl.35,fig.361.

Lectotype: Example figured by Gortani (1922) on Pl.10 (3),fig.9.

Material: Many fragments and some fairly well preserved proximal ends.

Horizon and Localities: Occurs in the author's zone of M.f.belophorus (in the top of the M.riccartonensis zone as defined by Watney and Welch 1911); Middle Gill (16M,13M). Fragments probably referable to this form have been seen at the same level in other localities.

Diagnosis: Maximum thickness 2·5 mms of a rhabdosome showing dorso-ventral curvature. Proximal end with dorsal curvature. Thecae number 10-7½ in 10 mms. Sicula 2 mms.

Description: The rhabdosome has the typical S-shaped curvature of the M.flexilis Group and widens gradually from a thickness of 0·6 - 0·9 mm to a probable maximum of 2·5 mms. The proximal dorsal curvature is stiff.

The broad sicula is 1·5 - 2 mms long, and the apex only reaches to the level of th.1. Throughout the rhabdosome the thecae are uniform and number 10-7½ in 10 mms. This varies somewhat with the compression and both higher and lower values have been obtained. The actual hook is between M.riccartonensis and M.flexilis in form, being rather beak-like.

Remarks: The number of badly preserved fragments obtained suggests that this fossil is quite common at the above horizon. Fossils, however, are usually difficult to obtain wherever this horizon is encountered, due to the cleavage.

Those specimens which have been obtained compare well with forms figured by Pribyl (1942, text fig.1,no.7 and 6) but the Cautley material shows a slight difference of thecal count (10-7½ in 10 mms cf. 9-5 in 10 mms). Well preserved distal fragments have not yet been obtained by the writer and it is possible that in such specimens the thecae might be more distant from each other than 7½ in 10 mms.

The sicula is also rather shorter but on the specimen figured as no.6 (text fig.1 Pribyl 1942) the sicula seems to be only 1mm long and its apex reaches to about th.1. The specimen figured as no. 7 (text fig.1) appears to have considerably more than the 9 in 10 mms given in the description (p.7) for a proximal fragment.

From M.flexilis falcatus (Meneghini), M.f.belophorus differs in being far more slender, and less recurved proximally. It is smaller in all dimensions.

It is equally distinct from M.f.flexilis Elles. The proximal end is less recurved, more slender, and has a very short sicula reaching only to th.1.

Monograptus ex. gr. flexilis

Plate 7,fig.1

Material: Single proximal end with sicula from Wandale Hill Gill B (43W), Zone of M. flexilis belophorus, Wenlock Series, Stage 3.

Specimen flattened.

Description: The form of the thecae, general form of the rhabdosome, and prescence of a long virgella ally this specimen with the fossils grouped about M.flexilis. Its slender nature and stiff dorsal curvature however distinguish it from M.flexilis flexilis Elles.

The sicula is 1·56 mms long and its apex reaches to the top of th.1. Both these facts also distinguish it from M.flexilis flexilis. The thecae number 14 in 10 mms over the first few thecae but this decreases to 10 in 10 mms after rather less than 1cm. The thecal apertures seem to be more "beak-like" than in M.flexilis flexilis and are perhaps closer to those of M.flemingii (Salter).

There is but slight increase in width from 0·78 mms at the level of th.1 to 0·91mm at the distal extremity (inclusive of hooks).

Remarks: M.ex. gr. flexilis has the same general form as M.flexilis belophorus (Meneghini)but the thecae are more closely spaced (14-10 in 10 mms cf. 9-5 in 10 mms). M.inflexus Pribyl has a similar thecal count (11-9 in 10mms) but the proximal end is not well figured and does not seem to be dorsally curved. In addition the sicula is long, its apex reaching to the level of th.3 (Pribyl 1942,p.11).

M.subflexilis Pribyl also has a thecal count of 11-9 in 10 mms and has thecae of the flemingii type. Although the distal parts are ventrally curved the proximal end shows dorsal curvature (see Pribyl, 1941,Pl.1,figs.3 &4). The short sicula and high thecal count of the proximal part distinguish M.ex. gr. flexilis from this form.

The closest form is probably M.flexilis belophorus (Meneghini). The form figured by Gortani (1922) as M.ballaesus is very close indeed in all characters except spacing of the thecae. One specimen (Pl.16(2) fig.14), has a thecal count proximally of 14 in 10 mms although it appears that this is a distorted specimen.

Monograptus marri Perner sensu lato

Plate 8,fig.4; Plate 31,fig.4; Plate 32,fig.7; Plate 33,fig.4.

1897 Monograptus Marri, n.sp. Perner p.21,Pl.11,figs.5,6,10,11,text figs. 23-25.

1912 " " Perner. Elles & Wood pp.422-3, text fig.284a-b,Pl.

42,figs.4a-d.

?1933 Monograptus marri Perner. Sun p.38; Pl.6,fig.4.
1945 " Marri Perner. Waterlot p.78,Pl.33,fig.336.
?1949 " (Pomatograptus) marri Perner. Obut p.23; pl.4,figs.5a,b.
1952 " (Monograptus) priodon marri Perner. Munch p.100,Pl.26,figs. 2a-b.
1958 " marri Perner. Obut pp.61-62,Pl.4,figs.7-11,text figs.10a-b.
1962 " " " Romariz p.252 Pl.16,fig.8.

Lectotype: Specimen figured by Perner (1897),Pl.11,fig.11.

Material: Many specimens, usually well preserved as impressions.

Horizon and Localities: Subzone of R.maximus, Zone of M.turriculatus, Zone of M.crispus and Zone of M.griestonensis (in the sense of Wilson 1953); Spengill (S124,10·25 - S264,5); Wards Intake (all localities in above zones); Hebblethwaite Hall Gill; Stockless Gill.

Description: The Cautley forms from the lower beds (subzone R.maximus and Zone of M.turriculatus) resemble previously described material in all essential characters. Compression causes rather higher and lower thecal counts than the 10 in 10 mms given by Perner (1897,p.21) and Elles and Wood (1912,p.422). However in specimens which are undistorted there is no noticeable deviation, and even in compressed specimens the thecal count is uniform throughout the rhabdosome.

Material from the zones of M.crispus and M.griestonensis was termed M. marri-priodon by Wilson (1953) but not described. These specimens have a higher thecal count in the proximal region of up to 12 in 10 mms and occasionally a lower one distally of 9 in 10 mms. (Distorted specimens show even more variability). In all other characters, particularly the nature of the hook, they seem quite indistinguishable from M.marri Perner.

Other specimens occur having a "pandus" - like appearance (see Pl.32,fig. 7). These are invariably compressed at right angles to the polypary and probably represent distal fragments of M.marri Perner.

It is possible that a direct line of evolution exists between M.marri Perner and M.priodon (Bronn), and it is unfortunate that at Cautley beds probably equivalent to the zone of M.crenulata are unfossiliferous.

A few specimens have been obtained (distal fragments e.g. Pl.13,fig.9) which resemble M.praecedens Boucek. They differ from M.marri in having a greater degree of overlap of the thecae. The exact nature of these forms has not yet been determined.

Material seen: Specimens in Elles and Wood Collection, Cambridge.

Monograptus knockensis Elles and Wood

Plate 6,fig.6; Plate 31,fig.1

?1892 Monograptus singularis Tornquist p.22,Pl.2,figs.9-11.

1912 " knockensis, sp. nov. Elles and Wood pp.462-3,text fig. 321a-b,Pl.46,figs.8a-b.

1945 " " Elles & Wood. Waterlot Pl.40,fig.404.

Material: Five fragmentary specimens preserved in relief, replaced by pyrites.

Horizon and Localities: Zone of M.sedgwicki (S80,8·4) Spengill.

Diagnosis: Proximal end unknown. Distal part of polypary with variable curvature, as commonly ventral as dorsal. Width 1·5 mms. Thecae with a unique lobation, and more or less isolated from each other, numbering 7½ in 10 mms.

Description: The largest fragment of rhabdosome observed is over 4 cms long and ventrally curved. (see fig.6,Pl.6).

The thecal tubes show no overlap but widen from a narrow protheca 0·26-0·3 mm in diameter. This is approximately circular in cross section and after 0·26 mm begins to widen to 0·4 mm at the distal extremity. The metatheca grows away from the axis at about 80° and its width in profile is 0·52 mm. This value is slightly reduced as the point of recurvature is approached. It is clear, however, that a certain amount of transverse expansion has occurred in this part of the metatheca.

After growing outwards for 1mm the metatheca is suddenly recurved so that the distal part, almost 0·8mm long, is adpressed to the early part of the metatheca. The thecal aperture faces the dorsal part of the rhabdosome. It is also plain that there is considerable torsion of the thecae to the obverse side.

Some specimens (Pl.31,fig.1) show more isolation of the metatheca than

HUR./S80,8·4/144a and b (Pl.6,fig.6) and these seem to be rather more proximal fragments.

Remarks: Elles and Wood (p.463) describe the thecal lobe as being coiled almost in a horizontal plane. This is rather ambiguous and may mean either the bedding plane (i.e. dorso-ventral plane) or the plane at right angles to the bedding plane and at right angles to the line of the polypary. Only occasionally is the torsion so great that the lobe lies approximately in the latter plane. Apart from this no differences have been noted from Elles and Wood's description.

On p.448 (1912) Elles and Wood include M.harrago Tornq. in their synonomy of M.lobiferus. Whilst most of Tornquist's figures are almost certainly lobiferus the specimen figured on Pl.3,(fig.7) seems much nearer to M. knockensis Elles and Wood. His description (p.116-17) also tallies closely, particularly his description of the adult thecae, which number 7-8 in 10 mms.

In the text (Elles and Wood 1912), M.knockensis is recorded from the Zone of M.crispus but in the distribution table (p.523) its occurrence here is questioned. Toernquist records his material from the Zone of P.folium.

It is fitting to mention here that specimens with a lobiferus-like appearance are common throughout the zone of M.sedgwicki, and are even found in association with M.knockensis. Because of their generally imperfect preservation they are not described here.

Material seen: Specimen labelled M.knockensis (S.M. no. A23826) collected by Professor W.B.R.King from Spengill, Cautley; specimens in the Sedgwick Museum labelled "M.lobiferus, harpago view" (A21,194a and b) which seem to the writer to be typical specimens of M.lobiferus; specimens figured Elles and Wood Pl.46,figs.8a,b; text figs.321a-b (S2197 a,b and A21973a and syntype A22019 a and b); specimens in H.M.Geological Survey Collections.

As has been pointed out above the Cautley material fits the description of Elles and Wood and in addition closely resembles some of their figured specimens (Pl.46,figs.8a,b, text fig.321 a-b). Some of the syntypes, however, contained in the Sedgwick Museum (e.g. A22019 a and b) have even more isolated metathecal parts than those specimens figured. Each of these syntypes is recorded from the M.crispus Zone (Swindale, Knock) and it is possible that the Cautley forms represent an early offshoot from M.lobiferus (or even, possibly extreme variants of a lobiferus population).

If M.lobiferus did give rise to M.knockensis then a tendency to isolation of the thecae would be involved - a tendency which has been noted in other groups.

Monograptus halli (Barrande)
Plate 31, figs.11,13

1850 Graptolithus Halli Barrande p.48,Pl.2,figs.12-13
1876 Monograptus Halli, Barr. sp. Lapworth pp.354-5,Pl.13,figs.1a-d.
1880 " crassus Lapw. sp. nov. Lapworth p.155,Pl.4,fig.8b.
1897 " Halli Barrande. Perner p.13,Pl.13,fig.20.
1912 " Halli (Barrande). Elles & Wood,PP.443-5,text fig.305a-e. Pl.44,figs.8a-f.
1919 " " " Kirste p.164,Pl.2,figs.32.
1929 " " Barrande. Glemerec pp.101-103,Pl.1,figs.7a-c.
1931 " " " Aigner figs.14a-b,15.
1931 " " Haberfelner Pl.1,figs.22a-b.
1945 " " Barr. Waterlot Pl.37,fig.378.
1952 " halli Perner. Munch p.105,Pl.30,figs.3a-b.
1957 " Halli. Romariz Pl.4,fig.2,not described.
1962 " " (Barr.). Romariz p.249,Pl.1,fig.4,?Pl.2,fig.5.

Lectotype: Specimen figured by Barrande (1850) Pl.2,fig.12.

Material: Mostly fragmentary material, but many specimens.

Horizon and Localities: Zone of M.turriculatus (including the whole of the subzone R.maximus); (S115,5 - S196,9·25, common in S117,3 and S124,10·25) Spengill.

Diagnosis: Fragments of rhabdosome rigid and attaining a maximum width of 3 mms. Thecae hooked and spinose, and thecal tube twisted towards the reverse side. Thecal count 9-8 in 10 mms in distal fragments. Overlap less than one half.

Description: The lack of complete specimens and proximal ends does not permit a detailed description of this species. The fragments are, however, quite common at some horizons and can only be confused with M.sedgwicki (Portlock).

From this species it can be distinguished by its small spines and torsion to the reverse (rather than the obverse) side. The specimen figured on Pl.31(fig.11) is a reverse view of a specimen with spines clearly visible yet these measure no more than 0·4mm long.

Remarks: Forms referable to this species have only been found above the Zone of M.sedgwicki.

Material seen: Specimens in H.M.Geological Survey Museum, and Sedgwick Museum.

Monograptus sedgwicki (Portlock)

plate 32, fig.6

1843 Graptolithus (Prionotus) Sedgewickii Portlock p.318,Pl.19,fig.1.

1912 Monograptus Sedgwickii (Portlock). Elles and Wood pp.441-443,text figs.304 a-e.

Holotype: Specimen figured by Portlock (1843),Pl.19,fig.1 and further described by Elles (1912).

Description: This species is not figured since no sufficiently well-preserved material has been obtained. Fragments probably referable to the species have been obtained throughout the Zone of M.sedgwicki but they are not common. Other slightly larger fragments belong to this species but until further material is forthcoming a detailed description is omitted.

Remarks: H.M.Geological Survey workers (1891) record M.spinigerus (=M.sedgwickii) from the Spengill Section and Wilson (1953) records this fossil from the same beds but more accurately delimits its range.

Material seen: Specimen figured Portlock 1843 Pl.19,fig.20 (Geological Survey Museum).

Monograptus gemmatus (Barrande)

Plate 30,figs.7-11.

1850 Rastrites gemmatus Barrande p.68,Pl.4,fig.5.

1897 Monograptus (Rastrites) gemmatus Barr. sp. Perner p.23,Pl.11,fig.33, text fig.26.

?1897 Monograptus attenuatus Hopkinson. Perner p.10,Pl.11,figs.30,32 (non 31).

?1933 " gemmatus (Barrande). Sun p.35,Pl.5,fig.8.

1951 " (?subgenus) gemmatus (Barrande,1850). Boucek and Pribyl pp.20-22; Pl.3,fig.13; text figs.4a,b,c.

non;

1913 Monograptus gemmatus (Barrande). Elles and Wood pp.436-7,Pl.XL111,figs. 5a-e.

1924 " " Barrande. Hundt Pl.5,fig.20.

?1931 " " Haberfelner Pl.1,fig.19.

Holotype: Specimen figured by Barrande (1850) Pl.4,fig.5. Zone of R.linnaei, Zelkovice, black shale.

Diagnosis: Rhabdosome frail, thin, with a maximum width of only 0·26 mm. Usually fragmentary. Thecal count varies from $5\frac{1}{2}$ in 10 mms to 10 in 10 mms. Thecal hook is loose and the aperture which shows no diminution in width, faces the proximal region of the rhabdosome.

Material: Eight fragmentary specimens each only a few mms long, and a few more doubtful fragments.

Horizon and Localities: Zones of M.sedgwicki and M.turriculatus (S94,7·4 and S219,0·25).

Description: The rhabdosome is always found in a fragmentary condition with two or three thecae to each fragment. The overall width never exceeds 0·26 mm in the Cautley material and half of this is taken up by the hook itself. The prothecae, in some of the later material (HUR./219,0·25/12, Pl.30,figs.11) is initially thread-like (0·03mm) but widens after about 0·5 mm to reach a maximum of 0·13 mm immediately prior to the hook. The whole prothecal portion is 1·5 mms long. Thecal counts in this species seem to be quite variable. Perner (1897) records 14 thecae in 10 mms (7 in 5 mms) whilst Boucek and Pribyl (1951) record 10 thecae in 10 mms (5 in 5mms). Those specimens from the Zone of M.sedgwicki at Cautley have a thecal count of 10 thecae per cm. (Pl.30,figs.7 & 8) but other material from the Zone of M.turriculatus shows only $5\frac{1}{2}$ and $6\frac{1}{2}$ thecae in 10 mms - though these are strongly compressed parallel to the rhabdosome. Earlier forms also differ from later ones in the Cautley material in having a longer and freer hook which is turned back more at its aperture thus becoming less distant from the preceding theca. The specimen figured on Pl.30,fig.9 clearly lacks a prothecal thread-like portion.

Remarks: The distinct nature of the hook in this species places it firmly in Barrande's Rastrites gemmatus. Boucek and Pribyl (1951) consider the fact that the apertural region does not become narrow to be a distinctive feature. The Cautley specimens agree in this respect and in fact a slight expansion is indicated in some cases (Pl.30,fig.8). Compression at right angles to the rhabdosome may blunt the hook (Pl.30,fig.11) and specimens of this type closely resemble Perner's figs.30,32,(Pl.11) and the specimen refigured by Boucek and Pribyl (1951) as text fig.4b and c.

It is possible that those forms from the M.sedgwicki Zone are distinct from later forms, but more material, examined with due regard to compressional features, will be needed before this can be determined.

Material seen: Specimens figured by Elles and Wood text fig.300b,Pl.43,fig. 5c (= M.capillaris).

In their synonomy of M.gemmatus (= M.capillaris) Elles and Wood include Graptolites attenuatus Hopkinson. Specimens labelled under this last name in the Sedgwick Museum (A21,119, Hopkinson Collection) are neither gemmatus nor capillaris but have introverted not hooked thecae and are close to the form here described as M.angustus sp. nov. (p.338).

Specimens from Rastrites Shales (M.sedgwicki Zone) Kongslena, Scania (e.g. S.M. no. A23383 a-b); some forms in this collection (e.g. S.M. no. 23327) do not seem to be true M.gemmatus (Barrande).

Monograptus ex. gr. gemmatus (Barrande)

not figured

Material: Many fragmentary specimens in relief from S166,8·5 Spengill.

Description: This material may represent the extreme proximal end of M.gemmatus (Barrande). It possesses the same general dimensions and thecal count but does not seem to have the hook turned back as far. This, however, may be a feature of the preservation. One of the specimens (not figured) bears a sicula which is fully 0·9 mm long but has an initial breadth of only 0·06 mm. The thecal characters on this specimen cannot be determined.

Monograptus barrandei (Suess)

Plate 32, figs. 1, 2

1851	Graptolithus	Barrandei	Suess p.126, Pl.9, fig.12
1876	Monograptus	"	Suess. sp. Lapworth pp.502-3, Pl.20, fig.5.
1877	"	"	" Lapworth Pl.5, figs.21.
1912	"	"	(Suess). Elles & Wood p.462, text fig.320, Pl.46 figs.6a, b.
?1929	"	"	Suess. Glemerec pp.110-111; Pl.2, figs.5a-c.
?1931	"	"	Haberfelner Pl.2, figs.9a-b.
1945	"	"	Suess. Waterlot Pl.39, fig.399.
1950	"	(Globosograptus) barrandei	(Suess). Gortani Pl.1, fig.14a and text figs.10, 11.
1951	"	(?) "	(Suess 1851). Boucek and Pribyl. pp.6-8, not figured.

Material: Three specimens quite well preserved as impressions.

Horizon and Localities: Very highest beds of M. turriculatus Zone; Spengill (S210, 8 and S219, 0·25).

Diagnosis: Rhabdosome straight, with a fairly uniform breadth of 0·6 - 0·65 mm distally. Lobes prominent. Thecae number approximately 9-9½ in 10 mms.

Description: One specimen 4 cms long shows no curvature whatever and other smaller pieces are quite straight. On the other hand all the specimens are compressed parallel to their lengths and this could obliterate any original gentle flexuring. At the same time such compression may have reduced the width of the rhabdosome and the thecal count.

The rhabdosome width is uniformly 0·6 - 0·65 mm opposite the lobes but one specimen (Pl.32, fig.1) thins proximally to 0·39 - 0·4 mm. Throughout the specimens the thecae number 9-9½ in 10 mms.

The apertural lobes appear to be simple recurvings of the thecal tubes, and there is certainly no obvious diminution in breadth as the aperture is approached. Moreover in one specimen the recurved portion of each theca is not quite adpressed to the axis suggesting that this latter feature is a compressional one.

Remarks: The Cautley specimens differ from those described by Elles and Wood (from Scotland and Co. Down) in being straighter, broader, and in having a higher thecal count. They are, however, regarded as synonymous since the whole polypary of the species is not known. The Cautley specimens may simply represent more distal fragments.

The thecal lobe is clearly very similar to that of M.gemmatus (Barrande) and the two must be regarded as being in the same group.

Monograptus simulatus sp. nov.

Plate 31, figs.6,7; Plate 32,fig.9; text fig.

Holotype: HUP./28W/25, long specimen preserved mainly as a mould.

Horizon of Holotype: Zone of C.centrifugus - C.insectus.

Material: Two well preserved specimens.

Horizon and Localities: Both specimens from Zone of C.centrifugus - C.insectus; Wandale Hill, Gill A (28W) and Bluecaster Middle Gill (4M).

Derivation of name: simulatus; L. feigned.

Diagnosis: Rhabdosome showing dorso-ventral curvature, slender. Thecae long, narrow, apertural hook, no overlap. Width of rhabdosome 0·3 mm. Thecae number 6-5 in 10 mms. Sicula not known.

Description: This rare fossil has a highly characteristic polypary. In the most proximal part known it shows dorsal curvature. More distally this becomes ventral and then once again dorsal. It widens almost imperceptibly from 0·26 mm to 0·3 mm (both readings including the hook).

The thecae are widely spaced numbering 6 in 10 mms proximally, falling to 5 in 10 mms distally. Throughout most of their length the thecae are adpressed to the axis but at their extreme distal end the aperture turns over in a small but prominent hook. As far as can be ascertained the hook is formed quite simply by the retroversion of the dorsal lip. There is no torsion of the thecal axis. The hook occupies about one-third to one-half of the width of the polypary at that level.

There is no overlap. The protheca arises as a slender tube approximately 0·07 to 0·09 mm in diameter and at this initial point often shows a crumpling similar to that figured by Wilson (1953) in the case of M.sartorius Tornquist. The protheca widens steadily throughout its length to a maximum of.19mm immediately prior to the hook itself. Thus the whole protheca takes the form of an axially elongated triangle.

Remarks: The form of the thecae and polypary is so distinctive as to enable separation immediately from other slender forms such as M.(Streptograptus) Yin and M.(Mediograptus) Boucek and Pribyl.

A form similar in general outline and thecal size is M.capillaris (Carr.) but in this species the hook is more prominent, the rhabdosome wider and the thecae more closely spaced.

Another similar form is the species M.crinitus which Wood (1900) recorded from the Ludlow Series (M. nilssoni Zone). This form has a similar thecal count, general size, and hook but is rather more robust, and the protheca has not the same distinctive shape. This species does, however, seem to be very close to M.simulatus sp. nov. though its occurrence at a very much higher level itself poses problems.

Monograptus ex. gr. elongatus Tornquist

text fig. 8f1

Plate 30, fig.6

1899 Monograptus elongatus n. sp. Toernquist pp.17-18,Pl.3,figs.12-18.

Material: Several fragments.

Horizon and Locality: Zone of M.sedgwicki; Spengill (75,9·4); M.turriculatus Zone, Spengill (S159,8·75).

Description: A few proximal fragments each showing only two thecae, have been obtained but these were considered so striking as to be worthy of description. (one of the thecae was unfortunately destroyed but not before the specimen had been fully measured and drawn).

The form is similar to M.elongatus Toernquist and M.cf. elongatus Elles and Wood in that a long proximal thread-like part precedes a sudden expansion as the thecal lobe is approached. In the Cautley specimens however, the thecae number only 5 in 10 mms and the thread-like portion is twice the length of the thecae themselves (It is assumed here that the thecae are completely isolated from each other).

Each "thread" is 0·04 mm wide (in relief) and 1·2 - 1·3 mms long. Each theca is 0·65 mm long and 0·32 mm wide at the maximum breadth. The thecae are triangular, inclined at a low angle to the dorsal "thread" and enrolled in their apertural regions.

M.ex. gr. elongatus differs from M.elongatus itself in the following points:-

a) The thread-like portion is twice as long as the isolated thecal tubes, not equal in length to them (see Tornquist 1899,Pl.3,fig.14).

b) The thecae number 5 in 10 mms although Tornquist's fig.14 (Pl.2) has 6½ in 10 mms.

c) The ventral margin of each theca is convex, not concave.

d) The thecae are enrolled into a distinct lobe (compare Pl.2,fig.14 of Tornquist).

A distal fragment from S159,8·75 (Spengill) resembles M.cf. elongatus Elles and Wood. This has a distinct, but shorter and thicker, thread-like portion. The thecae are very similar to those described above - triangular adpressed to the axis, and with hooked apertural regions. They number 10 in 10 mms though this value is slightly increased by compression. The width of the rhabdosome is slender and not more than 0·45mm.

Remarks: The two types of Cautley specimens occur at different horizons and cannot definitely be assigned to the same species. If they do in fact belong to one species then the change throughout the polypary of the thecal type would be similar to Tornquist's interpretation of M.elongatus, and furthermore a parallel might be found with the triangulate monograptids some of which also have isolate proximal thecae and more triangular distal thecae inclined at a lower angle to the axis of the rhabdosome.

Material seen: Specimen figured by Elles and Wood text fig.342 and Pl.49,fig. 5a; specimen in Elles Collection (S.M. no. A23095) from the zone of M.triangulatus Tenmarp.

Monograptus sp. A

Plate 32, fig. 3.

Material: Three specimens in relief, two showing the sicula and th.1 and 2, the third showing two proximal thecae.

Horizon and Localities: Low down in the C.centrifugus- insectus zone; Pickering Gill (5P); Five Gills (8Fi).

Description: The prominently hooked thecae of this species ally it with Monograptus Group E. Whilst it resembles M.priodon (Bronn) in some respects the thecal hooks are quite different and the proximal end straight.

The sicula is prominent and is at least 1·43 mms long but merges into the nema in such a manner that exact measurement is not possible. At its base the sicula is narrow being only 0·19 mm wide but it widens rapidly so that at a distance of 0·4 mm from its aperture it measures 0·32 mm across, and here gives rise to th.1. The apex of the sicula reaches midway between the apertures of th.1 and th.2.

Th.1 is 1·3 mms long, of which 0·4 mm are involved in the hook. Th.2 is the same length and has the same proportion involved in the hook. The thecal count is 12½ in 10 mms. At the aperture of th.2 the total width of the rhabdosome is 0·52 mms of which the hook occupies 0·15 mm or roughly between one quarter and one third.

Remarks: This species is rare but has distinct characters of its own. It is perhaps closest to M.riccartonensis Lapw. but is narrower, has less overlap, and the thecae are smaller. The hook itself is very similar.

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genus MONOGRAPTUS GROUP F

Group diagnosis: A somewhat artificial grouping of convenience containing of those species described, only M.discus (description below); specimens of this species flattened from the dorsal side show that the thecae posess fine spines; the fact that M.discus can be flattened in this way taken together with the fact that occasional α- shaped specimens are found suggests that there may be a slight tendency to spiral coiling and that the species may not be dissimilar in some respects to M.turriculatus (Barrande).

Monograptus discus Toernquist
not figured

1883	Monograptus discus n. sp.		Toernquist pp.24-25.
1892	"	"	Toernquist p.39,Pl.3,figs.27-28.
1912	"	"	Toernquist. Elles and Wood pp.439-440,text figs. 302 a-c,Pl.44,figs.5a-d.
1940	"	"	Tqt. Laursen p.26; Pl.1,fig.9; text fig.18.
1945	"	"	Tornq. Waterlot Pl.36,fig.376.
1950	"	(Monograptus) discus	Tornquist. Gortani Pl.1,figs.1,7c,11c; text figs.4,5.

Material: Many specimens, all flattened and mostly complete.
Horizon and Localities: Zones of M.crispus to M.griestonensis (sensu Wilson 1953); S231,2 to S259,1·25 Spengill; Wards Intake; Hebblethwaite Hall Gill etc.
Diagnosis: Rhabdosome small, coiled into a tight plane spiral of very characteristic appearance. Thecal count high, approximately 20 in 10 mms.
Description: The Cautley specimens of this species seem to be quite typical and no variations from the material described by the above authors has been noted. The writer's specimens, however, are not as well preserved as those figured by Elles and Wood (p.439) for example and the details of the thecae and sicula cannot always be made out.

Most of the Cautley specimens are sub-elliptical in outline (see Elles and Wood p.439) but this is clearly due to compression of the rock. The long axis of the ellipse is invariably parallel to the lineation present on the bedding plane surface. (i.e. the direction of elongation of the rock or the tectonic b direction.)

The sicula is not conspicuous. No thecal spines have been observed but in those forms flattened dorsally instead of laterally short spines project on either side of the axis suggesting that paired apertural spines are present.

Material seen: Specimens in the Sedgwick Museum, Cambridge.

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genus MONOGRAPTUS GROUP G

Group diagnosis: Polypary small, slender, with dorsal curvature; thecae lobed and sessile to rhabdosome; details of apertural coiling not clear.

Monograptus minimus cautleyensis subsp. nov.

Plate 33, figs. 1, 2; Plate 32, fig. 5

Holotype: HUR./1M/50, a specimen in low relief, almost complete, but lacking the sicula, preserved partly as a cast.

Material: About twenty specimens; not rare but apt to be overlooked because of its diminutive appearance.

Horizon and Localities: Restricted to the *C. centrifugus* - *C. insectus* Zone; Wenlock Series, Bluecaster Gills (Near and Middle Gill); Wandale Hill Gill A (29W, 28W); R. Rawthey, Mouth of Wandale Beck (49W); Wandale Hill Gill B (37W).

Diagnosis: Slender, dorsal curvature throughout. Widens very slowly indeed from a small sicula. Thecae inconspicuous, on the ~~dorsal~~ ventral side of the rhabdosome, apertural regions coiled, and closely sessile on the rhabdosome. Thecae number 9 in 10 mms. Max. breadth about 0·4mm.

Description: The rhabdosome is characteristic and can only be mistaken for forms included by Boucek and Pribyl (1951) under *Monograptus* (*Mediograptus*). Proximally the polypary has prominent dorsal curvature which becomes less as the distal end of the species is approached. The distal extremities may appear almost straight.

A gradual widening takes place from 0·19 mm - 0·2 mm at the level of the lobe of th.1, to a maximum breadth of 0·4 mm-0·5 mm after 2 cms.

The sicula is small (0·8 mm) but prominent and its apex almost reaches the lobe of th.1.

The thecae themselves are long and their apertures are coiled into a lobe which is adpressed to the rhabdosome. Details of the aperture cannot be seen and in many specimens it is impossible to detect the presence of a coiled aperture.

The presence of a slight overlap can be detected in the better preserved specimens. Throughout most of the polypary the thecae number 9 in 10 mms, but this value increases over the first half dozen thecae to 12 in 10 mms.

Remarks: The closest relatives of this form are Monograptus kolihai (Boucek) and Monograptus kodymi (Boucek.) From M.kolihae kolihad and M.kolihai minor Boucek, M.minimus cautleyensis subsp. nov. differs in its thecal count (6-7 in 10 mms as compared with 12-9 in 10 mms) and in the less prominent lobation. In M.minimus cautleyensis subsp. nov. the lobe occupies only one quarter to one fifth of the total breadth of the rhabdosome.

The Cautley form is, however, extremely close to M.(Mediograptus) minimus Boucek and Pribyl, from which it differs only in width and thecal count. M.m.minimus has a thecal count of 11-12 in 10 mms whilst M.m.cautleyensis has a count, throughout most of the rhabdosome of 9 in 10 mms and only at the proximal extremity is 12 in 10 mms reached. The usual width in Boucek and Pribyl's species is 0·2 to 0·3 mm (max. 0·4 mm) whilst the Cautley form is usually 0·4 mm and often more.

The Bohemian species is recorded from the C.murchisoni zone whereas the Cautley material is restricted to the preceding zone of C.centrifugus - C. insectus.

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genus MONOGRAPTUS GROUP H

Group diagnosis: Rhabdosome variously curved, slender; thecae axially elongated, triangular with apertural region of metatheca lobed so that the lobe stands well clear of the rhabdosome except in proximal thecae.

Monograptus crispus Lapworth

Plate 35,fig.10

1876 Monograptus crispus, sp. nov. Lapworth pp.503-4,Pl.20,fig.7a-c.
1897 " " Perner p.34,text fig.30
1907 " gemmatus Toernquist p.21,Pl.3,figs.26-27.
1912 " crispus, Lapworth. Elles and Wood pp.456-7,text figs.314, a-c,Pl.45,figs.6a-f.
1931 " " " Boncev p.57,Pl.1,fig.6.
1939 " " Hundt p.77,fig. on p.312.
1945 " " Waterlot p.83,Pl.38,fig.393.
1951 " (Globosograptus) crispus Lapworth, 1876. Boucek and Pribyl pp.8-10,Pl.1,figs.1-7,Pl.2,figs.1-3.
1952 " " crispus Lapworth. Munch p.107,Pl.32,figs.1 a-e.
1962 Globosograptus crispus (Lapworth). Pomariz p.262; Pl.19,figs.2; Pl.22, figs.10-15.

Holotype: Specimen figured by Lapworth 1876,fig.7a and refigured by Elles and Wood 1912, Pl.45,fig.6a.

Material: Many specimens in low relief or flattened, fragments common.

Horizon and Localities: Zone of M.crispus and base of zone of M.griestonensis (sensu Wilson 1958), Llandovery Series. S231,2 - S248,10·25, Spengill; Wards Intake; Five Gills etc.

Diagnosis: Distinctive curvature, extreme proximal end dorsally curved and extremely slender, mesial portion almost straight and still slender, distal parts ventrally curved and showing rapid widening to about 1mm breadth. Thecae enrolled at the aperture throughout, but sessile on the rhabdosome proximally and removed from it distally.

Description: The degree of curvature presents varying appearances depending upon its position with respect to the direction of elongation of the rock. In consequence features such as thickness and thecal size are very variable but generally fall within the ranges given by Lapworth (1876) and Elles and Wood (1912).

Lapworth records 20-30 thecae to the inch (i.e. rather more to rather less than 10 in 10 mms). Elles and Wood on the other hand give 7-9 in 10 mms whilst Boucek and Pribyl (1951,p.9) observed 11-7 thecae in 10 mms in their material. The figured specimen from Cautley (Pl.35,fig.10) shows 9 thecae in 10 mms at the proximal end. Compression will have reduced the value slightly for the distal thecae and increased it for the proximal thecae.

This figure also shows that the typical curvature described above is reduced in the distal portions and accentuated proximally, due to the compression, whilst the straight mesial part is now non-existent.

The striking contrast between proximal and distal thecae is also clear on the same specimen. Over 50°/o of the thecal tube is involved in the free portion of the distal thecae and about 30°/o in the actual lobe. The proximal thecae show only about 10°/o involved in the lobe which is pressed tightly against the rhabdosome.

The thecal overlap is nil throughout the polypary.

Material seen: Specimens in the Sedgwick Museum, Cambridge.

genus MONOGRAPTUS GROUP I

Group diagnosis: Rhabdosome slender, often small, and with dorsal or ventral curvature (or both); thecal tubes uniform, closely adpressed to the rhabdosome and metatheca wholly enrolled into a prominent lobe.

Monograptus antennulatus (Meneghini)

Plate 35,figs.5,9

1857 Graptolithus (Monograpsus) Antennulatus Meneghini p.156,Pl.B,I,1a-b.

1883 Monograptus capillaceus n. sp. Tullberg p.24,Pl.2,fig.28-29.

1912 " " Tullberg. Elles and Wood pp.458-9,text figs. 316 a-c,Pl.46,figs.4a-d.

1922 " antennularius Meneghini. Gortani p.156,Pl.B,figs.1,nos. 1a-b.

1942 Monograptus (Streptograptus) antennularius (Meneghini 1857). Boucek and Pribyl pp.14-15, Pl.3, figs.6-8; text fig.5, 1-p.
1945 " antennularius Meneghini. Waterlot p.83; Pl.38, fig.389.
1952 " (Streptograptus) antennularius Meneghini. Munch p.112, Pl. 35, fig.7

Lectotype: Meneghini's specimen on Table B, fig.I, la.
Material: Many specimens, all impressions.
Horizon and Localities: Zones of M.riccartonensis (top few feet), and M.antennulatus; Near Gill, Middle Gill, Hobdale Beck, R.Rawthey (mouth of Wandale Beck), Wandale Hill (Gill A, Gill B).
Diagnosis: Rhabdosome slender, flexuous, exhibiting double curvature. Thecae pressed to the rhabdosome but coiled into a lobe in the apertural region. Dorsal curvature at proximal end, and ventral curvature distally. Maximum width 1mm. Thecae number 10-7 in 10 mms.
Description: The length and form of the rhabdosome is very distinct. The proximal region shows a strong dorsal curvature over the first centimetre or two but then changes, in the mesial and distal regions, to a pronounced ventral curvature. A second phase of dorsal curvature is seen occasionally but more usually the distal extremities are straight, by which time a breadth of the order of 1mm has been attained. A length of 10 cms is achieved in adult rhabdosomes.

The sicula is 1mm long and 0·26 - 0·3 mm wide at the aperture. Its apex reaches almost to the level of the lobe of th.1. In individual specimens the thecal count does not vary greatly throughout the polypary unless one portion of the curve lies parallel to the direction of compression and another part oblique to it. Elles and Wood (p.438) describe forms in which the proximal thecae have their apertural regions more widely spaced. Whilst a fall in thecal count has been observed in the proximal parts of some Cautley specimens it is more usual to find a slight drop distally. The specimen figured on Pl.35, (fig.5), for example, has $8\frac{1}{2}$ thecae in 10 mms at the proximal end and $7\frac{1}{2}$ in 10 mms distally. It should be pointed out, however, that the direction of compression is more parallel to the distal thecae and more nearly at right angles to the length of the proximal thecae. In this particular specimen a thecal count of 8 in 10 mms throughout would probably be the case in the uncompressed state.

The thecae are coiled into lobes at their apertures and the lobe itself is about one-third the breadth of the polypary. Details of the coiling are not easy to unravel in this flattened material but in some cases it seems to be relatively simple with the aperture facing the dorsal side of the rhabdosome. Torsion of the thecal axis clearly occurs as in forms like M.nodifer Tornquist. A slight amount of overlap exists.

Remarks: This is a common species in its own zone (see p41) where it occurs in association with Monoclimacis vomerina basilica and Pristiograptus dubius.

Boucek and Pribyl (1942) in their detailed analysis of the subgenus Streptograptus (Yin) name this form Streptograptus antennularius (Meneghini) but in Meneghini's original (1857) description the specific name used is antennulatus.

Material seen: Specimens in Sedgwick Museum, Cambridge.

Monograptus exiguus (Nicholson)

Plate 7, figs.6,7; Plate 33, fig.11.

1868 Graptolites lobiferus var. exiguus Nicholson p.533,Pl.19,figs.27,28.
1871 Graptolithus plumosus Baily p.23,figs.1a-c.
1876 Monograptus exiguus, Nicholson, sp. Lapworth p.503,Pl.20,fig.6.
1892 " " Toernquist p.25,Pl.2,fig.22.
1899 " " Nicholson. Toernquist p.24-25,Pl.4,figs.26-28.
1912 " " ("). Elles and Wood pp.453-4,text fig.312 a-c,Pl.46,figs.1a-d.
1919 " " Kirste p.169,Pl.2,figs.40a-b.
1923 " " Gortani pp.13-14,Pl.1,figs.23-27.
?1931 " " Haberfelner p.135,Pl.2,figs.5a-c.
1932 " " Glemerec pp.108-110,Pl.2,figs.4a-d.
1939 " " Munch p.20,figs.27a-d, on p. 34.
1942 " (Streptograptus) exiguus (Nicholson 1868). Boucek and Pribyl p.5-6,Pl.1,figs.1-3,text fig.3a-d.
1949 " " exiguus (Nicholson). Obut pp.23-24,Pl.4,figs. 7a

1958 Streptograptus exiguus (Nicholson). Obut p.63,Pl.5,figs.3-4,text fig. 13.

1962 " " exiguus (Nicholson). Romariz pp.263-4,Pl.22, figs.13,11, and ?7.

Lectotype: Specimen figured by Nicholson (1868) on Pl.19,fig.27.
Material: Several hundred specimens, many well preserved, all flattened.
Horizon and Localities: Zone of M.turriculatus, except for the bottom two bands of the R.maximus subzone; Zone of M.crispus; Zone of M.griestonensis (sensu Wilson 1953); Spengill (S123,7·25 to S264,5); Wards Intake, Hebblethwaite Hall Gill, Five Gills, Stockless Gill,etc;
Diagnosis: Rhabdosome small, hook shaped and relatively robust. Extreme proximal end shows slight dorsal curvature, and the rest of the polypary very prominent ventral curvature. Distal fragments may be almost straight.
Description: The "hook" at the proximal end of the rhabdosome has variable acuteness depending upon the direction of compression of the fossil. All other measurable characters vary in a like manner.

Thecal counts of up to 20 thecae in 10 mms have been obtained where the specimen has been squashed at right angles to the line of the polypary. On the other hand counts of less than 12 in 10 mms have not been observed even on specimens squashed parallel to the line of the polypary, which suggests a generally high figure for the Cautley material. Elles and Wood (p.453) give a range of 14-12 in 10 mms in their detailed analysis of the species. The sicula is always prominent though quite small. Its apex reaches to about the level of the first thecal lobe.

In all other respects the Cautley specimens are close to those described by the above workers, particularly as regards general form and size.
Material seen: Specimens in Sedgwick Museum, Cambridge.

Monograptus pseudobecki Boucek and Pribyl

Plate 33, figs.7-10

1876 Monograptus Becki, Barrande, sp. Lapworth pp.500-501,Pl.20,fig.2a-b.
1912 " " ( ). Elles and Wood pp.452-3,text fig.311a-b Pl.45,figs.4a-f.

1923 Monograptus becki (Barr.). Gortani p.12,Pl.1,figs.21-22.

1942 " (Streptograptus) pseudobecki n. sp. Boucek and Pribyl, p.18, text fig.42b.

1950 " becki (Barr.). Gortani Pl.1,figs.7b-e,8 text fig.8.

?1962 Streptograptus pseudobecki Boucek & Pribyl. Romariz p.264,Pl.22,fig. 14.

Lectotype: Specimen figured by Lapworth (fig.2a) and refigured by Elles and Wood (text fig.311a and Pl.45,fig.4a).

Material: About 15 specimens, mostly in low relief and in varying states of preservation and fragmentation.

Horizon and Localities: First appears at the base of the R.maximus subzone in S115,5 Spengill and then sporadically throughout the zone of M.turriculatus.

Diagnosis: Very slight but distinctive double curvature, distal fragments almost straight. Proximal end extremely slender and complete specimens, with sicula attached, are not common. Thecae tightly coiled in apertural region and proximal thecae seem to be more closely pressed to the rhabdosome. Thecal count 14 to 15 in 10 mms at th.1 to th.2, rapidly falling to 12 in 10 mms at about th.7 and distally to 10 in 10 mms.

Description: The slight double curvature and very slender proximal end is very characteristic and distinguishes it from all other species having similar thecae. In specimens compressed parallel to the length of the rhabdosome the polypary may appear almost straight. Conversely specimens compressed at right angles to this line show excessive double curvature and appear rather more robust.

The sicula is small and slender and its apex reaches to the level of the coiled apertural region of th.1. At the base it is 0·12 mm across, and the maximum length is 0·78 mm. The thickness of the rhabdosome at the level of lobe of th.2 is 0·19 mm to 0·21 mm.

At the extreme proximal end the thecal count is high and numbers 14-15 in 10 mms (th.1 to th.2). It then falls rapidly as the thecae become larger until at th.7 to th.8 they number 12 in 10 mms. Following this there is a slower reduction as the rhabdosome widens and although the thecal tubes actually lengthen, a greater length is involved in the lobe of the apertural region. In the most distal parts the thecae number 10 in 10 mms.

Distally a greater length of the thecae is involved in the lobe though, in the Cautley material, this is not as pronounced as described by Lapworth (1876). Throughout the rhabdosome the lobe projects from the ventral margin to approximately the same extent.

The apertural characters of the thecae cannot be ascertained in great detail. They appear to be relatively simple and not as tightly coiled as in M.nodifer Tornquist for example.

Remarks: Lapworth (1876 Pl.20,fig.2b) figures a diversiform specimen but Strachan (1952 p.366), who examined the Lapworth Collection at Birmingham University, found no bilateral specimens and considered that further material would be required to confirm this point.

Elles and Wood (p.452) had no extreme proximal portions and pointed out that the sicula was unknown. It has not previously been described, although in the Cautley material such specimens with the sicula intact are not rare.

Material seen: Specimen labelled M.becki (S.M. no. A21895 Elles Collection); this specimen has a sicula and is from the Tarannon Shales, Forge Corner, Conway.

Monograptus (?)runcinatus pseudopertinax subsp. nov.

Plate 33, figs.5,6

Holotype: HUR./S140/5 , a proximal end in moderate relief having 7 thecae and sicula intact.

Horizon of Holotype: top of R.maximus subzone, zone of M.turriculatus, Spengill (Westmorland) (S140).

Material: About a hundred specimens mostly in low or moderate relief.

Horizon and Localities: From the base of R.maximus subzone to near top of the M.turriculatus zone; Spengill (S115,5 - S209,0.5).

Derivation of name:

Diagnosis: Proximal end straight, more distal portions show very slight ventral curvature. Sicula 1·17 mms long, apex reaching to the top of the lobe of th.1. Thecae number 14-12 in 1 0 mms proximally, falling to about 11 in 10 mms distally. Thecae are enrolled in the apertural region after the manner of M.nodifer Tornquist.

Description: The rhabdosome in this species resembles that of M.runcinatus pertinax Elles and Wood in being stiff rather than with the flexuous curvature of M.r.runcinatus Lapworth. It is, however, much more slender than M.r. pertinax and has more closely spaced thecae.

The sicula is 1·17 - 1·2 mms long and its apex reaches to the top of the lobe of th.1 and not beyond. In some specimens the sicula barely reaches this level. The holotype shows a slight constriction of the sicula at 0·06mm above the aperture. A virgella and short dorsal spine are present on the aperture of the sicula.

At the extreme proximal end the thecae commonly number 13 in 10 mms but fall within the range 14-12 in 10 mms. This value falls quickly to 12 in 10 mms (after 5 mms) and then more gradually to 11 in 10 mms throughout the remainder of the rhabdosome. It is possible that the number of thecae per cm. actually exceeds the ranges given since most of the good specimens examined were compressed parallel to the rhabdosome.

The apertural lobe is of the M.nodifer Tornquist type and, as in M.r. pertinax, the walls of the thecae are distinct. It may be contrasted in this respect with M.r.runcinatus. The early portion of each theca is broader than the part immediately preceding the lobe, and the lobe itself is not as prominent as in some other species. As a rule it occupies one-quarter to one-third of the total width of the rhabdosome, though this varies with the view presented to the observer.

Remarks: Strachan (1952) includes M.r.runcinatus Lapw. in the genus Diversograptus Manck since two stipes are developed which grow in opposite directions from the sicula. This material was found in the Lapworth Collection and Lapworth himself (1876, fig.4g) figures a bilateral M.runcinatus.

The material from Cautley should perhaps be included in the genus Diversograptus Manck but no diversiform specimens have been obtained and it is here retained, with reservations, in Monograptus.

M.(?)runcinatus pseudopertinax subsp. nov. differs from M.r.runcinatus Lapw. in the following points:-

a) The size and position of the sicula
b) the curvature of the rhabdosome
c) the more closely spaced thecae throughout the polypary,
d) the distinct nature of the thecal walls.

Material seen: M.runcinatus pertinax figured Elles and Wood fig.310 a-b, Pl.45 figs.3a,b,c and specimens of M.r.runcinatus in the same collection (Sedgwick Museum)

M.r.runcinatus figured Elles and Wood Pl.45, figs.2f,g and text fig. 309b (H.M.Geological Survey Museum)

Monograptus danbyi sp. nov.
Plate 33, fig.3

Holotype: HUR./8P/4 and counterpart /1 well preserved specimen in relief, with proximal region and sicula intact.
Horizon of Holotype: C.centrifugus - C.insectus Zone.
Locality: Pickering Gill (8P).
Derivation of name: After the writer's colleague the late Mr.C.M. Danby.
Material: One well preserved specimen, the holotype.
Description: The rhabdosome is dorsally curved throughout and is particularly strong in the initial few millimetres, where the sicula and th.1 and 2 lie in a line at right angles to the general trend of the more distal parts. Monograptus (Mediograptus) minimus Boucek and Pribyl is a species with similar curvature (see Boucek and Pribyl 1951 Pl.3, fig.9) but Monograptus danbyi sp. nov. has a much shorter recurved portion and is altogether stiffer. A maximum breadth of 0·52 mm is reached by th.8 or 7 and is maintained to the distal extremity.

The sicula is prominent, measures 0·9 mm in length and has a breadth at the base of 0·13 mm. Its apex reaches well above the apertural lobe of th.1.

At the proximal end the first few thecae are more closely spaced and, allowing for compression, number 11 in 10 mms. Distally this value falls to 10 in 10 mms and $9\frac{3}{4}$ in 10 mms.

The species has uniform thecae, the lobes of which occupy approximately half the breadth of the rhabdosome. A distinctive feature of the thecal tubes is the relatively broad initial part of each protheca which measures 0·26 mm in width. This narrows conspicuously as the lobe is approached and at its distal extremity the protheca is only 0·19 mm wide. A rapid narrowing then follows and the early part of the metatheca is 0·06 mm wide in profile view. However, it is clear that at this point the tube is transversely expanded and may be 0·2 mm wide in this direction. Thus whilst the initial part of each protheca is probably expanded in the dorso-ventral plane, the initial part of each metatheca is transversely expanded.

The metatheca is then coiled into a tight lobe. Torsion of the thecal tube begins in the initial part of the metatheca and can easily be detected where the succeeding protheca has been removed. (It is also apparent that at these points the initial bud of each theca must be extremely narrow in profile. The apertural region seems to be twisted more to the obverse side than the reverse side. In the case of M.nodifer the opposite appears to be true (Elles and Wood 1912, text fig.313 a-d; Boucek and Pribyl 1942, text fig.2).

Remarks: The thecal characters described above ally this species with those monograptids grouped by Yin (1937) into Monograptus (Streptograptus) and dealt with in more detail by Boucek and Pribyl (1942). On the other hand the continuous dorsal curvature of the rhabdosome suggests closer affinities with the group Monograptus (Mediograptus) Boucek and Pribyl 1948. These authors (1951.p.14) consider that M.(Mediograptus) is distinguished from M.(Streptograptus) Yin "only by the less coiled ends of the thecae, which are appressed to the axis of the rhabdosome, and by their occurrence on its dorsal side". Yin (1937) in his diagnosis of Streptograptus writes "Polypary with dorsal, ventral curvature".

On this basis M.danbyi sp. nov. is in an intermediate position between the two subgenera. Whilst the thecae are enrolled in a manner similar to M.(Mediograptus) the lobe itself is more pronounced than in any of the described species of the subgenus. It is interesting to note that M.(Med.) kodymi, M.(Med.) kolihai, and M.(med.) remotus Boucek and Pribyl seem to have thecae showing torsion towards the obverse side (Boucek and Pribyl, 1951, text fig.3d f,h,i,j).

Other thecal characters, particularly the distal diminution in breadth of the protheca, suggest a link with M.(Streptogfaptus) Yin. This feature is well illustrated by species such as M.runcinatus Lapw. and M.nodifer Tornquist. Dorsal curvature occurs proximally in some of the later species of M.(Streptograptus) as for example, in those of the M.(S) antennulatus Group. Boucek and Pribyl (1951, p.27) suggest the possibility that it was from such a group that M.(Mediograptus) may have separated.

The situation is further complicated by the fact that most of the material figured by Boucek and Pribyl seems to be preserved as impressions. If the distal part of the protheca in M.danbyi were transversely expanded to any degree (it must be at least slightly so) then upon being flattened it would produce a prothecal tube with approximately parallel sides and, at the same time, the conspicuous nature of the lobe would, at least in part, be lost. On the other hand the somewhat similar M.minimus cautleyensis subsp. nov. is preserved in low relief(? full relief) and the prothecal tube is uniform throughout its length being elliptical in cross section with the long axis of the ellipse in the dorso-ventral plane.

On balance the writer feels that M.danbyi sp. nov. is best considered as an intermediate form, at least from the morphological point of view, between M.(Streptograptus) Yin and M.(Mediograptus) Boucek and Pribyl, being perhaps closer to the former. The fact that it occurs in the C.centrifugus-insectus zone supports the possibility that it is close to an evolutionary line leading from the group M.(S) antennulatus to M.(Med.)

The stratigraphical distribution of this group is given below (Boucek and Pribyl zones of C.centrifugus and C.insectus are here grouped together):-

Post- C.murchisoni Zone;	antennulatus, retroflexus, floridus (M.antenulatus Group)
C.murchisoni Zone;	kolihai, minimus minimus, remotus (all Mediograptus) flexuosus (antennulatus Gp.)
C.centrifugus-C.insectus Zone;	kodymi, inconspicuous, minimus cautleyensis (Mediograptus); danbyi (uncertain position); (?) flexuosus (antennulatus Gp.)
Pre-C.centrifugus-insectus Zone;	runcinatus, retroversus, pseudobecki, extenuatus (all M.antennulatus Gp.)

genus MONOGRAPTUS GROUP J

Group diagnosis: Rhabdosome with varying degrees of dorsal curvature, usually strong in the proximal regions and gentle distally; proximal end may be enrolled into a plane spiral or a "fish hook" shape; distal thecae triangular, hooked and aperture either simple or with a dorsal lip and a pair of horns; often transversely expanded in the apertural regions; proximal thecae are triangular, triangular and axially elongated, or rastritiform.

Subgroup J.A: forms with at least a few rastritiform thecae at the proximal end, usually passing into distal triangular ones.

Subgroup J.B: forms with axially elongated thecae at the proximal end, giving place to triangular distal thecae.

Subgroup J.C: forms with triangular thecae throughout the length of the rhabdosome.

GROUP J.A

Monograptus triangulatus triangulatus (Harkness)

Plate 35, fig.11

1851 Rastrites triangulatus, Harkness. Harkness pp.59-60,(pars) Pl.1.
?1945 Monograptus triangulatus Harkness. Waterlot Pl.43,fig.429.
?1957 " " Romariz Pl.1,fig.5; Pl.2;fig.2; Pl.4,fig.1.
1958 " separatus triangulatus (Harkness). Sudbury pp.503-6,Pl.20, figs.52-63.
1959 " triangulatus triangulatus (Harkness, 1851). Sudbury p.172, non fig.
?1962 Demirastrites triangulatus triangulatus (Harkness). Romariz pp.273-4,Pl. 1,fig.7; Pl.19,fig.3.

Lectotype: The specimen figured by Harkness (1851) Pl.1,fig.3a (? 3b) designated by Pribyl and Munch (1942,p.4).

Material: Both distal and proximal fragments of variable length, preserved in relief, or flattened and compressed.

Horizon and Localities: Zone of M.triangulatus; Spengill (S24-28).

Diagnosis: Rhabdosome with dorsal curvature throughout, but only gently curved in the distal region. Proximal end hook-shaped. All thecae hooked, with a pair of horns. Proximal thecae rastritiform, distal thecae triangular. No overlap. Th.2 to th.11 rastritiform in most extreme cases; th.2 - th.8 is minimum of rastritiform thecae.

Description: The preservation of the Cautley material is not ideal but the species can usually be distinguished on the character, and number, of its rastritiform proximal thecae.

The shape of rhabdosome is similar to other fossils in the same group, e.g. M. t.separatus, M.t.fimbriatus, and the proximal end is sharply recurved. Distal fragments may appear more or less straight.

The sicula has not been observed, but proximal ends with th.1 preserved show that this is not rastritiform. It is adpressed to the axis for much of its length but the metatheca is higher than is the case in M.t.separatus.

Beyond th.11 the thecal tubes are always triangular, but measurement of height, thecal count etc, is always difficult because of compression. The distal thecae clearly expand transversely towards the aperture which consists of a pair of horns.

Remarks: M.t.triangulatus is distinguished from M.t.separatus in having rather more rastritiform proximal thecae. The rastritiform thecae themselves are different in being higher and thinner, and the parallel-sided portion of the protheca is narrower.

Bearing in mind the general preservation, the only form with which this species might be confused is M.t.predecipiens (Sudbury).

M.t.triangulatus is recorded from S24-28 in Spengill (i.e. collection was made from a 4' bed). Occurring quite commonly in the same bed is R.longispinus (Perner). As the collection was made, without discrimination, from the whole of this 4' bed, this occurrence does not preclude the evolutionary interpretation of Sudbury 1958 (M.t.triangulatus - M.t.extremus - R.longispinus) particularly in view of the fact that extremus-like forms occur in addition. (These, however, are badly preserved and more material is required before a diagnosis can be made).

Material seen: Specimens in Sedgwick Museum, including specimens figured by Sudbury 1958; specimens in H.M.Geological Survey Museum.

N.B. A single specimen of M.t.triangulatus has now been obtained from the top few inches of the preceding zone (S20-24, Spengill, Zone of P.cyphus) and it seems certain, therefore, that this species precedes R.longispinus.

Monograptus triangulatus separatus Sudbury

Plate 34,figs.2,3; Plate 35,fig.13

1958 Monograptus separatus separatus var. nov. Sudbury pp.496-499,Pl.19, figs.33-39.

1959 " triangulatus separatus Sudbury, 1958. Sudbury 1959 pp.171-2,fig. non.

(see Sudbury 1958 pp.496-7 for further references)

Holotype: The specimen figured as fig. 37,Pl.19 by Sudbury 1958.

Material: Many fragmentary specimens and several well preserved specimens.

Horizon and Localities: Zones of M.triangulatus, ?D. magnus; Spengill (S36-39 7); Watley Gill (5Wa).

Diagnosis: Triangular, non-overlapping, distal thecae, and rastritiform proximal thecae numbering 2-8. Rhabdosome dorsally curved, hook-shaped proximally and with gentle dorsal curvature distally.

Description: The Cautley specimens of this species agree with the description given by Sudbury (1958), though generally they are less well preserved.

The sicula is approximately 0·9 mm long and its apex does not reach the level of the aperture of th.1. The first theca is non-rastritiform, small in height, and is adpressed to the sicula for most of its length of 1mm.(increased by compression) whilst the metatheca is at least 0·2 mm long. Height is much affected by compression in the Cautley material. Figure 13,(Pl.35) for example has th.1 compressed towards the succeeding protheca; an original height of about 0·25 - 0·3 mm is reduced to less than 0·2 mm.

Succeeding thecae are rastritiform up to, in extreme variants, about th.8 Figure 3 (Pl.34) shows a specimen with 7 or 8 rastritiform thecae. The subspecies is distinguished from M.t.triangulatus in these cases by the lower height and more robust nature of the thecae.

Remarks: All except extreme variants are distinguished from M.t.triangulatus in having a smaller number of rastritiform thecae. From M.triangulatus fimbriatus it is distinguished by having at least two rastritiform thecae. M.t.predecipiens Sudbury has more slender rastritiform thecae and attenuated common canal regions. M.denticulatus is distinguished by its distal thecae which, although triangular, have parallel-sided common canals.

The species has been referred, in the past, to various other species, (see Sudbury 1958,p.499 "Remarks").

Material seen: Specimens figured by Sudbury (1958) contained in Sedgwick Museum, Cambridge.

Monograptus triangulatus major Elles and Wood
Plate 35,fig.8

1913 Monograptus triangulatus var. major var. nov. Elles and Wood pp.472-3, (pars) Pl.47,fig.5c,text fig.328b, ?Pl.47,fig.5d,non figs.5a,b,text fig.328a.

1945 " triangulatus var. major E & W.Waterlot Pl.43,fig.430.

1958 " separatus major (Elles and Wood) Sudbury pp.506-7,text fig. 10.

1959 " triangulatus major Elles & Wood. 1913. Sudbury p.172,non, fig.

?1962 Demirastrites " " (Elles & Wood). Romariz p.274, not figured.

Lectotype: Species figured by Elles and Wood text fig.328b (not Elles and Wood 1913, Pl.47,fig.5a as was suggested by Pribyl and Munch 1942, since this specimen is M.t.triangulatus (see Sudbury 1958,p.507)).

Material: A single definite specimen preserved in relief, but as a mould.

Horizon and Localities: Zone of M.triangulatus; Spengill (S36-39,7)

Description: The rhabdosome is dorsally curved in the manner illustrated by Sudbury (text fig.10, 1958) and Elles and Wood (1913,text fig.328b = same specimen as figured by Sudbury, but less completely figured). Eighteen thecae preserved as moulds of thecae in relief, are present on the Cautley specimens. These show the typical decrease in height as the proximal end is approached but the highest thecae are 2·21 mms. This figure compares well with those given by Sudbury (2·25 mms). The most proximal theca seen is only 1·17 mms and the succeeding theca 1·3 mms high.

Throughout the fragment the thecae are uniform and are long, narrow, triangular tubes showing no overlap and only a slight tendency to be rastritiform at the proximal end. They are distinctly hooked at the aperture and the hook may take the form of paired horn, though this cannot be ascertained in a specimen preserved in this manner.

Monograptus convolutus (Hisinger)

Plate 35,fig.7

1828	Krotka graptoliter from Furudal, Hisinger p.169,Pl.4,fig.lc.			
1837	Prionotus convolutus	Hisinger p.114,Pl.35,fig.7		
1912	Monograptus convolutus	(Hisinger).	Elles and Wood pp.467-9,text fig. 324a-b,Pl.47,figs.la-d.	
1945	" "	Hisinger.	Waterlot Pl.43,fig.426	
1949	Demirastrites "	(Hisinger).	Obut p.27,Pl.5,fig.5.	
1958	Monograptus "	"	Sudbury pp.511-3,text fig.13,Pl.21, figs.76-78.	
?1962	Demirastrites "	"	Romariz p.271,not figured.	

(further references Pribyl and Munch 1941,pp.15-16.

Holotype: Specimen figured by Hisinger (1837,Pl.35,fig.7), refigured by Tullberg (1882,Pl.2,fig.13).

Material: A few fragmentary specimens preserved in low relief or flattened.

Horizon and Localities: Zone of M.convolutus; Watley Gill (10Wa); Birks Beck (?5Bi,6Bi).

Description: All the fragments found show strong dorsal curvature even on short pieces. Examples have been found of the rastritiform proximal thecae and triangular distal thecae described by other workers, and both are figured (Pl.35, fig.7). These two specimens occur in close association suggesting spiral curvature of the rhabdosome, though this cannot be proved in any of the Cautley specimens.

The proximal rastritiform thecae are quite short (up to 2 mms) and six are seen on fig.7 (Pl.35). More distal thecae are usually 2·5 mms high and occasionally more. These have a very characteristic appearance in the flattened form being long, narrow, and tapering to a point which clearly represents a slightly recurved hook. The thecal count is very variable depending upon the direction of compression in relation to the fossil.

The sicula has not been seen.

Material seen: Specimens figured by Sudbury 1958 and contained in the Sedgwick Museum, Cambridge; specimens in H.M.Geological Survey Museum (e.g. specimen figured by Elles and Wood as text fig.324b, Geol. Survey no. 26314.

Monograptus decipiens Tornquist

Plate 34,fig.11; Plate 35,figs.2,3,4

1899	Monograptus	decipiens	n. sp. Toernquist pp.20-21,Pl.4,figs.9-14.
1912	"	"	Tornquist. Elles and Wood pp.469-70,text fig.325a (non b-d) Pl.47,figs.3a, (?b,e) (non c-d).
?1941	Demirastrites	"	decipiens (Tornquist 1899). Pribyl and Munch pp.13-14,text fig.1, no. 6.
1945	Monograptus	"	Tornq. Waterlot Pl.43,fig.427.
1958	"	"	Tornquist. Sudbury pp.510-11,Pl.21,figs.74-75.
1962	Demirastrites	"	decipiens (Tornquist). Romariz p.272; Pl.2,fig.3.

Lectotype: Specimen figured by Tornquist (1899,Pl.4,fig.10).

Material: Several fairly complete rhabdosomes, all with proximal ends.

Horizon and Localities: Zone of M.convolutus; Watley Gill (9Wa,11Wa).

Diagnosis: Rhabdosome coiled, possibly spirally, with a slender proximal end which has rastritiform thecae, and a quite robust distal portion with triangular thecae.

Description: The rhabdosome has a characteristic curvature. In some the coiling is simple and could result from an originally plani-spiral rhabdosome whilst the sigmoidal curvature of others suggests that the original coiling was in the form of a helical spiral (see Pl.35,fig.2).

The sicula is slender and 0·8 mm long. Its apex does not reach the level of the metatheca of th.1. The protheca of th.1 occupies about two-thirds of the length of the whole theca but the metatheca is also quite long (0·52mm) and slender so that it appears rastritiform. The width of the metatheca is about 0·08 mm narrowing (in profile) towards the aperture. The succeeding prothecae is parallel-sided and about 0·04 mm wide (in relief) and very long in proportion (0 52 mm). Theca 2 is 0·65 mm high showing a slight increase from th.1 though the width and distinct rastritiform appearance is similar.

The succeeding thecae increase slowly in height and remain rastritiform separated by long prothecae, until about th.7-10 when the very gradual change to a broader base and lower inclination to the axis becomes apparent. The thecae are about 1mm high at this point although distally they reach 1·3-1·4 mms. All these triangular thecae have concave ventral margins in profile view and in most specimens the apertural hook cannot be seen. They number, distally, about 8-11 in 10 mms though this value is quite variable and depends upon the direction of compression.

Material seen: Specimens in H.M.Geological Survey Museum.

Monograptus denticulatus denticulatus Tornquist

Plate 34,figs.6,10

1899	Monograptus denticulatus		n. sp. Toernquist p.18,Pl.3,figs.19-23.
1912	"	"	Tornquist. Elles and Wood pp.474-475,text fig. 330,Pl.48,figs.2a-f.
1941	Demirastrites	"	denticulatus (Tornquist 1899). Pribyl and Munch p.10, non fig.
1945	Monograptus	"	Tornq. Waterlot Pl.43,fig.432
1958	"	"	Tornquist. pp.509-510,Pl.21,figs.72-73.
?1962	Demirastrites	"	denticulatus (Tornquist). Romariz p.272, not figured.

Lectotype: The specimen figured by Tornquist (1899, Pl.3,fig.19).

Material: Fairly numerous fragments and some well preserved proximal ends.
Horizon and Localities: Zones of M.leptotheca - M.convolutus; Birks Beck (6Bi, 5Bi); Watley Gill (10Wa).
Diagnosis: Rhabdosome is hook-shaped and relatively small. Dorsally curved throughout, particularly so at the proximal end. First few thecae small and rastritiform; distal thecae with a prominent hook whose aperture faces the dorsal side of the polypary.
Description: This species is a highly characteristic form and is recognized more upon the characters of the gradually changing proximal thecae than upon the general shape of the rhabdosome which is similar, but smaller, to those of the M.t.triangulatus Group.

The sicula is about 0·78 mm long and its apex does not reach the metathecal portion of th.1. Theca 1 is about 0·58 mm high. There is a gradual increase following th.1 (th.2, 0·65 mm; th.3, 0·78 mm) to a distal maximum in the region of 1·3 mms. As a rule the first few thecae are rastritiform but even th.4 is sometimes slightly triangular. The long, parallel-sided prothecal parts are characteristic.

These distal thecae still have distinct parallel-sided prothecal portions about 0·26 mm wide and up to 0·39 mm long. The dorsal margin of each mesial theca is at right angles to the general line of the polypary. From the authors material it is not certain whether the thecae become inclined at a lower angle to the axis distally, though fig.6 (Pl.34, Spec, HUR./6Bi/42) suggests this.
Remarks: M.d.denticulatus can be distinguished from most triangulate monograptids by the small size and number of the rastritiform proximal thecae, and the characters of the distal thecae which are small and prominently hooked.

The proximal thecae also distinguish it from M.communis sl. M.planus and M.pseudoplanus whilst the distal thecae enable easy separation from M.decipiens The small number of proximal thecae also distinguish it from this latter species

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Monograptus sp. D

Plate 36,fig.7

Material: A single specimen 2½ cms long with several thecae preserved in pyrites in full relief.

Horizon and Locality: Zone of M.sedgwicki; Spengill (S73,11·4).
Description: The specimen shows gentle dorsal curvature and is about $2\frac{1}{2}$ cms long. The thecae are 1.95 mms high and clearly have paired horns of the type described by Sudbury (1958) for the M.t.triangulatus Group. The apertural region, however, is not recurved into a prominent hook and only shows a very slight recurvature of the kind shown by M.convolutus. Each theca is distinctly triangular, broad based, but at the same time relatively narrow in the later metathecal portion. There is a clear, but short, parallel-sided prothecal part about 0·4 mm wide. The thecal count is $8\frac{1}{2}$ in 10 mms.
Remarks: The general form of the thecae is very similar to that shown by M. convolutus to which species this specimen probably has the closest affinities. With a length of almost 2 mms the thecae are not particularly short, and are longer, for example than those in M.t.triangulatus, M.t.separatus etc.
Material seen: Specimens of the form described as M.knockensis occur in association with M.convolutus (e.g. figured specimen of Elles and Wood text fig.324b Geol. Survey no. 26314). This particular specimen of M.convolutus is very similar to Monograptus sp. D.

GROUP J. B

Monograptus communis communis Lapworth
Plate 34,figs.5,7; Plate 36,fig.8

1876a Monograptus convolutus, Hisinger, sp. Var (a) communis. Lapworth p.358 Pl.13,fig.4a, (non 4b).
1876b " spiralis Var (b) communis. Lapworth p.128,Pl.5,fig.16.
1876c " convolutus (communis) Lapworth, p.5,Pl.1,fig.18.
?1897 " communis, Lapworth. Perner pp.15-16,text fig.14,Pl.12,fig. 20,(non Pl.11,figs.18a-b,Pl.12,figs.5,6a-b,7-9)
1912 " " (Lapworth). Elles and Wood pp.480-1(pars) text fig.336(non b), Pl.49,figs.1a&c (non b,d,e)
1920 " " Gortani p.45,Pl.3,fig.31 (non 32).
?1929 " " Haberfelner p.119,Pl.11,figs.10a-b.

?1933 Monograptus communis (Lapworth). Sun p.40,Pl.6,fig.6.
1944 Spirograptus " communis (Lapworth 1876). Pribyl pp.29-30 (pars), Pl.8,figs.1,non figs.2,3.
1945 Monograptus " Lapw. Waterlot Pl.42,fig.418.
?1947 " " Lapworth. Ruedemann p.477,Pl.86,figs.42-43.
?1949 Campograptus " ("). Obut p.24,Pl.4,figs.8a-b.
1958 Monograptus " communis Lapworth. Sudbury pp.520-2,Pl.23,figs. 97-101.
1962 Spirograptus " " (Lapworth). Romariz p.267,Pl.14,figs. 3-4.

Lectotype: The specimen figured by Lapworth (1876a, Pl.13,fig.4a).
Material: Mainly poorly preserved fragments.
Horizon and Localities: Zones of M.triangulatus, M.leptotheca, and M.sedgwicki; Spengill (S36-39,7; S73,11·4 - S75,9·4); Birks Beck (6Bi); Watley Gill(?9Wa).
Diagnosis: Dorsal curvature throughout. Thecae triangular, axially elongated proximally, inclined at a higher angle distally with a characteristic hook.
Description: The fragments obtained were identified with difficulty but appear to be identical with M.c.communis. The detailed description by Sudbury (1958) has facilitated the placing of these fossils. They are distinct from M.c. rostratus in having rather lower thecae inclined at a lesser angle to the axis and can only be confused in this respect with M.communis obtusus subsp. nov. from the Zone of M.sedgwicki.
Remarks: This is not a common fossil at Cautley. Distal fragments occur in the M.sedgwicki zone but these may be synonymous with M.c.obtusus subsp. nov.
Material seen: Specimens in H.M.Geological Survey Museum (e.g. specimen figured by Elles and Wood, text fig.336a); specimens in Sedgwick Museum.

Monograptus communis rostratus Elles and Wood
Plate 35,fig.6

1912 Monograptus communis (Lapworth) var. rostratus var. nov. Elles and Wood pp.481-2 (pars) text fig.337,Pl.49,fig.2b (non a,c).

1912 Monograptus communis (Lapworth). Elles and Wood pp.480-481(pars),Pl.49, fig.1b.
1945 " " var. rostratus E & W. Waterlot Pl.42,fig.419.
1958 " " rostratus Elles and Wood. Sudbury pp.522-3,text fig.21,Pl.23,figs.102-105.
?1962 Spirograptus " rostratus (Elles and Wood). Romariz p.267, not figured.

non.
1945 Spirograptus communis rostratus Pribyl p.30-31.

Lectotype: Specimen figured by Elles and Wood Pl.49,fig.2b, and text fig.337.
Material: Numerous well preserved distal fragments.
Horizon and Localities: Zones of M.triangulatus to P.leptotheca; Birks Beck (6Bi); Watley Gill (6Wa).
Diagnosis: The rhabdosome, as in M.c.communis, is dorsally curved throughout with a loose hook-like recurvature at the proximal end. Distal thecae are higher than in M.c.communis and the spacing rather closer, i.e. they appear to be more "upright".
Description: As in the case of M.c.communis distal fragments are most common, but a few specimens which almost reach the proximal end have been found. The thecae throughout are exactly as described by Sudbury (1958) and show no transverse expansion of the aperture. The thecal hook is prominent but the recurved apertural region does not face the dorsal margin. It is, therefore rather an open hook with the aperture directed, in the most extreme cases towards the proximal end.
Remarks: M.c.rostratus is the common form in the Cautley beds although the proximal end has never been identified with certainty.
Material seen: Specimens in H.M.Geological Survey Museum, and Sedgwick Museum, Cambridge.

Monograptus communis obtusus subsp. nov.
Plate 7,fig.2; Plate 34,fig.12.

Holotype: HUR./S80,8·4/92 a proximal end with sicula and early thecae preserved in full relief in pyrites.

Horizon of Holotype: Zone of *Monograptus sedgwicki*; Spengill (S80,8·4).

Derivation of name: Obtusus: L. "blunt".

Material: Several specimens preserved in full relief.

Diagnosis: Curvature of rhabdosome as for *M.c.communis* and thecae throughout very similar, but the proximal end has no elongated thecae of the type seen in *M.c.communis* or *M.c.rostratus*.

Description: The rhabdosome is curved in a similar manner to the other two subspecies of *M.communis* but distal fragments may be almost straight.

The most distinctive feature is the absence of any axially elongated thecae at the proximal end. Theca 1 resembles about th.4 on *M.c.communis* and th.2 or 3 on *M.c.rostratus*.

The sicula is 0·91 mm long and its apex reaches fractionally above the level of th.1. At the base the sicula is 0·13 mm across and th.1 seems to arise almost at its base.

Thecae 1-4 all occupy an identical length of the axis (0·78 mm) but their height increases gradually as follows:- th.1, 0·39 mm; th.2, 0·52 mm; th.3, 0·78 mm; th.4, 0·91 mm.

Distally a maximum height of 1·17 mms has been observed, and here each theca occupies 1·3 mms of the axis so that the thecae are rather longer than high.

The hook itself is quite typical of the species and its aperture is directed proximally.

Remarks: *M.communis obtusus* subsp. nov. is clearly distinguished from *M.c.communis* and *M.c.rostratus* by the smaller height of the distal thecae and the lower angle of inclination of the ventral margin to the axis. The proximal end is quite distinct.

Sudbury (1958,p.539) suggests an evolutionary line from *M.c.communis* to *M.c.rostratus* involving the loss of two axially elongated thecae. *M.c.obtusus* subsp. nov. could be a further stage in this process when all such proximal thecae are lost and its occurrence in the Zone of *M.sedgwicki* strongly supports this.

Monograptus planus (Barrande)

Plate 34,fig.9

1850 Graptolithus proteus var. plana Barrande p.58,Pl.4,fig.15.
1912 Monograptus planus (Barrande). Elles & Wood text fig.340,Pl.48,figs. 6a-d.
?1931 " " Haberfelner Pl.3,fig.3.
1944 Spirograptus " (Barrande 1850). Pribyl pp.33-5,Pl.4,fig.1,8, Pl.8, figs.6-8,Pl.11,figs.5-6.
?1949 Campograptus " (Barrande). Obut p.24,Pl.4,figs.9a-b.
1958 Monograptus " " Sudbury pp.524-5,Pl.22,figs.92-93, fig.22b.

(further references may be found in Pribyl 1944, p.33)

Holotype: Specimen figured by Barrande (1850,Pl.4,fig.15).
Material: About 40 flattened specimens, mostly of proximal regions.
Horizon and Localities: M.turriculatus Zone including R.maximus subzone; Speggill (S117,3 - S176,2·5).
Diagnosis: Rhabdosome dorsally curved throughout but only gently so in the distal regions. Sharply recurved proximally but actual proximal extremity may be straight.
Description: Most of the specimens obtained are typical small proximal ends resembling, in outline, that specimen figured by Sudbury (1958,Pl.22,fig.93). The proximal end has not been found attached or is so badly preserved and slender that detail cannot be made out.

Although the proximal end is slender there is a rapid widening near the point of maximum curvature to give, at about the 7th - 9th triangular theca, a width of 1mm (see specimen fig.9,Pl.34). The most proximal thecae are axially elongated.

The apertures of the distal thecae cannot be seen in compressed specimens but there is no suggestion of their being horned as in the case of M.pseudoplanus Sudbury.

Monograptus pseudoplanus Sudbury

Plate 8,fig.6

1958 Monograptus pseudoplanus sp. nov. Sudbury pp.523-4,Pl.22,figs.94-96, fig.22a in text.

Holotype: The specimen figured by Sudbury (1958,Pl.22,fig.96).

Material: Several specimens preserved in full relief in pyrites but no complete specimens.

Horizon and Localities: Zone of D.magnus; Birks Beck (9Bi).

Diagnosis: Rhabdosome dorsally curved throughout but more strongly so at proximal end, curvature similar to that in M.planus (Barr.). Early thecae axially elongated; distal thecae high, triangular. Thecal apertures hooked throughout with transverse expansion and paired horns.

Description: No specimens show the sicula and only one specimen shows the proximal axially elongated thecae. The most proximal theca has a prothecal length of about 1mm and a height of 0·39 mm. Succeeding thecae increase rapidly in height to 0·78 mm 5 thecae beyond the lowest. In this region, about the point of maximum curvature, the prothecal portion decreases to 0·65 - 0·78 mm. The thecae are becoming higher than long.

The distal thecae reach a length of 1mm-1·04 mms (prothecal length) and a height of 1.3 mms. They number 9½-10 in 10 mms. Hence from the point of maximum curvature there is a slight increase in prothecal length similar to that of the initial region, and an increase in height sufficient to make the thecae higher than long.

The thecae are hooked and seem to have paired horns of the type figured and described by Sudbury (1958 p.524,Pl.22,fig.95).

Remarks: The Cautley specimens have the distal dimensions of the higher thecal types described by Sudbury (p.524) and the characters of the thecae of these specimens, preserved in relief, are sufficient to distinguish them from M. planus, M.communis etc.

Material seen: Specimens in Sedgwick Museum, Cambridge.

Monograptus proteus (Barrande)

Plate 34,fig.4

1850 Graptolithus proteus Barrande p.58,pl.iv,figs.12-14
1851 " " Suess p.39,pl.1X,figs.3a-d.
1851 " armatus Suess pl.1X,fig.2.
1852 Monograptus proteus Geinitz pp.44-45,Pl.1V,fig.13,14a-b,?29,(non fig. 4,6-12,15-18,20,23,25).
1876 " convolutus var. proteus Lapworth p.23,Pl.X111,fig.4e.
1877 " proteus Lapworth p.128,Pl.5,fig.18.
1890 " " Geinitz p.21,pl.A,fig.28.
1892 " " Tornquist p.40,pl.111,fig.29,30.
1897 " " Perner 111A,p.14,pl.X11,fig.21-23; text fig.13.
1897 " " Frech. Lethaea geog., 1 Leth. palaeoz. p.648.
1899 " " Tornquist p.23,pl.1V,fig.23-24.
1912 " " Elles & Wood pt.1X,p.447,pl.XLV111,fig.8a-c; text fig.332a-c.
1919 " " Kirste p.177-188(?pl.111,fig.10-11).
1919 " armatus Kirste p.178,pl.111,fig.12.
1920 " proteus Gortani p.48,pl.111,fig.37.
1923 " " " p.17,pl.1,fig.37-40.
1931 " " Haberfelner p.143,pl.111,fig.1a-b.
1939 " " Munch pp.8-9,19-29,Abb.6; fig.nastr. 34.
1939 " " " p.20,fig.25a-b na str. 34 = (non M.convolutus)
1939 " " Hundt. obr. na str. 32,154,166,184,314,334.
1944 " " Pribyl pp.11-14,obr. 11a-f, (? obr. 11a) Tab. 3,figs 4-8 Tabl 5,fig.7, Tab 9, figs.1-3.
?1945 " " Barr. Waterlot Pl.41,fig.411.
?1962 Spirograptus " (Barrande). Romariz p.268, not figured.

Material: More than 20 specimens, more or less incomplete, flattened and compressed together with better preserved fragments.

Horizon and Localities: M.turriculatus and M.crispus Zones; S174,10·5 to S231,2 Spengill.

Description: The Cautley forms of this species show close agreement with material described from other localities. The rhabdosome is spirally coiled and often only a small proportion of the specimen is seen on any one bedding plane, the rest being buried both above and below the plane along which the rock is split. More favourably flattened specimens show the typical curvature of the species from an extremely slender proximal region to a more robust distal portion. The thecal apertures are more distant proximally but the thecal count as a whole is extremely variable depending upon the disposition of the fossil with regard to the direction of compression. Readings from 7 thecae per cm to 15 per cm have been made. The thickness of the rhabdosome is likewise very variable but the distal portions may reach 1·5 mms in breadth. The sicula has not been seen.

The exact nature of the hook and the thecal aperture cannot be ascertained from the Cautley material. The early thecae have a small hook in proportion to the length of the protheca. Distally the angle of inclination of the thecae increases and the free, hooked portion is proportionately greater.

Remarks: Barrande in his original description gives a thecal count of 11-12 thecae per cm as does Pribyl (1944). Elles and Wood (p.477) give a thecal count of 7-10 thecae per cm for the British specimens, though their figures on Pl.XLVIII (figs.8a-c) show a greater range than this.

Material seen: Specimens in Sedgwick Museum, Cambridge.

Monograptus aff. intermedius (Carruthers)

not figured

aff.

1868	Graptolithus intermedius, sp. nov.		Carruthers p.126, Pl.5, fig.18.
1876	Monograptus	"	Carr. Lapworth pp.316-7, Pl.10, figs.10a-c.
1912	"	"	(Carruthers). Elles and Wood pp.485-6, text figs. 341a-d, Pl.49, figs.3a-c.

Material: A few flattened proximal fragments.

Horizon and Localities: Zone of M.convolutus; Birks Beck (5Bi).

Description: Some fragmentary specimens have been obtained which have affinities with this species, particularly the forms figured by Elles and Wood (1912, text fig.341a-d).

The thecae are similarly spaced, triangular, with free apertural regions and resemble closely fig.341c-d of Elles and Wood (1912). Dorsal curvature is shown throughout. The paucity of material precludes a full description.

Monograptus sp. B

Plate 35,fig.12

Material: Two flattened specimens associated with M.exiguus.

Description: The two rhabdosomes, one parallel and one at right angles to the direction of compression, are curved in a manner similar to M.planus (Barr.) One of the two has a poorly preserved proximal end which is similar in shape to that of Barrande's species and the thecae may become axially elongated in this region.

The distal thecae are non-overlapping, triangular, and hooked quite distinctly, and the general form is close to M.planus. The distal width of the rhabdosome even where flattened and compressed at right angles to the polypary only reaches a maximum of 0·9 mm. In this region the thecae number 12 in 10 mms allowing for compression.

Another species which M.sp. B resembles in general form of polypary and thecae is M.tullbergi Boucek although once again the rhabdosome seems to be narrower (1mm cf. 1·2 - 1·4 mms).

GROUP J. C

Monograptus triangulatus fimbriatus (Nicholson)

Plate 34,fig.1

?1853 Monograpsus pectinatus Richter p.461 (pars) Pl.12,fig.26,non 27.

?1868 Graptolithus convolutus, His. Carruthers p.127,(pars) non Pl.5,figs. 1a-c.

1868 Graptolites fimbriatus Nicholson p.536,Pl.20,fig.5,?figs.3,4.
1913 Monograptus " ("). Elles and Wood pp.482-3, (pars) text figs.338a-b (?c-d), Pl.48,figs.4a,d.(non b,c).
?1945 " " Nichols. Waterlot Pl.42,fig.416.
1958 " separatus fimbriatus (Nicholson). Sudbury pp.499-501,text fig.5,Pl.19,figs.40-51.
1959 " triangulatus fimbriatus (Nicholson). Sudbury p.172,non fig.
?1962 Demirastrites pectinatus pectinatus (Richter). Romariz p.272-3; Pl.5,fig. 8.

(further references see Sudbury 1958,pp.499-500,Boucek and Pribyl 1941,p.8).

Material: Several good proximal ends showing the sicula, and numerous less well preserved fragments.

Horizon and Localities: Zone of M.triangulatus; Watley Gill (5Wa); Birks Beck (9Bi).

Diagnosis: Rhabdosome with dorsal curvature throughout, this is particularly strong proximally where it is hooked. Thecae triangular and with paired horns

Description: The curvature of the rhabdosome is similar to other triangulate monograptids and the hooked proximal end is typically small.

It is distinguished from many forms by the lack of rastritiform proximal thecae, and from extreme variants of M.t.separatus by the higher th.1 and more robust sicula.

All the thecae are triangular. The most proximal thecae (th.2-4) have no parallel-sided prothecal portion; instead this widens continuously from its initial portion.

The distal thecae are broad-based, triangular and with very short initial prothecal parts. An average height is approximately 1·5 mms to 1·6 mms. They may number less than 8 in 10 mms in badly compressed specimens.

Remarks: No differences have been noted from the detailed descriptions given by Sudbury (1958). At Cautley, as in the Rheidol Gorge section, M.t.fimbriatus follows M.t.triangulatus in time and it may have a longer vertical range than in the Welsh locality.

Material seen: Specimens in Sedgwick Museum, Cambridge.

Monograptus spiralis (Geinitz) sensu lato

Plate 13,fig.11

1842 Graptolithus spiralis Geinitz p.700,Pl.10,figs.26-27.
1945 Monograptus " Gein. Waterlot Pl.41,fig.409.
1949 Spirograptus " (Geinitz). Obut p.26,Pl.5,figs.2-4.
1962 " " spiralis (Geinitz). Romariz p.268; Pl.2,fig.4; Pl.4,fig.3

(further references in Tornquist (1912,pp.615-7) and Pribyl (1944,pp.6-7))

Lectotype: The specimen figured by Geinitz (1842,Pl.10,fig.26) and again in 1852 (Pl.4,fig.32) as Monograpsus convolutus.

Material: Many specimens showing curvature and typical thecae but none showing the full form of the rhabdosome.

Horizon and Localities: Zones of M.crispus and M.griestonensis; Wards Intake (5Wi); Spengill (S209,0·5 - S210,8 and S255,3·25).

Description: A full description is not attempted in view of the paucity of good material. The rhabdosome appears to be spirally coiled and twisting of the thecae (on the bedding plane) from the dorsal to the ventral surface is common. Fig.11,Pl.13, shows characteristic adult thecae, compressed with the apertural regions tilted so that part is hidden (see also Sudbury 1958,Pl.21, fig.81). This figure also shows the very wide common canal which in this particular specimen (HUR./5Wi/8 is 1·3 mms across.

Remarks: The material often mentioned from "Rawthey Bridge" (Elles and Wood p.476, and Sudbury p.513) is probably from Wards Intake (716, 976) since Rawthey Bridge itself is on Ordovician strata. Wilson (1953) distinguished M.spiralis var. contortus (Perner) in the Cautley material.

Material seen: Specimen collected by T.Mck. Hughes from "Hall Intack, Rawthey Bridge", Geological Survey no 525.

genus RASTRITES Barrande, 1850

(= Rastograptus Hopkinson & Lapworth, 1875)

Type species: R.peregrinus Barrande, 1850; SD Miller, 1889

Generic diagnosis: Rhabdosome curved or hook-shaped, common canal thread-like, thecae widely spaced, straight, isolated, with tiny hooked apertures, extending from common canal at high angles; thecal apertures with paired horns in some species.

Rastrites maximus (Carruthers)

Plate 8,fig.8; Plate 37,figs.6,7.

1867	Rastrites maximus Carr.	Carruthers p.541, Fossils (90), fig.6
1868	" " "	" p.13,Pl.5,fig.14.
1876a	" " "	Lapworth p.313,non fig.
1876c	" " "	" Pl.1,fig.1.
1907	" " "	Tornquist p.15,Pl.2,figs.27-33,Pl.13,fig.1.
1913	Monograptus (Rastrites) maximus (Carruthers).	Elles and Wood pp.494-5 & 500, Text figs.350a-c,Pl.50,figs.6a-e.
?1924	Rastrites maximus Carruth.	Hundt Pl.10,fig.4,12-16, ?Pl.11,fig.1.
1923	Monograptus (Rastrites) maximus (Carruthers).	Gortani p.19,Pl.1,fig.48.
1941	Rastrites maximus, (Carruthers 1867).	Pribyl pp.13-14,non fig.
1945	Monograptus (Rastrites) maximus Carr.	Waterlot Pl.44,fig.439

Material: Many specimens, all fragmentary, but some showing thecae near the proximal end.

Horizon and Localities: Subzone of R.maximus, (Zone of M.turriculatus), Spengill (S115,5 to S136,1·23; S140,11).

Diagnosis: Rhabdosome long, variably curved, common canal very slender and thecae, in contrast, robust. Thecal tubes long, up to 14 mms hooked apertural region, numbering 1-3 in 10 mms in the distal region, and as many as 6½ in 10 mms at the extreme proximal end.

Description: The rhabdosome is highly characteristic, even in the fragmentary state. Only extreme proximal ends might be mistaken for R.linnaei. In the Cautley material the distal thecae are occasionally seen spaced as widely as 1 in 10 mms but usually there are two or three. The thecal tubes reach a length of 14 mms in some instances and the base (i.e. the protheca) may be 2 mms long. In the proximal region the thecae are proportionately smaller in all dimensions and may number up to $6\frac{1}{2}$ in 10 mms.

Remarks: The Cautley specimens of this species do not differ in any way from previously described material. It was first recorded by H.M.Geological Survey workers (Dakyns et al. 1891) who identified two bands containing this species. Wilson (1953) recognised several more bands and the writer records another probable occurrence in bed S140,11.

Material seen: Specimen from Belcraig Burn figured by Elles and Wood Plate 50, fig.6e (S.M. no. 22032).

Rastrites linnaei Barrande

Plate 37,fig.5

1850 Rastrites Linnaei Barrande p.65,Pl.4,figs.2,4.

1897 " " Barr. (R.fugax Barr.). Perner pp.7-8,figs.4,5; Pl.13, figs.29-31 (non 27-28).

1907 " " " Toernquist p.14,Pl.2,figs.21-26.

1913 Monograptus (Rastrites) Linnaei (Barrande). Elles and Wood pp.493-4,text figs.349a-b,Pl.51,figs.1a-c.

1923 " " " " Gortani p.20,Pl.1,figs.43-45.

?1924 Rastrites Linnaei Barrande. Hundt Pl.11,figs.9-14.

1931 " " " Haberfelner p.160-161,Pl.3,fig.12.

1939 " " Hundt p.268,fig.1 on p.224.

1941 " linnaei, Barrande 1850. Pribyl pp.10-11,Pl.2,figs.1-2,Pl.3, figs.1-8,text fig.1,figs.1-3.

1945 Monograptus (Rastrites) Linnaei Barr. Waterlot Pl.44,fig.438.

Material:Many specimens, some in full relief.

Horizon and Localities: ?Zone of M.sedgwicki to Zone of M.turriculatus (lower part but outlasts R.maximus) Spengill (?S94,7·4; S123,7·25 to S172,0·5; ?S176,2·5; ?S197,5·5; ?S131,10·25; ?S167,11·75; ?S169,6·5; except S145, 0·75 and S165,2·25).

Diagnosis: Rhabdosome usually dorsally curved, thecae shorter and more closely spaced than in R.maximus, numbering 8-4 in 10 mms.

Description: The general form of the polypary and thecae is close to R.maximus but the thecae are shorter and more closely spaced throughout. Th.1 is 1·3 mms long, th.2, ?1·43 mms and thereafter follows a rapid increase in length to 4·5 mms at th.4. The "base" of the thecae reaches about 1·3 to 1·5 mms in width. An interesting point is the distal extension of the protheca to produce the broad triangular "base". The protheca is, infact, extended distally past the general line of each metatheca for a greater distance than it occupies proximally. This also appears to be the case in R.maximus.

Remarks: The Cautley specimens are quite typical and the high thecal count recorded at the proximal end does not seem unusual. The specimens found in the Zone of M.sedgwicki, however, are rather doubtfully assigned to this species.

Material seen: Specimens in the Sedgwick Museum, Cambridge

Rastrites longispinus (Perner)
Plate 8,fig.9; Plate 10, fig.4; Plate 37,fig.10.

1897 Rastrites peregrinus var. longispinus Perner p.9,text fig.7,Pl.13,figs. 32 and 35.
1907 " longispinus Tornquist p.10.
1913 Monograptus (Rastrites) longispinus (Perner). Elles and Wood pp.489-490, Text fig.344a-b,Pl.50,figs.2a-g (?fig.1d).
1941 Rastrites longispinus Perner 1897. Pribyl pp.6-7,text fig.1,no. 4, Pl.1 figs.1-3,Pl.2,fig.3.
1945 Monograptus (Rastrites) longispinus Perner. Waterlot Pl.44,fig.434.
?1949 Rastrites longispinus (Perner). Obut p.37,Pl.5,fig.7
1958 " " " Sudbury pp.525-6,text fig.23,Pl.21,fig. 71.

Lectotype: Specimen figured by Perner 1897,p.9,text fig.7.

Material: Many specimens either in full relief or flattened.

Horizon and Localities: Zone of M.triangulatus, D.magnus; Spengill (S24-28, S32-36); Birks Beck (9Bi,?7Bi); Marsh Lane (1Ma); ?Zone of M.sedgwicki, (S73,11·4).

Diagnosis: Rhabdosome hook-shaped. Thecae short and more broadly spaced proximally; up to 3-4 mms long and rather more closely spaced distally; hooked, and transversely expanded towards the aperture. Thecal spacing varies greatly with the compression.

Description: The Cautley specimens agree more closely with the material described by Perner (1897) and Sudbury (1958) than they do with that described by Elles and Wood (1913). In particular the thecae are 3-4 mms long and none have been observed above 4 mms in length. The proximal thecae are much shorter and more widely spaced and the change from these to the distal type, coupled with the hook-shaped rhabdosome is the easiest means of identifying the species. Because of the amount of compression undergone by the specimens in the writer's collection it has not been possible to determine the degree of intraspecific variation but in some specimens the maximum length of the thecae does not seem to be reached for a considerable distance and fragments with thecae under 3 mms long are not uncommon.

From the M.sedgwicki Zone a few specimens preserved in full relief and relatively undistorted (see fig.4,Pl.10) have been obtained. In these the distal thecae are only 2·6 mms long and their proximal ones approximately 1·1-1·4 mms. They resemble a small R.longispinus (Perner) in all respects.

Remarks: Further discussion on the lowest stratigraphical limit of R.longispinus takes place on pp.

Material seen: Specimens in H.M.Geological Survey Museum.

Rastrites equidistans spengillensis subsp. nov.

Plate 37,fig.4

Holotype: HUR./S197,5·5/11.

Horizon of Holotype: Zone of M.turriculatus.

Derivation of name: After the locality of the holotype, Spengill, Westmorland.

Material: 17 specimens, none in relief.

Horizon and Localities: Zone of *M.turriculatus* (higher beds) to *M.crispus* (lower beds); Spengill (S172,0·25; S173,6; S197,5·5; ?S219,0·25; S231,2; S233,3).

Diagnosis: Rhabdosome variously curved. Thecae long tubes projecting almost at right angles to the polypary gradually increasing in length distally, but invariably shorter than the length of the adjacent interspaces which also increase in length distally. Th.2-5 in 10 mms.

Description: The rhabdosome is variously curved, and most commonly has ventral curvature. It resembles closely *R.e.equidistans* (Lapw.) but differs in the constant increase in length of the thecae and interspaces and in having the thecal tubes invariably shorter than the lengths of the adjacent interspaces.

The maximum thecal length observed with certainty is 2 mms (see fig.4,Pl.37). Here the thecae are rather more than half the length of the interspace. The interspace itself is 3.5 mms long and the thecae, therefore, number a little over 2 in 10 mms. In most of the distal fragments observed, the thecae are under 2 mms in length but the spacing remains fairly constant at 2 in 10 mms. As the proximal end is approached the thecal spacing decreases and readings up to 5 in 10 mms are obtained. Again, however, the thecal tubes are less than the length of the interspaces. Occasional fragments have been seen which resemble fig.2e (Pl.51) of Elles and Wood but these are so poorly preserved as to be unidentifiable. They also show a higher thecal count of 3½-4 in 10 mms and may represent distal fragments of *R.linnaei* which has been doubtfully recorded from S197,5·5.

Remarks: H.M.Geological Survey Workers recorded *R.distans* from the Spengill section and Elles and Wood (1913) mention *R.equidistans* from Spengill. The other localities listed by these writers are all in Southern Scotland. As has been shown above although *R.e.spengillensis* has the same general form, it is distinct in detail and should be regarded as a separate subspecies. It may represent a case of geographical subspecific variation.

Elles and Wood (p.500) propose the specific name "*equidistans*" to replace Lapworth's name "distans" in order to avoid confusion with M.distans (Portlock) Pribyl (1941 and 1942) on the other hand implies that no confusion can arise since the two are very distinct and are now placed in separate genera. He therefore, resurrects, Lapworth's name "distans".

The change in name proposed by Elles and Wood is here considered to be valid in view of both the situation at the time it was made (1913), and the acceptance of the name by later authors (e.g. Gortani 1923, and Haberfelner 1931).

Material seen: Specimens of R.e.equidistans in the Sedgwick Museum, Cambridge.

Rastrites spina (Richter)

Plate 36,fig.12; Plate 37,fig.3

1853 Monograpsus spina, Richter p.462,Pl.12,figs.32-33.

1912 Rastrites spina Eisel p.4,Pl.1,figs.3,9, (non 4,5,7).

1913 Monograptus (Rastrites) fugax (Barrande). Elles and Wood p.493(pars), Pl.50,figs.7a,d,?b, (non c), ?text fig.348.

?1919 Rastrites spina Kirste p.203,Pl.3,fig.41.

?1924 " " Kirste. Hundt Pl.10,figs.7-11.

1942 " " (Richter 1853). Pribyl pp.5-6,Pl.1,figs.20-21.

1945 Monograptus (Rastrites) fugax Barr. Waterlot Pl.45,fig.449.

Lectotype: Specimen figured by Richter (1853,Pl.12,fig.32).

Material: Several good specimens in relief, showing proximal end and sicula; other fragments.

Horizon and Localities: Zone of M.convolutus; Watley Gill (9Wa,10Wa).

Diagnosis: Rhabdosome short and inconspicuous with an extremely slender thread-like portion connecting the short, stout thecal tubes which project at right angles. Dorsal curvature at the extreme proximal end, which terminates in a relatively prominent sicula. Thecae number 13-10 in 10 mms proximally down to 5 in 10 mms more distally.

Description: The nature of the polypary is highly characteristic. It shows distinct dorsal curvature involving th.1 - th.3 and terminates in a prominent sicula.

The sicula is 0·78 - 0·91 mm long and 0·13 - 0·20 mm broad at the base. Its apex does not reach to the top of th.1. Th.1 arises near the top of the sicula and although fully 0·5 mm in length its height is only 0·32 mm. It does not project at right angles to the line of the polypary. The thread-like portion immediately following th.1 is quite short (0·4 mm) and the protheca of th.2 relatively long. The protheca grows in contact with the thread for a short distance before giving rise to the metatheca. The metatheca projects at a higher angle to the dorsal surface than does that of th.1 and reaches a greater height (0·52 mm)

All succeeding thecae project at right angles to the line of the polypary and have very minute prothecal portions. A height of 0·52 mm is rarely exceeded. The thecae become rapidly more distant so that at th.4 the spacing is 5 in 10 mms as compared to 13-10 in 10 mms at th.1-2.

Remarks: The Cautley specimens differ from those described by the above authors only in having shorter thecae.

Material seen: Specimen in the Sedgwick Museum on the slab (A21508) collected by Dr.J.E.Marr from the tamariscus band, M.convolutus Zone, Skelgill.

Rastrites fugax Barrande

Plate 37,fig.8

1850 Rastrites fugax Barrande p.66,Pl.4,fig.1

1913 Monograptus (Rastrites) fugax (Barrande). Elles and Wood p.493 (pars) Pl.50,fig.7c (non a,b,d, or text fig.348).

1924 Rastrites fugax Barrande. Hundt Pl.10,fig.6.

1931 " " Haberfelner p.162,Pl.3,fig.14 (?figs.9a,b).

1941 " " Barrande 1850. Pribyl pp.11-12,Pl.2,fig.11,Pl.3,figs. 10-12.

1945 Monograptus (Rastrites) spina Richter. Waterlot Pl.45,fig.450.

Material: A single badly preserved specimen.

Horizon and Locality: Zone of M.convolutus; Watley Gill (9Wa).

Description: The rhabdosome has slight dorsal curvature and the thecae are short pointed, and directed backwards. They number 8½ in 10 mms and have a length of 0·9 mm.

Remarks: A full description cannot be given but the general form of the specimen as well as its thecal form and spacing resembles Barrande's species. Elles and Wood record M.(R) fugax from the Zone of M.sedgwicki whereas the Cautley specimen occurs in the Zone of M.convolutus.

Rastrites sp. A

Plate 37, fig.12

Material: A single flattened specimen showing the sicula and th.1-4.

Horizon and Locality: Zone of M.sedgwicki; Spengill (S75,9·4).

Description: This specimen is unusually small. The sicula is 0·65 mm long and its apex reaches midway between the base of th. 1 and th.2. All three visible thecae are completely rastritiform and th.2 has a length of about 0·8 mm. The thecae are slender and pointed with the apertures obscured. At this point on the rhabdosome the thecae number approximately 28 in 10 mms.

Remarks: This specimen is probably the proximal end of a form whose proximal characters are not known. From the material available however, an alliance cannot yet be suggested.

Rastrites sp. B

Plate 37, fig.11

Material: One flattened specimen, and two more doubtful large specimens preserved in relief.

Horizon and Localities: Zone of M.triangulatus; Spengill (S24-28,?S36-39,7).

Description: The smaller specimen, comprising 9 thecae, occurs on a slab with several specimens of R.longispinus (Perner). From this latter species it may be distinguished by its more slender thecae, even though these are flattened. On the other hand the specimen has been compressed parallel to the length of the thecae and this has had the effect of making them appear more slender than they really are. They are about 4 mms long and project at right angles to the dorsal surface. The thecae number 20 in 10 mms but this high figure is almost certainly a result of compression since a specimen of R.longispinus (Perner) lying in the same position also has 20 in 10 mms.

Remarks: The specimen from S36-39,7 has 14 in 10 mms and thecae almost 5 mms long. Once again, however, the specimen has suffered considerably from compression though not, in this case, flattening. This form may simply be a distorted specimen of R.longispinus and like this species, differs from Rastrites sp.B in having more robust thecae.

Material seen: Rastrites sp. B may prove to be synonymous with R.setiger Elles and Wood since some of the figured specimens of this latter species are very close to the Cautley forms (e.g. specimen figured by Elles and Wood Pl.50,fig. 3b)

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subfamily CYRTOGRAPTINAE Boucek, 1933
(nom transl. Yin, 1937 (ex Cyrtograptidae Boucek, 1933))

genus CYRTOGRAPTUS Carruthers, 1867
(= Lapworthograptus Boucek & Pribyl, 1952)

Type species: C.murchisoni Carruthers 1867

Generic diagnosis: Rhabdosome more or less spirally coiled, usually helicoidally at proximal end, with cladia developed on main stipe (primary cladia) and in many species on the cladia themselves (secondary and higher orders); thecae biform, proximally triangulate (at extreme proximal end may be axially elongated) with lateral apertural spines, becoming simpler distally.

Cyrtograptus murchisoni murchisoni Carruthers
Plate 9,fig.1; text fig. 8f; 11.

1867	Cyrtograpsus Murchisoni	Carruthers	p.541, Fossils 90,fig.1
1868	" "	"	p.127,Pl.5,fig.17.
1869	" "	Carr. Hopkinson	p.8,Pl.8,fig.6.
?1899	Cyrtograptus Murchisoni,	Carr. Perner	p.21,text fig.28 (non cetera).
1900	" "	Elles	p.413,Pl.24,fig.6.
1913	" "	Carruthers. Elles and Wood	pp.515-7,text fig. 352a-b,Pl.51,figs.3a-c.

non.

1883 Tullberg p.35,Pl.4,figs.9-11.

1889 Perner text fig.29,Pl.14,fig.5,Pl.16,figs.18,20a-b.

1921 Hundt p.190,Pl.5,figs.6-7.

1924 Hundt p.75,Pl.8,figs.13-14.

1929 Averianow p.106,Pl.34,figs.6a,b

1933 Boucek pp.30-32,Text fig.5e,f,Pl.2,figs.1-3.

Holotype: The specimen figured by Carruthers 1867, p.570, Fossils 90,fig.1

Material: One very large and almost complete specimen and several other specimens showing secondary cladia.

Horizon and Localities: Zone of C.murchisoni as here defined and rarely in the top of the Zone of C.centrifugus - C.insectus; Wandale Hill, Gill B (37W); R.Rawthey, Mouth of Wandale Beck (50W); Birksfield Beck (6Bf); Hebblethwaite Hall Gill (?9H); Whinny Gill (12Wh).

Diagnosis: Rhabdosome large with both primary and secondary branches. Proximal end coiled eccentrically into a helicoid spiral.

Description: The helical spiral coiling of the proximal end and the general form of the rhabdosome with its secondary, as well as primary, cladia are the most characteristic features of the species.

Because of the fact that the proximal end is coiled in a helical spiral the sicula and adjacent thecae have not been seen attached to a specimen showing more distal features. The large specimen figured on Pl.9,(fig.1) has its proximal end deeply buried in the rock and it is clear that the distal parts all lie in one plane - or at the most in a very low cone. Those specimens occuring in the C.murchisoni Zone which do show siculae and proximal thecae are tabulated below:

Specimen No.	Thecal count	Length of sicula
HUR./50W/6	14 in 10 mms	1·25 mms
HUR./50W/	15 in 10 mms	1·25 mms
HUR./12Wh/1	13 in 10 mms	1·3 mms
HUR./37W/1	15 in 10 mms	/

C.murchisoni is the most common cyrtograptid in the murchisoni Zone (C.aff insectus being rare here) and it is likely that the 1·25-1·3 mms long sicula belongs to this species. Its apex does not reach the top of th.1. The first few thecae are axially elongated though distinctly hooked, but by the time the first coil has been formed they are much higher and more triangular. Even the most distal thecae on the polypary are hooked and triangular, and at the same time are more widely spaced (12-10 in 10 mms cf. 15-13 in 10 mms proximally). The maximum width of the rhabdosome is approximately 1·7-1·8 mms (in relief).

There are 6 primary arms and 8 secondary arms on the best specimen although this is not complete. This specimen covers an area of over 100 sq. cms and the rhabdosome when complete would occupy an elliptical area on the bedding plane, though this is clearly a result of compression. Compression may also have increased the curvature of some of the arms. Fragments in the rock at locality 37W, apparently belonging to the same specimen, suggest that the rhabdosome might well cover an area of about one square foot when fully developed.

The spacing of both the primary and secondary arms increases distally. Listed below are the numbers of thecae between the primary arms. The first value is the number of thecae separating the first and second primary branches: 5; 5; 9; 9; 13. The corresponding figures quoted for a specimen by Elles and Wood (1913,p.506) are: 5; 5; 5; 8.

Remarks: A single specimen, the best, has been obtained from the top few feet of the preceding zone but the species is fairly common in its own zone where it occurs with an essentially different fauna.

Boucek (1933) describes C.murchisoni murchisoni from Mala Chuchle but these specimens differ in having a very open coil at the proximal end, and are probably closely related to C.m.bohemicus Boucek which also has an open coil but no secondary arms. (Dr. Strachan, personal communication).

Carruthers' species is probably most closely related to C.centrifugus Boucek which at Cautley predates C.m.murchisoni Carr.

Material seen: Specimen from Crosshaw Beck, Cautley (S.M.no A22419 collected by J.E.Marr). This has closer spacing of the arms than C.insectus and may have secondary arms.

Cyrtograptus centrifugus Boucek

Plate 38, figs.2,3

1919 Cyrtograptus centrifugus Perner and Kodym p.12 not described.
1922 " " " " " p.58 " "
1931 " " n.sp. Boucek p.304, figs.14a-d.
1933 " " Boucek 1931. Boucek pp.27-28, Text fig.3a-d, Pl.3, figs.1-4.

Holotype: The specimen figured by Boucek in 1931 (text fig.14a-d), and again in 1933 (Pl.3, fig.2, Text fig.3a-b).

Material: Many specimens in full relief, none showing the proximal end and sicula attached, but several showing three cladia.

Horizon and Localities: Stage 1 Zone of C.centrifugus - C.insectus; Bluecaster Gills, Middle Gill (1M,4M); Near Gill 912N,8N); Far Gill (1F); Wandale Hill, Gill A, (?26W,28W,29W); Gill B (?46W,); Mouth of Wandale Beck (?49W,?51W); Pickering Gill (10P,8P).

Diagnosis: Rhabdosome large when fully developed, with two or three cladia of great length. Proximal end enrolled into a helicoid spiral. Thecae number 10-9 in 10 mms.

Description: This species is the most common cyrtograptid in Stage 1 but is only rarely seen in any degree of completeness (see specimen HUR./5Wh/1 figured on Pl.38 fig.2,3). When fully developed there are three primary branches the positions of origin of branches 1 and 3 being at 180° to each other.

The extreme proximal end and sicula are not known actually attached to the distal part of the polypary since, as in the case of C.murchisoni Carr. this is coiled into a helicoid spiral which is either buried in the rock or broken off. Those siculae which have been observed are noted below, together with the thecal spacing of the first few thecae:

Specimen No.	Thecal Count	Sicula length
a) HUR./28W/82	13 in 10 mms	1·3 mms
b) HUR./28W/54	10½ in 10 mms	/
c) HUR./28W/42	12½ in 10 mms	0·75 mms
d) HUR./28W/50	10 in 10 mms	/
e) HUR./4M/	10 in 10 mms	1.23 mms

Specimen No.	Thecal Count	Sicula length
f) HUR./4M/	$10\frac{1}{2}$ in 10 mms	1·23 mms

The proximal end, if these specimens do belong to C.centrifugus is very similar to that of C.m.murchisoni Carr. and differs only in having a more widely spaced thecae (13-10 in 10 mms cf. 15-13 in 10 mms). The size and position of the sicula is the same. (In the above list c. may be a different species).

The table below records the position of the arms; the actual figures being the number of thecae between the arms:-

Specimen No	Sicula to branch 1	br.1-2	br.2-3
HUR./28W/115	/	3	5
HUR./28W/52a	/	/	?5
HUR./28W/129	14+	5	/
HUR./28W/81 & 79	?17	5	/
HUR./28W/89	/	5	/
HUR./28W/104	/	4	6
HUR./28W/82	14+	5	/
HUR./28W/55a	?18	5	/
HUR./28W/55	/	4	6
HUR./4M/9	/	4	6
HUR./4M/	/	5	/
HUR./4M/	/	4	/
HUR./4M/	/	3	/
HUR./5Wh/1	/	4	/
HUR./5Wh/	/	4	8

Corresponding figures taken from Boucek's holotype are:

	25	6	8

In his description Boucek (1933) gives:

	25-28	6-7	7-9

The Cautley specimens, therefore, have their branches rather more closely spaced but it is interesting to note that in Boucek's specimens with four branches (exceptional) the arms are more closely spaced and have 5-6 thecae between them. (Boucek 1933 p.28). They agree, however, in having 1 to 3 branches (see Boucek 1933 p.28) with the 1st and 3rd at 180° to each other.

The main stipe reaches a maximum width (relief) of about 2 mms and has been found up to 23 cms in length. In this particular instance it had two arms developed, both in the normal positions, and a length of 21 cms with no branches at all. Branches have been found up to 12 cms long but are undoubtedly much longer when complete. Their maximum width is rather less than that achieved by the main stipe. The branches are rather stiff.

Remarks: The Cautley specimens are clearly conspecific with C.centrifugus Boucek since they agree in all essential characters of coiling, and branch type and spacing. The helical spiral of the proximal end distinguishes them from C.m.bohemicus Boucek which has an open coil, more branches, and branches 1 and 3 separated by less than 180° . From C.m.murchisoni Boucek it can also be distinguished by its proximal spiral coiling, paucity of primary arms, and lack of secondary arms; and from C.m.murchisoni Carruthers in the two latter features and in addition by its stiffer primary arms. C.centrifugus Boucek is closest to C.m.murchisoni Carruthers.

Material seen: Specimens in the Sedgwick Museum from Professor Shotton's locality "g" (1935,p.661) resemble C.centrifugus but none of the specimens which the author has seen has more than two arms.

Cyrtograptus aff. insectus Boucek

Plate 9,figs.3,4; Plate 38,fig.7; text fig. 87.

aff.

1919	Cyrtograptus	insectus	Perner Kodym p.12,not described.	
1922	"	"	" " p.58, " "	
1931	"	"	n.sp. Boucek p.304,Text fig.12	
1933	"	"	Boucek 1931.	Boucek pp.37-39,text fig.7,Pl.2, figs.4-8,Pl.6,fig.1

Holotype: The specimen figured by Boucek 1931, text fig.12a.

TEXT FIG. 8f

1. Monograptus ex. gr. elongatus Tornquist, sedgwicki Zone, Spengill; two thecae in full relief; (description p.280), HUR/S73,9·4/79.

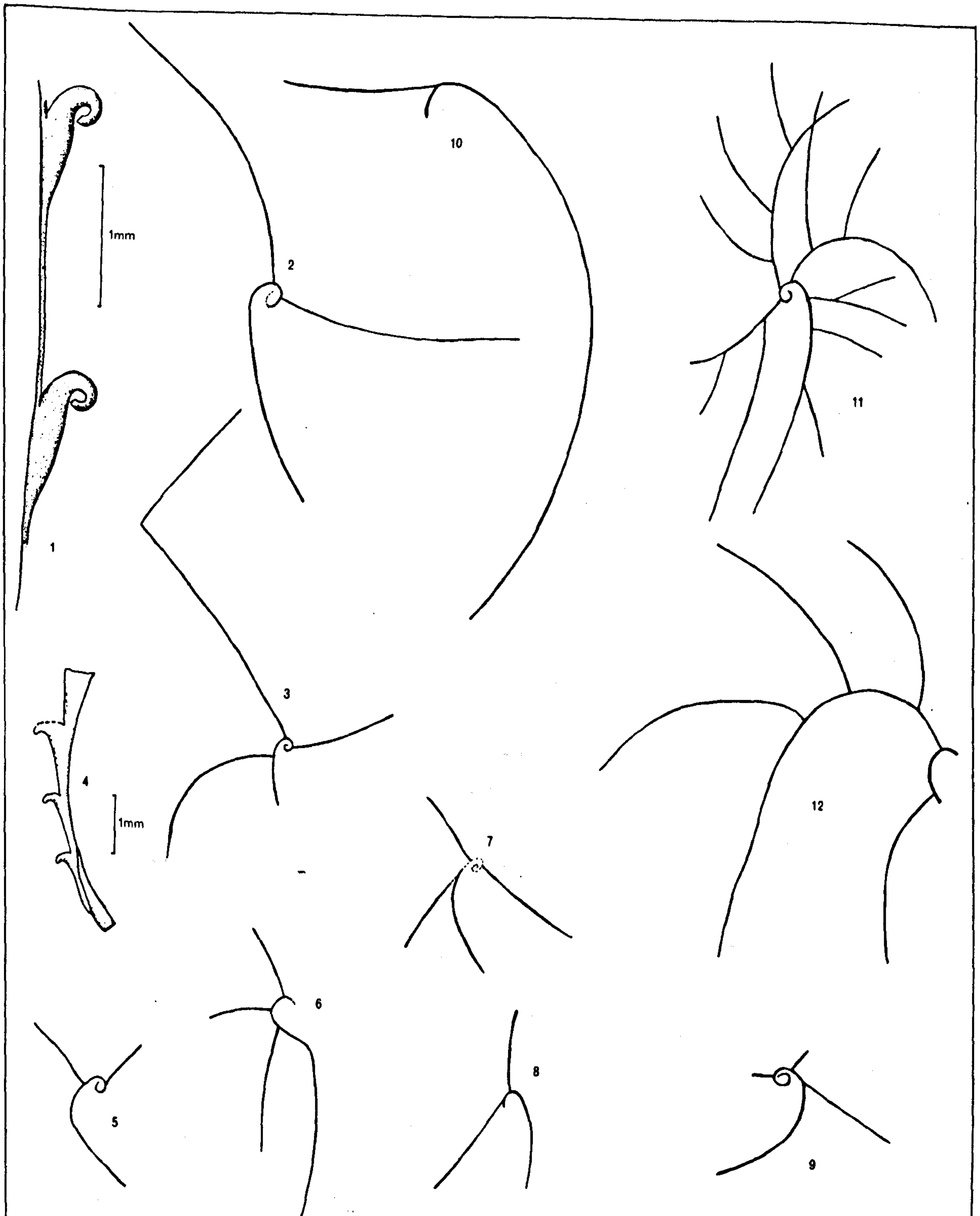
2-3 & 5-9, Cyrtograptus centrifugus Boucek, general form sketches of specimens in relief from localities 4M,1M, and 5Wh, Wenlock Series Stage 1, All x ½ (p.327).

4. Cyrtograptus centrifugus Boucek, proximal end associated with other more complete specimens from locality 1M, Wenlock Series, Stage 1.

10. Cyrtograptus linnarssoni Tullberg, general form of specimen HUR/16N/153, approximately natural size. (p.333)

11. Cyrtograptus murchisoni Carruthers, general form sketch, x ½, Wenlock Series, Stage 1, locality 37W. (p.324) (drawn from specimen HUR/37W/1.)

12. Cyrtograptus aff. insectus Boucek, general form sketch, x ½, Wenlock Series, Stage 2, murchisoni Zone, locality 50W (p.329) (drawn from HUR/50W/20a).


1mm
1
2
3
4
1mm
5
6
7
8
9
10
11
12

Material: About 12 specimens in full relief with proximal ends invariably broken off or deeply buried.
Horizon and Localities: Fairly common in the Zone of C.centrifugus - C.insectus, rare in the Zone of C.murchisoni; R.Rawthey, Mouth of Wandale Beck (50W); Wandale Hill Gill A (28W,29W, ?26W).
Diagnosis: Rhabdosome large when fully developed but small specimens in full relief showing only a single cladium are most common. Secondary and possible tertiary cladia occur on the adult. Proximal coil is large and open with only a slight tendency to helical coiling. The maximum width of about 1·8mms is achieved quite rapidly. The thecae number 11 in 10 mms in the region of the first cladium.
Description: This species is similar in its width, thecal type, and thecal spacing to the Cautley specimens of C.centrifugus but it differs in having a much larger and more open coil. The first branch, which is the only one seen in small specimens, arises usually from the point of maximum curvature. No definite proximal end and sicula has yet been seen but the earlier thecae are less high and are axially elongated. The proximal end shows a slight tendency to coil out of the main plane of the rhabdosome and is usually buried or broken off.

The largest specimen is one showing secondary and possible tertiary branches and was obtained from the Zone of C.murchisoni. This shows a badly preserved primary stipe giving rise to the first and second cladia. Each of these has 2 and probably 3 secondary branches. The point of origin of the 1st and 2nd primaries agrees with Boucek's large figured specimen (1933,Pl.6 fig.1) as does the point of origin of the first secondary branch. A tertiary branch may originate in a similar position to the only tertiary branch figured by Boucek (1933,Pl.6,fig.1).
Remarks: The spacing of the cladia in C.aff. insectus is much greater than in C.m.murchisoni Carr. and the whole rhabdosome is probably larger. More material is needed before a complete description of this species can be given but it has distinct affinities with C.insectus Boucek and may be conspecific with it.
Material seen: A large slab (S.M.no. S22425) in the Sedgwick Museum collected by J.E.Marr from Hebblethwaite Hall Gill (Cautley) has numerous small cyrtograptids and some larger specimens resembling C.insectus. The small specimens

seem to have arms rather too closely spaced for C.insectus and may represent C.murchisoni Carruthers. The appearance of this slab suggests that the bedding plane containing the fossils is the same as that found by the writer on the R.Rawthey (Mouth of Wandale Beck, locality 50W) in the C.murchisoni Zone. This bedding plane is slightly calcareous and is crowded with specimens including C.aff.insectus (see text fig.8f)

Cyrtograptus rigidus Tullberg mut.

Plate 38,figs.4,5,6

1857	Graptolithus	(Monograpsus) colonus? Meneghini p.83,Pl.B,fig.2,no.3.
1883	Cyrtograptus	rigidus n. sp. Tullberg p.38-9,Pl.4,figs.12-14.
1897	"	" Tullb. Frech p.653,Text fig.206/4.
1900	"	symmetricus, sp. nov. Elles p.410-11,Pl.24, figs.4A-B
1911	"	rigidus Tullb. Watney and Welch pp.234-5,text figs.2-3.
1913	"	symmetricus, Elles. Elles and Wood pp.509-10,text fig.355, Pl.51,figs.5a-c.
1922	"	rigidus Tull. Gortani p.59,Pl.11,figs.5-11,Pl.13,figs.4D, D'-5A,A'.
1922	"	dispar Gortani p.61,Pl.11,figs.12-15,Pl.13,figs.3a
1922	"	mediterraneus Gortani p.61,Pl.11,figs.16-17,Pl.13,fig.5.
1933	"	rigidus Tullberg 1883,Boucek pp.41-45,Text figs.8c-d,Pl.5, figs.7,8

Holotype: The specimen figured by Tullberg Pl.4,fig.12.

Material: Many specimens, all flattened.

Diagnosis: Rhabdosome similarly curved but more robust than C.linnarssoni, with a single arm arising from th.7 or 8. Sicula prominent, reaching almost to the end of the protheca of th.1, 1·3-1·4 mms long. Thecae number 10-8 in 10 mms.

Description: The sicula is 1·3-1·4 mms long and its apex reaches almost to the top of the protheca of th.1. Th.1 arises approximately 0·4 mm above the base of the sicula which possesses a short, slender virgella. The height of th.1 is 0·4-0·6 mm and like succeeding thecae it often appears to have a short spine at the aperture. Later thecae are more triangular and higher, with a greater proportion of their lengths involved in the hook. Near the position of origin of the cladium the rhabdosome breadth is 1·1-1·3 mms. Distally the thecae are relatively long, overlapping tubes with short hooks and the width both on the main stipe and the arm reaches a maximum of 1·3 mms in these regions. There are 8-10 thecae of the proximal type, but the change to the distal type is gradual and takes place in the region of maximum curvature. (The arm also usually arises in this latter position).

Remarks: The Cautley specimens were first described in 1911 by Watney and Welch who considered them intermediate between C.rigidus Tullb. and C.symmetricus Elles (two forms which are now considered synonymous). In 1910 they used the specific name "symmetricus" but in 1911 changed it to "rigidus".

Elles and Wood (1913) point out that specimens from the Welsh Borderland give rise to the cladium at th.6 but that in the Lake District specimens the corresponding position is at th.7-8. In this sense the Cautley specimens are intermediate between C.rigidus Tullb. (= C.symmetricus Elles) and C.ellesi Gortani. Furthermore the actual rhabdosome is less robust than the Welsh material for which Elles (1900) records a distal width of 1·587 mms whereas the writer's specimens do not exceed 1·3 mms. In this latter respect also they begin to approach the more slender C.ellesi, and it is possible that there is an evolutionary line:- C.rigidus Tullb. - C.rigidus Tullb. mut. (Cautley) - C.ellesi Gort. This interpretation is supported by the stratigraphy which is discussed on p.

Material seen: C.symmetricus (= C.rigidus) figured Elles and Wood Pl.51, fig.5b (S.M. no. A22,444). This specimen is certainly broader than the Cautley specimens.

Specimen from Cautley (S.M. no. A224578 presented by Dame Ethel Shakespear) labelled "C. symmetricus mut. cautleyensis Elles MS"

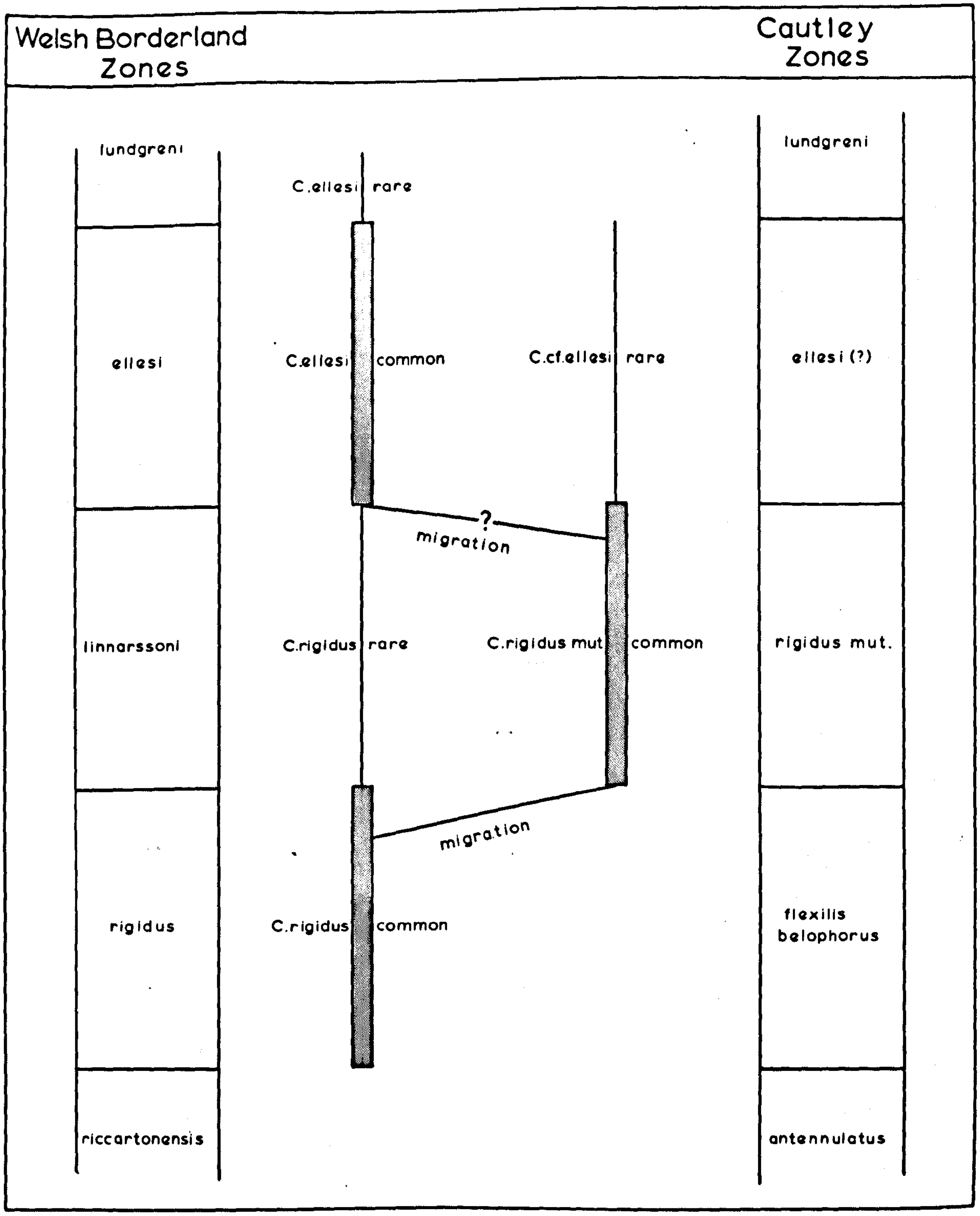
Cyrtograptus cf. ellesi Gortani

Plate 37, fig.13.

cf.

1900 Cyrtograptus rigidus, Tullb. Elles pp.409-410, Text figs.23-24, Pl.24, TEXT FIG. 8g

Suggested evolution and migration of some *C. rigidus* group forms.



Welsh Borderland Zones
Cautley Zones
lundgreni
ellesi
linnarssoni
rigidus
riccartonensis
C.ellesi rare
C.ellesi common
C.cf.ellesi rare
?
migration
C.rigidus rare
C.rigidus mut common
migration
C.rigidus common
lundgreni
ellesi (?)
rigidus mut.
flexilis
belophorus
antennulatus

figs.2A-C.

1913 Cyrtograptus rigidus, Tullberg. Elles and Wood pp.5-8-9, Text fig. 354a-b, Pl.52, figs.2a-c.

1922 " ellesi Gortani pp.60-61.

Material: A single flattened specimen, showing the cladium but with the extreme proximal end missing, and two fragmentary specimens.
Horizon and Locality: ?Zone of C.ellesi, the significance of this fossil is discussed fully on p.46 ; Ecker Secker Beck (12Ra)
Description: This specimen is not well preserved but is sufficiently intact to show an unusual number of thecae prior to the cladium. Eight thecae prior to the one giving rise to the cladium can be quite easily seen since they are well preserved and at least a further 5 can be detected. The cladium, therefore, arises at least as distally as th.14. A sicula is not seen.

At the proximal end the rhabdosome is slender and the thecae number 8 in 10 mms. Distally the spacing of the thecae decreases and immediately before the arm they number 10 in 10 mms. A width of 1mm is reached at the point of maximum curvature near the arm.
Remarks: In all the characters so far ascertained the specimen agrees with C.ellesi Gortani (= C.rigidus of Elles and Wood).
Material seen: C.rigidus (= C.ellesi) figured Elles and Wood Pl.52, fig.2b, and text fig.354a. The width of this species is close to that of the Cautley specimens described here as C.rigidus mut. but the number of thecae prior to the arm is greater in the Builth specimen, and is in fact close to C.cf. ellesi

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Cyrtograptus linnarssoni Lapworth

Plate 38, figs.8, 9; text figs.

1880 Cyrtograptus Linnarssoni sp. nov. Lapworth p.158, Pl.4, figs.12a-b.

1900 " " Lapw. Elles Pl.24, fig.3A, not described.

1913 " " Lapworth. Elles and Wood pp.511-12, text fig. 357a-b, Pl.51, fig.4.

Holotype: The specimen figured by Lapworth 1880, Pl.4, fig.12a; refigured by Elles 1900, Pl.24, fig.3A, and again by Elles and Wood 1913, Text fig.357a-b, Pl. 51, fig.4. Specimen in the Lapworth Collection, Birmingham University no. B.U. 1707 and counterpart.

Material: Many specimens, all flattened and generally not as well preserved as other fossils from the same horizon.

Horizon and Localities: Zone of C. linnarssoni; Near Gill (16N).

Diagnosis: Rhabdosome very large with at least two cladia. Width of rhabdosome not great (0·9 to 1·0 mm) but both main stipe and cladia very long giving a slender appearance to the whole. Thecae number 10-9 in 10 mms, triangular and hooked proximally, more tubular and slightly hooked distally. The proximal recurved portion is short and open but still shows strong traces of helical spiral growth.

Description: The slender appearance and large size of the rhabdosome is very characteristic. A maximum width of 0·9 to 1·0 mms (flattened) is achieved almost immediately, and invariably bu th.6.

The sicula is quite prominent and measures up to 1·7 mms long. Its apex reaches to about the level of the distal extremity of th.1 There is a short slender virgella. Th.1 arises approximately 0·3 mm above the base of the sicula, is fully 1·6 mms long, and is axially elongated. As a result of this last feature, its height is lower than succeeding thecae, which are more triangular and have a greater proportion of their length involved in the hook.

The first branch usually grows from the aperture of th.7 and is itself as gracefully curved as the rest of the polypary.. On the main stipe the change to the distal type of theca takes place gradually but the thecae of the first cladia are typically "distal" although growing from a pronounced triangular th. 7. The second branch has not been seen on a specimen showing the proximal end and cladium 1, and it undoubtedly occurs at a great distanced from the proximal end. Specimens showing 15 cms of the main stipe have shown no traces of cladium 2 but distal fragments showing branches are common. No secondary branching has been detected. The full spread of the rhabdosome may well be over two feet.

Remarks: The holotype figured as text fig.357a by Elles and Wood (1913) is drawn showing the cladium emerging from th.5 and a sicula at the proximal end. In actual fact the specimen may have no sicula and has two more thecae develop ed giving at least 6 prior to the appearance of an arm. It would appear that there is a certain amount of variability in the position of origin of the first cladium since in their description (drawn from material from the Welsh Borderland and the Dee Valley) Elles and Wood give it as "commonly five or six thecae before the first cladium is given off".

Each time the holotype has been figured it has been depicted with the second cladium arising at no great distance from the first - at about 2 cms in fact. This may be the case, but the arm in question has the appearance of being in accidental juxtaposition since it approaches the main stipe at a slightly lower level. On the other hand it does not, apparently pass under the main stipe as the specimen has been "dug out" here and no trace detected.

In all characters, therefore, except the position of the second cladium the Cautley specimens agree with the type specimen and the detailed description of Elles and Wood.

<u>Cyrtograptus lundgreni</u> Tullberg

Plate 9,fig.2.

1850 Graptolites nilssoni Barrande Pl.2,fig.17.
1850 Fragment de Graptolites priodon? Barrande Pl.2,fig.18.
1883 Cyrtograptus Lundgreni sp. nov. Tullberg p.39,Pl.3,figs.8-11.
?1883 " Carruthersi Lapw. Tullberg Pl.3,fig.25.
1899 " Lundgreni Perner p.19,Pl.16,figs.13-16,Pl.17,figs.16,text fig.23-24.
1900 " " Tullb. Elles Pl.24,figs.1A B,text fig.24.
1913 " " Tullberg. Elles and Wood pp.507-8 (pars) text fig.353a-b,Pl.52,figs.1a-c,(non d).
1919 " " Tullberg. Kirste p.201,Pl.3,fig.40.
1933 " lundgreni , Tullberg 1883. Boucek pp.50-52,text fig.9a-c, Pl.4,figs.4-6.
1951 Tull. Cope,

<u>Holotype</u>: Specimen figured by Tullberg (1883,Pl.3,figs.18).

<u>Material</u>: Numerous flattened and fragmentary specimens, but one well preserved specimen showing two cladia.

Horizon and Localities: Stage 4, Lower beds of Zone of C.lundgreni; Bluecaster Gills, Near Gill (?25N,26N,27N,29N); R.Rawthey, Mouth of Wandale Beck (72W).

Diagnosis: Rhabdosome slender, thecae small, hooked, appearing on both concave and convex sides, numbering 10 in 10 mms on the main stipe and rather less on the cladia.

Description: When fully developed the rhabdosome has a very characteristic "open" curvature and in the best specimen has two arms developed.

The thecae on the proximal parts of the main stipe number 10 in 10 mms and are small and hooked. Thecal overlap in this region is negligible but distally - and throughout the cladia - the thecae are rather longer, overlapping tubes with small hooks.

The rhabdosome does not exceed a width of 0·8 mm and the proximal regions are very slender. The sicula has not been seen.

Remarks: C.lundgreni was first recorded at Cautley by Watney and Welch (1911) but it seems to be absent from the upper part of their zone of the same name. Further discussion takes place on p. 47

Material seen: Specimens figured Elles and Wood Pl.52,figs.1d,1a,1b, and text fig.353a (Sedgwick Museum Collection); specimens obtained by R.N.Cope from the Devilsbit Mountains, Tipperary (Sedgwick Museum Collection).

Cyrtograptus ?carruthersi Lapworth

not figured.

1876	Cyrtograptus	Carruthersi	Lapworth pp.321,544,Pl.10,figs.6a-c.
1900	"	"	Lapw. Elles p.408,text fig.21.
1913	"	"	Lapworth. Elles and Wood pp.512-13,text fig. 359,Pl.52,figs.4a-c.

Note: A few fragments have been found from Wandale Hill (locality 3W) of a form resembling C.carruthersi Lapw. The thecae do not appear to be hooked but the apertural margin is somewhat pointed as in Elles and Woods text fig. 359,p.513). Cladia are developed, the nature of whose origin is obscure and at their point of origin are extremly slender.

Loc.3W is fault bounded both upstream and downstream. The associated fossils are: M.f.flemingii, M.f.primus, P.dubius and C.lundgreni. This association has not been detected elsewhere.

Material seen: Specimens of C.carruthersi in the Sedgwick Museum.

genus BARRANDEOGRAPTUS Boucek 1933
emend Boucek and Pribyl 1952

Type species: Cyrtograptus pulchellus Tullberg 1883

Generic diagnosis: Rhabdosome slender, thecae non-spinose, coiled inwards (i.e. introverted) at their apertures.

Barrandeograptus pulchellus (Tullberg)
Plate 38,fig.1

1883 Cyrtograptus pulchellus n. sp. Tullberg pp.36-37,Pl.3,figs.12-13.
1883 " flaccidus n. sp. " p.37,Pl.3,figs.14-15.
1897 " pulchellus Frech p.653,text figs.2-3.
1933 " (Barrandeograptus) pulchellus, Tullberg 1883,Boucek text figs 15a-c,Pl.7,figs.1-6.
1938 " " " Tull. Bulman p.d.84.
1940 " " " " Laursen p.30,text fig.27.
1940 " bornholmensis n. sp. Laursen p.30,p.35-36,Pl.3,figs.1-4.
1952 Barrandeograptus pulchellus (Tullberg 1883). Boucek and Pribyl text figs 5a-d,Pl.3,figs.3; Pl.4,figs.1-3.

Material: A single well preserved, but flattened specimen.

Horizon and Locality: Zone of M.riccartonensis; Wandale Hill (30W).

Description: The specimen is $3\frac{1}{2}$ cms long with gentle ventral curvature and a maximum width of 0·65 mm. The thecae number 6+ in 10 mms and are long tubes with little, if any, overlap. The apertural regions are free but the characters not easy to ascertain. They are not simple tubes, nor are they hooked, whilst there is a distinct introversion in some of the thecae. These thecae closely resemble some of those figured by Laursen (1940,p.13) and which Boucek and Pribyl (1952) regard as synomymous with B.pulchellus. If the apertural coil is twisted away from the observer in a flattened specimen as may be the case here, then the nature of the coil is bound to be obscure.

Remarks: This specimen is indistinguishable on its general form, size and thecal characters from B.pulchellus Tullb. whilst the probable nature of the aperture agrees with the generic redefinition of Boucek and Pribyl (1952).

Material seen: Specimen listed Elles 1900, p.396 as Cyrtograptus flaccidus Tullberg (= Barrandeograptus pulchellus), Zone of M.riccartonensis, Walcott Quarry, Chirbury.

INCERTAE SEDIS

Monograptus angustus sp. nov.

Plate 36,figs.5,6

Holotype: HUR./S140,11/1 a proximal end with the sicula preserved intact.

Horizon and localities: Subzone of R.maximus, S140,11 Spengill.

Other material: More distal fragments, thought to be referable to this species, from the zone of M.sedgwicki (HUR./S73,11·4/58) and a more doubtful distal fragment from the zone of M.turriculatus (HUR./S173,6/ 7 and counterpart).

Derivation of name: Angustus: L. "narrow".

Diagnosis: The extreme tenuity of the proximal end and the form of the thecae are characteristic. Initial breadth is about 0·1mm which is maintained until at least th.6. Thecal count, proximally, rather less than 7 thecae in 10 mms.

Description: The holotype is the only proximal end known, and this is 10·5 mms long comprising 7 complete thecae and a portion of the eighth protheca. The sicula is relatively robust being 0·9 mm long and 0·13 mm broad at the base. Th.1 seems to emerge near near its apex and the aperture of th.1 is 0·78 mm above this point.

In spite of the fact that the specimen is preserved in low relief the characters of the thecal apertures are not easily discerned. They do, however seem to be distinctly introverted so that the aperture faces the dorsal margin of the rhabdosome (pl.36,fig.5). It is not possible to say whether there is any introtorsion involved.

The thecae do not overlap and the protheca, at its inception, is 0·06 mm wide, thence widening gradually until the maximum width is achieved in the region of the aperture.

Distal fragments, probably referable to this species, have been found. The specimen figured on plate 36 (fig.6) seems to show overlap of the thecae but this may be due to compression of the apertural region against the rhabdosome. The thecae otherwise show the same characters and number 8½ in 10 mms. A width of 0·26 mm is reached.

Specimen HUR./S173,6 /7 is only doubtfully referred to this species since there is an abrupt expansion in the region of the aperture to give a maximum width of 0·45 mm. It is possible that this is a compressional feature, the compression and direction of elongation being oblique to the rhabdosome. Obscure though the thecal characters are, there does seem to be introversion of the apertural margin.

Remarks: In some respects this form approaches members of Monograptus Gp. A but there is a complete lack of sigmoidal curvature and overlap of thecae, whilst even M.sandersoni Lapw. appears to be more robust.

This species shows characters similar to Barrandeograptus as redefined by Boucek and Pribyl (1952) particularly in the introversion of the apertural margin and the general form of the thecae. It is not impossible that it is intermediate in form between Monograptus Gp. A and Barrandeograptus. Further material will be required however, before this species can be placed in a group other than "Incertae Sedis".

Monograptus fragilis sp. nov.

Plate 36,figs.1-4

Holotype: HUR./S24-28/29, specimen on a small slab with several thecae preserved in relief, among fragments of less well preserved specimens.

Horizon and Localities: M.triangulatus zone, Spengill S24-28.

Other material: The above-mentioned fragments on the same slab and others from the same horizon and locality; a few specimens showing more proximal fragments from 9Bi, Birks Beck.

Derivation of name; fragilis, L. "frail".

Diagnosis: Width distally about 0·26 mm, proximally a breadth of 0·06 mm has been noted. Sicula unknown. Thecae number 8 in 10 mms proximally, and less than 7 in 10 mms more distally. Apertural margin may be slightly everted.

Description: This species is even more slender in the proximal region that the previously described M.angustus sp. nov. The general form of the rhabdosome is similar, and equally fragmentary. Specimens from Birks Beck (9Bi) show that the proximal end is at least as narrow (0·06 mm). The sicula and adjacent thecae have not been found. Distally a width of 0·26 mm is achieved in some specimens. Curvature, as might be expected in so slender an organism , is variable.

Throughout the rhabdosome the thecae are simple, straight tubes which widen gradually from a narrow prothecal portion to reach their maximum width in the region of the aperture. Early prothecal portions are about 0·04 mm wide at their inception, and in the broadest distal parts are 0·08 mm.

The thecal tubes overlap slightly. This does not seem to be a compressional feature since all specimens show the same degree of overlap - about one-twelth the thecal length. The characters of the apertural regions are, as in the case of M.angustus sp. nov., difficult to unravel. Generally the apertures appear to be slightly everted and there is no suggestion of complications in the specimens examined.

The thecae number 8 in 10 mms proximally and rather less than 7 in 10 mms distally.

Remarks: In the general form of the rhabdosome this species is close to M. angustus sp. nov. but differs in the following respects:-

a) The thecal tubes show overlap in M. fragilis.

b) Thecal apertures are simple and everted in _fragilis_ but introverted in _angustus_.

c) The proximal end in _fragilis_ is even more slender than in _angustus_.

Like _M. angustus_ sp. nov. this species shows similarities with _Monograptus Gp. A_ and is perhaps even closer to this group in that a certain amount of overlap does occur. Those members of _Monograptus Gp. A_ which show evertion of the aperture, low amounts of overlap, and small amounts of sigmoidal curvature may be considered closest to _M.fragilis_ at least from a morphological point of view.

Being closer to _Monograptus Gp. A_, _M. fragilis_ is further removed from _Barrandeograptus_ (Boucek 1933 emend. Boucek and Pribyl 1952) than is _M.angustus_ although it is similar in the general form of theca and rhabdosome to that group.

Monograptus aff. involutus (Lapworth)

Plate 37,fig.2

1876 Monograptus intermedius var. involutus, Lapworth, p.316,Pl.X,fig.11.

1912 " involutus (Lapworth). Elles and Wood p.478-9,Pl.XL1X,figs. 4a-c.

Material: One specimen associated with doubtful fragments, loc. 9Wa, Watley Gill. All poorly preserved. Specimen no. HUR./9Wa/87, Zone of _M. convolutus_.

Description: In the general form of the polypary and thecal characters this form is close to _Monograptus intermedius var. involutus_ Lapworth and the material described by Elles and Wood as _M. involutus_ (Lapworth). The Cautley specimen is associated with similarly curved, but extremely tenuous, fragments.

The thecae number 6-11 in 10 mms depending upon the attitude of the rhabdosome with respect to the direction of compression. All the material is poorly preserved but as far as can be ascertained the thecae agree in character withe those described by Elles and Wood.

Remarks: Neither Lapworth nor Elles and Wood describe the characters of the proximal part of the rhabdosome and no mention is made of the sicula. Elles and Wood (p.479) do point out, however, that the proximal end is very slender and the thecae minute.

It is possible that the fragments associated with the Cautley specimen represent the proximal portions. The thecae on these are long, narrow tubes (0·03 mms wide) showing no signs of hooked apertural regions. They are closely adpressed to the axis and the whole rhabdosome in this region is only 0·06 mm wide. Other than this nothing can be said.

Monograptus sp. C.

Plate 36,fig.10

Description: A single flattened specimen of an indeterminate species has been obtained from S219,0·25, Spengill. The thecae are hooked and beak-like but closely adpressed to the axis. They number 15 in 10 mms proximally and 14 in 10 mms more distally, although the specimen is compressed at right angles to the rhabdosome. This compression will also have increased the width which at its maximum is only 0·19 mm. A sicula is present and measures about 0·78 mm long, its apex reaching above the aperture of th.1. There may be slight overlap of the thecae. The prothecal portion widens gradually to reach its maximum prior to the hook. This form bears a certain resemblance to *M. dextrorsus* figured by Elles and Wood (1912, p.460, text fig.318a).

? Monograptus sp. G

Plate 36,fig.9

Description: This form is represented by a small specimen so poorly preserved as almost to defy description. A description is attempted here only because of its apparent unusual nature. The specimen has a small rhabdosome, dorsally curved and forming a "fish-hook" about 2 mms across. Several thecae can be seen and the first two appear to be hooked. The second of these gives rise to a slender, ventrally-curved branch about 2½ mms long. This branch has four thecae which rapidly increase in size from a slender thread-like origin, so that the fourth is about 0·26 mm broad. The apertures are not clear but the thecae upon the cladium do not appear to be hooked.

This specimen is associated with a specimen probably referable to M. angustus sp. nov.

EVOLUTION OF SOME OF THE FORMS DESCRIBED

In spite of the fact that the Cautley material is generally poorly preserved and that no one group has been studied in more detail than any other (the main object being to secure the broad stratigraphy and succession of faunas rather than the minutiae of evolutionary plexuses), several short evolutionary steps have been observed and are listed below.

Glyptograptus

The stratigraphical recordings of the species under this genus support the detailed analysis undertaken by Packham (1962). A specimen close to Glypto graptus tamariscus tamariscus form C has been recorded from the D.magnus Zone at Cautley suggesting that the postulated root for the form (Packham 1962, p. 524 text fig.6) is correct.

Glyptograptus packhami sp. nov., recorded from the Zone of M. sedgwicki, is thought to have evolved directly from Glyptograptus tamariscus distans Packham which it closely resembles. The latter species occurs in the zones of cyphus and gregarius (Packham 1962,p.524,text fig.6). Such a change, however, would involve the growth of a median septum, whereas Davies (1929) has shown that in some climacograptids and glyptograptids loss of the median septum takes place as the species evolve. On the other hand Packham (op. cit.) found that the position of the median septum in Glyptograptus elegans and Glyptograptus sinuatus bears no relation to stratigraphic horizon.

A further change in this step is the loss of angularity of the geniculum coupled with a shortening of the supragenicular wall. In general terms the result is to make the thecal tubes physically more independent of each other, though the step in this direction is admittedly small.

A similar change has been noticed in the proposed step from Glyptograptus sinuatus sinuatus (Nicholson) to Glyptograptus sinuatus crateriformis subsp. nov As in the above case this is also an instance of a new form appearing in the Zone of M.sedgwicki, the type subspecies having been detected in the Zones of M.triangulatus to P.leptotheca. The change towards physical independence of the cells is greater than in G.packhami sp. nov. Thus the thecal tubes are more robust, show less overlap, are inclined at a lower angle to the axis and are widely spaced. No change in either the position or nature of the median septum has been detected.

Spinograptus

An evolutionary line is suggested from S. spinosus prespinosus subsp. nov. (Wenlock Series) to S.s.spinosus (Ludlow Series) involving a decrease in size and increase in length of the spines. Decrease in size and increase in spinosity are two features commonly expressed by the graptolites of the Ludlow Series, and the proposed lineage is not abnormal in this respect. The presence of S.s.prespinosus in the Zone of M.riccartonensis was first noted as long ago as 1911 by Watney and Welch as Retiolites spinosus Wood, but seems to have been ignored by Boucek and Munch (1952). In their generic distribution chart (p.8) they record a minimum in the M.riccartonensis Zone with no retiolitids recorded and on p.109 state "....at any rate we do not so far possess any representative of the family from this period". Whilst S.s.prespinosus is therefore of interest in filling this gap it does not affect the double maximum concept of these authors and, as pointed out, it has close ties with the younger of the two groups of retiolitids.

Dimorphograptus

The subspecies defined here (pp.181) as D.e.erectus and D.e.nicholsoni subsp. nov. seem to represent the only case in dimorphograptids where stratigraphical collecting has shown a change in the number of thecae contained in the uniserial portion of the rhabdosome. Thus D.e.nicholsoni in the M. atavus Zone has two such thecae whilst in the upper part of the P.acinaces Zone forms of similar dimensions have either two or three with the latter number predominating. It remains to be seen (by further collecting) whether specimens in the P.cyphus Zone invariably have three thecae in the uniserial portion or whether they show occasional specimens with two. On consideration of size and thecal spacing alone material from the P.cyphus Zone can be separated as D.e.erectus

The fact that dimorphograptids can increase the length of the uniserial portion step by step does not prove that they gave rise to monograptids in this manner. Clearly, in this case, the time taken to increase the uniserial portion by one theca is almost equal to the length of time occupied by the whole genus. Such a process would have to be greatly accelerated (see also Bulman, 1960, p.67,et. seq.) if it were to result in monograptid graptolites.

Monoclimacis

The author's definition of the vomerine species in this genus (pp.188) is built up mainly on a basis of the Cautley specimens. This is admittedly incomplete since it fails to take full account of M.crenulata (the holotype of which is lost) and of M.v.gracilis. But it is considered more appropriate to explore evolutionary possibilities here, in thesis form, than in other media, particularly as a considerable amount of information is known upon which the above definitions are based.

Pribyl (1940) includes M.cfr. griestonensis Elles and Wood in his synonymy of M.linnarssoni (Tullberg). Although these two forms are distinct (v.p. 201) they are in fact closely related and the former (= Monoclimacis sp. Wilson 1953) may have given rise to M.linnarssoni which occurs at a slightly higher level (Pribyl, 1940,p.16). Elles and Wood record M.cfr.griestonensis from just below the Zone of M.crenulata and Wilson noted Monoclimacis sp. from his M.griestonensis Zone. The specimens described here as ?Monoclimacis sp.A , if truly monoclimacid, could be the root of the series:-

?Monoclimacis sp. A   M.cfr. griestonensis   M. linnarssoni

This lineage would involve gradual loss of "hooked" thecae from completely "hooked" in the case of ?M. sp. A, to two or three in M.cfr. griestonensis, and finally none in M.linnarssoni. The proximal ends remain similar throughout and are characterized by a long sicula which reaches well above the aperture of th.1 and in the case of ?M. sp. A even to the aperture of th.2. An increase in the thecal spacing also takes place.

Elles and Wood (p.414) consider M.cfr. griestonensis "intermediate in character between Monogr. griestonensis and M.vomerinus var. crenulatus..." The distinctive characters of the first of these seems to the writer to exclude it from a direct relationship with M.cfr. griestonensis but it is conceivable that M.crenulata evolved from a ?M. sp. A - M.cfr. griestonensis line. This change would involve loss of "hooks" and increase in rhabdosome size. Increase in gross rhabdosome size is probably a common trend at this time culminating in such forms as M.v.basilica in the Wenlock Series.

Elles and Wood went as far as to think (p.412) it probable that M.crenulata then gave rise to M.v.vomerina.

In the lowest Wenlock beds consideration of evolutionary trends becomes more difficult in view of the fact that several forms require re-examination and definition.

The origin of M.kingi sp. nov. is not clear, but its large sicula and distinctive proximal end may furnish a clue when a revision of the earlier forms is complete. The degree of excavation of the ventral margin of the thecae is rather less than normal and it resembles some of the Ludlow species in this respect. By the time Stage 4 is reached it has certainly changed to an even more slender and graceful form (v. p. 197).

Pristiograptus

It seems probable that the representatives of P.gregarius from the M.sedgwicki Zone are distinct from earlier forms and have evolved directly from them.

The Wenlock subspecies P.dubius pseudolatus subsp. nov. is defined on p. . This form has almost certainly evolved from P.dubius dubius and it is interesting to note that broad forms of P.dubius, such as P.d.latus (Boucek) have been recorded from other regions at about the same stratigraphical level. These may be early reflections of the tendency of some Pristiograptids to increase their width, a process which resulted later in P.vulgaris etc.

At the same time there are instances of decrease in width of pristiograptids. At Cautley for example, P.m.meneghini shows slight changes in time (p. 219) which if continued would result in P.pseudodubius. The lineage P. meneghini - P.pseudodubius is supported by these changes as well as by the occurrence of the latter fossil at a higher horizon.

Monograptus Group A

Another evolutionary change detectable in the Zone of M.sedgwicki is that from M.a.argutus (M.triangulatus to M.convolutus Zones) to M.argutus sequens subsp. nov. (M.sedgwicki Zone). The main change involved is one of size. In M.a.sequens the polypary is narrower and the thecae smaller and closely spaced.

Monograptus Group E

An evolutionary line is suggested from M.riccartonensis to M.irfonensis with M.irfonensis inclinatus subsp. nov. as an intermediate form (p.260). If this is the case then the new characters are introduced at the proximal end, as has been noted in other species. Thus M.i.inclinatus has a proximal region similar to M.i.irfonensis and a distal end reminiscent of M.riccartonensis.

Loss of these distal characters would give rise to M.i.irfonensis.

Monograptus Group J

Sudbury (1958) suggests the change: M.c.communis to M.c.rostratus. This involves the loss of some axially elongated thecae. M.c.obtusus subsp. nov. from the M.sedgwicki Zone may represent a further stage in this series in which the last of the axially elongated proximal thecae has been lost.

Cyrtograptus

The evolution of some rigidus Group fossils has already been discussed (p.332) and is summarized in text fig. 8g.

C.centrifugus Boucek, as recorded and described from Cautley, may give rise to C.m.murchisoni Carruthers. C.centrifugus precedes Carruthers' species which appears for the first time at the very top of the C.centrifugus - C.insectus Zone, this zone being defined on the whole fauna and not merely on the presence or absence of particular cyrtograptids. No specimens of C.centrifugus have been obtained at, or above, this horizon. The change from centrifugus to murchisoni would involve a slight increase in the curvature of the cladia, the development of more primary cladia, and the growth of secondary cladia. Thus the derivation of murchisoni directly from centrifugus requires a considerable amount of rapid change. At Cautley murchisoni follows so closely upon centrifugus that either this rapid change has taken place or the former species has arrived by influx from another region.

Conclusions

a) It is considered that collection of the Llandovery at closer stratigraphic intervals will yield further information on the evolution of some graptolites. The change from Middle to Upper Llandovery (i.e. into the M.sedgwicki Zone) merits closer attention since the Zone of M.sedgwicki is particularly well exposed for collecting. Clearing of the Birks Beck Section would greatly facilitate study of the faunas of the Lower and Middle Llandovery, since it appears to be relatively undisturbed and the graptolites are well preserved.

b) It is perhaps surprising that more lineages have not been detected in the Wenlock Series which compreses at least 800' of strata apparently uninterupted by unconformities or major facies changes. There is no doubt, however, that few forms have evolved actually in the Cautley region. Thus M.riccartonensis M.f.flexilis, C.rigidus mut., C.linnarssoni, and C.lundgreni etc. all make their appearance quite suddenly. In addition it has been shown that Stages 3 and 4 are not complete and it is particularly difficult to obtain fossils from the latter. In spite of these disadvantages further examination of the higher beds of the Wenlock Series might give useful clues as to the nature of the roots of the Ludlow faunas.

Class TRILOBITA Walch, 1771

Order PHACOPIDA Salter, 1864

SubOrder PHACOPINA Struve, 1959

Superfamily DALMANITACEA Vogdes, 1890

Family DALMANITIDAE Vogdes, 1890

Subfamily ZELISZKELLINAE Delo, 1935

DELOPS GROUP nov.

Group diagnosis: Prominent transgression of the anterior margin by a swollen frontal lobe distinguishes these forms from the subfamily Dalmanitinae Vogdes, and shows their affinity to the subfamily Zeliszkellinae Delo. From the Zeliszkella Group of this latter subfamily the Delops Group differs on the following points:-

a) In the zeliszkella Group the cephalic margin is entire and the anterior border visible in front of the glabella.

b) The members of the Delops Group have prominent genal spines.

c) The pygidium is larger in proportion to the cephalon than in the zeliszkella Group.

d) The eyes are situated at a greater distance from the anterior border furrow and are larger.

e) The glabellar lobation is quite distinct.

The Delops Group differs from the Dalmanitina Group of the Zeliszkellinae in the following respects:-

a) The genal spines may be larger and are of different shape than in the Dalmanitina Group.

b) The eyes are larger and are situated closer to the glabella.

c) The 2p glabellar furrows do not reach the axial furrows.

d) The pygidium is non-mucronate and the posterior extremity of the pygorachis does not reach the posterior margin of the pygidium.

Struve (1959 p.0475) considers that "With little doubt the Dalmanitinae are descendants of the Dalmanitina group of the Zeliszkellinae." If this is the case then certain major changes in morphology have taken place. These include a distinct increase in the size and change in position of the eyes, a tendency to enclose the frontal lobe within the cephalic margin, an increase in the size of the genal spines, and modification of the glabellar furrows. The *Delops* Group may be regarded as a descendant of the *Dalmanitina* Group in which only a few of these tendencies have become manifested. Thus, while the 1p furrows retain traces of the adaxial bifurcation typical of members of the *Zeliszkellinae*, the 2p furrows have become modified and do not reach the axial furrows. Similarly the frontal lobe has remained swollen and protrudes beyond the anterior border but the eyes have grown larger and have moved away from the anterior border furrow to a more central position.

Genus *DELOPS* gen. nov.

Type Species: *Phacops* (*Odontochile*) *obtusicaudata* Salter, 1855

Derivation of name: In honour of D.M.Delo.

Generic diagnosis: Exoskeleton moderately large and tuberculate; cephalon semicircular in outline with prominent genal spines; border furrow well developed except anteriorly where it, and the margin, is transgressed by a swollen frontal lobe; eyes large crescentic, close to glabella and extending from 3p almost to 1p furrows; glabella club-shaped, axial furrows moderately diverging 1p furrows with traces of adaxial bifurcation; 2p furrows transversely straight, deep, but do not reach axial furrows resulting in fusion of the 2p and 3p lobes; 3p furrows well defined, directed anteriorly; facial suture distinct, cuts the lateral cephalic border approximately opposite the 2p furrows; pygidium in the shape of an obtuse angled isosceles triangle, non-mucronate, pygorachis strongly convex, 9-13 axial rings, 6-9 pygidial pleurae; pygidium margin wither entire or with slight lateral denticles seen both on internal and external moulds.

Remarks: The peculiar association of biocharacters, some primitive and others advanced, is sufficient to distinguish *Delops* from other described genera. *Delops* almost certainly represents a specialized late offshoot from the *Dalmanitina* Group. It differs from *Dalmanitina* (*Dalmanitina*), *D* (*Chattiaspis*), and

Eudolatites in the lobation of the glabella. There are superficial resemblences to several other genera, but the complete lack of an anterior border makes for easy distinction from Dalmanites and Odontochile whilst the pygidial characters are quite unlike any of the Dalmanitinae. Some of the later genera such as Greenops, Neometacanthus etc. have similar posterior lobation of the glabella but the nature of the frontal lobe in Delops, as well as the unusual pygidium, is sufficient to distinguish it from these forms.

Delops obtusicaudatus obtusicaudatus (Salter)

Plate 40, figs. 1, 3, 4a, 4b

1845	Asaphus caudatus Sedgwick p.446 not figured or described			
1849	Phacops obtusicaudatus Salter p.7, not figured			
1851	"	(Odontochile)	obtusi-caudata Salter. McCoy p.161 not figured	
1855	"	(")	obtusicaudata Salter sp. n. Salter Pl.ii, appendix A, Pl.1G, figs.15,16.	
?1864-1883		"	"	Salter Pl.1, figs.42-45.

Lectotype: Headshield figured by Salter, 1855, Pl.1G, fig.15 and refigured here Pl.40, fig.1. The specimen is now housed in the Sedgwick Museum, Cambridge, S.M. no. A38,682.

Horizon and Locality of Lectotype: Coldwell Beds, Coldwell, Westmorland.

Horizon and Localities: Middle Coldwell Beds, Upper Coldwell Beds, Lake District: Coldwell Quarry; West of Hundreds Road, nr. Skelgill; Troutbeck, Westmorland; Coniston, Lancashire.

Diagnosis: Exoskeleton moderately large, tuberculate, and with a prominent doublure; cephalon semicircular, anterior border interrupted by protruding frontal glabellar lobe, genal spines present, border furrow well developed except anteriorly; eyes large, crescentic, extending from top of 3p lobes to midway between 2p and 1p furrows; cephalic axial furrows widen steadily from occipital ring; 1p, 2p, and 3p lobes graduated and increasing in size anteriorly, 2p and 3p lobes fused abaxially so that 2p furrows do not reach furrows; frontal lobe large, swollen, protruding beyond anterior cephalic margin, with a posteriorly-positioned pit; whole cephalon ornamented with coarse tubercles;

pygidium relatively large, well segmented, pygorachis with 11-13 axial rings, and pleural regions with about 9 pleurae; pygidial margin entire and doublure well developed.

Description: D.o.obtusicaudatus does not seem to occur outside the Lake District and the headshields obtained from Coldwell etc. and contained in the various museums are not well preserved. Nevertheless the general pattern of a coarsely tuberculate semicircular cephalon can usually be ascertained and in occasional better preserved specimens the nature of the various biocharacters can be seen.

The genal spines are relatively short reaching a length equal to about half that of the glabella, whilst the lateral margin is a direct continuation of the posterio-lateral cephalic margin. Both the cephalic margin and the border furrow are transgressed by the frontal lobe of the glabella, but otherwise the border is a distinctive feature and is ornamented by the same kind of tubercles as the rest of the cephalon. Details of these tubercles are not easily ascertained since they are usually "streaked out". The eyes are large and similar to those in Dalmanites but are not as centrally situated and are positioned rather more anteriorly. The posterior branch of the facial suture is directed forwards and cuts the lateral cephalic margin at a level midway between the 2p and 3p furrow.

A most distinctive feature of D.o.obtusicaudatus is the glabellar lobation. Owing to compression the fusion of the 2p and 3p lobes is only occasionally seen, but the graduation in size from the 1p to 3p lobes is always discernable. The 1p and 2p lobes are quadrangular and the 3p lobes triangular. The 3p furrows diverge anteriorly and bound the swollen frontal lobe. In most of the specimens examined the frontal lobe just transgresses the frontal cephalic margin but the nature of preservation often makes it difficult to assess the part played by distortion. The frontal lobe is collapsed in several instances, and in these cases the anterior cephalic margin is visible from above.

Thoracic segments have not been seen.

The pygidium is relatively large, has 11-13 axial rings on the pygorachis, and about 9 pleurae in each of the pygidial pleural fields. Both pleural and interpleural furrows are well developed. An important feature of the pygidium is the entire margin and broad doublure (v. Pl.40,figs.3,4). At the anterior end, the pygorachis is approximately one third of the total width of the pygidium, and its posterior extremity reaches to the margin. None of the specimens examined show any signs of tuberculation upon the pygidium and may be contrasted in this respect with the cephalon which, in spite of its generally poor preservation, shows the tubercles. This suggests that lack of tubercles on the pygidium is not merely a result of their obliteration by compression.

Remarks: The specimen originally figured by Salter (1855,Pl.1G,fig.15), and designated here as thelectotype, was not included by him in his 1873 catalogue of the fossils contained in the then Cambridge Museum. As a result the fossil was missing for many years and in fact was only found by the writer in 1963 in another tray of specimens. The pygidium figured at the same time as the headshield could not be found and it may be either a composite drawing or an idealized drawing.

Delops obtusicaudatus howgillensis subsp. nov.

Plate 40,figs.2,5,6; Plate 41,figs.1,2,3; Plate 42,figs.5,6,8,10,11; text fig.

?1911	Phacops obtusicaudatus.	Watney and Welch, mentioned in text
?1913	" (D.) " .	Marr mentioned in text
?1913	" (Dalmannites?) sp. 1	Marr p.17, not figured.

Holotype: HUR./1D/384, the headshield figured Pl.41,fig.1, internal mould of almost complete cephalon.

Horizon and Locality of Holotype: Basal Ludlow limestone, Zone of P.nilssoni; Bluecaster (1D).

Horizon: Rare in the top few feet of the Brathay Flags (Stage 4) and common in the bipartite limestone immediately overlying the Brathay Flags.

Localities: Bluecaster, (1D); Mouth of Backside Beck (2Ck,3Ck).

Diagnosis: Exoskeleton moderately large with a very narrow doublure; cephalon semicircular, anterior border interrupted by protruding frontal glabellar lobe; genal spines long and robust; border furrow well developed except anteriorly; occipital ring with mesial tubercle; eyes large crescentic, extending from top of 3p lobes to 1p grooves; cephalic axial furrows widen steadily from occipital ring; 1p, 2p, and 3p lobes graduated and increasing in size anteriorly, 2p and 3p lobes fused abaxially so that 2p furrows do not reach axial furrows; frontal lobe large, swollen, protruding beyond the cephalic margin, and having a posteriorly-positioned pit; whole cephalon ornamented with large tubercles interspaced with more numerous smaller ones; pygidium well segmented, tuberculate, pygorachis with 9-10 axial rings and pleural regions with 6-8 pleurae; pygidium margin showing at least three lateral denticles, doublure very narrow; hypostome tuberculate, with three denticles along posterior margin, anterior wings and maculae similar to Chattiaspis.

Description: The subspecies D.o.howgillensis can be distinguished from D.o.o. on the following criteria:-

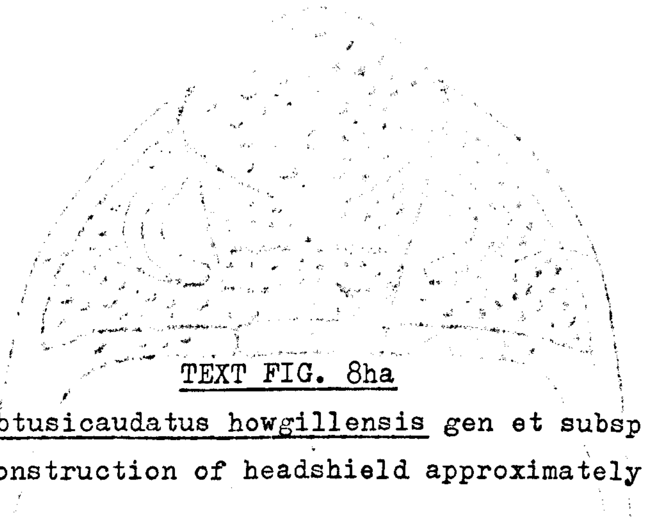
a) the margin of the pygidium is not entire but denticulate
b) the doublure is very narrow
c) the pygidium shows the same tuberculate ornamentation as the cephalon but to a slightly less degree
d) the pygorachis has 9-10 axial rings (cf. 11-13)
e) the pygidial pleural regions have 6-8 pleurae
f) the pygorachis does not reach the posterior border of the pygidium
g) the pygidium is probably smaller in proportion to the cephalon
h) the genal spines are longer and more robust
i) the eyes are larger
j) the posterior branch of the facial suture cuts lateral cephalic margin at the level of the 2p grooves.

It is possible that when further material becomes available the ornamentation of the cephalon may be seen to be different on the two subspecies.

Delops nobilis (Thomas)
not figured

1900 Phacops (Dalmania) nobilis, sp. nov. Thomas pp.617-618,Pl.34,figs.1-3

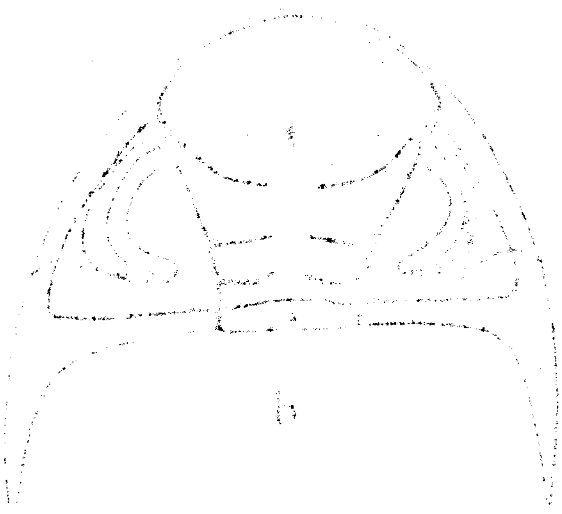
Remarks: The species described by Thomas (1900) is a typical Delops and is very closely related to the species D.obtusicaudatus (Salter). It differs, however, from both D.o.obtusicaudatus and D.o.howgillensis in several small, but signif-

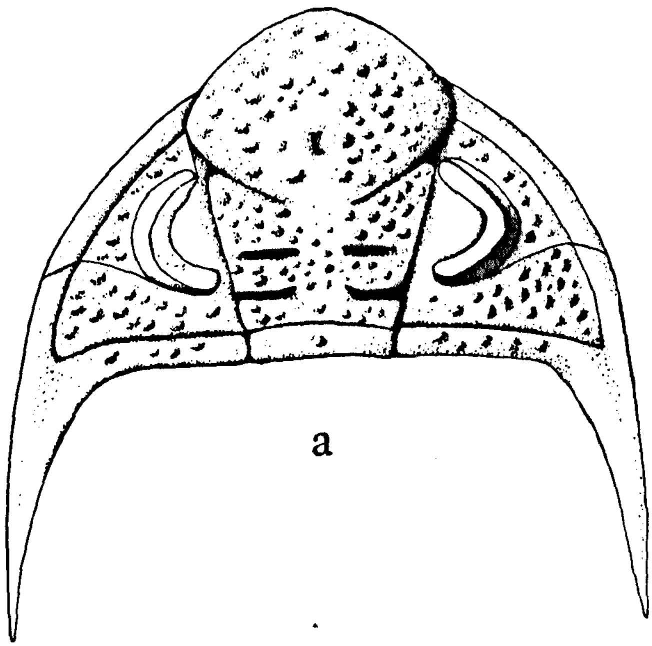


TEXT FIG. 8ha

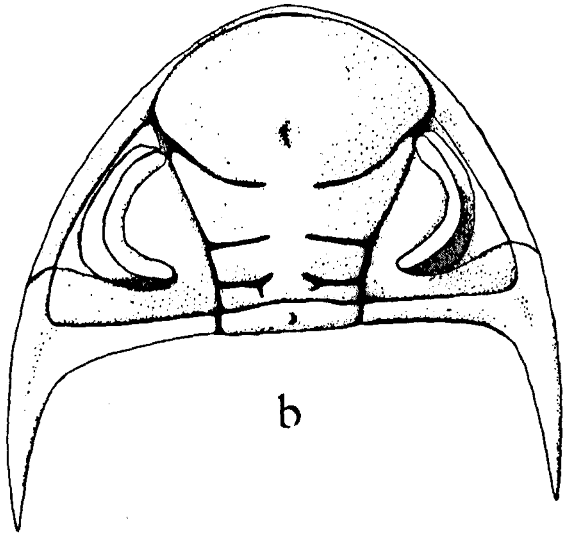
Delops obtusicaudatus howgillensis gen et subsp. nov. reconstruction of headshield approximately X 2.

Struveria torvus gen.et sp. nov. reconstruction of headshield approximately X 2.





a



b

icant characters. The headshield is very close to howgillensis but the eyes are rather larger and their posterior extremities reach midway between the occipital furrow and the 1p furrow whilst the palpebral area is slightly tuberculate in contrast to the smooth area of howgillensis. In his reconstruct-Thomas show the 2p furrows as extending abaxially to the axial furrows. This is incorrect and is clearly based on the type specimen (Pl.34,fig.1) which has the 2p furrow crushed. Other specimens contained in the University Museum, Oxford (e.g. C558) show the typically deep 2p furrows which fade out before the axial furrow is reached. The frontal lobe is possibly even larger than in howgillensis.

The pygidium has 9 rings on the pygorachis as has D.o.howgillensis but the doublure is broad, rounded, and very similar to that seen in D.o.obtusicaudatus. There is a faint tendency to deticulation of the anterior-most pleural segment of the pygidium margin.

Thomas records nobilis from the Wenlock Shale and the figured specimens are labelled "1 ml. E. of Builth, 150 yds from Bank of Wye". This is probably in the Zone of C.lundgreni and may be near the summit (v. Elles, 1900, map p.385). It is possible, therefore, that D.nobilis precedes D.o.howgillensis and it seems likely that it gave rise directly to the latter mainly by reduction of the doublure and increased denticulation of the pygidial margin.

DALMANITINA GROUP

Genus STRUVERIA gen. nov.

Type Species: Struveria torvus sp. nov.

Generic diagnosis: Cephalon semicircular, genal spines long and robust; border furrow distinct but unlike cephalic margin does not pass in front of frontal glabellar lobe; eyes large and are positioned near the anterio-lateral border furrow as in other members of the Dalmanitina Group; posterior branch of facial suture cuts lateral cephalic margin opposite 2p furrows, and anterior portion can be seen passing round front of glabella in suitably preserved specimens; glabellar lobation very similar to Dalmanitina (Dalmanitina), D.(Chattiaspis) and Eudolatites with 1p furrows adaxially bifurcating; 1p and 2p furrows converge towards axial furrows; axial furrows only slightly divergent until 2p furrows reached when they flare suddenly to produce a club-shaped glabella; 1p and 2p lobes of similar size but 3p lobes much longer and frontal lobe dominant, but not transgressing anterior cephalic margin; pygidium relatively large, moderately convex, very similar to Eudolatites, margin entire, indistinct, non-mucronate; 9-10, ?11 axial rings on pygorachis, 7 or 8 pygidial pleurae.

Remarks: From Dalmanites and Odontochile, Struveria can be distinguished on the characters of both the pygidium and cephalon. It lacks the ornate cephalic features of the other genera in the Dalmanitinae. Struveria differs from Dalmanitina (Dalmanitina) in having larger eyes, a non-mucronate pygidium and in having the whole of its frontal lobe contained within the cephalic margin. Dalmanitina (Chattiaspis) lacks the club-shaped glabella and also has a mucronate pygidium. The pygidium of Struveria is very similar in appearance to that of Eudolatites but has a smaller number of axial rings and pleural segments. The glabellae are also similar in general shape but the frontal lobe in Eudolatites transgresses the anterior cephalic margin. In spite of these differences the writer considers that Eudolatites Delo is the closest genus. If there is a tendency in later representatives of the Dalmanitidae to enclose the frontal lobe within the anterior border of the cephalon then it is conceivable that Struveria has evolved from Eudolatites which ranges from the Ordovician to ? Middle Silurian. Such a change would also involve a fall in the number of pygorachial segments from a minimum of 11 (in Eudolatites) to 9 or 10.

Struveria torvus gen. et sp. nov.

Plate 39,figs.4-9; Plate 41,figs.4-9; Plate 42,figs.9-12;text fig.

?1913 Phacops (Dalmannites) sp. 2 Marr p.17, not figured.

Holotype: HUR./ 1D/ 260 and 260 a, internal and external moulds of almost complete cephalon; latex cast of external mould fig.1 Pl.41,fig.4.

Horizon of Holotype: Basal Ludlow limestone, Zone of P.nilssoni.

Locality: Bluecaster, 1D

Material: Over 100 headshields and pygidia.

Horizon and Localities: Restricted to the bipartite basal Ludlow limestone, Zone of P.nilssoni; Bluecaster (1D); Mouth of Backside Beck (3Ck).

Diagnosis: Cephalon semicircular, genal spines robust, border furrow absent anteriorly; eyes large positioned antero-laterally; glabella club-shaped, prominent frontal lobe, 1p grooves adaxially bifurcating, 2 p grooves directed slightly posteriorly in abaxial region, 3p lobes large and roughly triangular; pygidium relatively large, pygorachis with 9-10, ?11 rings, 7-8 pygidial pleurae; pygidium margin entire, hardly reached by interpleural grooves.

Description: The cephalic outline varies somewhat with the direction of compression but is approximately semicircular with prominent genal spines which are only occasionally longer than the glabella length. Immediately in front of the glabella the border is extremely narrow and only occasionally can the facial suture be traced in this region (v. Pl.39,fig.8). Large crescentic eyes and palpebral lobes dominate the cheeks. The eyes extend from the most anterior point of the 3p lobes almost down to the level of the 1p furrows whilst the posterior branch of the facial suture extends in an anterior direction along the base of the sub-vertical lensed surface of the eye and then curves outwards to cut the lateral margin of the cephalon almost opposite the 2p furrows.

The axial furrows are approximately parallel from the occipital groove to the 2p furrows but then diverge strongly, bounding a swollen frontal lobe, and giving the whole glabella a club-shaped appearance. This feature is very typical of the Dalmanitina Group. Adaxial bifurcation of the 1p grooves is shown by most of the specimens and in some instances is accentuated by compression (v. Pl.41,fig.4). A more typical instance is shown by the specimen figured on Pl.41 as fig.8. This would seem to be a primitive feature which is not shown by members of the subfamily Dalmanitinae. Convergence of the 1p and 2p furrows is also typical of the Dalmanitina Group and in S.torvus is usually detectable (Pl.41,figs.4-9). The 3p furrows are not straight but convex towards the posterior thus resulting in only an approximate triangular shape to the 3p lobes. In this respect S.torvus may be contrasted with D.obtusicaudatus. The sharp contrast in size between the 3p and posterior lobes also serves to distinguish S.torvus from the species included in the Dalmanitinae. The frontal lobe is elliptical in outline and has the long axis of the ellipse directed transversely. It occupies up to half the total width of the cephalon but in neither transverse nor sagittal sections is it strongly convex, whilst most specimens show a shallow pit situated on the sagittal line in a posterior position. The occipital ring is of the same convexity as the glabella except for the presence of a short mesial tubercle.

Only fragments of thoracic segments have been found.

The pygidium is relatively large with an entire margin completely devoid of spines or protruberences whilst the broad pygorachis does not reach the posterior border. Nine or ten axial rings are usually present and possibly eleven in some specimens. Of these rings the anterior three show the articulating half rings very clearly but the posterior rings are more closely packed. At its widest point the pygorachis occupies fractionally less than one third of the total width of the pygidium. Seven or eight pleurae are developed, each with a distinct pleural groove which, however, does not reach as far towards the border as the interpleural furrows. The whole appearance of the pygidium, and particularly of the axis, is reminiscent of some species of Dalmanites but is distinct in having few axial rings and more pygopleurae.

Some hypostoma have been obtained in association with S.torvus and these are similar to the hypostome of Chattiaspis except that three posterior denticles are developed.

Remarks: S.torvus is a more common fossil at the same horizon than D.o.howgillensis but unlike this latter species has not been obtained below the limestone. Marr (1913) briefly describes a form as Phacops (Dalmannites) sp. 2 which is almost certainly synonymous with S.torvus. It is also mentioned by Marr (op. cit. p.17) as occurring in the "Obtusicaudatus Beds of Lakeland". This he called Ph.torvus Wyatt-Edgell but goes on to say that "I cannot find the specimen of Wyatt Edgell which led me to make this identification". A tray in the Sedgwick Museum, Cambridge was labelled by Marr as "Phacops torvus (Edgell MS) NE. side of Helm Knott, Coniston Flags". All these specimens except S.M. no. A37158 (a headshield) are D.o.howgillensis. It appears then that Marr was not altogether clear in his mind as to the biocharacters which defined the form he called Ph. torvus. The writer has examined many specimens from the Sedgwick Museum, Cambridge, the Geological Survey Museum, and the British Museum, and all the specimens referable to S.torvus were obtained either from the Howgill Fells or the nearby Helm Knott etc.

In view of the fact that the specific name "torvus" has not been used in publication and that it was probably originally applied to the form described here, the name is retained.

Order ODONTOPLEURIDA Whittington, 1959
Family ODONTOPLEURIDAE Burmeister, 1843
Subfamily ODONTOPLEURINAE Burmeister, 1843

Genus ODONTOPLEURA Emmrich, 1839

Type species: O.ovata Emmrich, 1839
Generic diagnosis: Glabella with relatively large lateral lobes; median part of occipital ring elevated and produced into long pair of occipital spines, also with faint occipital lobes; small eye lobes situated opposite basal glabellar furrows, angle between anterior and posterior sections of facial sutures 120^o , slender librigenal and anterior pleural spines and long posterior pleural spines. Pygidium relatively wide, posterior part with long pair of major border spines.

Odontopleura hughesi (Lake)
Plate 42,figs.1,2,3,4, and 7

1873 Acidaspis hughesii sp. n. Salter p.93 not figured.
1891 " hughesi Salter. Woods not figured.
1893 " hughesii Salter ms. Hughes p.154 not figured.
1896 " hughesi Lake ex Salter ms. Lake p.242,Pl.8,fig.4.

Lectotype: The specimen figured by Lake, 1896, Pl.8,fig.4; and refigured here Pl.42,fig.4; now contained in the Sedgwick Museum, Cambridge as specimen no. A37135a and b.

Horizon and Locality oflectotype: Bannisdale Slates, Casterton Low Fell, Westmorland (? Gale Garth).

Material: Several complete specimens and many fragments.

Horizon and Localities: O.hughesi appears first of all quite low down in the zone of P.nilssoni towards the top of the 250' Banded Unit (containing Graptolite Band no. 12), and continues through into the zone of M.leintwardinensis and the higher Bannisdale Slates. It is a characteristic fossil of the Banded Unit facies. Cautley Crags (1Cc,8Cc); Clough River (1C); Wygarth Gill (2Wg); Greenside (1Gr); Bowderdale (1Bo); Dale Gill (2Da).

Diagnosis: Exoskeleton small, oval, only the axis strongly convex; cephalon sub-rectangular in outline with prominent, obliquely directed genal spines, and numerous, slender librigenal spines; occipital ring elevated with a pair of occipital spines and rudimentary occipital lobes; border furrow distinct; lateral glabellar furrows occupying one quarter of the glabellar width; eyes small, opposite basal pair of glabellar lobes; cephalon covered with small tubercles; axis of thorax occupies only one quarter of the total width of the thorax, shows paired tubercles upon each axial ring; pleurae each with a major tubercle situated midway between axial furrow and lateral border of exoskeleton, small tubercles on either side of the main tubercle, long posterior spine and short slender anterior spines; pygidium short, broad, pygorachis with two distinct axial rings and traces of a third, all three having a pair of tubercles but much reduced on the posterior ring; pygorachis does not reach posterior border; pair of long posterior spines have their origin at the anterior ring of the pygorachis and cross the pleural field as paired ridges; between pair of long posterior spines are four shorter spines, and in an anterior position to the long pair are five pairs of short, slender spines; the anterior most of these spines is small and apt to be overlooked.

Remarks: Lake in his original description figured four pairs of spines in an anterior position to the long pair of posterior pygidial spines, but in the description wrote "... 4 or perhaps 5 outside each of the larger spines". The lectotype (pl.42,fig.4) is not well preserved and does not show the pygidial characters adequately. All the other specimens examined by the writer have five pairs of spines in this position though the anterior pair is of small spines which can be easily overlooked. Specimens have been seen from: Casterton Low Fell; Pont Lawnt, Denbigh; Howgill Fells.

O.hughesi is very similar to O.prevosti (Barrande 1846), a likeness which was realized by Elles (1900) when she named fossils from the Wenlock Shale by the former name. The specific name hughesi is retained here pending further investigations.

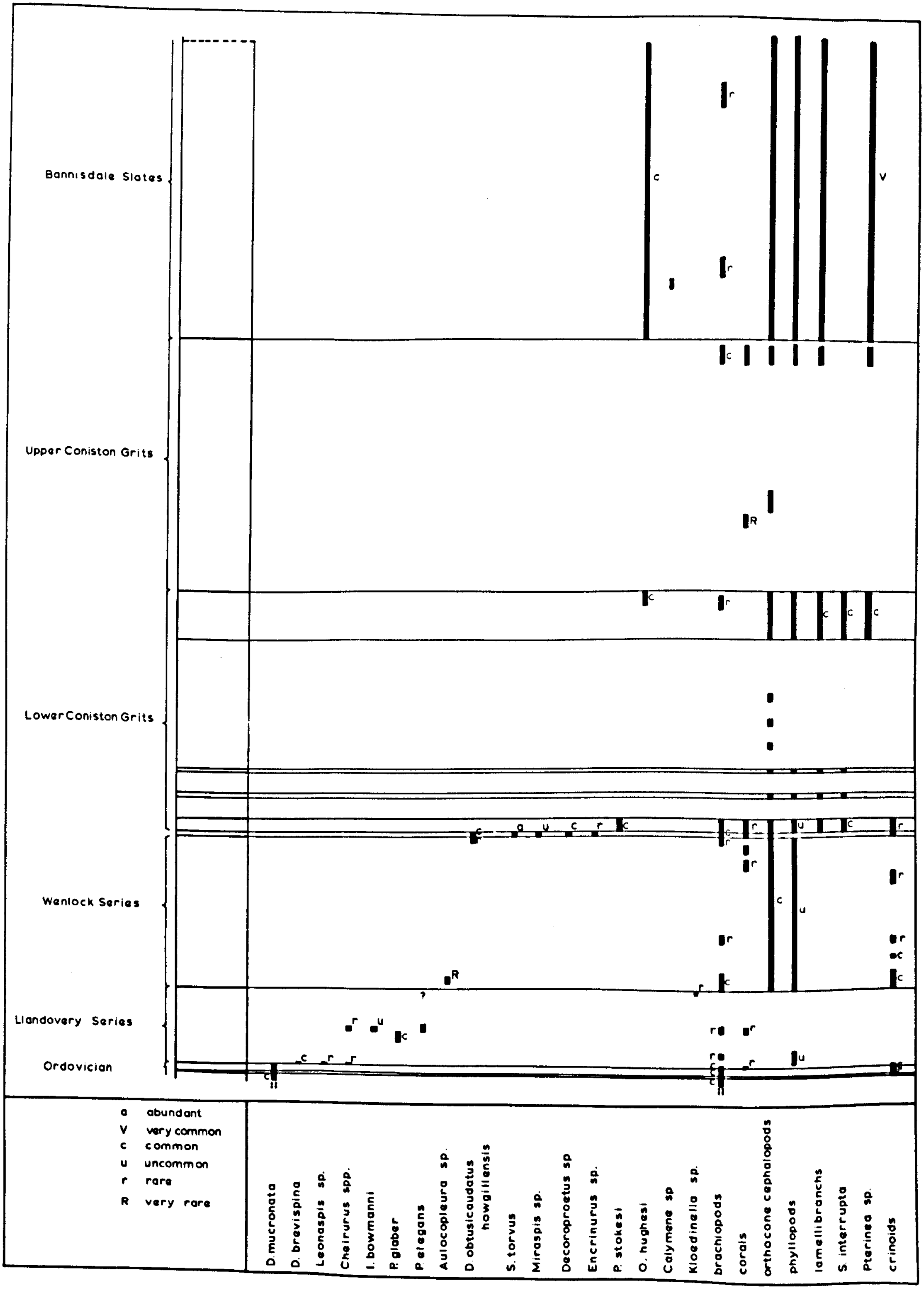
Notes on the Shelly Fossils

It is beyond the scope of this work to describe in detail all the shelly fossils of the region. The presence of shelly fossils, particularly at certain horizons such as the basal Silurian limestone, has been known since the earliest work in the region and the members of H.M.Geological Survey made perhaps the greatest contribution to our knowledge in this direction. Text fig. 8i shows the distribution of various fossils other than graptolites against the stratigraphical column worked out on a combination of lithological grounds and succession of graptolite faunas. It is considered that upon the basis of the stratigraphy outlined in this thesis the shelly fossils can now be studied more fully. Many forms (e.g. O. hughesi, S.interrupta) are long ranging species upon which the stratigraphic succession could not initially be built up, particularly in view of the fact that considerable thicknesses of rock contain such fossils only at long intervals.

Orthocone cephalopods occur throughout the succession but only at certain horizons are these preserved in three dimension (v. text fig. 6d). They might however, provide a useful confirmatary zonal scheme if studied with this object in mind. Most of the other fossil groups(e.g. trilobites) occur only at certain levels, or are rare (e.g. phyllopods) and at best can be used only as marker horizons. This is not to say, however, that they are unimportant from the point of view of palaeontology or, occasionally,long range stratigraphic correlation.

TEXT FIG. 8i

Showing general distribution of shelly fossils in the Silurian strata.



Bannisdale Slates
Upper Coniston Grits
Lower Coniston Grits
Wenlock Series
Llandovery Series
Ordovician
a abundant
V very common
c common
u uncommon
r rare
R very rare
D. mucronata
D. brevispina
Leonaspis sp.
Cheirurus spp.
I. bowmanni
P. glaber
P. elegans
Aulacopleura sp.
D. obtusicaudatus howgillensis
S. torvus
Miraspis sp.
Decoroproetus sp
Encrinurus sp.
P. stokesi
O. hughesi
Calymene sp
Kloedinella sp.
brachiopods
corals
orthocone cephalopods
phyllopods
lamellibranchs
S. interrupta
Pterinea sp.
crinoids

CONCLUSIONS

Little modern work has been done on the Silurian rocks of the Howgill Fells and details of the succession have been singularly lacking. A most valuable contribution was that of Misses G.R.Watney and E.G.Welch (1911) on the Salopian rocks but prior to this date only Marr and Nicholson (1888) had examined the Llandovery Series. A further note on the Silurian rocks was published by Marr (1913). Perhaps the most important work has been that of Wilson (1954) who examined the Middle and Upper Llandovery strata in great detail. This work unfortunately is not yet published. In the present thesis the Lower Llandovery strata are described throughout the region and particular attention has been paid to the nature of the change in conditions in passing from the Ordovician to the Silurian. The Salopian strata have been similarly examined. As a result of this, and the work by Dr.Wilson, the Silurian succession is known in some detail and it has been possible to produce a map of the district which takes into account the numerous dislocations. A summary is given immediately below of the various general conclusions.

A. The Ashgill Shales Grit has been shown to be variable throughout the area and to decrease in grain-size and thickness from SE to NW. Measurement of current bedding foreset beds suggests a source of supply in the SE.

B. It was concluded that the Basal Beds of the Silurian were probably conformable upon the Ordovician. The Ashgill Shales Grit may be a single transgressive grit and alternatively it may consist of two or three grits occupying different horizons.

C. The Basal Beds thicken to the south. The distribution of the limestone and shelly fragments suggests deposition under rather turbulent conditions.

D. The overlying Lower Llandovery can be conveniently divided into the following Zones:

M.triangulatus
P.cyphus
P.acinaces
M.atavus
A.acuminatus

The top of the Lower Llandovery cannot be proven.

E. There is a distinct thickening of the middle three Zones of the L.Llandovery Series from the Spengill area in the north to the Pickering Gill - Wards Intake line further south. This line may represent an axis of thickening since the atavus Zone on Birks Wood Beck even further south is the same thickness as on Spengill.

F. The Middle Llandovery Zones of magnus, leptotheca (= argenteus) and convolutus have been identified and it is possible that the magnus Zone is incorporated in the top of the "fimbriatus shale". The top of the Middle Llandovery is faulted wherever these beds are seen.

G. Four Stages have been recognised in the Wenlock Series:-

Stage 4	(Zone of C.lundgreni
Stage 3	?Zone of C.ellesi Zone of C.rigidus mut. Zone of M.flexilis belophorus
Stage 2	Zone of M.antennulatus Zone of M.riccartonensis Zone of C.murchisoni
Stage 1	Zone of C.centrifugus-C.insectus

Stages 1 and 4 are probably divisible into further Zones but this has not been attempted in the present state of knowledge. Although the total thickness of the Wenlock Series is similar to that recorded by Watney and Welch 1911 the older Zones are much thinner than suggested by those workers. There is a general thickening of the Wenlock Series to the south which is proved in the lower Zones and probably also occurs at higher levels. The succession in Stage 3 is not completely established and the nature of the boundary between Stages 3 and 4 is not known.

H. The base of the Ludlow Series is formed by a bipartite limestone which varies in thickness throughout the area and the upper limestone has been removed from one locality by slumping. Within the limestone is a graptolitic mudstone bed yielding P.nilssoni and M.scanicus and an associated nilssoni-scanicus Zone fauna. A vulgaris Zone is not recognized and, indeed, strata equivalent to the vulgaris Zone of other regions cannot be identified with certainty, though it is not impossible that the lowest part of the bipartite limestone is of this age.

I. The detailed succession of the Ludlow Series consisting of alternations of greywacke, graptolitic mudstone and the Banded Unit Facies, is demonstrated and the following major subdivisions defined.

Bannisdale Slates		leintwardinensis Zone l.incipiens Zone
Coniston Grits	Upper Lower	nilssoni- scanicus Zone

The whole succession (v.text fig. 4c) consists of rythmic alternations of the above facies in which the graptolitic mudstone and greywacke units are gradually, but not entirely, replaced by the Banded Unit Facies. The Lower Coniston Grits consist of 1000' of thin graptolitic mudstone units and thicker (approximately 90') of greywacke units, whilst the Upper Coniston Grits contain less, but thicker, greywacke units and Banded Units. Finally the Bannisdale Slates are composed of thick Banded Units and subordinate greywacke units.

J. The distribution of facies types has been discussed and it has been shown that graptolitic mudstone facies evolves during the Silurian in response to changing conditions. Generally the change is towards more aerated bottom conditions in which the current activity is demonstrably greater from riccartonensis Zones times onwards. The changing conditions are more conducive to benthonic life and this is reflected in the gradual appearance of shelly fossils.

It is concluded that the Ashgill Shales mudstones continue into the Silurian in a modified form where they alternate with graptolitic mudstones. The problems of the fine grained barren mudstones of the Upper Llandovery and the barren greywackes of the Ludlow are discussed.

K. The structural geology of the region is extremely complicated but consists basically of Caledonian folds and faults with an approximately E-W trend upon which a Hercynian fracture pattern has been superimposed. Evidence has been adduced to show that some of the faults are tear faults.

L. It has been demonstrated that palaeocurrent indicators suggest an E-W current in Wenlock times changing firstly to a current from SW to NE in the earliest Ludlow beds and then to a current from NW to SE through most of the nilssoni-scanicus Zone.

Suggestions for Further Research

During the progress of this work the present writer has become aware of several promising lines of research which have so far not been followed up due to the limitations of time, imposed upon the present study. Thus whilst the main purpose, that of establishing a detailed stratigraphical and palaeontological succession in those beds where this had not been done has been achieved there remain several aspects of the geology which could only be touched upon. It is suggested, for example, that in view of the succession now known the shelly faunas might be more profitably studied and those apparently long ranging species such as S.interrupta, O.hughesi etc. might be subjected to close examination.

It is equally clear that a mineralogical study of the sediments would do much to solve some of the problems left unanswered in this work. The author feels strongly, however, that it would be short-sighted to confine such a study to but one Series of the Silurian but that in view of the comformable succession and gradually changing environments of deposition all three Series should be examined and compared with their lateral equivalents.

The present work has allowed the recognition of certain aspects of the structural geology of the area. It is suggested that work with a structural analysis as the main objective would achieve valuable results.

Finally it is clear that the graptolite faunas themselves are worthy of further examination particularly since several Continental species such as P.m.meneghini and M.haupti have been found. Stratigraphical collection from the Wenlock Stages 1 and 4 is certain to be a laborious and difficult task but it is equally certain that Stage 1 will prove capable of subdivision and that Stage 4 will yield further records of graptolite species. Faunal work on the Ludlow Series is at present in a preliminary stage and further work on both the shelly and graptolitic faunas should provide interesting results.

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Appendix 1

Palaeocurrent Indicator Recordings

Key to pp.407-418

S = Series

T = Type (g = orientated graptolites; gr = groove moulds; sl. = slumped beds; Lo = load moulds; fl = flute moulds; c = current bedding foreset beds; b = orientated brachiopod hinges; cr = orientated crinoid arms.)

L = locality

O = observation number

D = dip of strata

P = plunge of folds

W = correction factor

C = corrected bearing

α = smallest angle between lineation and strike measured on the bedding plane.

β = bearing to dip direction in degrees east of north

γ = pitch of lineation measured clockwise as viewed from above.

S	T	L	O	α	β	γ	β+γ	-90	D	P	±	ω	C	source
W	g	18 N	1	28SW.					35NW S52				80	
"	"	"	2	68WNW					"				120	
"	"	"	3	32SW.					"				84	
"	"	"	4	30SW.					"				82	
"	"	"	5	38SW.					"				80	
"	"	"	6	68WNW					"				120	
"	"	19 N	7	80WNW					37NW S40				120	
"	"	20 N	8	45WNW					37NW S50				95	
"	"	"	9	22SW.					"				28	
"	"	"	10	45WNW					"				95	
"	"	"	11	45WNW					"				95	
"	"	"	12	45WNW					"				95	
"	"	11 N	13	70ENE					25SNE S128				58	
"	"	1 Wh.	14	58 NW					26NW S48				170	
"	"	"	15	71 NW					"				157	
"	"	"	16	28 N					"				20	
"	"	"	17	30 N					22NW S35				5	

S	T	L	O	α	β	γ	β+γ	-90	D	P	±	ω	C	source
W	g	1 Wh.	18	21 N					22NW S35				14	
Ll. A. acum.	"	Spengill	19	18SE					34NE S134				296	
Lu. B.U.	c	Bowder-dalelBo	20	118NW	250	118	368	278	29SW S160	30	+	0	278	SE
"	"	"	21	116W	"	116	366	276	"	"	+	"	276	SE
"	"	"	22	78SW	"	78	328	238	"	"	+	"	238	NE
"	"	"	23	86SW	"	86	336	246	"	"	+	"	246	NE
"	"	"	24	78SW	"	78	328	238	"	"	+	"	238	NE
"	"	"	25	60NW	"	120	370	280	"	"	+	"	280	SE
"	"	"	26	55NW	"	125	375	285	"	"	+	"	285	SE
"	"	"	27	70NW	"	110	360	270	"	"	+	"	270	E
"	sl.	"	28	55NW	"	125	375	285	"	"	+	"	285	SE
"	c	"	29	64NW	"	116	366	276	29W S160	"	+	"	276	SE
"	"	"	30	64NW	"	116	366	276	"	"	+	"	276	SE
"	"	"	31	64NW	"	116	366	276	"	"	+	"	276	SE
"	"	"	32	86SW	"	94	346	256	"	"	+	"	256	NE
"	"	"	33	86SW	"	94	346	256	"	"	+	"	256	NE
"	"	"	34	76SW	"	76	326	236	"	"	+	"	236	NE

S	T	L	O	α	β	γ	β+γ	-90	D	P	±	ω	C	source
Iu. B.U.	c	Bowder- dl. 1Bo	35	76SW	250	104	354	264	29W S160	30	+	0	264	NE
"	"	"	36	60W	"	120	370	280	"	"	+	"	280	SE
W	L.	Gt.Rand y Gill	37	12SW	117	168	285	195	37SE S27	24	-	6	189	
Ashgill grit	c	Ecker Secker	38	35NW	335	35	370	280	39NW S65				280	SE
"	"	"	39	45NW	335	45	380	290	"				290	SE
Lu.2nd bottom	L.	Cautley Sp. G.	40	70SW	230	70	300	210	25SW S140	28	+	2	212	
"	"	"	41 46	70SW	230	70	300	210	"	28	+	2	212	
"	"	"	47 48	83SW	230	83	313	223	"	28	+	2	225	
"	"	Screes	49 54	80SW	275	80	355	265	28NW S5	28	-	0	265	
"	"	"	55 58	61SW	295	61	356	266	25NW S25	28	-	4	264	
"	fl. gr.	"	59 65	8 N	295	172	467	377	"	"	-	"	15	SW
"	gr.	"	66 69	2 N	295	178	473	383	"	"	-	"	21	SW
Lu.2nd grap	g.	"	70 73	76NW	295	104	399	309	"	"	-	"	30	
"	g	"	74 78	87NW	295	93	388	298	"	"	-	"	296	
"	g	"	79 83	84NW	295	96	391	301	"	"	-	"	299	
Lu. 2nd gr. bottom	L.	"	84 86	88W	260	92	352	262	43W S170	"	-	"	258	
"	"	"	87 92	55NW	260	125	385	295	30 W S170	"	-	"	224	SW

S	T	L	O	α	β	Y	β+Y	-90	D	P	±	ω	C	source
Lu 2nd Grap Bottom	c	Screes	93	58SW	260	58	318	228	30W S170	28	-	4	224	SW
Lu. top. 2nd Grap.	gr	Hobdale Beck	94	78NW	299	102	401	311	40NW S29				311	
"	fl.	"	95 96	78NW	299	102	401	311	"				311	NW
Ludlow	gr	Hob-dale B	97 98	90NW	299	90	389	299	40NW S29				299	
"	"	"	99	89NW	299	91	390	300	"				300	
"	L•	"	100 101	32SW	299	32	331	241	"				241	
"	Sl	"	102	56SW	270	56	326	236	59W S0				236	SW
"	c	"	103 107	80NW	290	100	390	300	43NW S20				300	NW
"	"	"	108 113	86NW	290	94	384	294	"				294	NW
"	gr	"	114 120	78NW	314	78	392	302	53NW S44				302	
"	"	"	121 122	85NW	314	85	399	309	"				309	
"	g.	Knott 8Bd.	123 129	72NW	315	72	387	297	55NW S45	0			297	
"	c	Caut. Crags	130	12NW	239	12	251	161	32SW S149	18	-	5·5	155·5	NW
"	fl	"	131	88NW	239	92	341	251	"	18	-	5·5	246·5	SE
"	gr	"	132 138	38NW	270	142	412	322	27W S0	18	-	5·5	316·5	
"	"	"	139 143	33NW	270	147	17	327	"	18	-	5·5	321·5	
"	fl	"	144 150	45NW	247	135	382	292	44SE S157	18	+	5·5	297·5	NW

S	T	L	O	α	β	γ	β+γ	-90	D	P	±	ω	C	source
Ludlow	c	Caut. Crags	150 153	14NW	247	166	413	323	44SE S157	18	+	5·5	328·5	NW
"	"	"	154	6NW	247	174	421	331	"	18	+	5·5	336·5	NW
"	fl.	"	155	18SE	247	18	265	175	"	18	+	5·5	180·5	NW
"	gr.	"	156 169	30NW	230	150	380	290	40SE S140	18	+	"	294·5	
"	"	"	170 175	62SW	230	118	348	358	"	18	"	"	265·5	WSW
"	fl.	"	176	60NW	230	120	350	260	"	28	"	7·5	270·5	WNW
"	gr.	"	177 182	89NW	297	89	386	296	35NW S27	30	-	5	291	
"	"	"		86NW	297	94	391	301	"	"	-	5	296	
"	gr. fl.	Ashb. Gill	186	48NW	355	48	403	313	39NW S85				313	?SE
"	Lo	"	187	90NW	352	90	422	332	46N S82				322	
"	"	"	188	86NW	352	86	418	328	"				328	
"	fl. gr.	"	189	9NW	359	9	368	278	42N S89				278	NW
"	"	"	190	18NW	359	18	377	287	"				287	NW
"	fl	Settle beck G	191 198	20NW	207	20	227	137	69SW S117				137	NW
"	"	"	199 204	40NW	207	40	247	157	"				157	NW
"	"	"	205 209	56	207	56	263	173	"				173	NW
"	"	"	210	68	207	68	275	185	"				185	N

S	T	L	O	α	β	γ	β+γ	-90	D	P	±	ω	C	source
Ludlow	fl.	Settle beck G	211 213	4	0	176	176	86	68N S90				(266) 86	WSW
"	"	"	214 220	70NW	0	70	70	340	"				340	NW
"	"	"	221 223	80NW	0	80	80	350	"				350	NW
"	"	"	224 226	80NW	0	80	80	350	"				350	NW
"	L.	"	227 229	36NW	232	144	376	286	25SW S142				286	
"	"	"	230 232	32NW	232	148	380	290	"				290	
"	"	"	233	50NW	232	130	362	272	"				272	
"	"	"	234 235	17SE	42	163	205	115	50NE S132				115	
"	fl	"	236 241	58NW	6	58	64	334	62NE S96				334	NW
"	"	Hob-dale B	242	46NW	314	46	360	270	53NW S44				270	W
"	?L	Arthlegarth.	269	12NW	15	12	27	297	40NE S105				297	
"	"	Grimes Gill.	243	18SW	302	18	320	230	50NW S32				230	
"	fl	"	244 245	50N	302	130	432	342	"				342	?NW
"	"	Stone. Gill	246 248	10NW	50	10	60	330	24NE S140				330	NW
"	g.	Gais gill	249 250	50SW	10	130	140	50	56NE S100				50	NE
"	"	"	251 254	45SW	10	135	145	55	"				55	NE
"	"	"	255 261	40NE	10	140	150	60	"				60	NE

S	T	L	O	α	β	Y	β+Y	-90	D	P	±	ω	C	source
Ludlow	gr	Gais gill	262 268	0NW	10	0	10	280	75NE S100				280	
"	c	Arthle garth	268 290	30NW	16	30	46	326	29NE S166				326	NW
"	c	"	291 296	23NW	16	23	39	319	"				319	NW
"	c	"	297 301	33NW	16	33	49	329	"				329	NW
"	Lo	"	302 305	26SE	16	154	170	80	"				80	
"	Lo	"	306 310	14SE	16	166	182	92	"				292	
"	fl	"	311 318	40NW	16	40	56	326	"				326	NW
"	c	Wy-garth	319 324	45NW	18	45	63	333	48NE S168				333	NW
"	c	"	325 326	54E	50	94	144	54	31NE S140				54	WSW
"	fl	"	327 334	4NW	45	4	49	319	46NE S135				319	NW
"	gr	"	335	4NW	45	4	49	319	"				319	
"	"	Dale Gill	336 339	22NW	350	22	372	282	80N S80				282	
"	gr	"	340 343	18NW	350	18	368	278	"				278	
"	gr	"	344 349	5NW	350	5	355	265	70N S80				265	
"	gr	"	350 357	18NW	350	18	368	278	"				278	
"	gr	"	358 362	9NW	350	9	359	269	"				269	
"	gr	"	363 371	28NW	350	28	378	288	"	0			288	

S	T	L	O	α	β	γ	β+γ	-90	D	P	±	ω	,C	source
Lu. ?Pre-leint. Z.	c	Swarth Gill	372 375	14SE	42	166	268	118	44NE S132	0			118	NW
"	fl	Settle Beck G	376 379	13SE	217	13	220	130	69SW S117	0	+	0	130	NW
Lu. Pre-Leintw. Z.	fl	Winder	380 383	20SE	207	20	227	137	56SW S117	0		0	137	NW
"	c	Bram Rigg	384 387	65-70 NNW	310	110 115	423	333	76NW S40	40	+	28½	361½	N
"	c	"	388 395	70-75 NNW	310	110 105	418	328	"	"	+	"	365½	NW
Lu. Leintw. Zone	Le	Brant Fell	396 403	65-70 WSW	240	115 110	363	273	21SW S150	20	+	0	273	
"	"	"	404 405	60-65 WSW	240	115 120	358	268	26SW S150	20	+	0	268	
"	"	"	406 420	65-70 WSW	240	115 110	363	273	21SW S150	20	+	0	273	
"	"	"	421 424	60-65 WSW	240	115 120	358	268	21SW S150	20	+	0	268	
"	"	"	425 431	25-30 W	215	150 155	368	278	26SW S125	22	+	0	278	
"	"	Bram Rigg B	432 433	70-75 WSW	256	110 105	364	274	21SW S166	0			274	
"	"	"	434 438	55NW	324	55	379	289	36NW S54	15	+	4·5	293·5	
Lu. 1st grw. Unit	fl	Yarl-side	442 439	70SW	260	70	330	240	33SW S170	35	-	6·5	233·5	SW
"	"	"	443	80SW	260	80	340	250	"	35	-	6·5	243·5	SW
"	"	"	444 454	80SW	250	80	330	240	40SW S160	35	-	"	233·5	SW
"	gr	"	455 459	50-55 SW	250	50-55	303	213	"	"	-	"	206·5	
"	fl gr	"	460 462	50-55 SW	250	50-55	303	213	"	"	-	"	"	SW

S	T	L	O	α	β	γ	β+γ	-90	D	P	±	ω	C	source
Lu. 1st grw. Unit	fl gr	Yarl- side	463 473	55-60 SW	250	55-60	308	218	40SW S160	35	-	6·5	211·5	SW
"	"	"	474 477	60-65 SW	250	60-65	313	223	"	35	-	"	216·5	SW
Lu. top 1st grw. Unit	fl	"	478 482	70SW	230	70	300	210	26SW S140	35	-	4	206	SW
Lu. 1st grw. Unit	gr	"	483 484	50SW	230	50	280	190	38SW S140	35	-	4	184	
Lu. top 1st grw. Unit	"	"	485 495	50-55 NW	270	125 130	398	308	37W S0	35	+	3	311	
"	"	"	496 499	40-45 NW	270	135 140	408	318	"	35	+	3	321	
"	"	"	500 503	55-60 NW	270	120 125	393	303	38W S0	35	+	4	307	NW
"	gr fl	"	504 508	45-50 SW	213	130 135	346	256	63SW S123	26	+	14	270	W
"	gr	"	513 509	85-90 NW	323	85 90	411	321	39NW S53	35	-	6 5	314 5	
Lu. 2nd grw. Unit	L	"	514 520	85-90 W	268	85 90	360	270	33W S178	35	-	0	270	
"	gr fl	"	521 526	30-35 SW	270	30-35	303	213	35W S0	35	+	0	213	SW
"	gr	"	527 537	45-50 SW	270	45-50	318	228	"	"	+	0	228	
"	"	"	538 540	65-70 SW	270	65-70	338	248	"	35	+	0	248	
"	"	"	541 550	30-35 SW	270	30-35	303	213	"	35	+	0	213	
"	"	"	551 555	35- 40SW	270	35-40	308	218	"	35	+	0	218	
Ashgill Grit	c	nr.11Wh Crossh.	556 561	40- 45S	215	140 135	353	263	40SW S125	24	+	6·5	270·5	E
"	c	"	562 565	35-40 SE	215	140 145	358	268	"	24	+	6 5	275 5	ESE

S	T	L	O	α	β	Y	β+Y	-90	D	P	±	ω	C	source
Ashgill Grit	c	Nr.1Bf	566 568	30SW	260	150	410	320	54SW S170	30	+	14	344	SSE
"	c	Nr. 10Wi	569 573	75-80 S	190	75-80	268	178	42S S100	35	+	7	185	S
"	c	"	574	10W	190	170	360	270	"	35	+	7	277	ESE
Ludlow	Lo	Ivy Crag	575	0	183	0	183	93	27SW S93	10	+	2	95	
"	Lo	Bram Rigg	576 580	0	183	0	183	93	"	10	+	2	95	
Ashgill Grit	b.	Spen-gill	581 585	15-20 NW	0	15-20	18	288	20N S90				288	
"	"	"	586	"	"	"	"	"	"				"	
Llandovery	?L.	4Bf	587 591	30-35 SW	262	30-35	295	205	10W S172	30	+	0	205	
"	"	"	592 595	29-33 W	262	29-33	293	203	"	"	+	0	203	
"	g.	5Bi	596 600	50-55 SW	270	50-55	323	233	40W S0	40	-	9	223	
"	"	2Bi	601	55-60 SW	270	55-60	328	238	"	"	"	"	228	
Wenlock	"	30-33 W	602	40-45W	232	132	364	274	33SW S142	26	+	5	279	
"	"	"	603	45-50W	"	"	"	"	"	"	"	"	"	
"	"	"	604 607	50-55W	"	127	359	269	"	"	"	"	274	
"	"	"	608	15-20SE	"	15-28	250	160	"	"	"	"	165	
"	"	"	609	55-60W	"	122	344	254	"	"	"	"	259	
"	"	"	610 614	40-45W	"	137	369	279	"	"	"	"	284	

S	T	L	O	α	β	γ	β+γ	-90	D	P	±	ω	C	source
Wenlock	g.	30-33W	615 621	45-50W	232	132	364	274	33SW S142	26	+	5	279	
"	"	"	622 631	45-50W	"	"	364	274	"	26	+	"	"	
"	"	"	632	"	"	"	"	"	"	26	+	"	"	
"	"	"	633 637	"	"	137	369	279	"	26	+	"	284	
"	"	"	638	55-60W	"	122	344	254	"	26	+	"	259	
"	"	39W	639 642	85 WNW	288	85	373	283	22NW S18	26	+	0	283	
"	"	"	643 646	90 WNW	"	90	378	288	"	26	+	0	289	
"	"	"	647 649	50-55 NW	"	135-130	410	320	"	26	+	0	320	
"	"	1Wh	650	5-10 NE	290	192	482	32	32NW S20	10	+	2•5	34•5	
"	"	"	651 652	15-20 NE	290	162	452	2	"	10	+	"	4•5	
"	"	"	653 655	35-40 SW	290	35-40	328	238	"	10	+	"	240•5	
"	"	"	656	65-70W	290	65-70	358	268	"	10	+	"	270•5	
"	"	53W	657	15-20					31SW S115	0			90-95	
"	L	57W	658	0					"	0			115	
"	"	"	659	0					"	0			115	
"	g.	58W	660	40-45					"	0			155-160	
"	L	6W	661	5					35N S97	0			[illegible]	

S	T	L	O	α	β	γ	β+γ	-90	D	P	±	ω	C	source
Wenlock	L•	10H	662	45-50					8NW S44	0			89-94	
"	"	"	663 664	"					"	0			"	
"	cr	Nr.5 Bf	665 666	30-35 W	301	30-35	334	244	30NW S31	30	+	0	244	
"	"	4Ra	667 669	90NNW	316	90	406	316	40NW S46	30	-	7·5	308·5	?NW
"	"	"	670	80-85 WNW	316	80-85	399	309	"	"	-	"	301·5	?NW
"	"	"	671	70-75 WNW	"	70-75	389	299	"	"	-	"	291·5	?NW
Ludlow	gr	Kens- griff	672 673	50-55 SW	299	50-55	35	26	33NW S29	"	-	3	259	
"	L•	"	674 675	60-65 NW	272	115- 120	80	300	33W S2	"	+	3	302½	
"	sl	Rawth. Crossh.	676 677	10-15					33NW S57	0			42	NE
"	"	"	678 683	40-45					"	0			12-17	NE
"	L•	"	684 689	65-70					11SW S165	0			100- 105	
Wenlock	?L•	Hob- dale	690	82	252	82	334	244	31SW S162	30	+	0	244	
"	"	"	691	83	313	83	396	306	50NW S43	30	-	12	294	

PLATE 1

all figs. x 5

Fig.1 Climacograptus miserabilis (Elles & Wood), HUR./S5-9/125; Zone of M. atavus, Llandovery Series, Spengill; narrow form, flattened and compressed. (p.125)

Fig.2 Climacograptus medius Tornquist?, HUR./S1-5/73; Zone of M. atavus, Llandovery Series, Spengill; flattened and strongly compressed. (p.129)

Fig.3 Climacograptus normalis Lapworth, HUR./2Bi/96; Zone of P. acinaces, Llandovery Series, Birks Wood Beck; flattened and compressed with a bent virgella. (p.124)

Fig.4 Climacograptus miserabilis (Elles & Wood), HUR./2Bi/44; Zone of P.acinaces, Birks Wood Beck; flattened specimen of typical proportions with both nema and virgella well preserved. (p.125)

Fig.5 Climacograptus miserabilis (Elles & Wood), HUR./1Bi/35; Zone of M. atavus, Birks Wood Beck; flattened specimen (p.125)

Fig.6 Climacograptus ex. gr. scalaris (Hisinger), HUR./S73,11·4/3; Zone of M.sedgwicki, Spengill; apertural view of one series of thecae of a specimen in full relief. Zigzag suture visible and "cup-like" nature of thecal aperture displayed. (p.126)

Fig.7 Climacograptus innotatus exquisitus subsp. nov., holotype, HUR./1Bi/26; Zone of M. atavus, Birks Wood Beck; flattened and compressed, showing virgella and thecal spines. (p.138)

Fig.8 Climacograptus extremus H.Lapworth, HUR./S75,9·4/222; Zone of M. Sedgwicki, Spengill; flattened and compressed specimen. (p.134)

Fig.9 Climacograptus ?tangshanensis linearis Packh. HUR./14P/4 and 7a;

PLATE 1

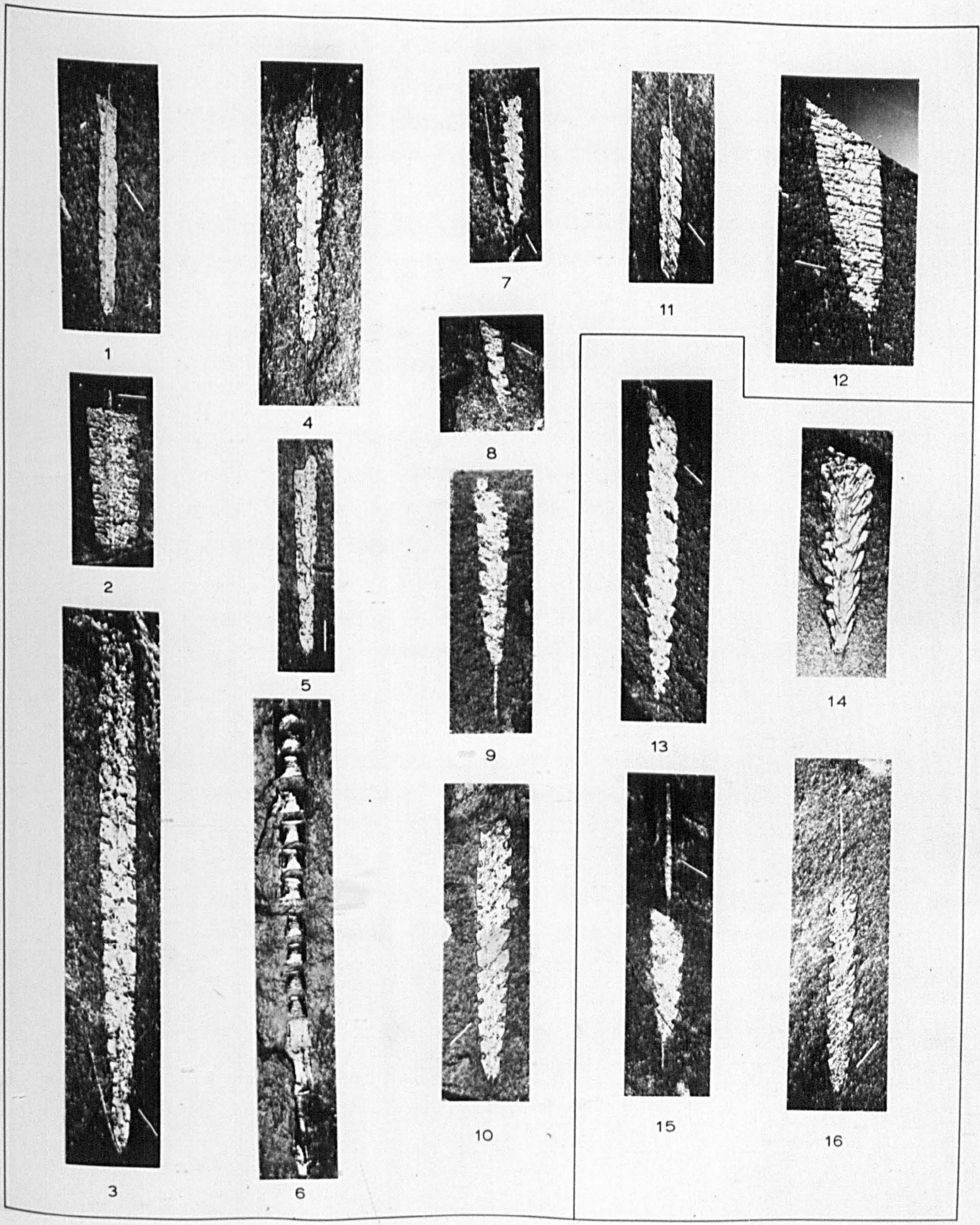


Fig.9 L. Llandovery, Zone of P. cyphus, Pickering Gill; flattened but uncompressed, with virgella preserved. (p.131)

Fig.10 Climacograptus pseudonormalis sp. nov. Holotype. HUR./2Bi/4; Zone of P. acinaces, Birks Wood Beck; flattened and compressed. (p.128)

Fig.11 Climacograptus aff minutus Carruthers. HUR./S9-13/101; Zone of P. acinaces, Spengill; specimen flattened and compressed. (p.135)

Fig.12 Climacograptus medius Tornquist. HUR./3Wa/25; Zone of M. atavus Watley Gill; specimen flattened and strongly compressed. (p.129)

Fig.13 Diplograptus modestus tenuis. subsp. nov. Holotype HUR./S1-5/18; Zone of M. atavus, Spengill; specimen flattened and compressed; showing proximal excavations and distal thecae with flowing sigmoidal curvature. (p.142)

Fig.14 Diplograptus magnus H.Lapworth. HUR./9Bi/26; Zone of D.magnus, Birks Wood Beck; external mould of specimen in moderate relief.(p. 139)

Fig.15 Diplograptus modestus tenuis subsp. nov.? HUR./S9-13/102; Zone of P.acinaces, Spengill; flattened, compressed, with virgella and nema well preserved. (p.142)

Fig.16 Diplograptus sp.A HUR./1Bi/3; Zone of M. atavus, Birks Wood Beck; specimen flattened, compressed, with nema preserved. (p.144)

PLATE 2

All figs. x 10

Fig.1 Climacograptus pseudonormalis sp. nov. paratype. HUR./2Bi/11; Zone of P. acinaces, Birks Wood Beck; flattened and more strongly compressed than Pl.1, fig.10. (p.128)

Fig.2 Diplograptus modestus diminutus Elles & Wood. HUR./2Bi/32; Zone of P. acinaces, Birks Wood Beck; flattened and compressed. (p.141)

Fig.3 Glyptograptus t. tamariscus (Nicholson) aff form B. Packham. HUR./6Bi/41; Zone of P. leptotheca (= argenteus), Birks Wood Beck, specimen in relief, external mould. (p.145)

Fig.4 Climacograptus pseudonormalis sp. nov. paratype HUR./2Bi/84; Zone of P. acinaces, Birks Wood Beck; flattened and strongly compressed. (p.128)

Fig.5 Glyptograptus packhami sp. nov. paratype. HUR./S80,8·4/62; Zone of M. sedgwicki, Spengill; distal fragment well preserved in full relief. (p.149)

Fig.6 Glyptograptus packhami sp. nov. holotype. HUR./S73,11·4/6; Zone of M. sedgwicki, Spengill; proximal end in full relief with sicula preserved, obverse view. (p.149)

Fig.7 Glyptograptus tamariscus angulatus Packham, HUR./6Bi/63; Zone of P. leptotheca (= argenteus), Birks Wood Beck; specimen flattened, incomplete. (p.146)

Fig.8 ?Glyptograptus sp.A HUR./6Wa/27; Zone of D. magnus, Watley Gill; fragmentary specimen in full relief, apertural view showing the outward-facing apertures. (p.157)

PLATE 2

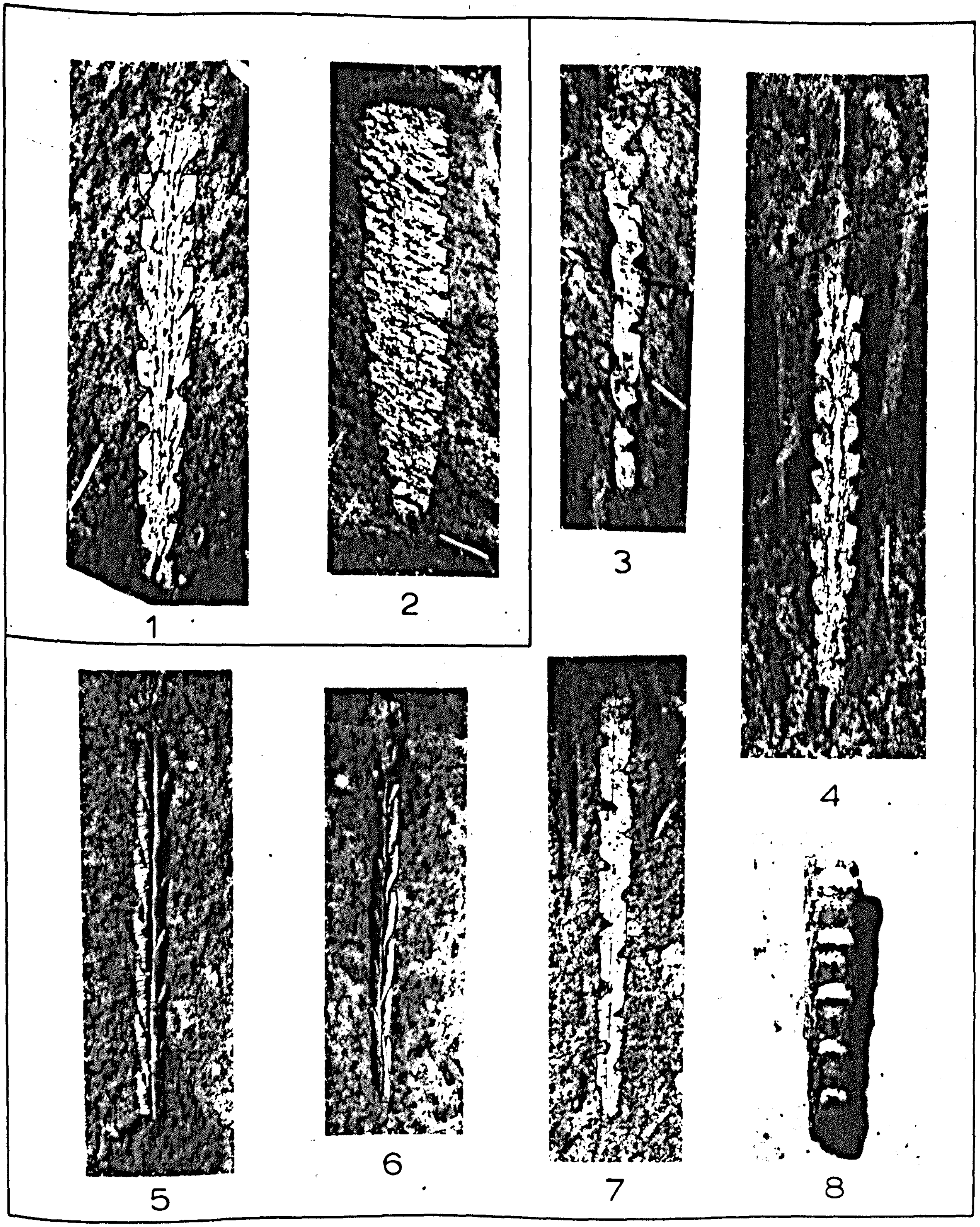


PLATE 3

All figs. x 10

Fig.1 *Glyptograptus cuneatus* sp. nov., holotype, HUR./14P/20; Zone of *P. cyphus*, Pickering Gill; specimen well preserved, but flattened, uncompressed. (p.152)

Fig.2 *Orthograptus attenuatus* sp. nov., holotype, HUR./14P/7; Zone of *P. cyphus*, Pickering Gill; specimen well preserved, but flattened, uncompressed. (p.161)

Fig.3 *Orthograptus vesiculosus* Nicholson. HUR./3Wa/29; Zone of *M. atavus*, Watley Gill; proximal end showing sicula, and first two thecae.(p.158)

Fig.4 *Petalograptus minor finitimus* subsp. nov. paratype HUR./6Bi/23; Zone of *P. leptotheca* (= *argenteus*), Birks Wood Beck; specimen in part external mould, full relief. (p.167)

Fig.5 *Petalograptus ovatoelongatus* Kurck. HUR./6Bi/43; Zone of *P. leptotheca*, Birks Wood Beck; specimen well preserved in full relief. (p.164)

Fig.6 *Petalograptus minor minor* Elles. HUR./7Bi/12; ?Zone of *M. triangulatus*, Birks Wood Beck; external mould of specimen in full relief. (p.165)

Fig.7 *Gothograptus nassa* Holm HUR./4W/3; Zone of *C. lundgreni*, Wenlock Series, Wandale Hill; complete specimen, well preserved. (p.175)

PLATE 3

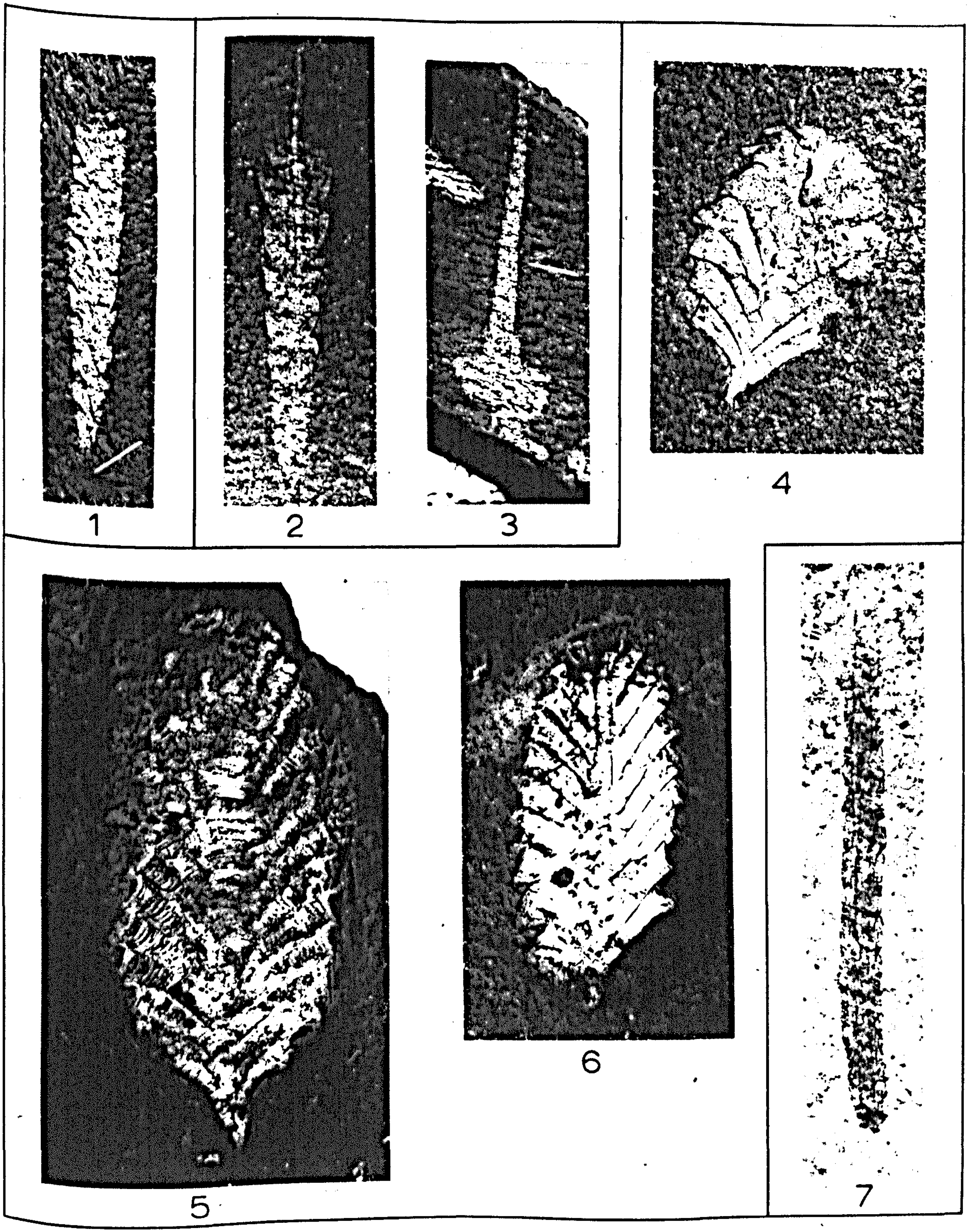


PLATE 4

All figs. x 5

Fig.1 Dimorphograptus confertus confertus Nicholson. HUR./S13-17/1; Zone of P. acinaces or P. cyphus, Spengill; specimen flattened and compressed. (p.179)

Fig.2 Dimorphograptus erectus nicholsoni subsp. nov., paratype, HUR./2Bi/22; Zone of P. acinaces, Birks Wood Beck; typical specimen strongly compressed. (p.181)

Fig.3 Monoclimacis vomerina basilica (Lapworth), part of specimen figured by Lapworth (1880) pl.4. figs.6a,b, retouched. (p.188)

Fig.4 Monoclimacis vomerina basilica (Lapworth), HUR./8P/7; Zone of C.centrifugus-C. insectus, Pickering Gill; proximal end in full relief showing sicula, and typical "thorn-like" appearance of proximal end. (p.188)

Fig.5 Monoclimacis vomerina basilica (Lapworth), HUR./28W/29; Zone of C. centrifugus-C. insectus, Wandale Hill; distal specimen (part of) in full relief except proximally where the increase in width due to flattening is seen. (p.188)

Fig.6 Monoclimacis vomerina basilica (Lapworth), HUR./28W/2; Zone of C. centrifugus-C. insectus, Wandale Hill; proximal end with sicula (pale coloured) and mesial portions.(p.188)

Fig.7 Monoclimacis vomerinus vomerinus (Nicholson) figured Elles & Wood Pl. 41, fig.1b. specimen in relief.

Fig.8 Pristiograptus leptotheca (Lapworth), HUR./S75,9·4/55; Zone of M. sedgwicki, Spengill; specimen of distal thecae, somewhat distorted, in full relief. (p.206)

PLATE 4

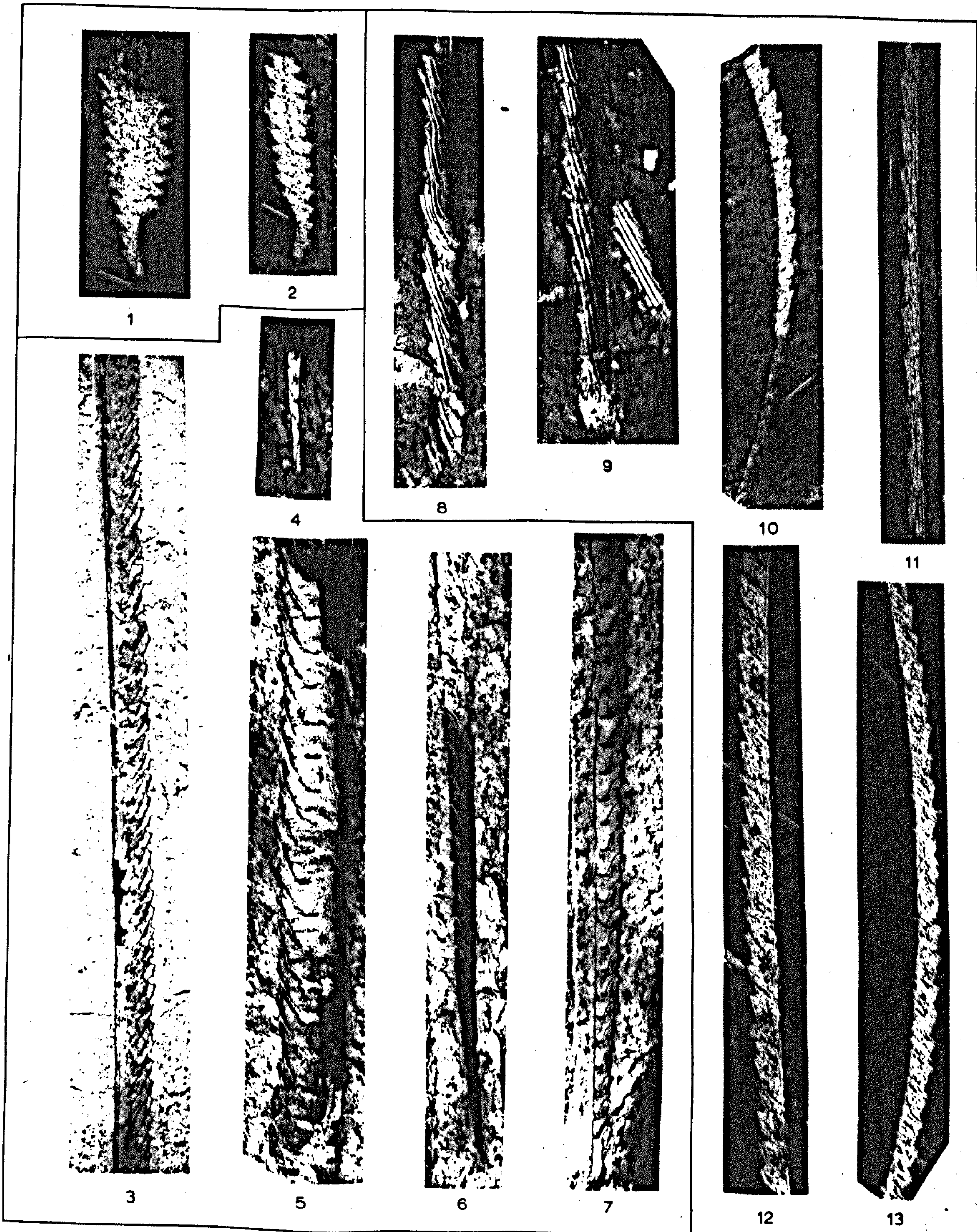


Fig.9 Pristiograptus leptotheca (Lapworth), HUR./S75,9·4/223; Zone of M. sedgwicki, Spengill; distal fragment with thecae preserved in full relief. (p.206)

Fig.10 Pristiograptus cyphus (Lapworth). HUR./S13-17/2; Zone of P. acinaces or P. cyphus, Spengill; specimen near proximal end, flattened, compressed. (p.204)

Fig.11 Pristiograptus aff acinaces (Tornquist). HUR./S13-17/3; Zone as fig.10; flattened and compressed specimen. (p.205)

Fig.12 Pristiograptus cyphus (Lapworth) HUR./S13-17/4; Zone as figs.10,11; flattened and compressed. (p.204)

Fig.13 Pristiograptus cyphus (Lapworth) HUR./S13-17/5; Zone as figs.10-12; flattened and compressed. (p.204)

PLATE 5

Fig.1 Pristiograptus regularis (Tornquist), HUR./S140,11/2; Zone of M. turriculatus (Subzone R. maximus), Spengill; specimen flattened, compressed proximal and mesial portion, sicula intact. x 5 (p.212)

Fig.2 Pristiograptus nudus (Lapworth), HUR./5Wi/6; Zone of M. crispus, Wards Intake; specimen well preserved but flattened. x 5 (p.208)

Fig.3 Pristiograptus concinnus (Lapworth), HUR./S75,9·4/123; Zone of M. sedgwicki, Spengill; fragmentary specimen in full relief. x 5 (p.214)

Fig.4 Pristiograptus dubius dubius (Suess), HUR./44W/2; Zone of M. flexilis belophorus, Wenlock Series, Stage 3, Wandale Hill; proximal end with sicula, flattened. x 5 (p.215)

Fig.5 Pristiograptus dubius dubius (Suess), HUR./7W/25; Zone nilssoni-scanicus, Ludlow Series; proximal end, flattened. x 2½ (p.215)

Figs.6,7,8, Pristiograptus auctus sp. nov. respectively HUR./7W/43, HUR./7W/46, and the holotype HUR./7W/62; Zone of nilssoni-scanicus, Ludlow Series; all flattened specimens in very low relief. x 5 (p.223)

Fig.9 Pristiograptus auctus sp. nov. paratype HUR./7W/34., Zone nilssoni-scanicus, Ludlow Series, Wandale Hill; specimen flattened and showing globule-shaped virgella. x 2½ (p.223)

Fig.10 Monograptus atavus Jones, HUR./2Bi/26, Zone of P. acinaces, Birks Wood Beck; fragmentary flattened specimen. x 5 (p.231)

Fig.11 Monograptus atavus Jones, HUR./1Bi/149, Zone of M. atavus, Birks Wood Beck; fragmentary, flattened. x 5 (p.231)

PLATE 5

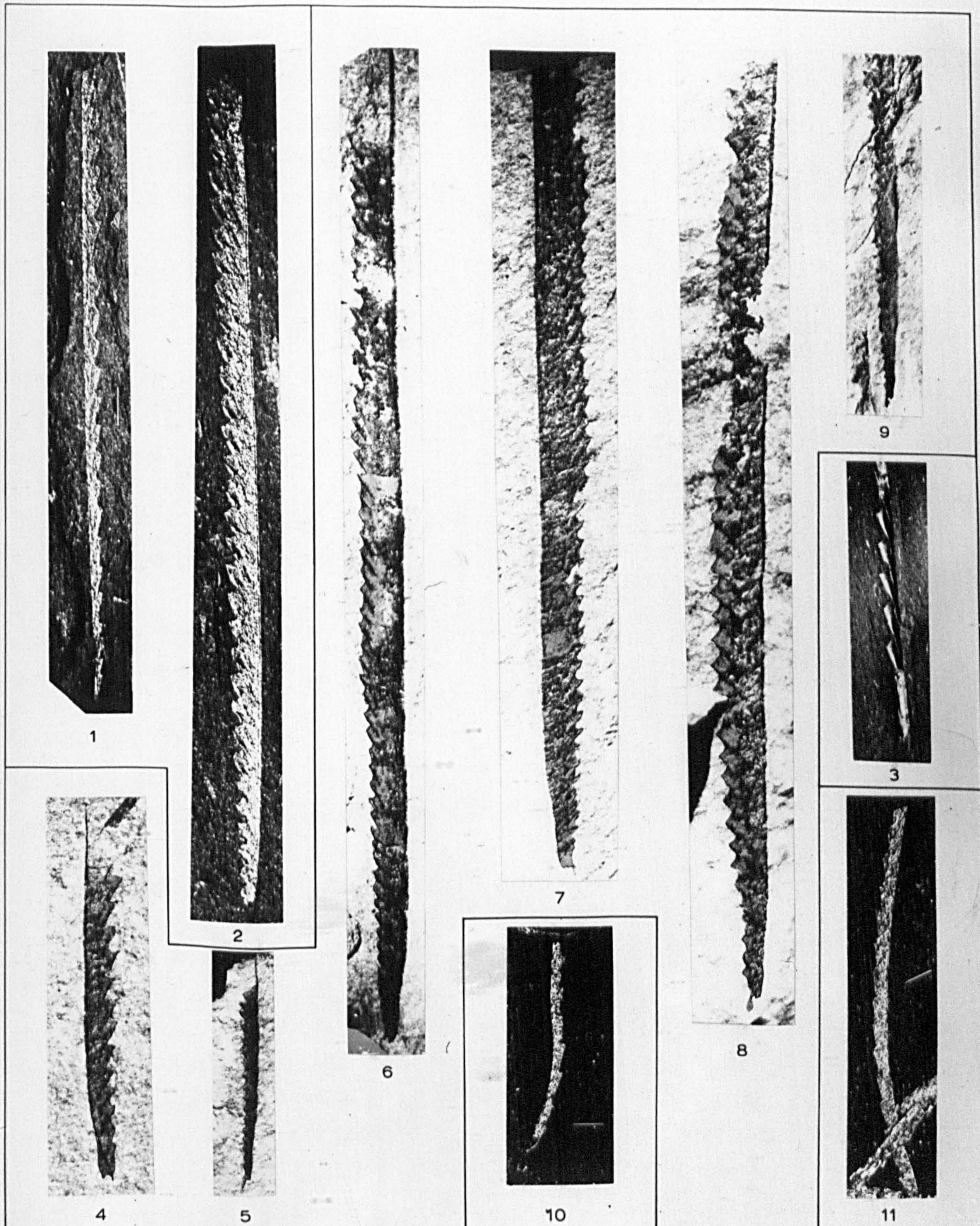


PLATE 6

All figs. x 5

Fig.1 Monograptus leintwardinensis incipiens Wood. HUR./2W/137; Zone of nilssoni-scanicus, Ludlow Series, Wandale Hill; specimen, complete flattened, uncompressed and showing proximal thecal spines. (p.252)

Fig.2 Monograptus varians Wood s.l., HUR./3S/6; Zone of nilssoni-scanicus, Ludlow Series, Spengill., flattened. (not described)

Fig.3 Monograptus priodon (Bronn) s.l. HUR./28W/69; Zone of C.centrifugus-C.insectus, Wenlock Series, Stage 1, Wandale Hill; specimen well preserved in full relief, extreme proximal end less well preserved. (p.256)

Fig.4 Monograptus priodon (Bronn) s.l. HUR./28W/22; Zone as fig.3; specimen in relief - contrast with fig.5.(p.256)

Fig.5 Monograptus priodon (Bronn) s.l. HUR./1M/75; Zone as figs.3,4,; specimen flattened. (p.256)

Fig.6 Monograptus knockensis Elles & Wood. HUR./S80,8·4/144; Zone of M. sedgwicki, Spengill; specimen in full relief. (p.272)

Fig.7 Monograptus riccartonensis Lapworth, HUR./32W/26; Zone of riccartonensis, Wandale Hill; specimen showing rather proximal dorsal curvature than usual; robust nature of proximal end well displayed. (p.259)

Fig.8 Monograptus flexilis flexilis Elles. HUR./16N/202a; Zone of C. rigidus mut., Wenlock Series Stage 3, Near Gill; specimen well preserved, flattened. (p.267)

Fig.9 Monograptus flexilis flexilis Elles, HUR./17N/179; Zone as fig.8; specimen well preserved, flattened. (p.267)

PLATE 6

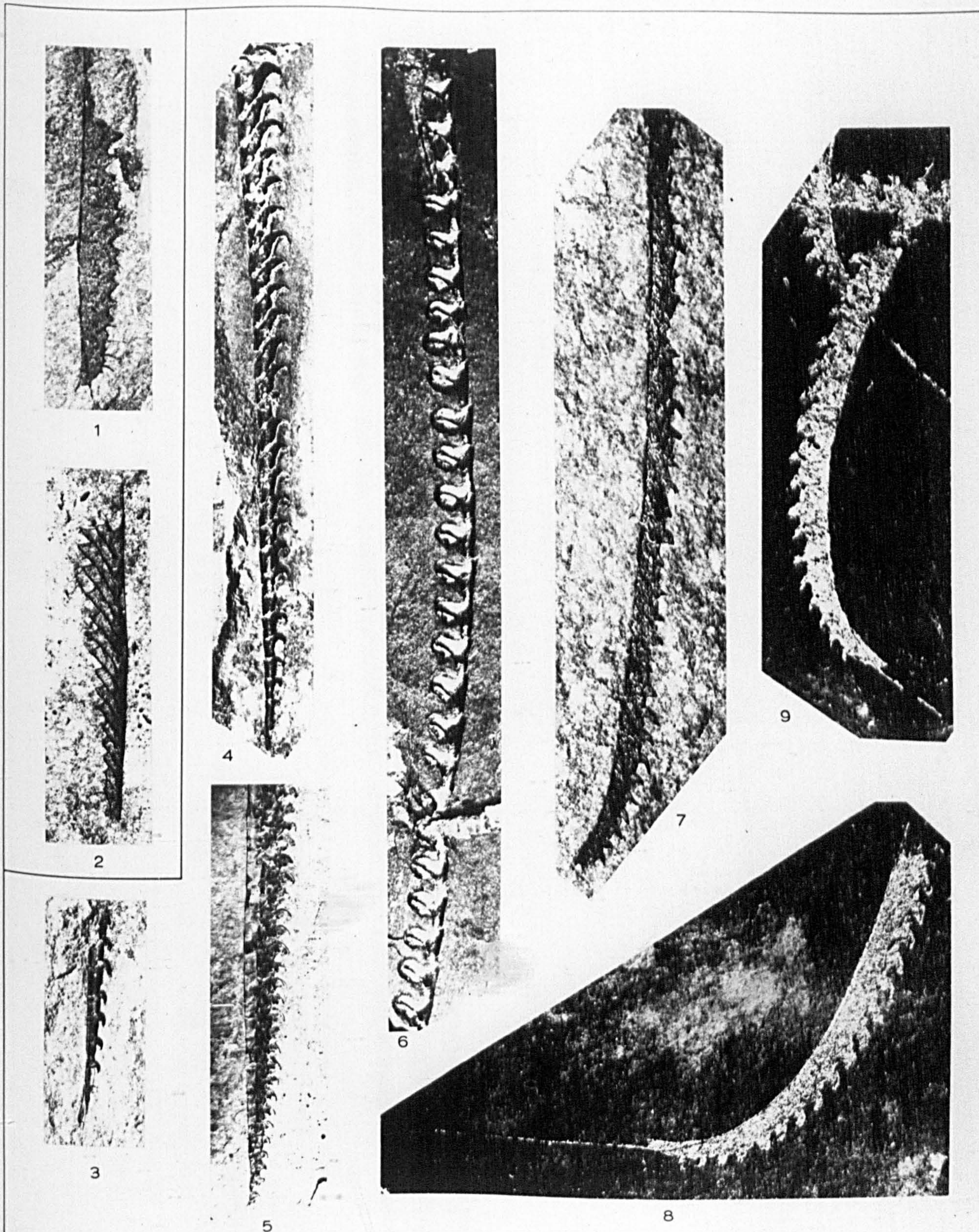


PLATE 7

All figs. x 10

Fig.1 Monograptus ex. gr. flexilis Elles. HUR./43W/8; Zone of M. flexilis belophorus, Wenlock Series Stage 3, Wandale Hill; specimen flattened. (p.269)

Fig.2 Monograptus communis obtusus subsp. nov. holotype, HUR./S80,8·4/90; Zone of M. sedgwicki, Spengill; specimen in full relief, proximal end with sicula, preserved partly as an external mould. (p.307)

Fig.3 Monograptus communis communis Lapworth. HUR./6Bi/38; Zone of P. leptotheca (= argenteus), Birks Wood Beck; specimen of distal thecae in full relief. (p.305)

Fig.4 Monograptus(?) runcinatus pseudopertinax subsp. nov? HUR./S162,10·25/23; Zone M. turriculatus, Spengill; specimen very strongly compressed and flattened both acting to increase the width. (p.292)

Fig.5 Monograptus pseudobecki Boucek & Pribyl, HUR./S219,0·25/3; Zone M.turriculatus, Spengill; specimen flattened. (p.290)

Fig.6 Monograptus exiguus (Nicholson), HUR./S231,2/142; Zone of M. crispus, Spengill; flattened specimens associated with a new species of climacograptid (Wilson's species), specimens appear to be orientated. (p.289)

Fig.7 Monograptus exiguus (Nicholson), HUR./S231,2/145; Zone as fig.6; specimen flattened. (p.289)

PLATE 7

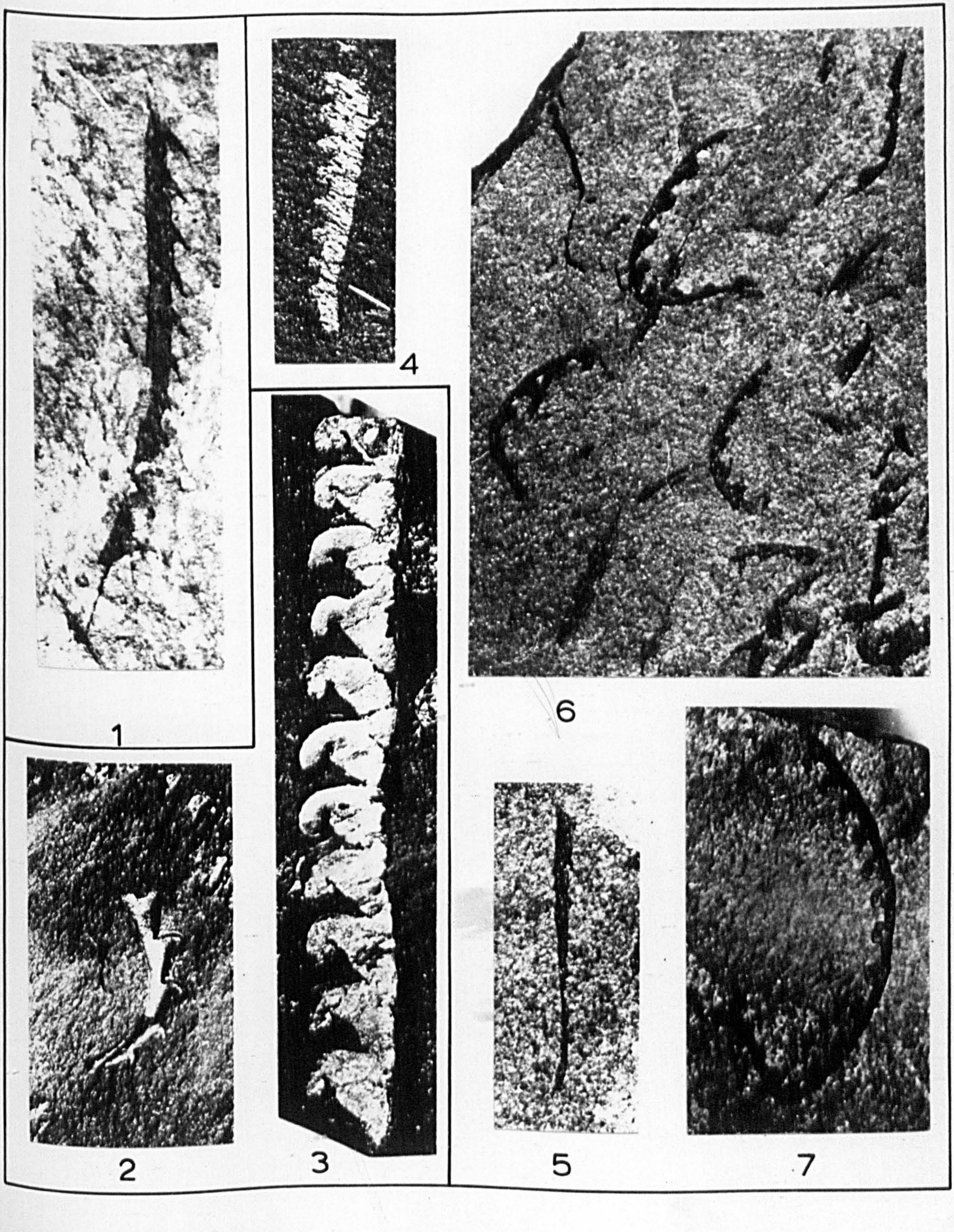


PLATE 8

All x 5 except fig.3

Figs.1,2 Monograptus priodon (Bronn) s.l., respectively HUR./10P/17 and /16; Zone of C. centrifugus-C.insectus, Pickering Gill; specimens of distal thecae in full relief. (p.256)

Fig.3 Monograptus riccartonensis Lapworth. HUR./32W/17; riccartonensis Zone, Wenlock Stage 2, Wandale Hill, specimen flattened. (p.259) x 2½.

Fig.4 Monograptus marri Perner s.l. HUR./4Wi/56; Zone of M. crispus, Wards Intake; specimen flattened. (p.270)

Fig.5 Monograptus denticulatus Tornquist. HUR./6Bi/42; Zone of P. lept-theca (= argenteus Zone), Birks Wood Beck; specimen in relief. (p.303)

Fig.6 Monograptus pseudoplanus Sudbury. HUR./9Bi/11; Zone of D. magnus Birks Wood Beck; specimen in relief. (p.310)

Fig.7 Monograptus triangulatus fimbriatus (Nicholson) HUR./6Wa/2; ?Zone of D. magnus, Watley Gill; specimen partly flattened and compressed, extreme proximal end missing. (p.313)

Fig.8 Rastrites maximus (Carruthers) HUR./S117,3/122; Subzone of R.maximus, Spengill; two fragmentary, flattened thecae. (p.316)

Fig.9 Rastrites longispinus (Perner) HUR./9Bi/11; Zone of D.magnus, Birks Wood Beck; specimen in relief. (p.318)

PLATE 8

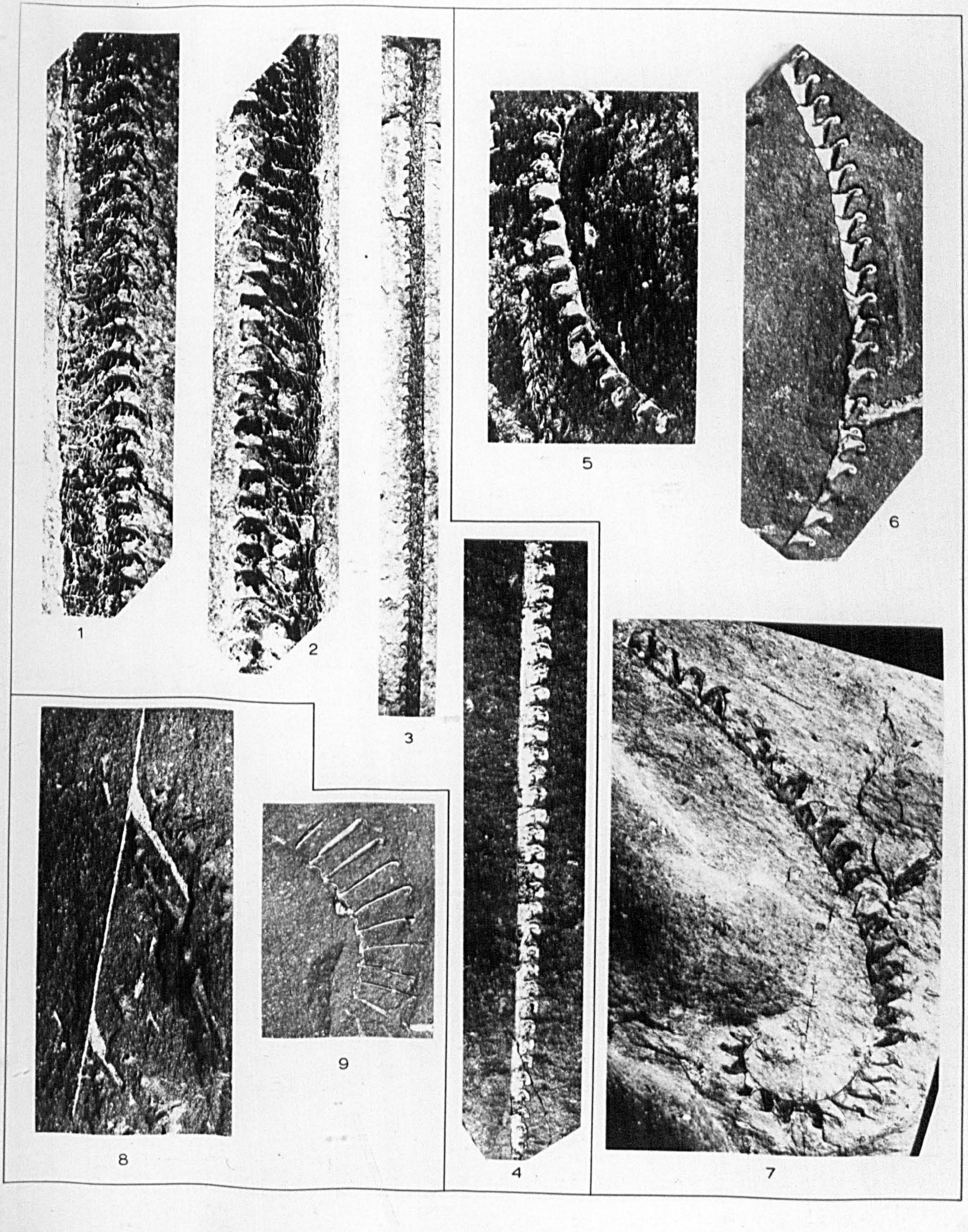


PLATE 9

Fig.1 Cyrtograptus m.murchisoni Carruthers (non Boucek); HUR./37W/1; Zone of C.centrifugus-C.insectus (topmost beds), Wandale Hill; specimen in full relief. x 1 (p.324)

Fig.2 Cyrtograptus lundgreni Tullberg. HUR./27N/23a; Zone of C.lundgreni (Stage 4), Near Gill; specimen flattened x $2\frac{1}{2}$. (p.335)

Fig.3 Cyrtograptus aff insectus Boucek, HUR./28W/78; Zone of C.centrifugus-C.insectus, Wenlock Stage 1, Wandale Hill; specimen in full relief. (p.329) x $2\frac{1}{2}$

Fig.4 Cyrtograptus aff insectus Boucek, HUR./28W/84; Zone as fig.3; specimen in full relief. x 5 (p.329)

Fig.5 Monograptus f.flexilis Elles, slab HUR./17N/179 of several specimens, all flattened; Zone of C.rigidus mut. Near Gill. x 1 (p.267)

PLATE 9

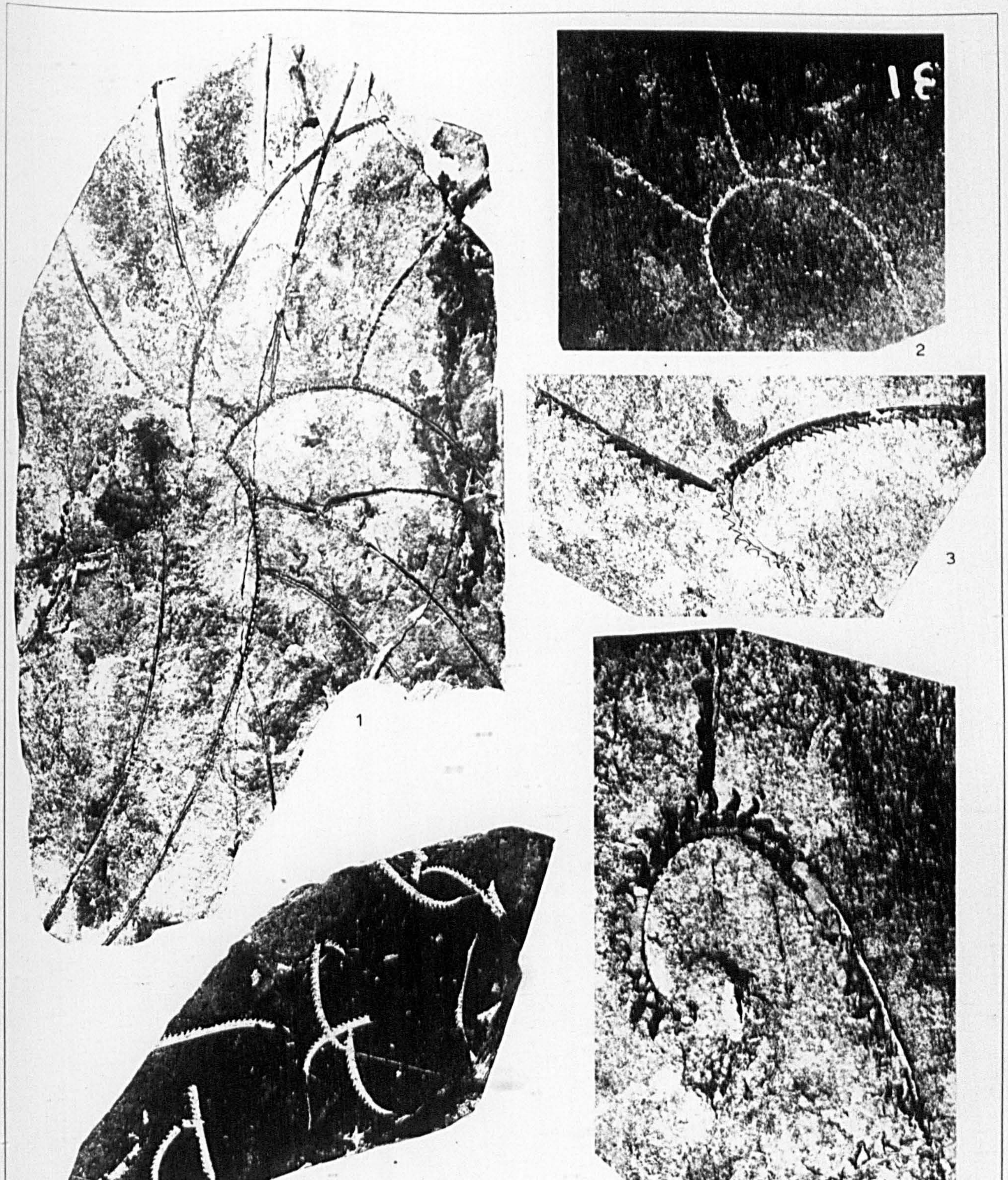


PLATE 10

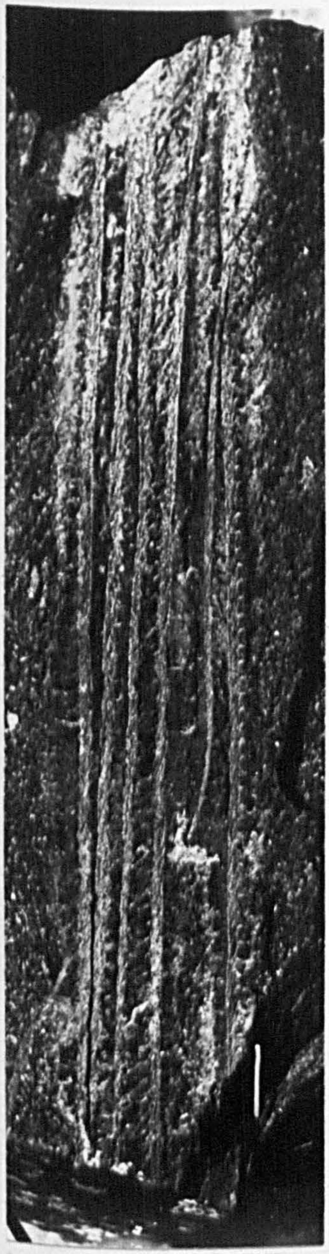
Fig.1 Monograptus irfonensis inclinatus subsp. nov. slab of several specimens, orientated parallel. HUR./39W/3, approximately x 2 (p.260)

Fig.2 Slab with roughly orientated specimens of M.kingi sp. nov. x 2. (p.) HUR./10Ra/3.

Fig.3 Monograptus riccartonensis Lapworth, HUR./32W/17; riccartonensis Zone, Wandale Hill; long flattened distal fragment, approximately x 2. (p.259)

Fig.4 Rastrites aff longispinus (Perner), HUR./S73,11 4/74; Zone of M. sedgwicki, Spengill; specimen in full relief. x 10 (p.318)

PLATE 10



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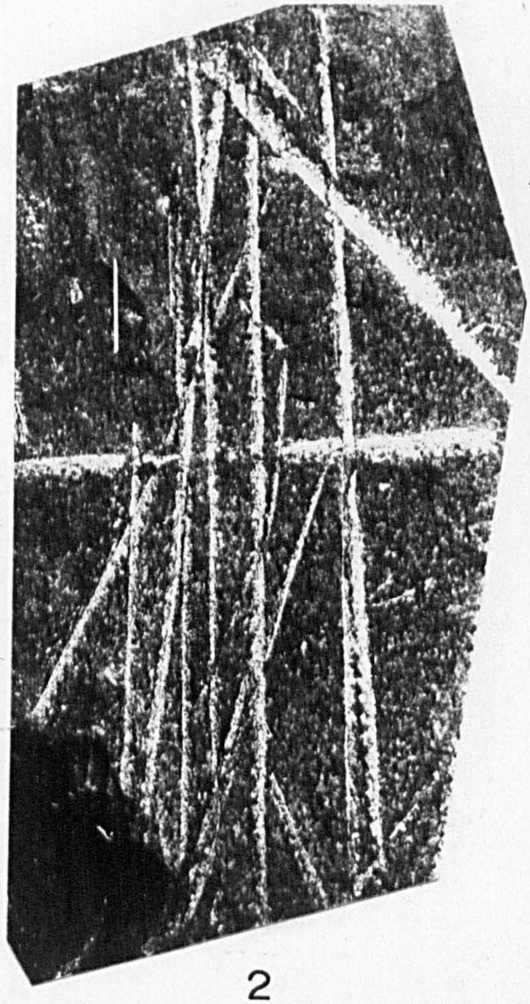

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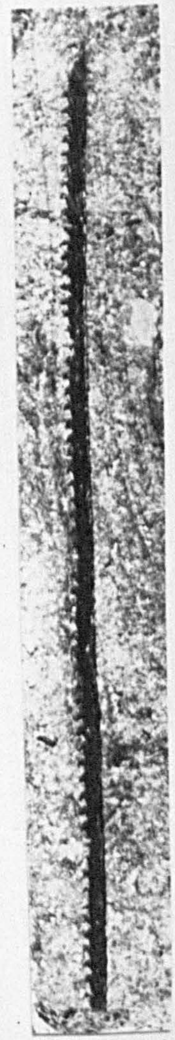


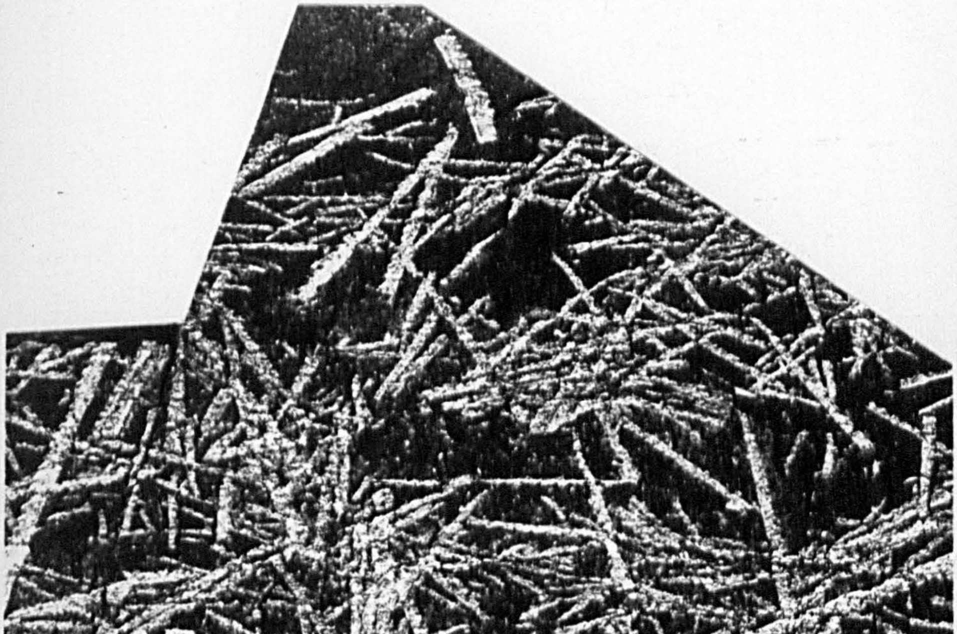
3

4

PLATE 11

Fig.1 Slab showing variously orientated specimens of M.kingi sp. nov. from same locality as Pl.10, fig.2. HUR./10Ra/2 x 2 (p.197)

Fig.2 Monograptus priodon (Bronn) s.l. HUR./10P/17; Wenlock Stage 1, Pickering Gill; specimen in full relief. x 2 (p.256).



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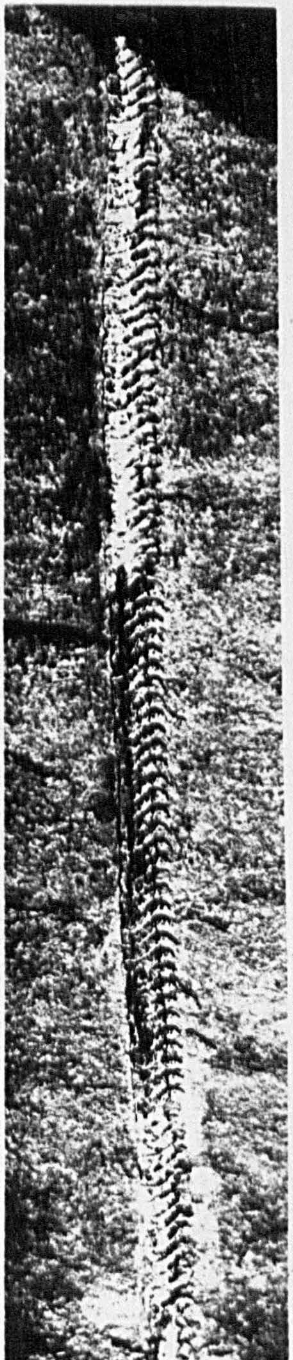

2

PLATE 12

All figs. x 10

Fig.1 Diplograptus modestus tenuis subsp. nov. holotype, HUR./S1-5/18; see also pl.1,fig.13. (p.142)

Fig.2 Diplograptus magnus H.Lapworth. HUR./9Bi/26; see also pl.1,fig. 14. (p.139)

Fig.3 Climacograptus medius Tornquist HUR./3Wa/25; see also pl.1 fig.12. (p.129)

Fig.4 Climacograptus pseudonormalis sp. nov. HUR./2Bi/4, holotype. see also pl.1,fig.10. (p.128)

Fig.5 Climacograptus rectangularis (M'Coy). HUR./S9-13/103; Zone of P. acinaces, Spengill; specimen flattened, virgella preserved. (p.130)

Fig.6 Climacograptus extremus H.Lapworth. HUR./S75,9·4/222; see also pl. 1,fig.8 (p.134)

Fig.7 Climacograptus aff minutus Carruthers. HUR./S9-13/101; see also pl.1,fig.11 (p.135)

Fig.8 Climacograptus ?tangshanensis linearis Packham HUR./14P/7; see also pl.1,fig.9 (p.131)

Fig.9 Climacograptus miserabilis (Elles & Wood). HUR./1Bi/35. see also pl.1,fig.5. (p.125)

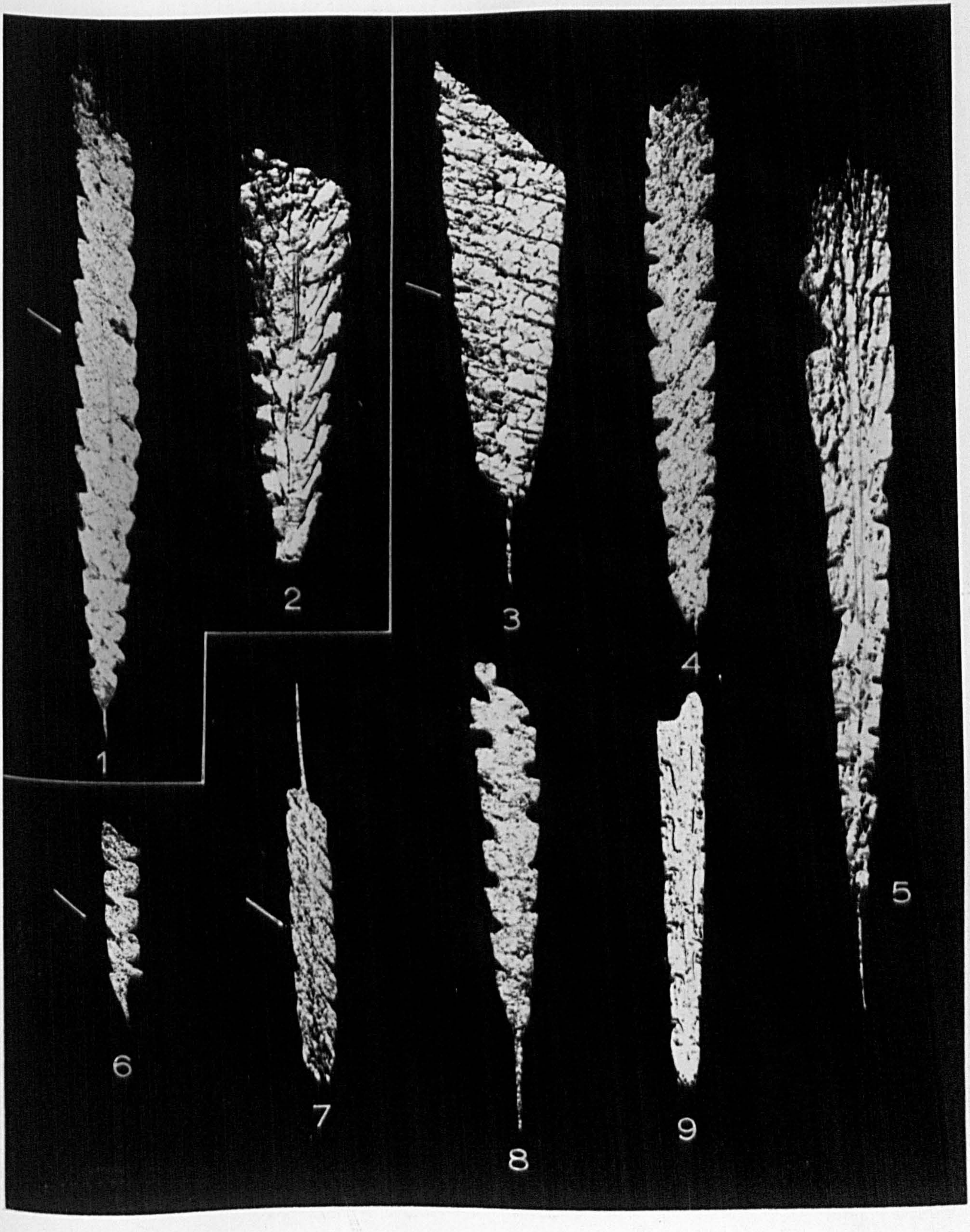
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PLATE 13

All figs. x 5

Fig.1 Monoclimacis vomerina basilica (Lapworth). HUR./28W/91; Wenlock Stage 1, Wandale Hill; specimen of distal thecae in full relief. (p.188)

Fig.2 Monograptus vomerinus var. gracilis Elles & Wood. figd. Elles & Wood pl.41,fig.3a.

Fig.3 Monoclimacis vomerina aff vomerina (Nicholson). HUR./4M/71; Wenlock Stage 1, Middle Gill; specimen in relief. (p.191)

Fig.4 Monograptus priodon (Bronn) s.l. HUR./28W/40a; Wenlock Stage 1, Wandale Hill; specimen in full relief preserved partly as an external mould (p.256)

Fig.5 Monograptus f.flemingii Salter. HUR./1Tw/1; Wenlock Stage 4, Two Gills; specimen of distal thecae in full relief obtained from a calcareous nodule. (p.262)

Fig.6 Monograptus priodon (Bronn) s.l. HUR./1M/32; Wenlock Stage 1, Middle Gill; flattened specimen of proximal end. (p.256)

Figs.7,8, Pristiograptus watneyi sp. nov. holotype, HUR./37W/17; Wenlock Stage 1, Wandale Hill; specimen in full relief; fig.7 shows proximal end and sicula, fig.8 distal thecae. (p.210)

Fig.9 Monograptus ?marri Perner. HUR./5Wi/7; Zone of M.crispus, Wards Intake; specimen flattened and showing peculiar arrangement of thecal hook mentioned in description of M.marri Perner s.l. (p.270)

Fig.10 Pristiograptus leptotheca (Lapworth), HUR./S75,9·4/142; Zone of M.sedgwicki, Spengill; distal fragment in full relief. (p.206)

PLATE 13

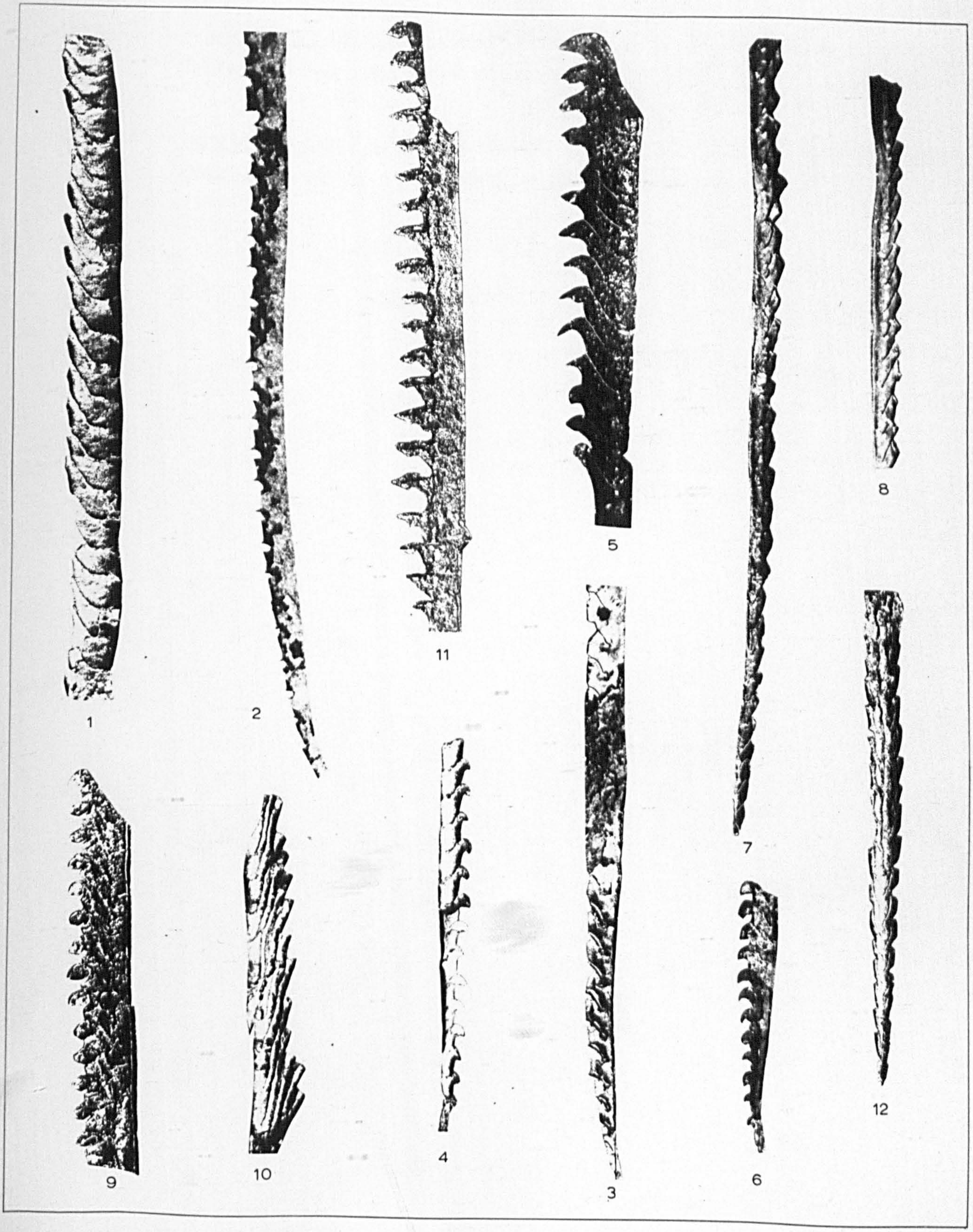

Fig.11 *Monograptus spiralis* (Geinitz)s.l., HUR./5Wi/8; Zone of *M.crispus* Wards Intake; specimen flattened. (p.315)

Fig.12 *Glyptograptus ?enodis* Packham, HUR./S73,11 4/43; Zone of *M.sedgwicki*, Spengill; specimen in full relief. (p.)

PLATE 14

All figs. x 10

Fig.1 Pseudoplegmatograptus obesus (Lapworth), HUR./S124,10·25/1; Subzone of R.maximus, Spengill, fragmentary specimen in full relief. (p.173)

Fig.2 Diplograptus modestus diminutus Elles & Wood HUR./2Bi/32; see also pl.2,fig.2 (p.141)

Fig.3 Diplograptus sp. A HUR./1Bi/3; see also pl.1,fig.16 (p.144)

Fig.4 ?Diplograptus rarus sp. nov. holotype HUR./1Bi/139; Zone of M.atavus, Birks Wood Beck; long specimen showing proximal end and proximal thecae with excavations; virgella and nema present. (p.143)

Fig.5 Climacograptus pseudonormalis sp. nov. paratype HUR./2Bi/11; see also pl.2,fig.1 (p.128)

Fig.6,7. Petalograptus minor finitimus subsp. nov. respectively the holotype HUR./6Bi/41 and a paratype HUR./6Bi/15; Zone of P.leptotheca (= argenteus Zone), Birks Wood Beck; specimens in relief. (p.167)

Fig.8 Climacograptus miserabilis (Elles & Wood) HUR./2Bi/44; see also pl.1,fig.4. (p.125)

Fig.9 Climacograptus inotatus exquisitus subsp. nov. holotype, HUR./1Bi/26; see also pl.1,fig.7. (p.138)

PLATE 14

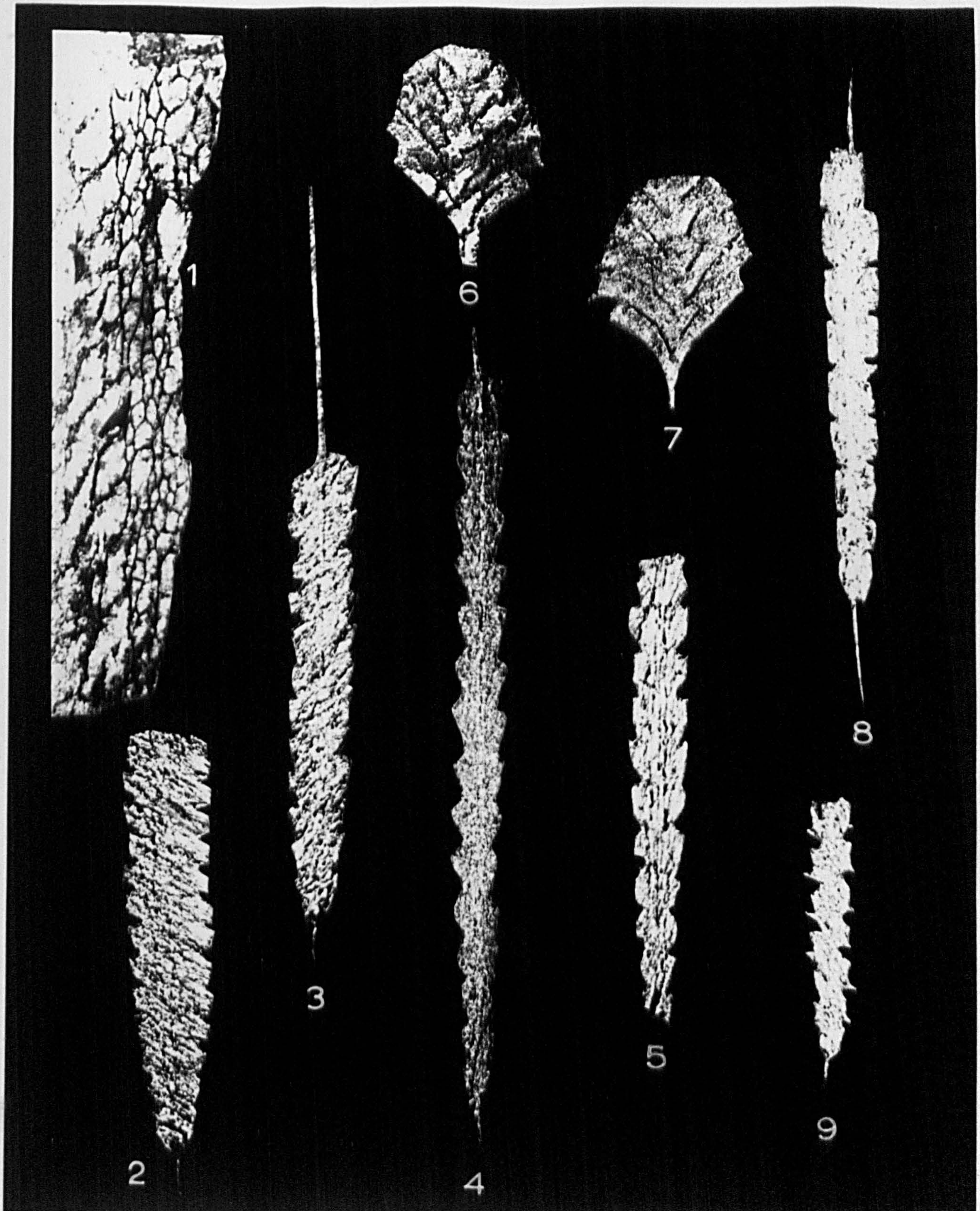

PLATE 15

All figs. x 10

Figs.1,2,3. Orthograptus vesiculosus (Nicholson) respectively HUR./S5-9/229, HUR./1Bi/61 and HUR./S9-13/104; fig.2 from Zone of P.acinaces, others from atavus Zone. (p.158)

Fig.4 Orthograptus bellulus Tornquist HUR./11Wa/3; Zone of M.atavus, Watley Gill; specimen flattened and compressed.(p.161)

Fig.5 Glyptograptus ?enodis latus Packham, HUR./9Bi/52; Zone of D.magnus Birks Wood Beck; specimen in full relief but fragmentary, sub-apertural view. (p.151)

Fig.6 Glyptograptus tamariscus linearis (Perner), HUR./9Wa/67; convolutus Zone, Watley Gill; specimen in low relief, reverse view. (p.147)

Fig.7 Climacograptus miserabilis (Elles & Wood). HUR./S5-9/125; see also pl.1,fig.1 (p.125)

Fig.8 Climacograptus i.innotatus Nicholson. HUR./2Wa/23; Zone of M. atavus, Watley Gill; small specimen in low relief, spines not clearly visible. (p.137)

Fig.9 Climacograptus normalis Lapworth HUR./2Bi/96; see also pl.1,fig. 3. (p.124)

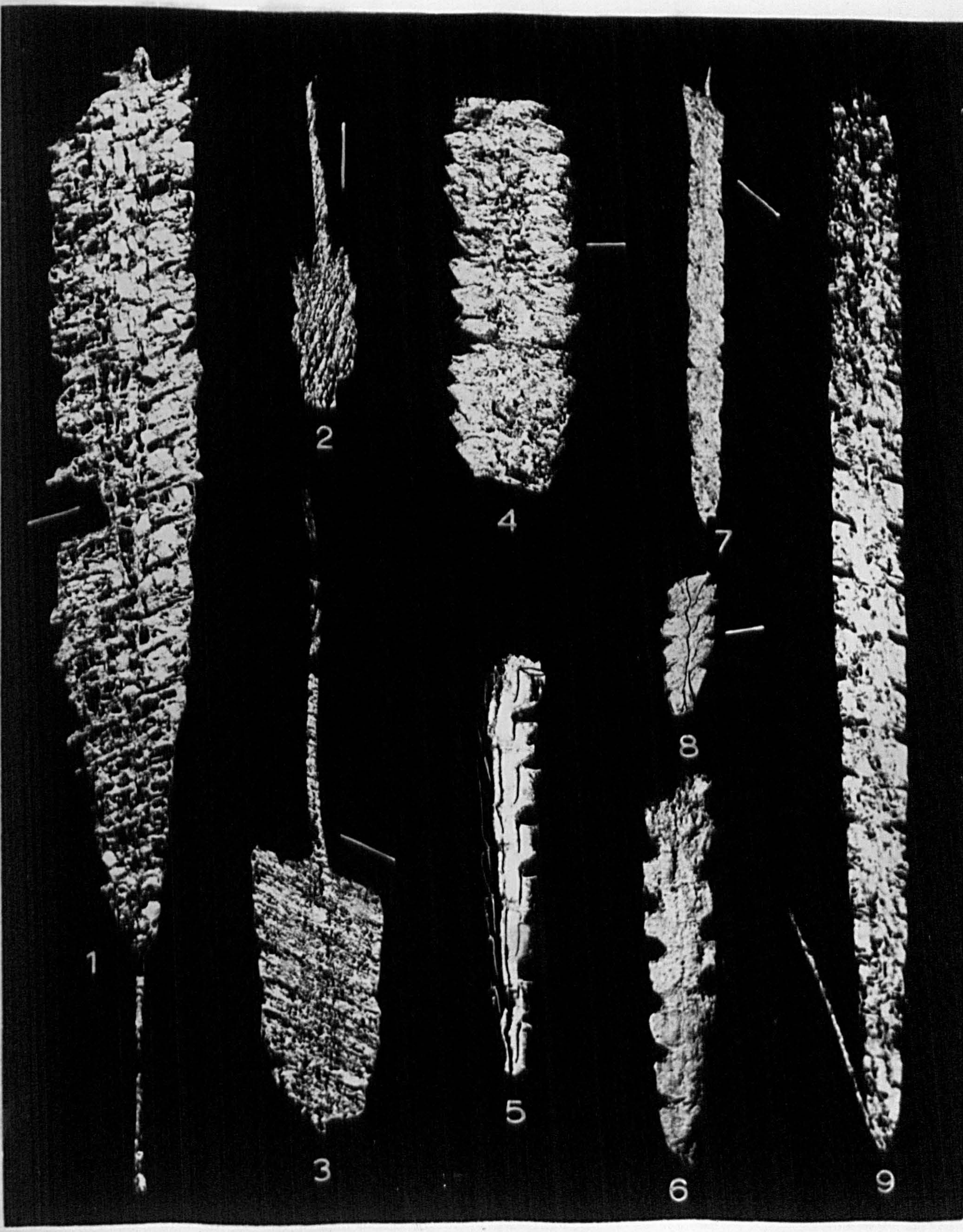
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PLATE 16

All figs. x 10

Fig.1 Retiolites g.geinitzianus Barrande, HUR./25W/6; Wenlock Stage 1, Wandale Hill; specimen in full relief. (p.170)

Fig.2 ?Glyptograptus sp.A, HUR./6Wa/17; ?magnus Zone Watley Gill; fragmentary specimen in full relief. (p.157)

Fig.3 Glyptograptus sinuatus crateriformis subsp. nov., holotype, HUR./S75,9·4/74; sedgwicki Zone, Spengill; specimen in full relief but with extreme proximal end missing. (p.154)

Fig.4 Glyptograptus ?enodis latus Packham, HUR./9Bi/41; magnus Zone, Birks Wood Beck; specimen incomplete, in full relief. (p.151)

Fig.5 Glyptograptus sinuatus sinuatus (Nicholson), HUR./6Bi/30; Zone of P.leptotheca (= argenteus Zone). Birks Wood Beck; specimen complete, in full relief, with nema and virgella preserved; reverse view. (p.153)

Fig.6 Glyptograptus packhami sp. nov., holotype, HUR./S73,11·4/6; see also pl.2,fig.6. (p.149)

Fig.7 Glyptograptus sp.3, HUR./S75,9·4/153; sedgwicki Zone, Spengill; specimen fragmentary but preserved in full relief. (p.156)

Fig.8 Climacograptus ex.gr. scalaris (Hisinger), HUR./S73,11·4/3; sedgwicki Zone, Spengill; specimen fragmentary but in full relief. (p.126)

Fig.9 Climacograptus simplex sp. nov. paratype, HUR /S75,9·4/12; sedgwicki Zone, Spengill; proximal end in full relief, sicula visible. (p.127)

Fig.11 Climacograptus simplex sp. nov. holotype HUR./S75,9·4/33; Zone as

PLATE 16

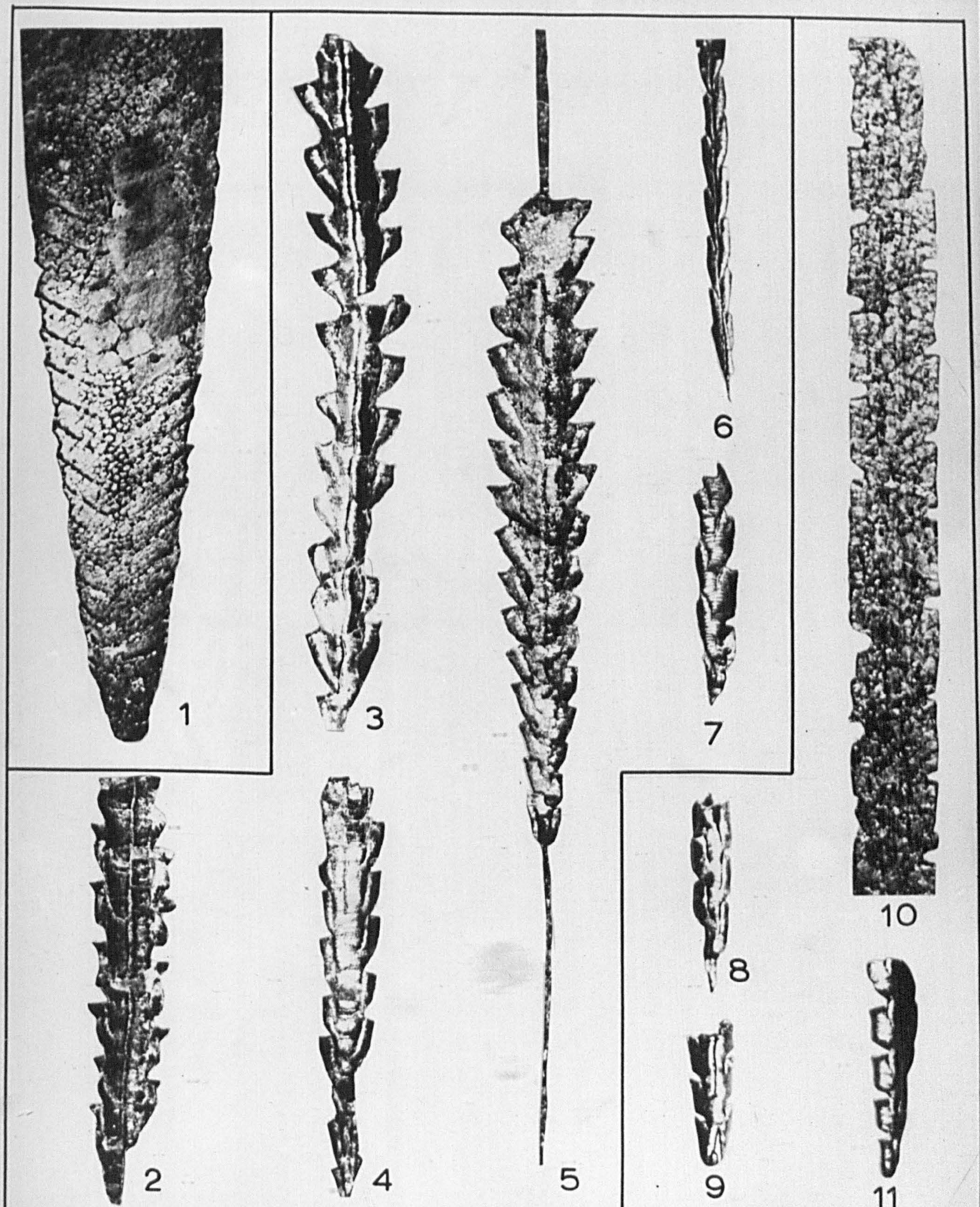

fig.9; mesial specimen in full relief showing characters of thecal tubes. (p. 127)

Fig.10 Climacograptus normalis Lapworth HUR./S17-20/1; cyphus Zone, Spengill; mesial fragment, flattened. (p. 124)

PLATE 17

All figs. x 10

Fig.1 Climacograptus miserabilis (Elles & Wood)? HUR./S17·2/3; cyphus Zone, Spengill. (p.125)

Fig.2 Climacograptus miserabilis (Elles & Wood), HUR./1Bi/35; see also pl.1, fig.5. (p.125)

Fig.3 Climacograptus extremus H.Lapworth, HUR./9Bi/23; magnus Zone, Birks Wood Beck; well preserved specimen in full relief, nema preserved. (p.134)

Fig.4 Climacograptus aff minutus Carruthers, HUR./S9-13/101; see also pl.1, fig.11 (p.135)

Fig.5 Climacograptus hughesi (Nicholson), HUR./9Bi/24; magnus Zone, Birks Wood Beck; proximal end in full relief showing sicula. (p.132)

Fig.6 Climacograptus simplex sp. nov. paratype, HUR./S75,9·4/12; see also pl.16,fig.9. (p.127)

Fig.7 Climacograptus medius Tornquist? HUR./S1-5/73; see also pl.1,fig. 2. (p.129)

Figs.8,9,10. ?Climacograptus retroversus sp. nov., respectively HUR./S80, 8·4/119; the holotype HUR./S73,11·4/81 and HUR./S80,8·4/119 (same slab as fig.8); all specimens from sedgwicki Zone, Spengill; preserved in full relief but usually fragmentary. (p.135)

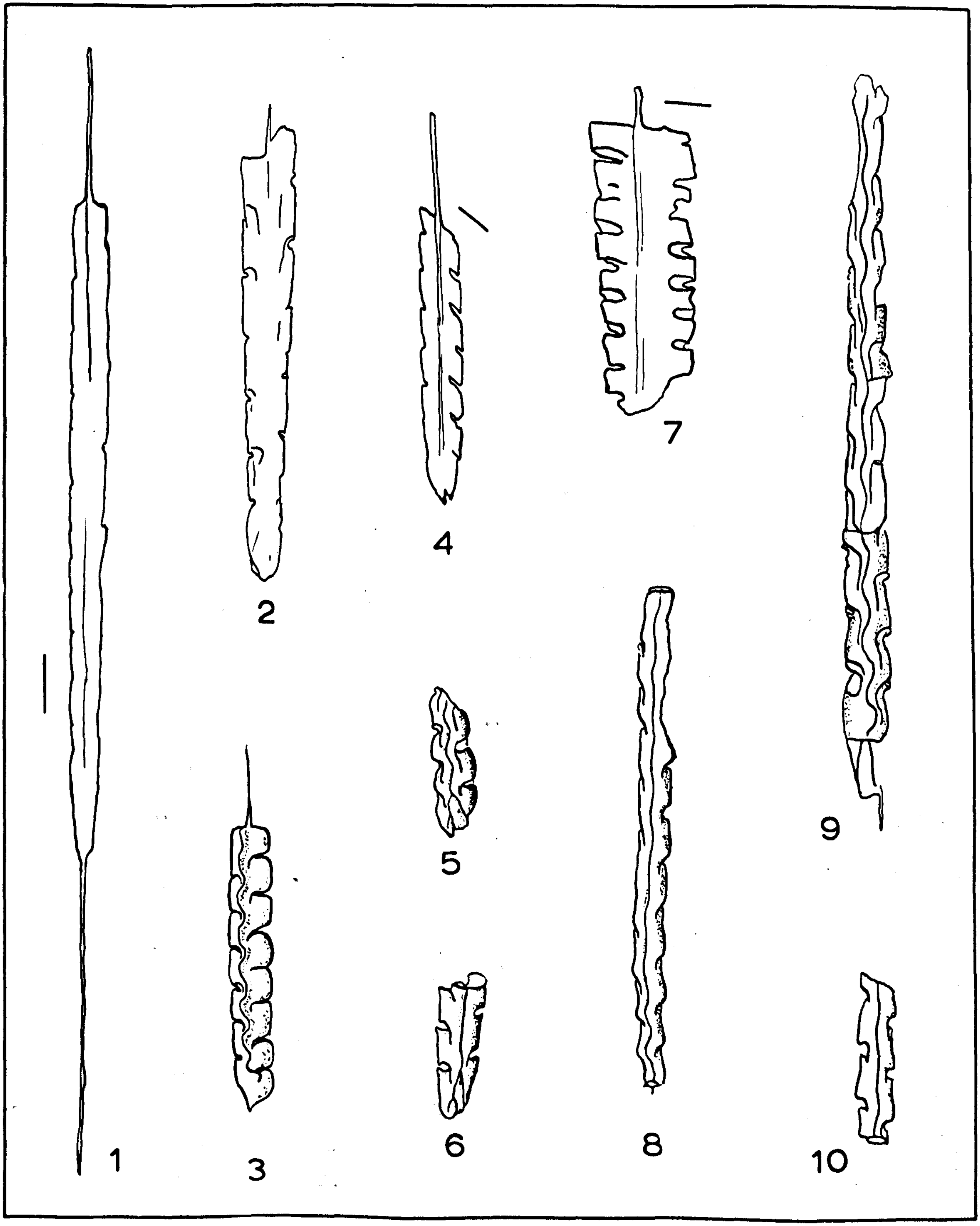
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PLATE 18

All figs. x 10

Fig.1 ?Climacograptus retroversus sp. nov. paratype HUR./S80,8·4/119; Zone as pl.17,figs.8,10. (p.135)

Fig.2 Glyptograptus tamariscus tamariscus (Nicholson) aff form B Packham HUR./6Bi/41; Zone of P.leptotheca (= argenteus Zone), Birks Wood Beck; specimen in full relief, obverse view showing sicula (p.145)

Fig.3 Glyptograptus aff incertus (Elles & Wood), HUR./7Bi/1; ?magnus Zone, Birks Wood Beck; proximal end in relief with sicula.(p.150)

Fig.4 Glyptograptus sp.2, HUR./S80,8·4/44; sedgwicki Zone Spengill; specimen in low relief. (p.156)

Fig.5 Glyptograptus t.tamariscus (Nicholson), HUR./S32-36/112; triangulatus Zone, Spengill; specimen in full relief, compressed. (p.145)

Fig.6 Glyptograptus t.tamariscus (Nicholson) aff form C Packham, HUR./9Bi/18; magnus Zone, Birks Wood Beck; fragmentary specimen in full relief. (p.145)

Fig.7 Glyptograptus elegans Packham?, HUR./6Bi/81,(not described); Zone P.leptotheca, Birks Wood Beck; specimen in relief.

Fig.8 Glyptograptus sp.1, HUR./1Wa/37; acuminatus Zone, Watley Gill; flattened specimen with attenuated periderm but a prominent nema. (p.155)

Fig.9 Glyptograptus tamariscus aff varians Packham, HUR./6Bi/37; P.leptotheca Zone, Birks Wood Beck; specimen flattened. (p.148)

Fig.10,11. Orthograptus aff insectiformis (Nicholson), respectively HUR./11Wa/18 and /8; convolutus Zone, Watley Gill; specimens flattened and compressed. (p.162)

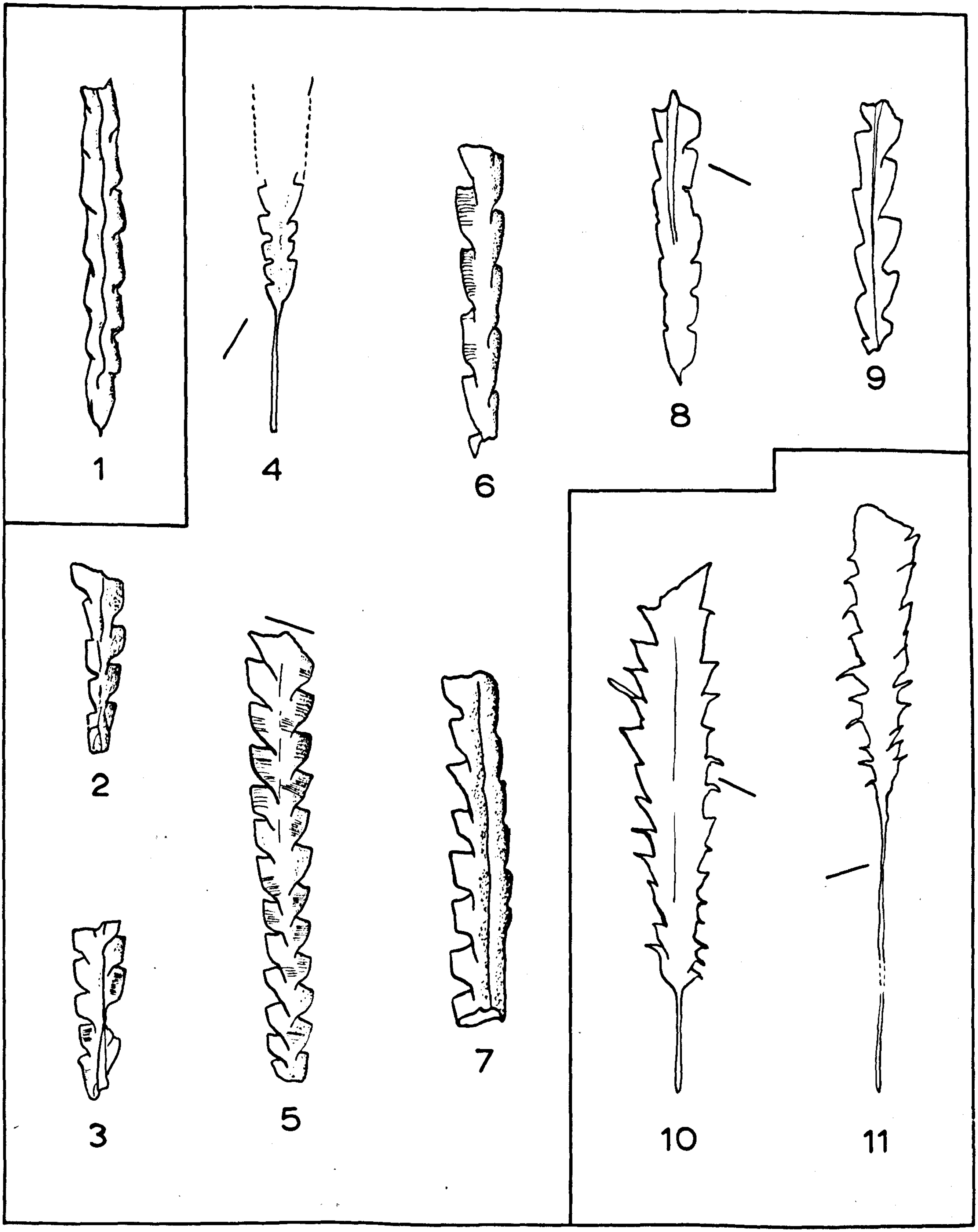
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PLATE 19

All figs. x 5

Fig.1 Climacograptus normalis Lapworth, HUR./S17-20/1; see also pl.16, fig.10. (p.124)

Fig.2 Climacograptus normalis, Lapworth, HUR./1Wa/3; acuminatus Zone Watley Gill; specimen flattened. (p.124)

Fig.3 Climacograptus rectangularis (M'Coy), HUR./S9-13/103; see also Pl. 12, fig.5. (p.130)

Fig.4 Glyptograptus tamariscus linearis (Perner), HUR./9Wa/67; convolutus Zone, Watley Gill; specimen in relief but weathered. (p.147)

Fig.5 ?Diplograptus rarus sp. nov.?, HUR./S9-13/105; acinaces Zone, Spengill; flattened distal fragment with long nema. (p.143)

Fig.6 Diplograptus m.modestus (Lapworth), HUR./4Wa/52; atavus Zone, Watley Gill; specimen flattened and compressed. (p.140)

Fig.7,8,9. Rhaphidograptus toernquisti (Elles & Wood), respectively HUR./S20-24/31; HUR./9Bi/14; HUR./S13-17/2; fig.8 is from the magnus Zone, Birks Wood Beck and is preserved in relief; Figs. 7 & 9 are flattened and compressed. (p.186)

Fig.10 Pseudoplegmatograptus obesus (Lapworth), HUR./S140,11/3; Subzone of R.maximus, Spengill; specimen flattened, not well preserved. (p.173)

Fig.11 Spinograptus spinosus proespinosus subsp. nov. four specimens on a slab HUR./20N/40, the holotype is the left hand specimen showing thecal spines. (p.177)

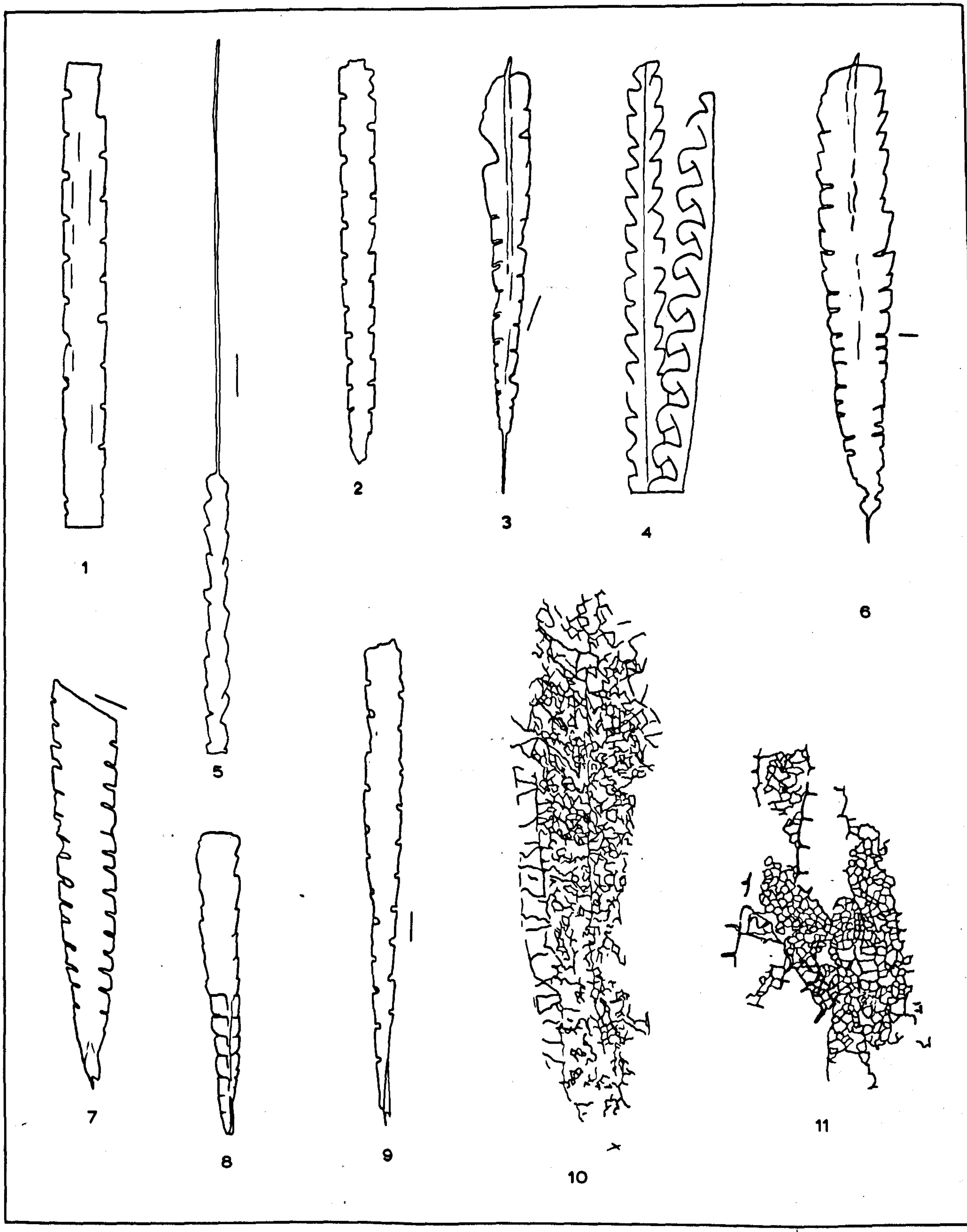
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PLATE 20

All figs. x 10

Fig.1,2,3. Petalograptus kurcki sp. nov., HUR./S73,11·4/40 holotype, fig. 1; sedgwicki Zone, Spengill; specimens in full relief but strongly compressed. (p.167)

Fig.4 Cephalograptus cometa aff extrema Boucek & Pribyl, HUR./S94,7·4/32; sedgwicki Zone, Spengill; small badly preserved fragment, in relief. (p.169)

Fig.5 Orthograptus aff cyperoides (Tornquist), HUR./S36-39,7/30; triangulatus Zone, Spengill; specimen in relief but weathered. (p.160)

Fig.6 Orthograptus cyperoides (Tornquist), HUR./5Wa/16; Zone of M. triangulatus, Watley Gill; specimen in full relief obverse view. (p.159)

Fig.7 Orthograptus attenuatus sp. nov. holotype, HUR./14P/7; cyphus Zone, Pickering Gill; flattened specimen with an attenuated periderm and prominent nema. (p.161)

Fig.8 Diplograptus modestus tenuis subsp. nov. holotype, HUR./S1-5/18; see also pl.1, fig.13. (p.142)

Fig.9 ?Diplograptus rarus sp. nov. holotype HUR./1Bi/139; see also pl. 14, fig.4. (p.143)

Fig.10 Diplograptus magnus H.Lapworth, HUR./9Bi/26; see also pl.1, fig. 14. (p.139)

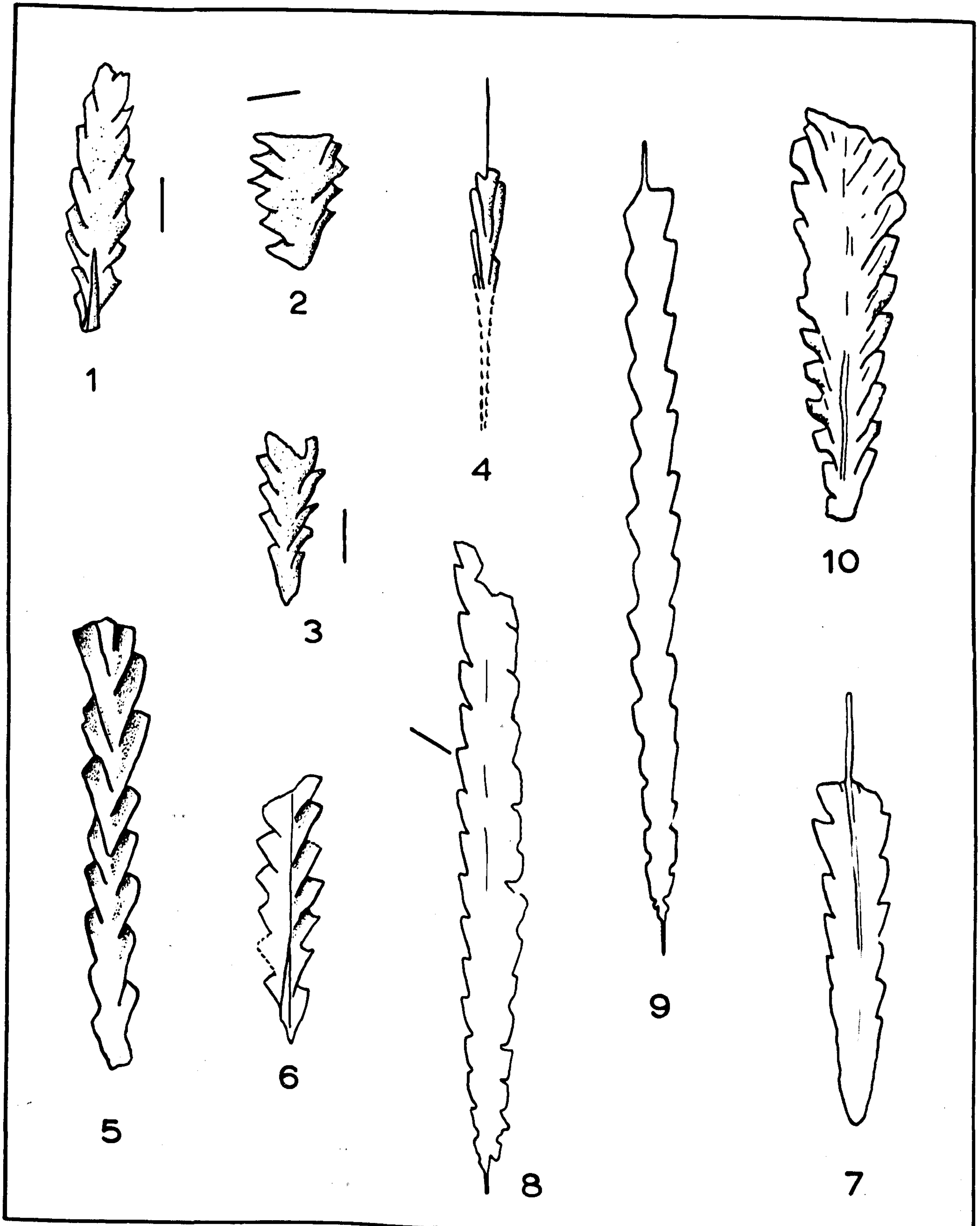
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PLATE 21

All figs. x 10

Fig.1 *Dimorphograptus erectus nicholsoni* subsp. nov., holotype, HUR./1Bi /64; *atavus* Zone Birks Wood Beck; specimen complete but flattened. (p.181)

Fig.2 *Dimorphograptus erectus nicholsoni* subsp. nov., paratype, HUR./2Bi /22; *acinaces* Zone (base), Birks Wood Beck; specimen complete but flattened. (p.181)

Fig.3 *Akidograptus a. acuminatus* (Nicholson), HUR./S/1; *acuminatus* Zone, Spengill; specimen in relief. (p.183)

Fig.4 *Akidograptus a. praematurus* Davies, HUR./S/2; *acuminatus* Zone, Spengill; specimen in relief. (p.185)

Fig.5,6. *?Monoclimacis sp. A* respectively HUR./S233,3/21 and 22; *crispus* Zone, Spengill; both specimens flattened and not well preserved. (p.200)

Fig.7 *Monoclimacis griestonensis nicoli* subsp. nov. paratype, HUR./28W /86; Wenlock Stage 1, Wandale Hill; specimen in low relief, sub-dorsal view. (p.196)

Fig.8 *Monoclimacis griestonensis nicoli* subsp. nov. holotype, HUR./8P /19; Wenlock Stage 1, Pickering Gill; specimen in relief preserved partly as an external mould. (p.196)

Fig.9 *Monoclimacis griestonensis* (Nicol), figd. Elles & Wood text fig. 279a.

Fig.10 *Monoclimacis* cf. *griestonensis* (Nicol), E & W. figd. Elles & Wood pl.41, fig. 6a.

? = M. [illegible] p.194. or what?

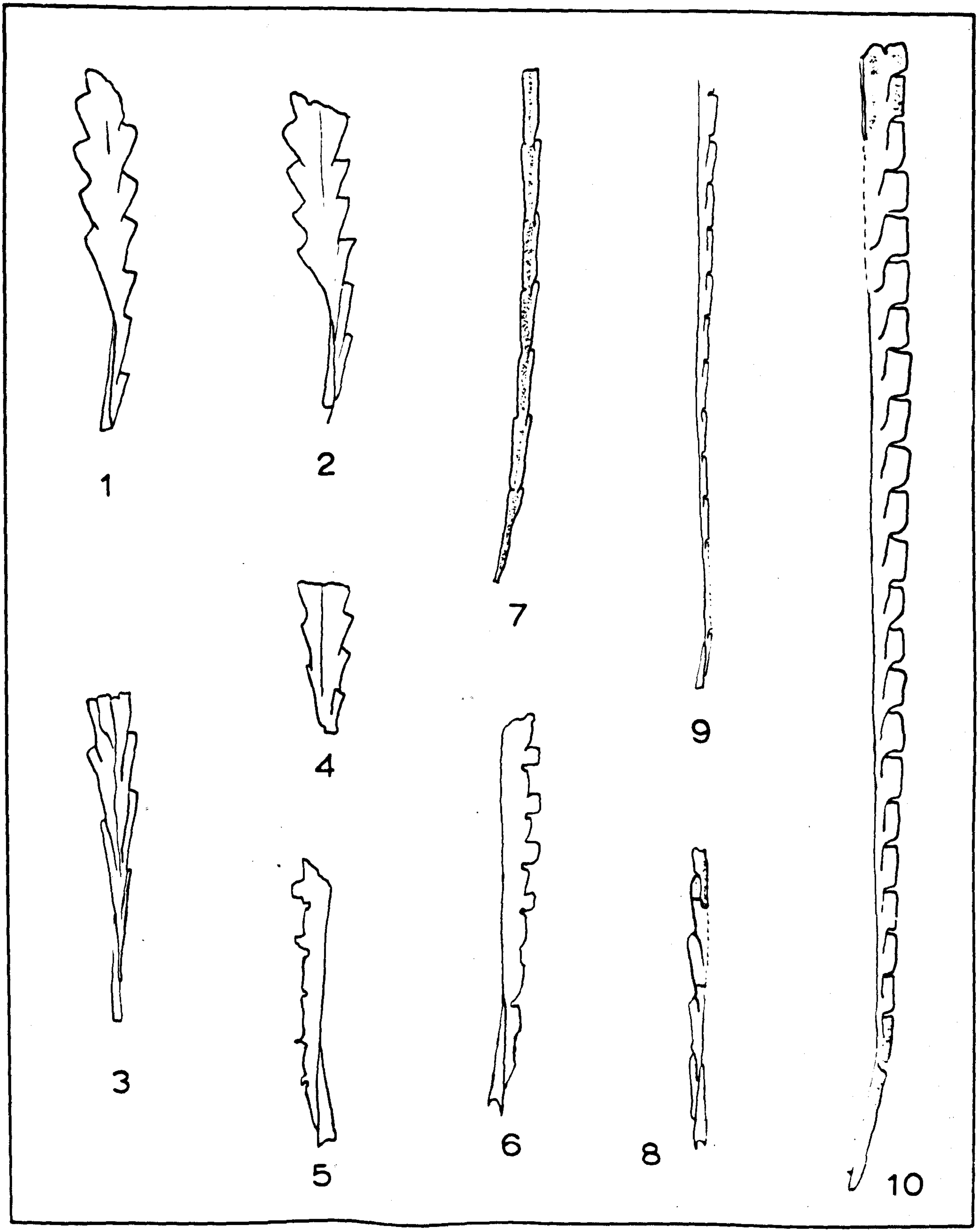
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PLATE 22

Fig.1 *Dimorphograptus epilongissimus* sp. nov. holotype, HUR./S20-24/32; *cyphus* Zone, Spengill; flattened, proximal end broken. (p.180) x 5.

Fig.2 *Dimorphograptus epilongissimus* sp. nov. paratype, HUR./S20-24/33; Zone as fig.1 (p.180) x 5.

Fig.3b *Dimorphograptus epilongissimus* sp. nov. paratype, HUR./S20-24/32; Zone as fig.1 (p.180) x 5.

Fig.3a *Dimorphograptus erectus erectus* Nicholson, HUR./S20-24/32; Zone as fig.1, specimen flattened. x 5.

Fig.4 *Retiolites geinitzianus augustidens* Elles & Wood, HUR./25W/3; Wenlock Stage 1, Wandale Hill; specimen in full relief. (p.172) x5

Figs.5-10. *Monoclimacis kingi* sp. nov., holotype fig.10,HUR./19N/70; others respectively HUR./17N/244; HUR./17N/232; HUR./17N/216; HUR./17N/19; HUR./17N/10; Wanlock Series, Near Gill; all are flattened, and figs. 5 & 10 show a characteristic slight double curvature. (p.197) x 5.

Fig.11 *Monograptus vomerinus var. crenulatus* Tornquist. figd. Elles & Wood, text fig.278a. x 5

Fig.12 *Monoclimacis vomerina basilica* Lapworth, specimen figured by Lapworth; see also pl.4,fig.3. x 2 (p.188)

PLATE 22

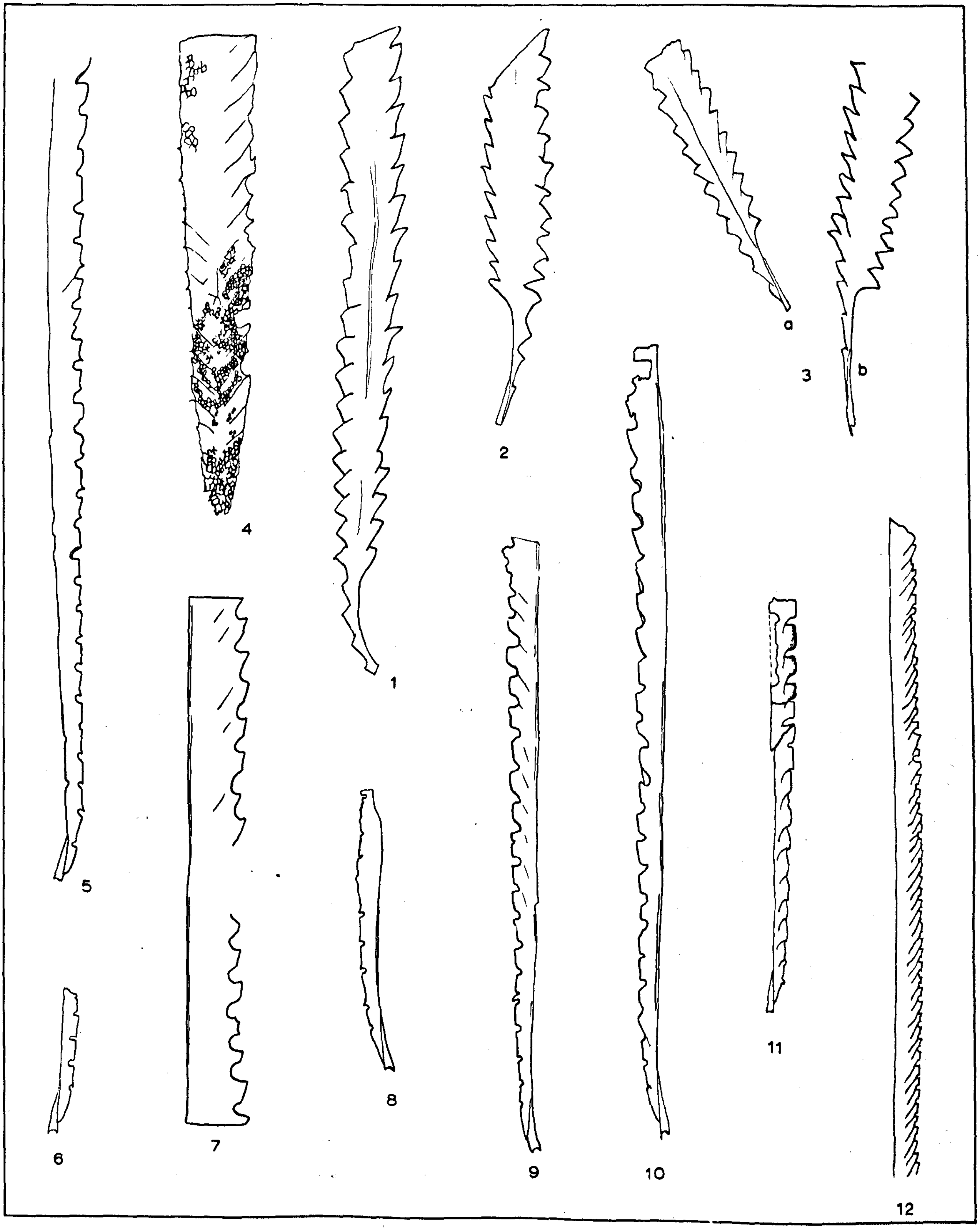

PLATE 23

All figs. x 10 except fig.11

Fig.1 Monoclimacis vomerina basilica (Lapworth), HUR./3P/11a; Wenlock Stage 1, Pickering Gill; specimen in low relief. (p.188)

Fig.2 Monoclimacis vomerina basilica (Lapworth), HUR./5Wh/22; Wenlock Stage 1, Whinny Gill; specimen in low relief. (p.188)

Fig.3 Monoclimacis vomerina aff vomerina (Nicholson), HUR./28W/76; Wenlock Stage 1; Wandale Hill; distorted specimen in low relief. (p.191)

Fig.4 Monoclimacis haupti (Kuhne), HUR./2W/35; nilssoni-scanicus Zone, Wandale Hill; specimen in relief, a little distorted. (p.199)

Fig.5 Monoclimacis shottoni sp. nov., holotype, HUR./28W/76; Wenlock Stage 1, Wandale Hill; specimen complete, well preserved in full relief. (p.193)

Fig.6,9. Pristiograptus leptotheca (Lapworth) respectively S75,9·4/58 & 19; sedgwicki Zone, Spengill; proximal fragments in full relief. (p.205)

Fig.7 Pristiograptus cyphus (Lapworth), HUR./9-13/106; acinaces Zone, Spengill; fragmentary, flattened, proximal end. (p.204)

Fig.8 Pristiograptus gregarius (Lapworth), HUR./6Bi/33; leptotheca Zone, Birks Wood Beck; proximal end in full relief. (p.202)

Fig.10 Pristiograptus welchi sp. nov. holotype, HUR./1Ab/22; leintwardinensis Zone, Adamthwaite Bank; flattened specimen. (p.224)

Fig.11 Pristiograptus vicinus (Perner), HUR./8W/59; nilssoni-scanicus Zone, Wandale Hill; flattened specimen. x 2½ (p.222)

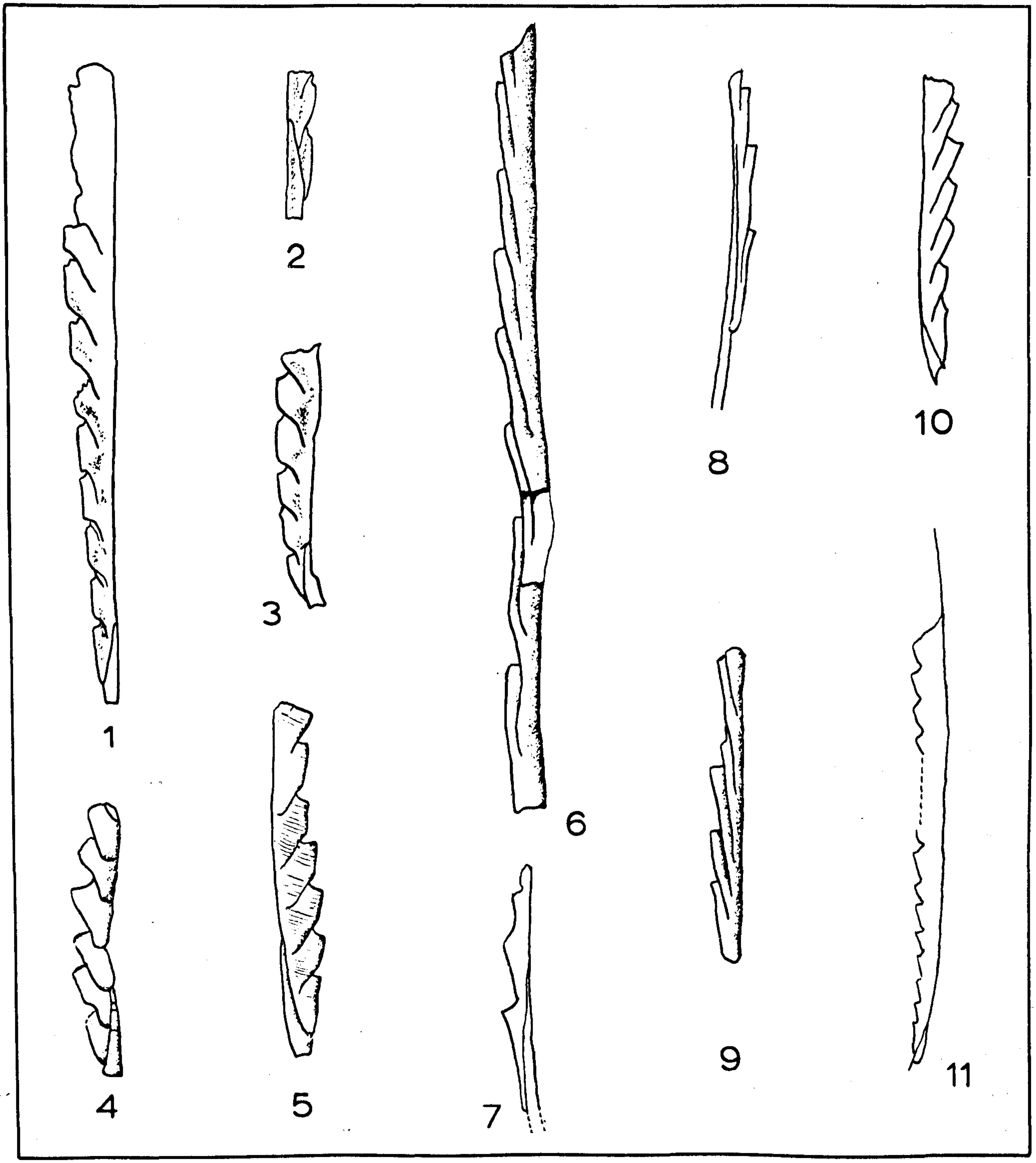

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PLATE 24

All figs. x 5 except fig.3

Fig.1 Monoclimacis linnarssoni (Tullberg), HUR./4M/72; Wenlock Stage 1, Middle Gill; long distal fragment in relief. (p.195)

Fig.2 Monoclimacis linnarssoni (Tullberg), HUR./10P/41; Wenlock Stage 1, Pickering Gill; proximal end with sicula, in relief. (p.195)

Fig.3 Monograptus vomerinus Nicholson, figured Elles & Wood, pl.41,fig. 1a, x 2½

Fig.4 Monograptus vomerinus Nicholson, same slab as the specimen figured by Elles & Wood as pl.41,fig.1b.

Fig.5 Monoclimacis vomerina aff vomerina (Nicholson)?, HUR./30W/8; compressed and flattened specimen, ? sub-dorsal view. (p.191)

Fig.6 Monoclimacis vomerina basilica (Lapworth)?, HUR./4M/56; Wenlock Stage 1, Middle Gill; crushed specimen in relief. (p.188)

Fig.7 Monoclimacis vomerina basilica (Lapworth), HUR./28W/24; Wenlock Stage 1, Wandale Hill; sicula and proximal end in full relief, small specimen. (p.188)

Fig.8 Monoclimacis vomerina aff vomerina (Nicholson), HUR./5Wh/6; Wenlock Stage 1, Whinny Gill; proximal end in full relief. (p.191)

Fig.9 Pristiograptus cyphus (Lapworth), HUR./S17-20/4; cyphus Zone, Spengill; straight distal fragment, flattened. (p.204)

Fig.10 Pristiograptus gregarius (Lapworth), HUR./8Bi/1; magnus Zone, Birks Wood Beck; proximal end with sicula, in relief. (p.202)

Fig.11 Pristiograptus aff acinaces (Tornquist), HUR./S13-17/3; acinaces or cyphus Zone, Spengill; specimens flattened. (p.205)

PLATE 24

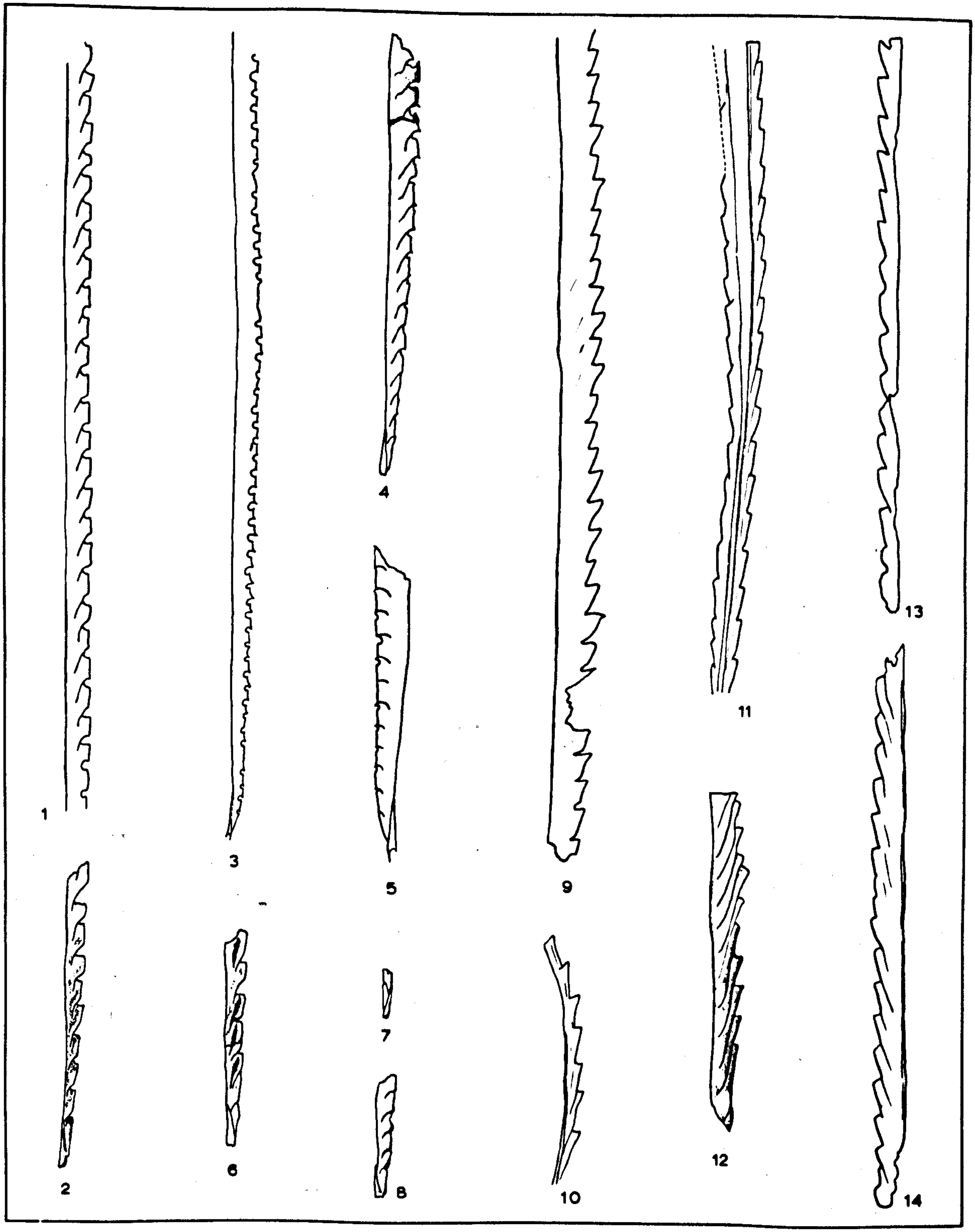

PLATE 25

Fig.1 Pristiograptus dubius dubius (Suess), HUR./18N/6; Wenlock Series, flexilis belophorus Zone, Near Gill; almost complete but flattened specimen. (p.215) x 2½

Fig.2 Pristiograptus dubius pseudolatus subsp. nov., holotype, HUR./18N/53a; Wenlock Series, Near Gill; almost complete but flattened specimen. (p.218) x 2½

Fig.3 Pristiograptus vicinus (Perner), HUR./8W/85; nilssoni-scanicus Zone Wandale Hill; flattened specimen with distal extremity missing. (p.222) x 2½

Fig.4 Pristiograptus auctus sp. nov. HUR./7W/25; nilssoni-scanicus Zone, Wandale Hill; flattened specimen. (p.223) x 2½

Fig.5 Pristiograptus d.dubius (Suess), HUR /21N/9; Wenlock Series, C.rigidus mut. Zone, Near Gill; flattened proximal end. (p.215) x 5

Fig.6 Pristiograptus m.meneghini (Gortani), HUR./17N/46; Wenlock Series, C.rigidus mut. Zone, Near Gill; flattened specimen. (p.219) x 5

Fig.7 Pristiograptus d.dubius (Suess), HUR./16N/9; Wenlock Series, C.rigidus mut. Zone, Near Gill; somewhat narrow, flattened specimen, (p.215) x 5

Fig.8,9. Pristiograptus pseudodubius (Boucek), HUR./28N/1 and HUR./26N/11; Wenlock Series, Stage 4, Zone of C.lundgreni, Near Gill; fig.9 is a particularly typical specimen, both are flattened. (p.220) x 5

Fig.10 ?Pristiograptus wandalensis (Watney & Welch), HUR./2W/203; distal thecae in full relief, showing slight ventral curvature of rhabdosome. (p.226) x 2½

PLATE 25

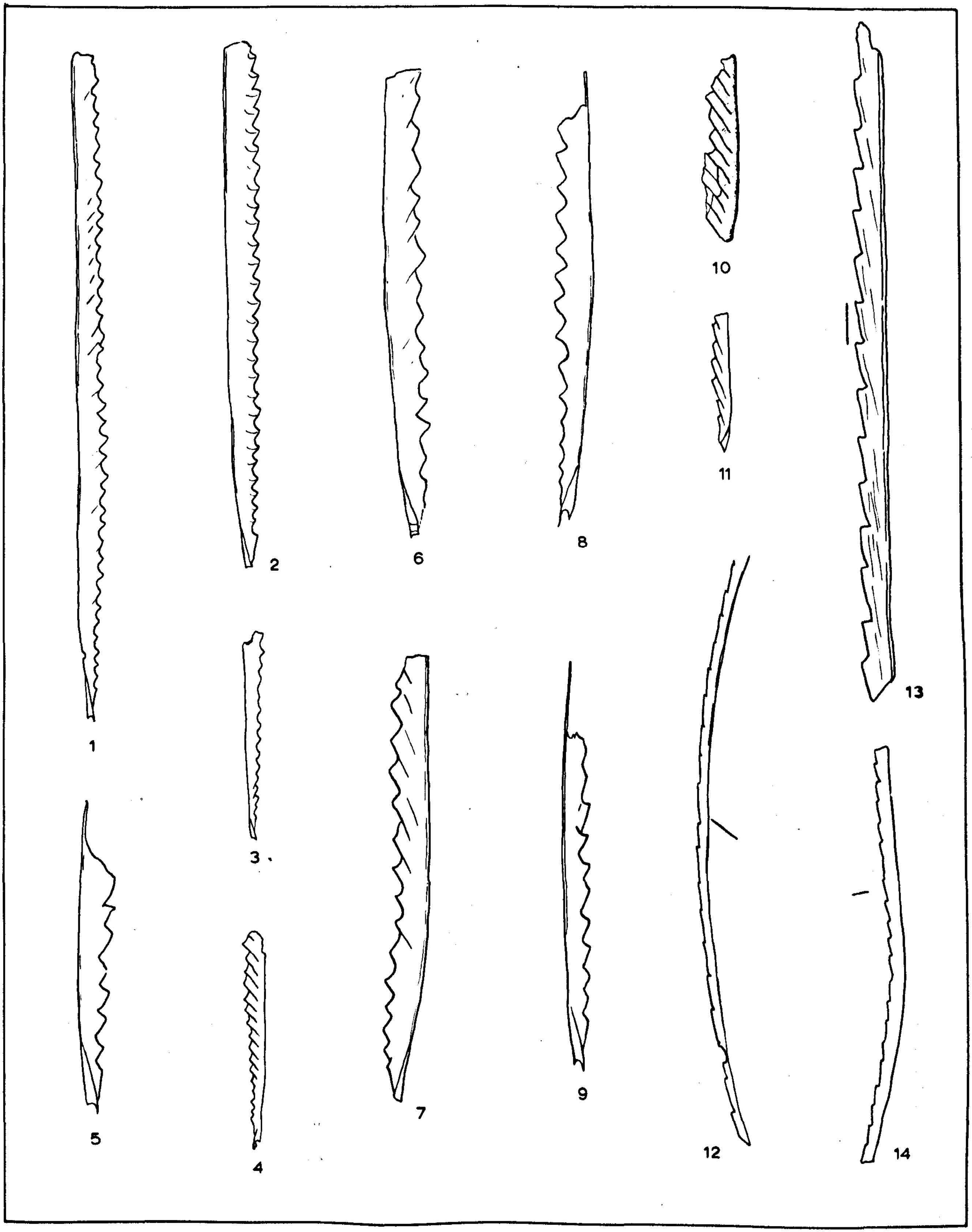

Fig.11 Pristiograptus welchi sp. nov. holotype, HUR./1Ab/22; see also pl. 23, fig.10. (p.224) x5

Fig.12 Monograptus incommodus Tornquist, HUR./S17-20/5; cyphus Zone, Spengill; incomplete flattened, proximal fragment. (p.236) x 5

Fig.13 Monograptus atavus Jones, HUR./S5-9/35; atavus Zone Spengill; specimen flattened. (p.231)

Fig.14 Monograptus atavus Jones, HUR./S5-9/68; atavus Zone, Spengill; proximal fragment showing ventral curvature. (p.231)

PLATE 26

All figs. x 10

Fig.1 Pristiograptus bohemicus (Barrande), HUR./2W/173; nilssoni-scanicus Zone, Wandale Hill; fragmentary specimen in full relief, showing cup-like nature of thecal tubes. (p.227)

Figs.2,3. Pristiograptus bohemicus (Barrande), HUR./2W/176 and 172; nilssoni-scanicus Zone, Wandale Hill; fragmentary specimens in full relief. (p.227)

Fig.4 ?Pristiograptus wandalensis (Watney & Welch), HUR./2W/4; nilssoni-scanicus Zone, Wandale Hill; small straight specimen in full relief. (p.226)

Fig.5,6. Monograptus atavus Jones, HUR./2Bi/95 and 72; acinaces Zone, Birks Wood Beck; fragmentary specimens in full relief showing sigmoidal curvature of thecal tubes. (p.231)

Fig.7 Monograptus argutus Lapworth, HUR./9Bi/27; magnus Zone, Birks Wood Beck; fragmentary specimen in full relief showing peculiar character of thecal apertures. (p.233)

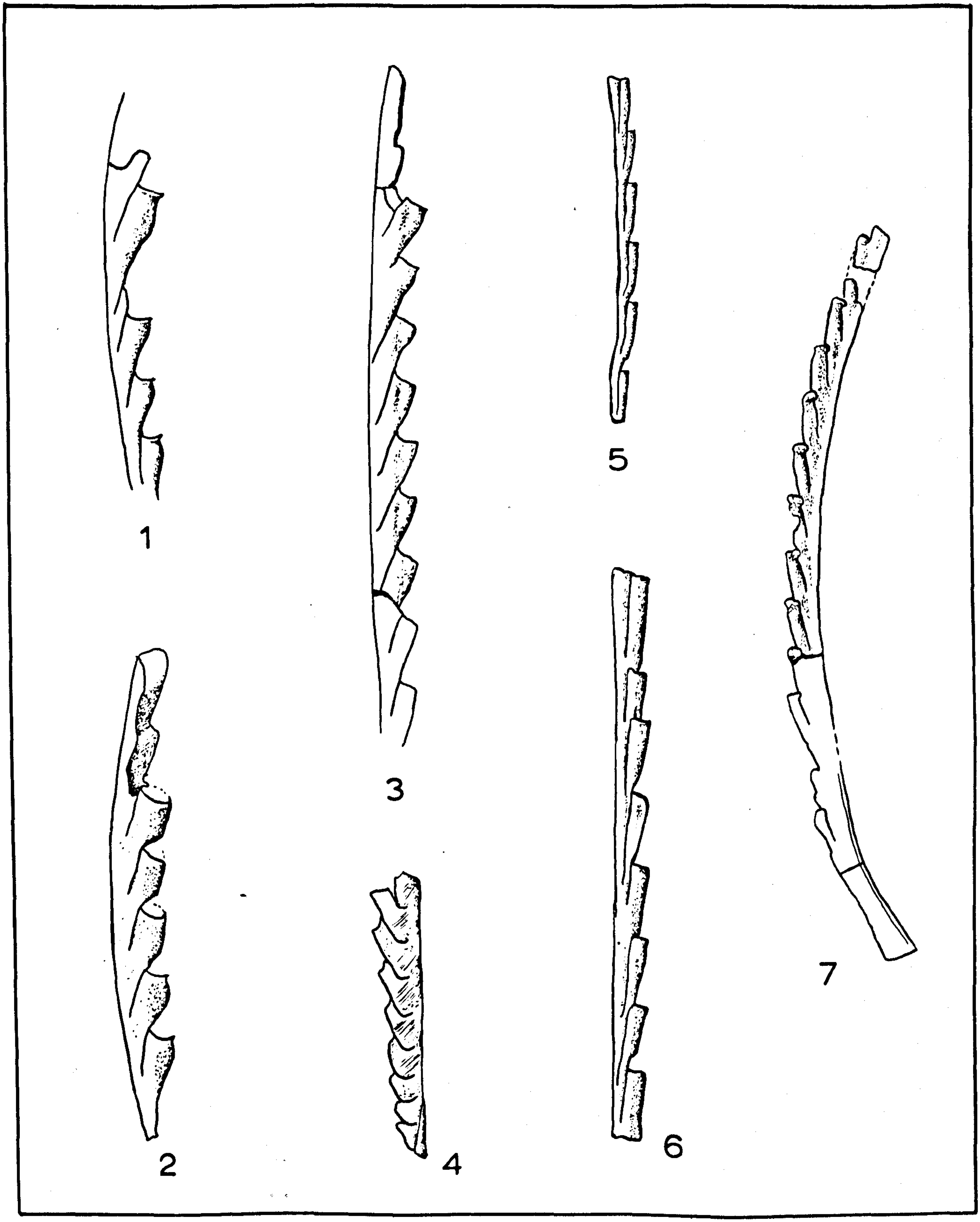
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PLATE 27

All figs. x 10

Fig.1 Monograptus jonesi sp. nov. holotype, HUR./6Bi/76; leptotheca Zone, Birks Wood Beck; specimen fragmentary but in relief. (p.234)

Fig.2 Monograptus sandersoni Lapworth, HUR./S24-28/510; triangulatus Zone, Spengill; flattened fragment showing thecal characters. (p. 235)

Fig.3 Monograptus incommodus Tornquist, HUR./S13-17/4; acinaces or cyphus Zone, Spengill; small flattened fragment. (p.236)

Fig.4 Monograptus argutus sequens subsp. nov. holotype HUR./S73,11·4/73; sedgwicki Zone, Spengill; external mould of specimen in full relief. (p.234)

Fig.5 Monograptus argenteus cygneus (Tornquist), HUR./6Bi/3; leptotheca (= argenteus Zone), Birks Wood Beck; specimen in low relief. (p.239)

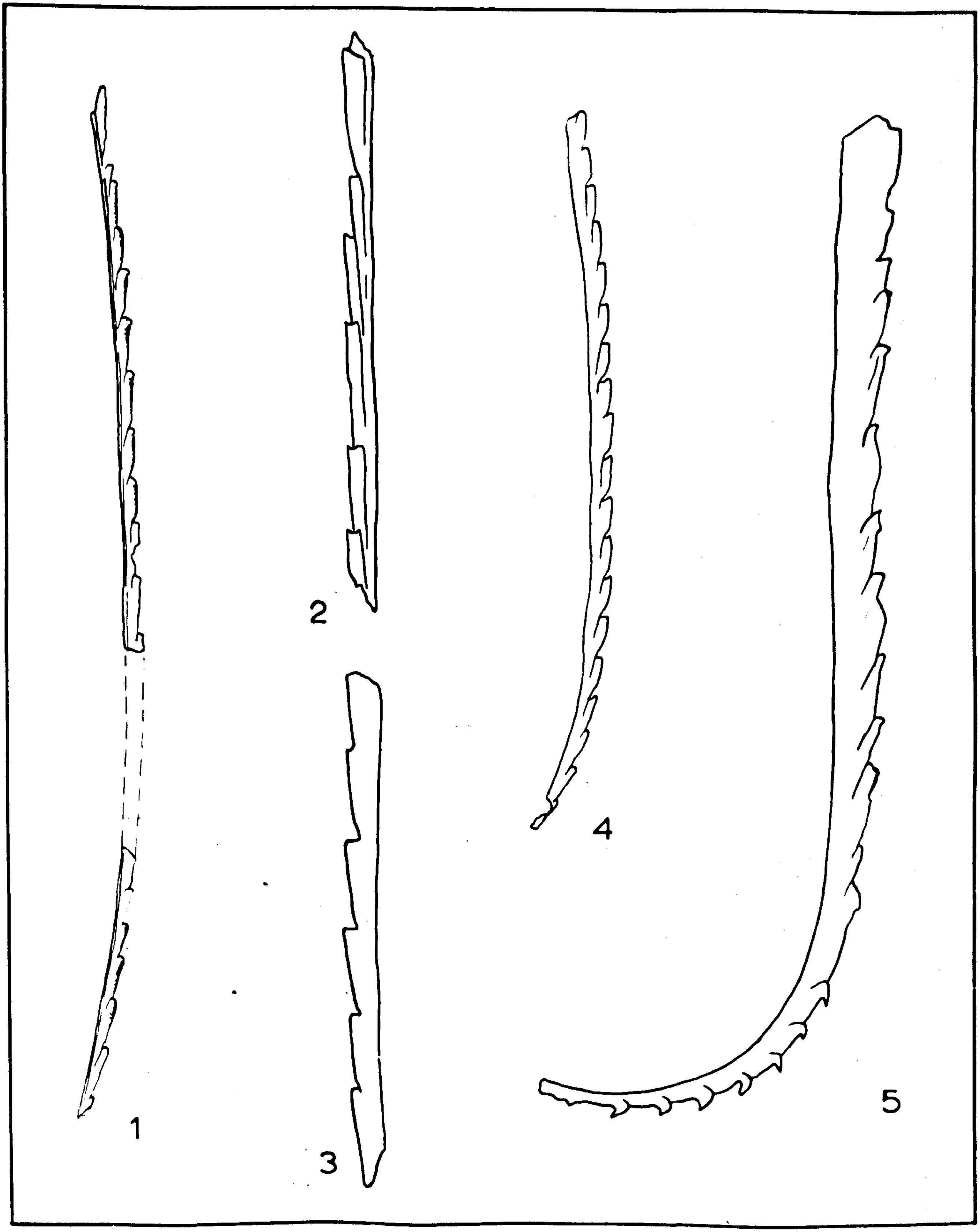

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PLATE 28

All figs. x 5

Fig.1 Monograptus incommodus Tornquist, HUR./S17-20/6; acinaces Zone, Spengill; flattened fragment. (p.236)

Fig.2 Monograptus atavus Jones, HUR./S13-17/5; acinaces or cyphus Zones; Spengill; flattened fragmentary specimen. (p.231)

Fig.3 Monograptus atàvus Jones, HUR./S5-9/27; atavus Zone, Spengill; flattened and compressed specimen superficially resembling M. incommodus (cf. fig.1). (p.231)

Fig.4 Monograptus limatulus Tornquist), HUR./9Wa/99; convolutus Zone, Watley Gill; proximal end in relief. (p.240)

Fig.5 Monograptus argenteus cygneus (Tornquist), HUR./6Bi/58; leptotheca Zone (= argenteus Zone) Birks Wood Beck; mesial fragment in low relief. (p.239)

Fig.6 Monograptus argenteus aff argenteus (Nicholson); HUR./6Bi/17; leptotheca (= argenteus Zone), Birks Wood Beck; specimen in low relief, but compressed. (p.238)

Fig.7 Monograptus argenteus cygneus (Tornquist), HUR./6Bi/13; leptotheca Zone (= argenteus Zone), Birks Wood Beck; specimen in relief with proximal extremity missing. (p.239)

Fig.8 Monograptus colonus colonus (Barrande), HUR./2W/128; nilssoni-scanicus Zone, Wandale Hill; specimen almost complete, in full relief. (p.243)

Fig.9 Monograptus roemeri (Barrande), HUR./1Y/14; nilssoni-scanicus Zone, Yarlside; fragmentary specimen in full relief. (p.245)

PLATE 28

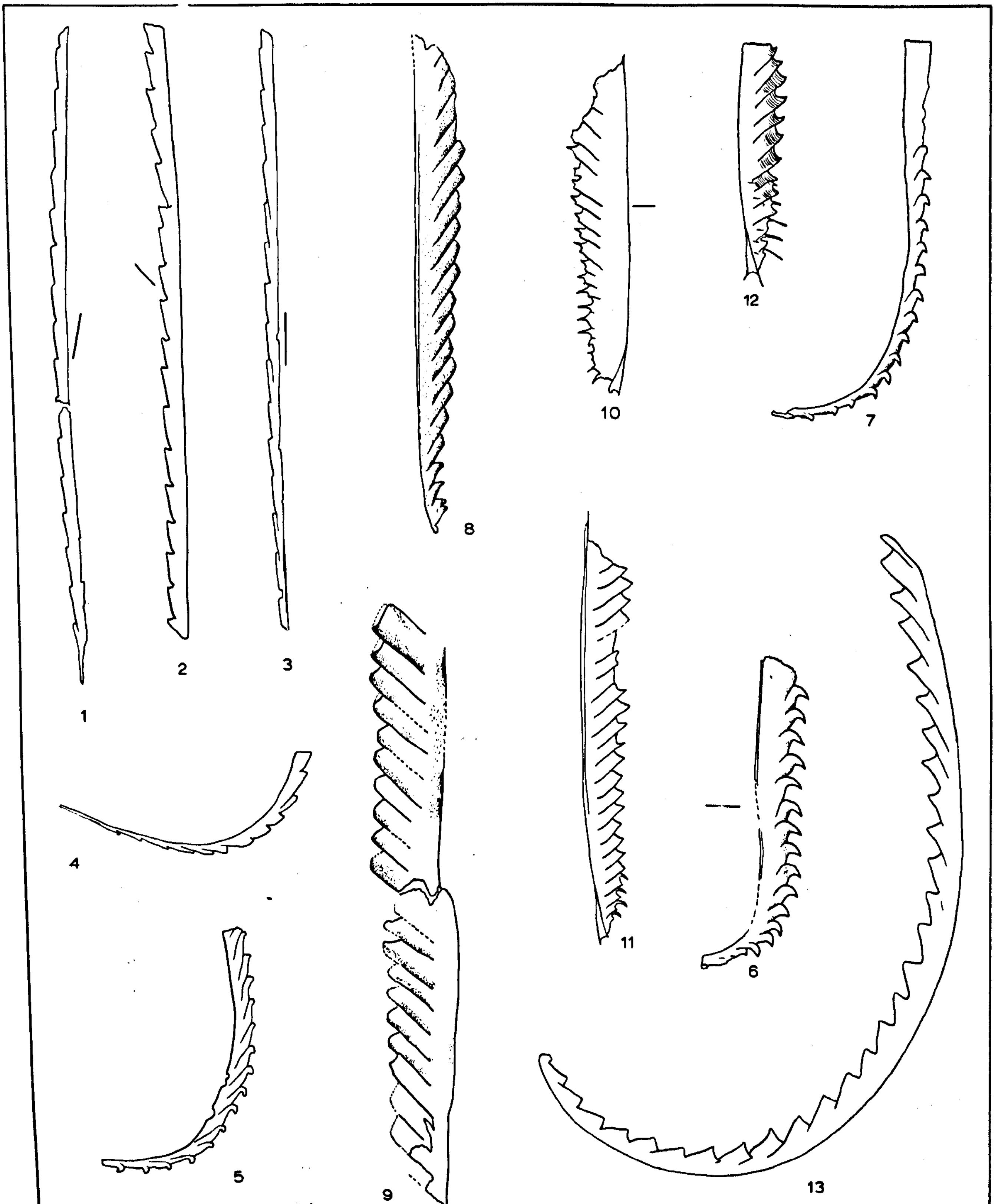

Fig.10 Monograptus c.chimaera (Barrande), HUR./6Bd/1; nilssoni-scanicus Zone; specimen in low relief, compressed. (p.247)

Fig.11,12 Monograptus leintwardinensis incipiens Wood, HUR./2W/125 and 211; nilssoni-scanicus Zone, Wandale Hill; specimens flattened. (p.252)

Fig.13 Pristiograptus bohemicus (Barrande), HUR./2W/198; nilssoni-scanicus Zone, Wandale Hill; large, well preserved but flattened specimen (p.227)

PLATE 29

All figs. x 10

Fig.1 Monograptus chimaera salweyi (Lapworth), HUR./2W/28; nilssoni-scanicus Zone, Wandale Hill; specimen in relief but spines poorly preserved. (p.249)

Fig.2 Monograptus leintwardinensis incipiens Wood, HUR./2W/133; Zone as fig.1; specimen flattened but showing proximal spines well developed. (p.252)

Fig.3 Monograptus varians pumilis Wood, HUR./2W/134; Zone as fig.1; specimen in relief but poorly preserved. (p.254)

Fig.4 Monograptus varians pumilis Wood, HUR./2W/144; Zone as fig.1; specimen flattened and somewhat compressed. (p.254)

Fig.5 Monograptus colomus colonus (Barrande), HUR./9W/6; Zone as fig.1; specimen well preserved and in full relief. (p.243)

Fig.6 Monograptus argenteus cygneus (Tornquist), HUR./S75,9 4/224; sedgwicki Zone, Spengill; distal fragment in full relief; (p.239)

Fig.7 Monograptus limatulus Tornquist, HUR./9Wa/58; convolutus Zone, Watley Gill; proximal end in full relief. (p.240)

PLATE 29

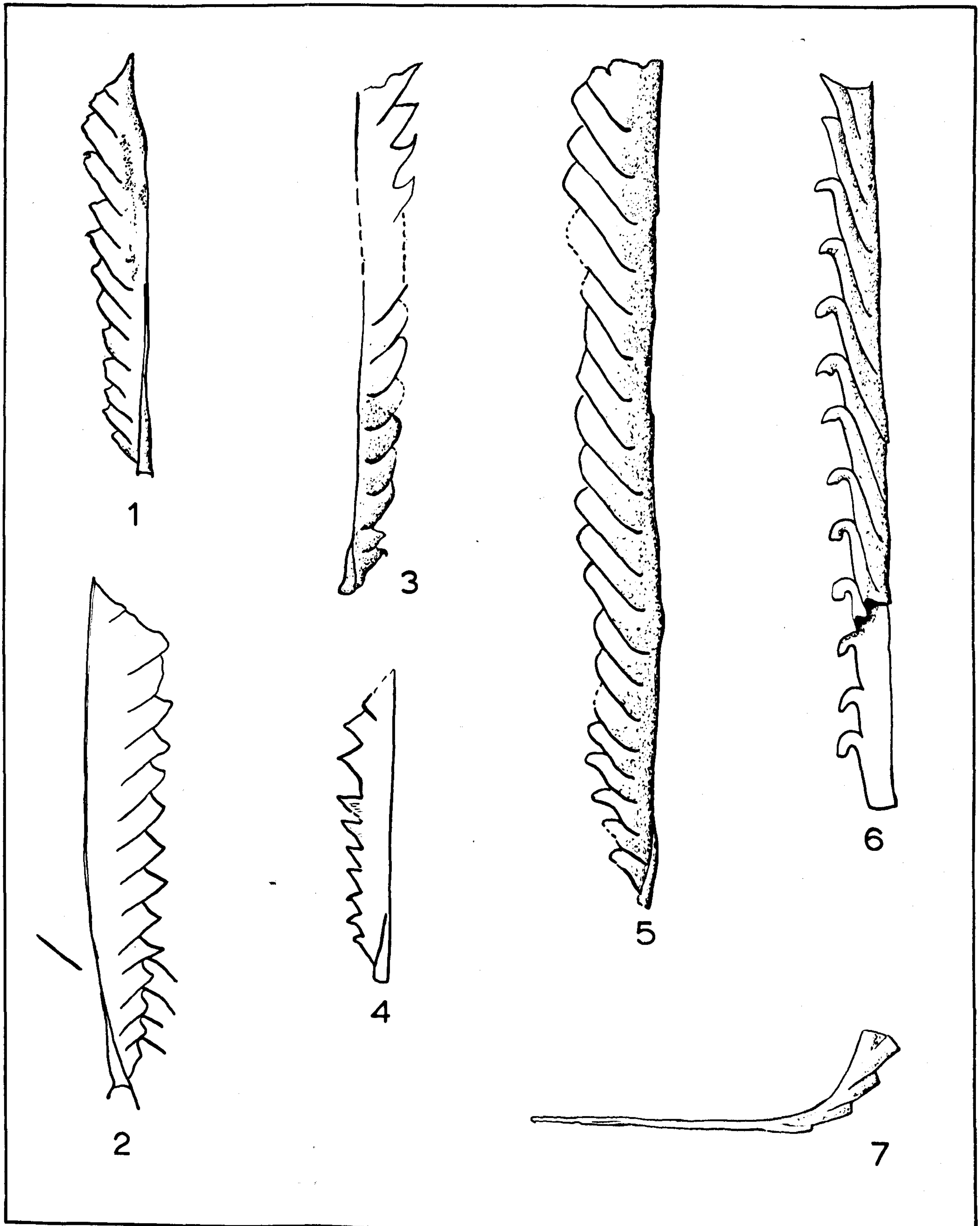

Plate 31 (continued)

Fig.11 Spengill; badly preserved specimen but showing full degree of spinosity. (p.274)

Fig.12 Monograptus irfonensis inclinatus subspl nov., holotype, (proximal end) HUR./39W/3; Wenlock Stage 2, riccartonensis Zone; specimens flattened and somewhat compressed. (p.260)

Fig.13 Monograptus halli (Barrande), HUR./S140,11/4; R.maximus Subzone, Spengill; specimen flattened. (p.274)

PLATE 30

All figs. x 10

Fig.1,2. Monograptus l.leintwardinensis Lapworth, HUR./1Ab/60 and 21; leintwardinensis Zone, Adamthwaite Bank; small flattened and compressed specimens. (p.250)

Fig.3,4. Monograptus l. aff incipiens Wood, HUR./1Ab/21 and 44; leintwardinensis Zone, Adamthwaite Bank; compressed specimens in full relief. (p.254)

Fig.5 Monograptus varians pumilis Wood, HUR./2W/243; nilssoni-scanicus Zone, Wandale Hill; flattened specimen. (p.254)

Fig.6 Monograptus ex. gr. elongatus Tornquist, HUR./S159,8 75/52; turriculatus Zone, Spengill; small fragment, flattened. (p.)

Fig.7,8,9,10,11. Monograptus gemmatus (Barrande), HUR./S94,7·4/40& 17; HUR./S219,0·25/22; HUR./166,8·5/113; HUR./S219,0·25/12; sedgwicki and turriculatus Zones, Spengill; all fragments either flattened or in low relief. (p.275)

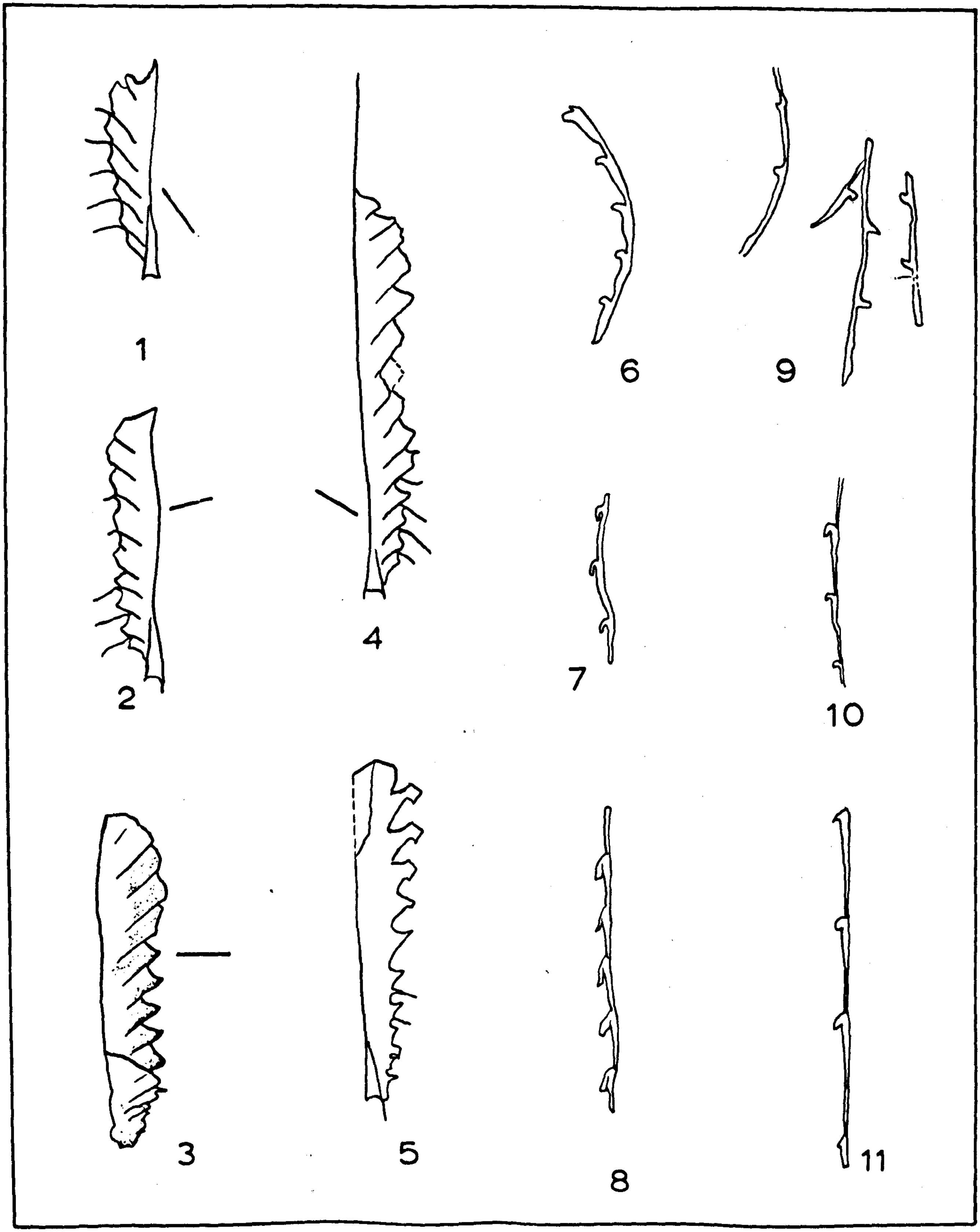
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PLATE 31

Fig.1 Monograptus knockensis Elles & Wood, HUR./S80,8 4/231; sedgwicki Zone, Spengill; specimen in low relief. (p.272) x 5

Fig.2 Monograptus "flemingii-priodon", HUR./15M/22; Wenlock Series, Stage 2, antennulatus Zone; poorly preserved, flattened and compressed fragment. (p.264) x 5

Fig.3 Monograptus flexilis belophorus (Meneghini), HUR./16M/20; f. belophorus Zone, Wenlock Stage 3, Middle Gill; flattened fragment. (p.268) x5.

Fig.4 Monograptus marri Perner, HUR./4Wi/56a; M.crispus Zone, Wards Intake; well preserved specimen in low relief. (p.270) x 2½

Fig.5 Monograptus priodon (Bronn)s.l. HUR./1M/75; Wenlock Stage 1, Middle Gill; specimen in low relief and compressed. (p.256) x 2½

Fig.6,7. Monograptus simulatus sp. nov. holotype (fig.7) HUR./28W/25, fig. 6 is HUR./4M/62; both from Wenlock Stage 1; preserved in relief. (p.279) x 5.

Fig.8 Monograptus flexilis belophorus (Meneghini), HUR./13M/74; Wenlock Stage 2, riccartonensis Zone; proximal end without sicula, badly preserved. (p.268)

Fig.9 Monograptus flemingii primus Elles & Wood, HUR./3W/34; Wenlock Stage 4; flattened and compressed specimen. (p.263)

Fig.10 Monograptus sedberghensis sp. nov. holotype, HUR./40W/1; Wenlock Series, riccartonensis Zone; flattened specimen but not strongly compressed. (p.265)

Fig.11 Monograptus halli (Barrande), HUR./S115,5/3; R.maximus subzone,

plate description continued prior to Pl.30

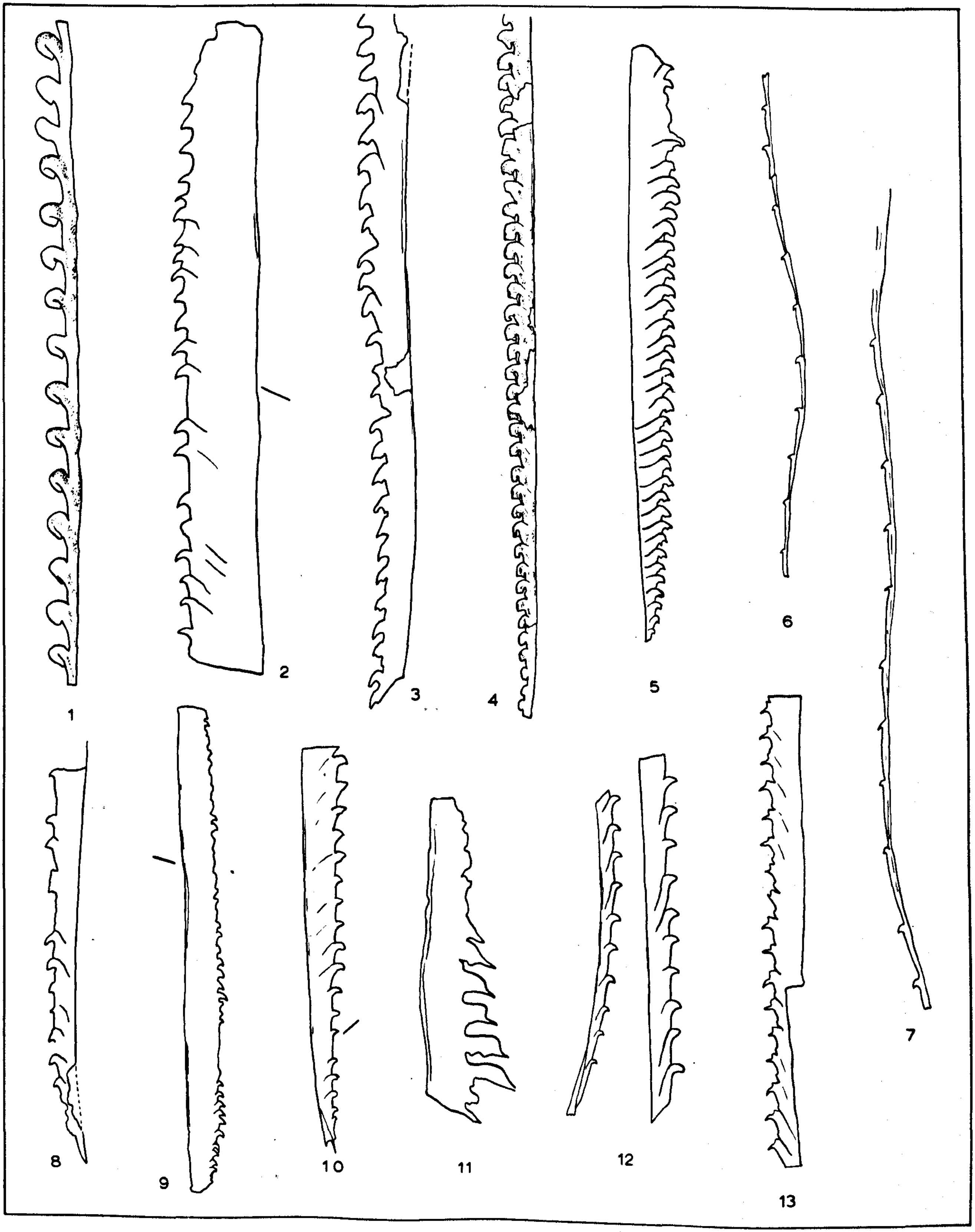
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PLATE 32

All figs. x 10 except fig. 9

Fig.1,2. Monograptus barrandei (Suess), HUR./S210,8/3 and HUR./S219,0·25 /18; turriculatus Zone, Spengill; both specimens flattened. (p. 278)

Fig.3 Monograptus sp. A HUR./5P/13; Wenlock Stage 1, Pickering Gill; specimen well preserved in full relief. (p.282)

Fig.4 Monograptus priodon (Bronn) s.l. HUR./28W/58; Wenlock Stage 1, Wandale Hill; specimen in full relief, shows unusually enrolled hooks. (p.256)

Fig.5 Monograptus minimus aff cautleyensis subsp. nov. HUR./1M/116; Wenlock Stage 1, Middle Gill; specimen in relief preserved partly as an external mould. (p.284)

Fig.6 Monograptus sedgwicki (Portlock), HUR./S94,7·4/54; sedgwicki Zone, Spengill; proximal end with sicula.(p.275)

Fig.7 Monograptus marri Perner, HUR./S233,3/23; crispus Zone, Spengill; specimen showing "pandus"-like appearance as a result of compression. (p.270)

Fig.8 Monograptus flemingii flemingii (Salter), HUR./3W/33; Wenlock Stage 4, Wandale Hill; well preserved but flattened proximal end. (p.262)

Fig.9 Monograptus simulatus sp. nov. HUR./28W/25, holotype; see also pl. 31,fig.7. x 7 approximately. (p.279)

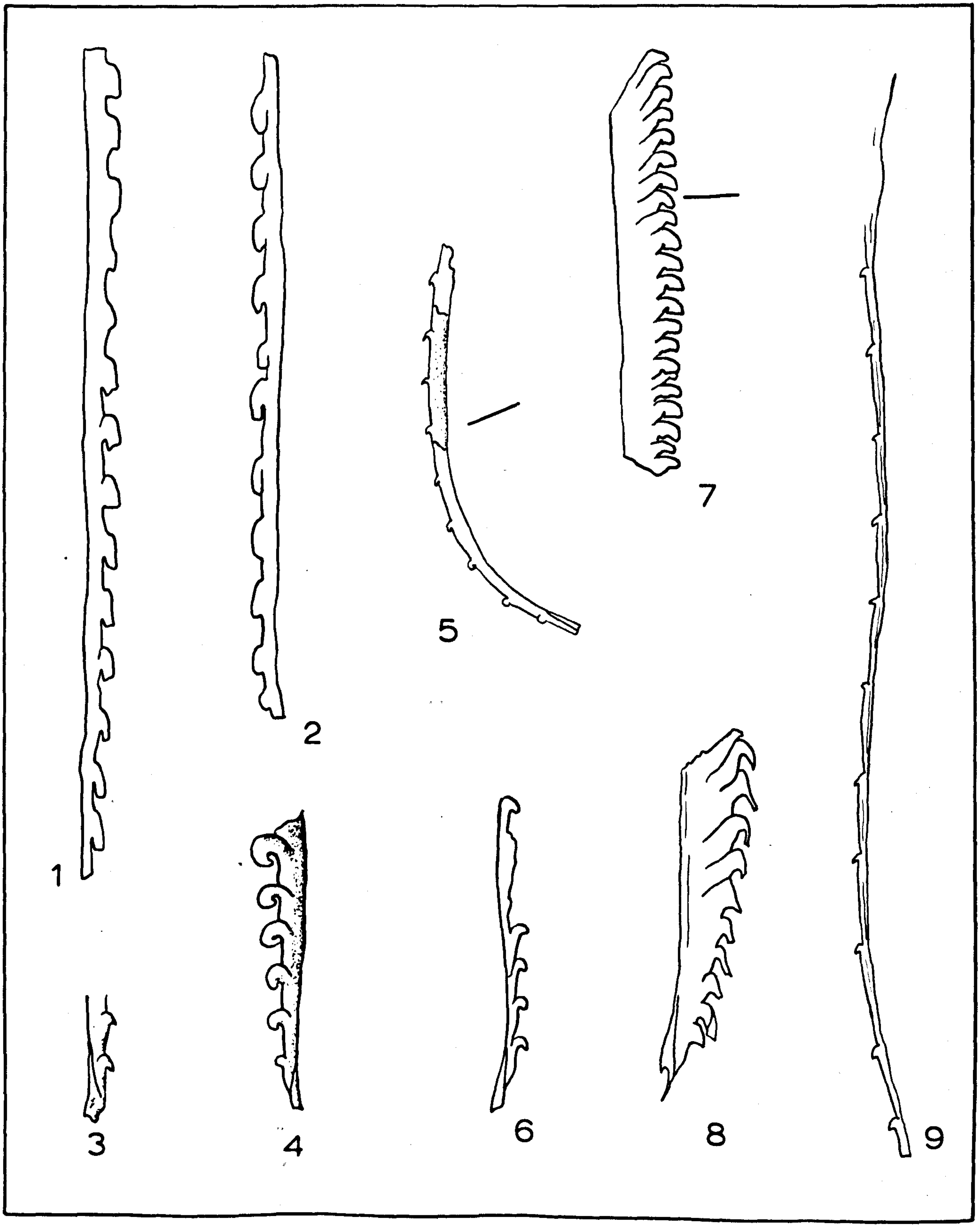
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PLATE 33

All figs. except 9, x 10

Fig.1,2. Monograptus minimus cautleyensis subsp. nov. holotype (fig.1) HUR /1M/50; fig.2 HUR./1M/117, paratype; Wenlock Stage 1, Middle Gill; specimens in relief. (p.284)

Fig.3 Monograptus danbyi sp. nov. holotype, HUR./8P/1; Wenlock Stage 1, Pickering Gill; specimen in relief. (p.294)

Fig.4 Monograptus marri Perner, HUR./4W/15; crispus Zone, Wards Intake; flattened proximal end. (p.270)

Fig.5 Monograptus? runcinatus pseudopertinax subsp. nov. holotype HUR. /S140,11/5; Subzone of R.maximus, Spengill; specimen in relief. (p.292)

Fig.6 Monograptus r.pseudopertinax subsp. nov. paratype, HUR./S115,5/24; Subzone R.maximus, Spengill; somewhat robust specimen in low relief. (p.292)

Figs.7-10. Monograptus pseudobecki Boucek & Pribyl, HUR./S115,5/31; HUR. /S115,5/12; HUR./S115,5/ ; R.maximus Subzone, Spengill; specimens in relief. (fig.9 about x 20) (p.290)

Fig.11 Monograptus exiguus (Nicholson), HUR./S197,5·5/11; turriculatus Zone, Spengill; specimen flattened and compressed. (p.289)

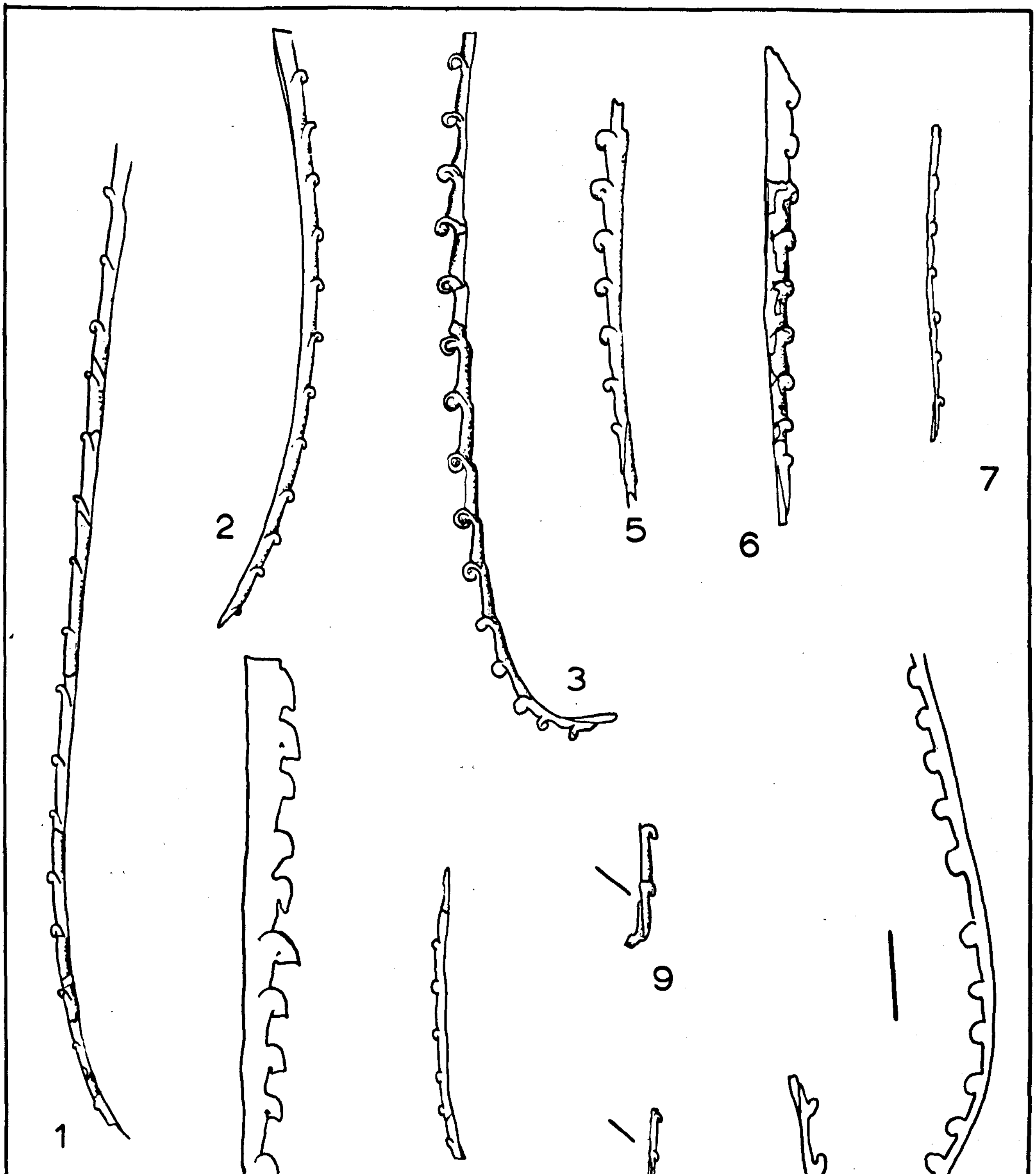
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PLATE 34

All figs. x 10

Fig.1 Monograptus triangulatus fimbriatus (Nicholson), HUR./9Bi/33; magnus Zone, Birks Wood Beck; proximal end in low relief, with sicula. (p.313)

Fig.2 Monograptus triangulatus separatus (Sudbury), HUR./7Bi/2; ?triangulatus Zone, Birks Wood Beck; specimen in low relief preserved in part as an external mould. (p.299)

Fig.3 Monograptus triangulatus separatus (Sudbury), HUR./S24-28/511; triangulatus Zone, Spengill; variant approaching M.t.triangulatus; preserved in relief partly as an external mould. (p.299)

Fig.4 Monograptus proteus (Barrande), HUR./S231,2/11; crispus Zone, Spengill; specimen flattened and compressed. (p.311)

Fig.5 Monograptus c.communis Lapworth, HUR./6Bi/38; Zone of leptotheca, Birks Wood Beck; specimen in full relief. (p.305)

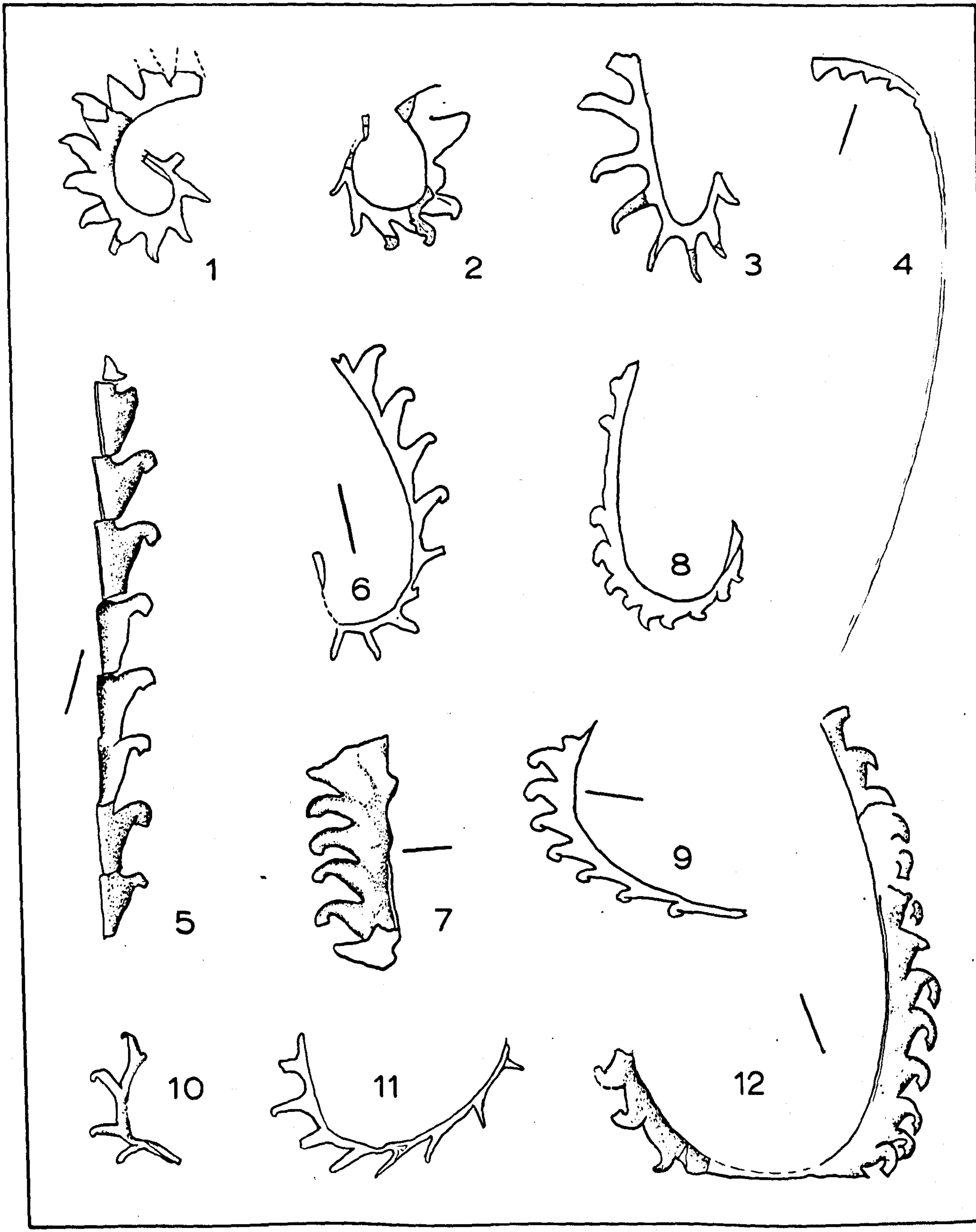
Fig.6 Monograptus denticulatus Tornquist, HUR./5Bi/35; convolutus Zone, Birks Wood Beck; specimen in low relief. (p.303)

Fig.7 Monograptus c.communis Lapworth, HUR./S73,11·4/11; sedgwicki Zone Spengill; distal thecae in full relief, strongly compressed. (p. 305)

Fig.8 Monograptus difformis ?subsp., HUR./S80,8·4/261; sedgwicki Zone, Spengill; proximal end in low relief. (p.241)

Fig.9 Monograptus planus (Barrande), HUR./S159,8·75/37; turriculatus Zone, Spengill; specimen flattened and compressed. (p.309)

Fig.10 Monograptus denticulatus Tornquist, HUR./10Wa/4; convolutus Zone,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Watley Gill; proximal end in full relief. (p.303)

Fig.11 *Monograptus decipiens* Tornquist, HUR./9Wa/60; *convolutus* Zone, Watley Gill; proximal fragment in low relief. (p.302)

Fig.12 *Monograptus communis obtusus* subsp. nov. paratype, HUR./S73,11·4/113; *sedgwicki* Zone, Spengill; specimen in relief, somewhat compressed. (p.307)

PLATE 35

All figs. x 5

Fig.1 Monograptus proteus (Barrande), HUR./S177,8·25/6; turriculatus Zone, Spengill; mesial compressed and flattened fragment. (p.317)

Fig.2,3. Monograptus decipiens Tornquist, HUR./11Wa/3; HUR./9Wa/3; convolutus Zone, Watley Gill; specimens in low relief. (p.302)

Fig.4 Monograptus decipiens Tornquist, HUR./9Wa/65; Zone as figs.2,3; thecae partially flattened. (p.302)

Fig.5,9. Monograptus antennulatus Meneghini, HUR./7Wh/15 & 5; Wenlock Series, Whinny Gill; specimens flattened. (p.287)

Fig.6 Monograptus communis rostratus Elles & Wood, HUR./6Wa/1; ?magnus Zone, Watley Gill; specimen preserved in relief. (p.306)

Fig.7 Monograptus convolutus (Hisinger), HUR./10Wa/4; convolutus Zone, Watley Gill; proximal rastritiform fragment associated with a distal fragment. (p.301)

Fig.8 Monograptus triangulatus major Elles & Wood, HUR./S36-39,7/68; triangulatus Zone, Spengill; somewhat distorted specimen in relief but preserved as an external mould. (p.300)

Fig.10 Monograptus crispus Lapworth, HUR./S248,10·25/20; crispus Zone, Spengill; flattened specimen. (p.286)

Fig.11 M.t.triangulatus (Harkness), HUR./S24-28/224; triangulatus Zone, Spengill; flattened and compressed specimen. (p.297)

Fig.12 Monograptus sp. B, HUR./S197,5·5/11; turriculatus Zone, Spengill; specimen preserved as a flattened and compressed film. (

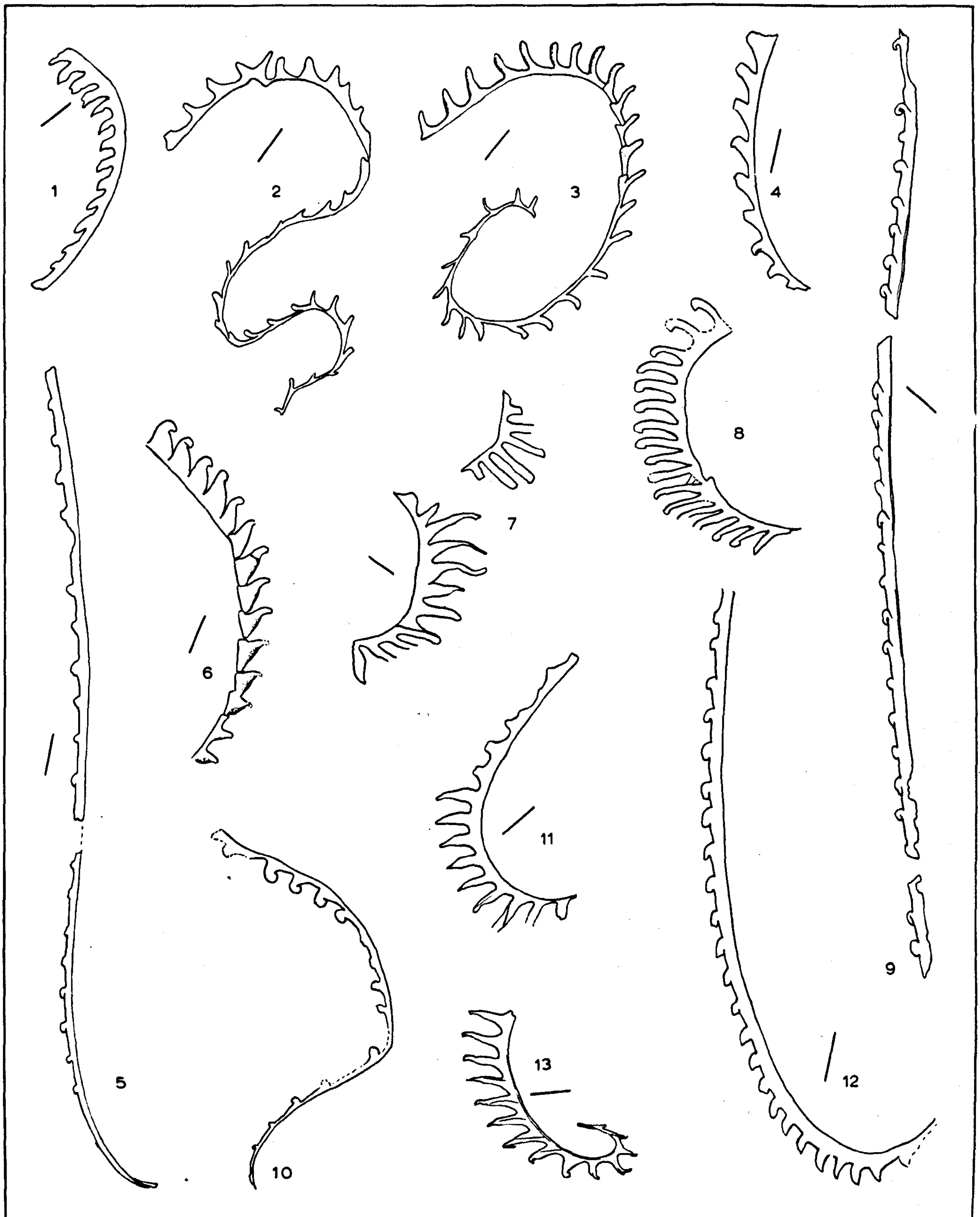
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Fig.13 _Monograptus triangulatus separatus_ (Sudbury), HUR./S24028/512; _tri-angulatus_ Zone, Spengill. (p.299)

PLATE 36

All figs. x 10

Figs. 1-4 Monograptus fragilis sp. nov. holotype (fig.1, longest fragment) HUR./S24-28/29; others HUR./9Bi/25; holotype, Zone of triangulatus, Spengill; others magnus Zone, Birks Wood Beck; all specimens in low relief. (p.340)

Figs.5-6. Monograptus angustus sp. nov. holotype (fig.5) HUR./S140,11/4; Subzone of R.maximus, Spengill; specimen in relief; fig.6 HUR./S73,11·4/58; sedgwicki Zone, Spengill; specimens in relief. (p.338)

Fig.7 Monograptus sp. D, HUR./S73,11·4/42; sedgwicki Zone, Spengill; specimen in full relief. (p.304)

Fig.8 Monograptus c.communis Lapworth, HUR./S73,11·4/15; sedgwicki Zone, Spengill; specimens preserved in relief. (p.305)

Fig.9 ?Monograptus sp. G, HUR./S75,9·4/47; sedgwicki Zone, Spengill; very poorly preserved flattened fragment. (p.342)

Fig.10 Monograptus sp. C, HUR./S219,0·25/18; turriculatus Zone, Spengill; badly preserved specimen preserved as a flattened film. (p.342)

Fig.11 Rastrites cf. hybridus Lapworth, HUR./S80,8·4/110; sedgwicki Zone, Spengill; fragmentary specimen preserved in relief.

Fig.12 Rastrites spina (Richter), HUR./9Wa/45; convolutus Zone, Watley Gill; proximal end in full relief with sicula preserved. (p.321)

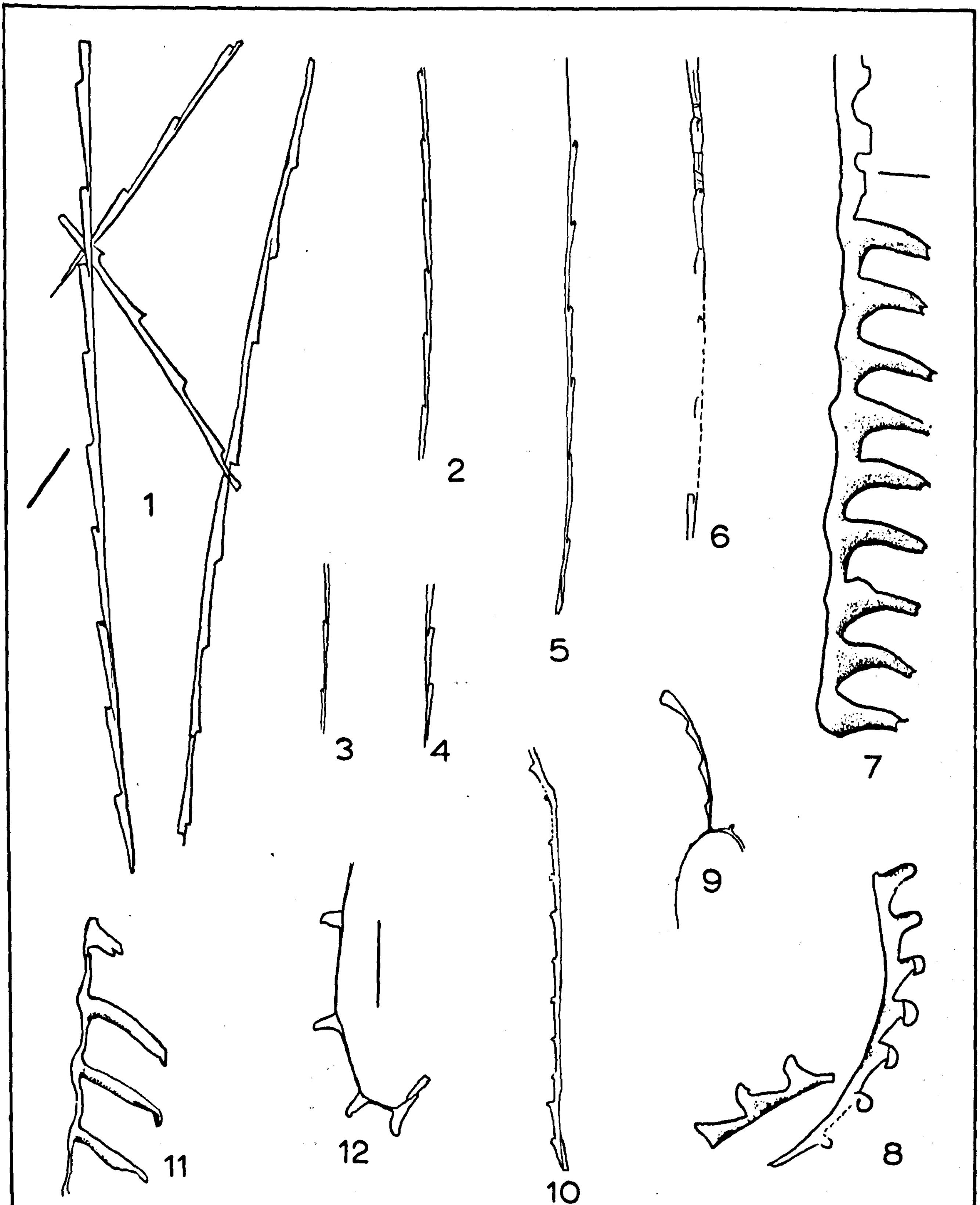
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PLATE 37

All figs. x 5 except fig.12

Fig.1 *Monograptus sp.* (not described), HUR./S173,6/7; *turriculatus* Zone, Spengill; flattened specimen in which apertural region appears to be isolated but not hooked.

Fig.2 *Monograptus aff involutus* (Lapworth), HUR./9Wa/87; *convolutus* Zone, Watley Gill; associated with proximal slender fragments possibly assignable to same form. (p.341)

Fig.3 *Rastrites spina* (Richter), HUR./10Wa/4; *convolutus* Zone, Watley Gill; proximal end in relief. (p.321)

Fig.4 *Rastrites equidistans spengillensis* subsp. nov. holotype HUR./S197, 5 5/11; *turriculatus* Zone, Spengill; part of a long specimen preserved as a film. (p.319)

Fig.5 *Rastrites linnaei* Barrande, HUR./S136,1 25/2; Subzone of *R.maximus* Spengill; specimen flattened. (p.317)

Fig.6,7. *Rastrites maximus* (Carruthers), HUR./S115,5/46 & HUR./S123,7·25/19; Subzone of *R.maximus*, Spengill; specimens preserved in low relief. (p.316)

Fig.8 *Rastrites fugax* Barrande, HUR./9Wa/102; *convolutus* Zone, Watley Gill; very poorly preserved specimen. (p.322)

Fig.9,11. *Rastrites sp. B*, HUR./S24-28/513 and HUR./S36-39,7/36; *triangulatus* Zone, Spengill; strongly compressed specimens; fig.9flattened and fig.11 in low relief. (p.323)

Fig.10 *Rastrites longispinus* (Perner), HUR./S24-28/514; *triangulatus* Zone Spengill; specimen flattened and compressed. (p.318)

PLATE 37

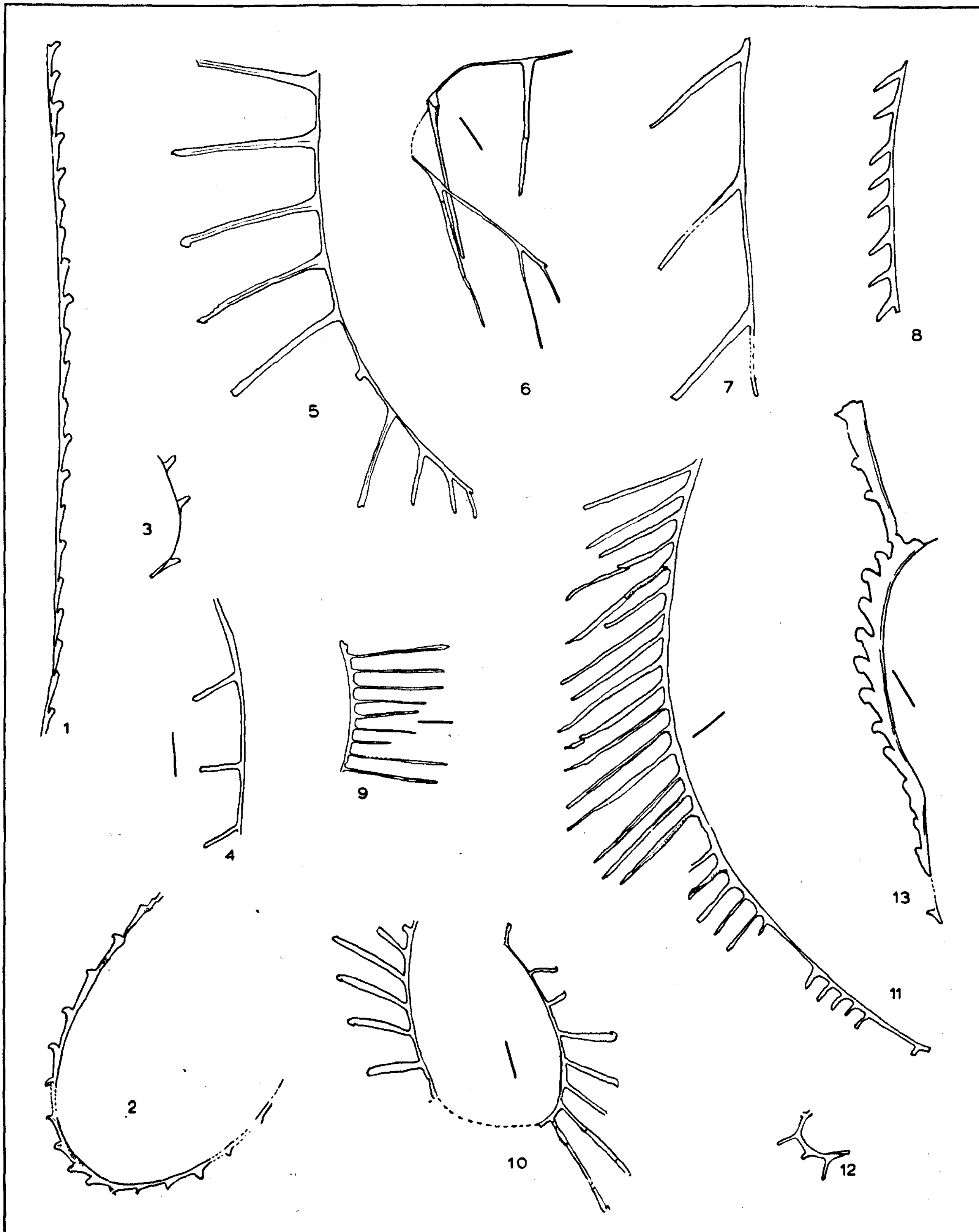

Fig.12 Rastrites sp. A, HUR./S75,9 4/225; sedgwicki Zone, Spengill; small proximal end x 20 approximately. (p.323)

Fig.13 Cyrtograptus cf. ellesi Gortani, HUR./12Ra/11; Wenlock Series, ?Zone of C.ellesi, Ecker Secker Beck; badly preserved, flattened specimen. (p.332)

PLATE 38

Fig.1 Barrandeograptus pulchellus (Tullberg), HUR./30W/6; Wenlock Series, Stage 2, Wandale Hill; specimen flattened. x 5 (p.337)

Fig.2,3. Cyrtograptus centrifugus Boucek, HUR./28W/115 and 109; Wenlock Stage 1, Wandale Hill; specimens in relief. x 2½ (p.327)

Fig.4 Cyrtograptus rigidus mut. HUR./16N/289; Zone of C.rigidus mut. Near Gill; specimen flattened. x 2½ (p.331)

Fig.5,6 Cyrtograptus rigidus mut. HUR./16N/307; Zone as fig.4; proximal ends showing early thecae and sicula. x 5 (p.331)

Fig.7 Cyrtograptus aff insectus Boucek, HUR./28W/35; Wenlock Stage 1, Wandale Hill; specimen in full relief but with proximal end missing. x 2½ (p.329)

Fig.8 Cyrtograptus linnarssoni Tullberg, HUR./16N/153; Zone as fig.4; specimen showing branching. x 10 (see also text fig. no.10) (p.333)

Fig.9 Cyrtograptus linnarssoni Tullberg, HUR./16N/177; Zone as fig.4; sketch of general form X1. (thickness of line not to scale). (p.333)

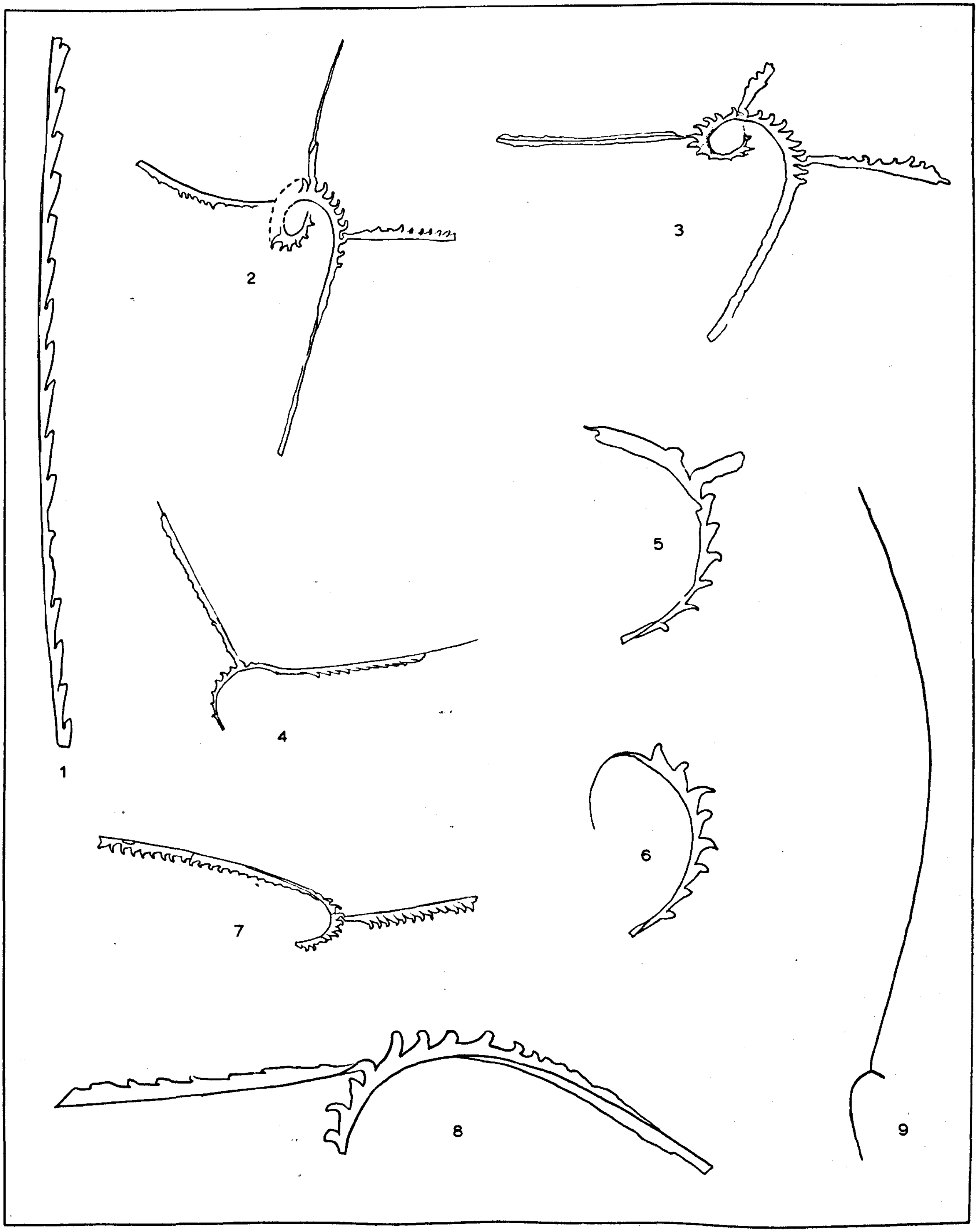
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PLATE 39

Fig.1 "Phacops" sp. HUR./1D/307; Basal Ludlow Limestone, Cross Keys; internal mould of large glabella and portions of fixigenae, dorsal view. x 2½

Figs.2,3, ?"Phacops" sp. HUR./1D/43a, and HUR./1D/222; locality as fig. 1; internal moulds of pygidial fragments. x 2½

Figs.4-7,9 Struveria torvus gen. et sp. nov. pygidia variously flattened and distorted, respectively HUR./1D/161a (internal mould), HUR./1D /161 (latex cast, external mould); HUR./1D/382 (internal mould of fragmentary pygidium); HUR./D1/197 (internal mould of compressed pygidium); HUR./1D/383 (internal mould); all figs. x 2½. (p.357)

Fig.8 Struveria torvus gen et sp. nov., HUR./1D/1; incomplete headshield, latex cast of external mould x 2½ (p.357)

PLATE 39

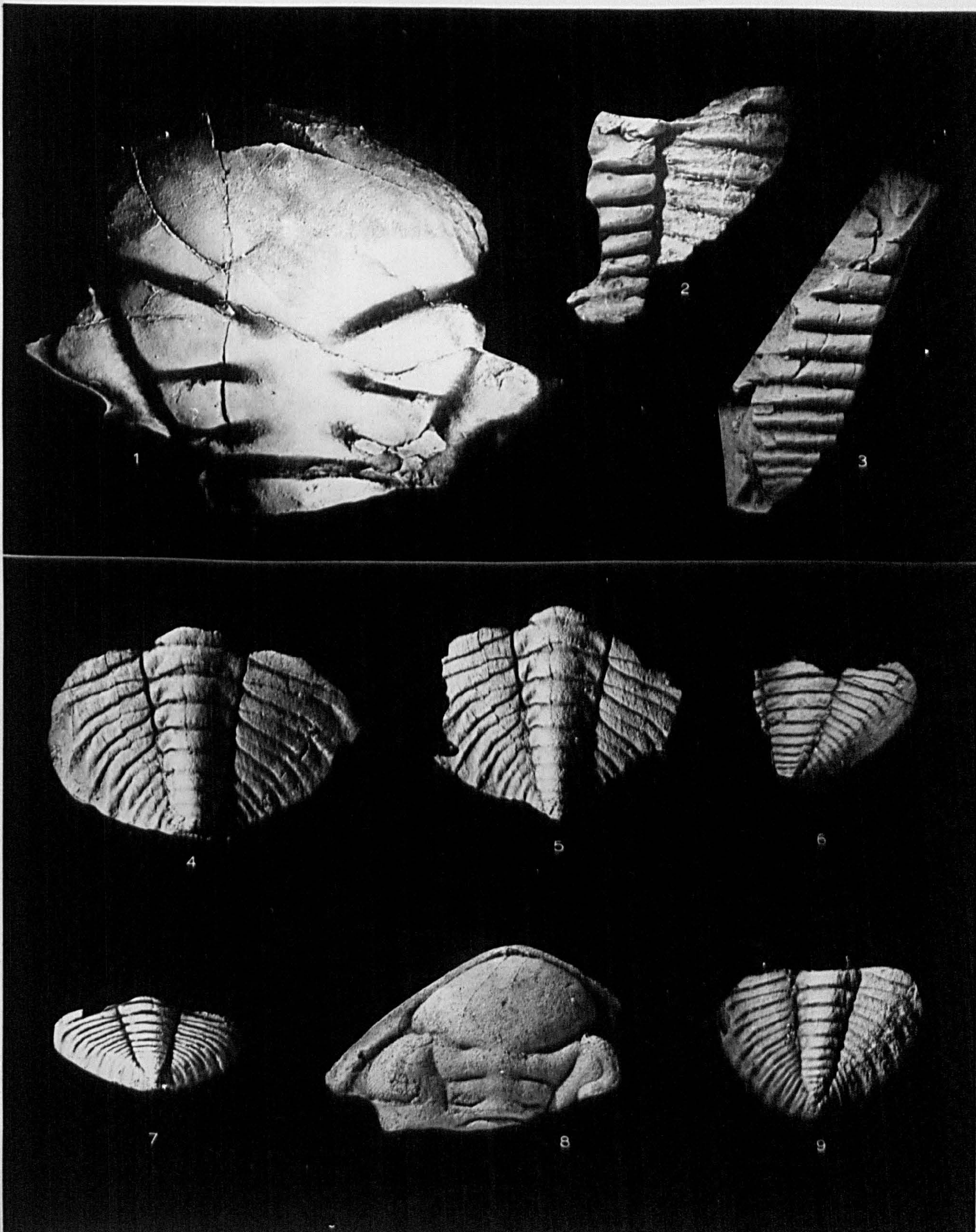

PLATE 40

Fig.1 Delops o. obtusicaudatus (Salter), gen. nov. lectotype, Sedgwick Museum, A38682; internal mould of incomplete, badly preserved cephalon; figured by Salter (1855) as pl.1G, fig.15. x3 (p.352)

Fig.2 Delops obtusicaudatus howgillensis gen. et subsp. nov. paratype, well preserved internal mould of incomplete cephalon; Sedgwick Museum A38678; locality: north side of Helm Knott. x 3 (p.354)

Fig.3 Delops o. obtusicaudatus (Salter); gen. nov. badly preserved internal mould of pygidium; British Museum specimen number In 55901. x 3 (p.352)

Fig.4a,b. Delops o. obtusicaudatus (Salter) gen. nov.; pygidium (4a) associated with pygidium of fig.3 but compressed in a different sense. Fig.4a is a latex cast of an external mould. B.M. no. In 55901. x3 (p.352)

Figs.5,6, Delops o. howgillensis gen et subsp. nov.; respectively internal mould (HUR./1D/177a) and external cast (latex cast of HUR./1D/177); Basal Ludlow limestone, Cross Keys, Cautley. x $2\frac{1}{2}$ (p.354)

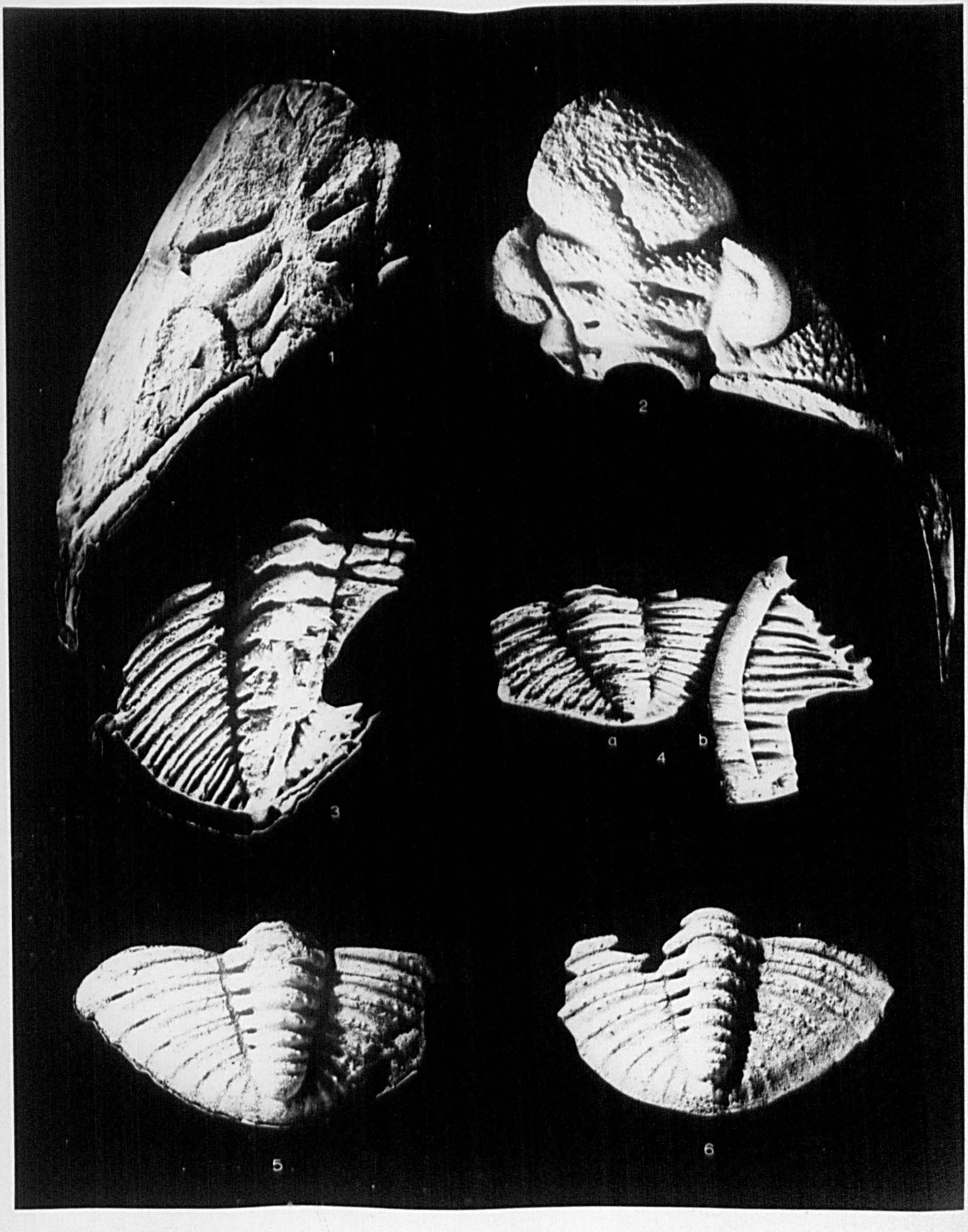
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PLATE 41

Fig.1 Delops o. howgillensis gen. et subsp. nov. holotype, HUR./1D/384; almost complete head shield, internal mould. x 2½ (p.354)

Fig.2 Delops o. howgillensis gen. et subsp. nov. plasto-type; latex cast of external mould showing eye lenses and glabellar furrows. HUR./1D /6; x 2½ (p.354)

Fig.3 Delops o. howgillensis gen. et subsp. nov. paratype; external mould showing nature of tuberculation and 1p and 2p furrows. HUR./1D/385; x 2½ (p.354)

Figs.4-9 Struveria torvus gen. et sp. nov. holotype is fig.4, latex cast of external mould of HUR./1D/260; figs.5-9 are respectively: HUR. /1D/192 (internal mould); Sedgwick Mus. A41025a; HUR./1D/193 (internal mould of almost complete cephalon); HUR./1D/208 (internal mould); HUR./1D/301 (internal mould). x 2½ (p.357)

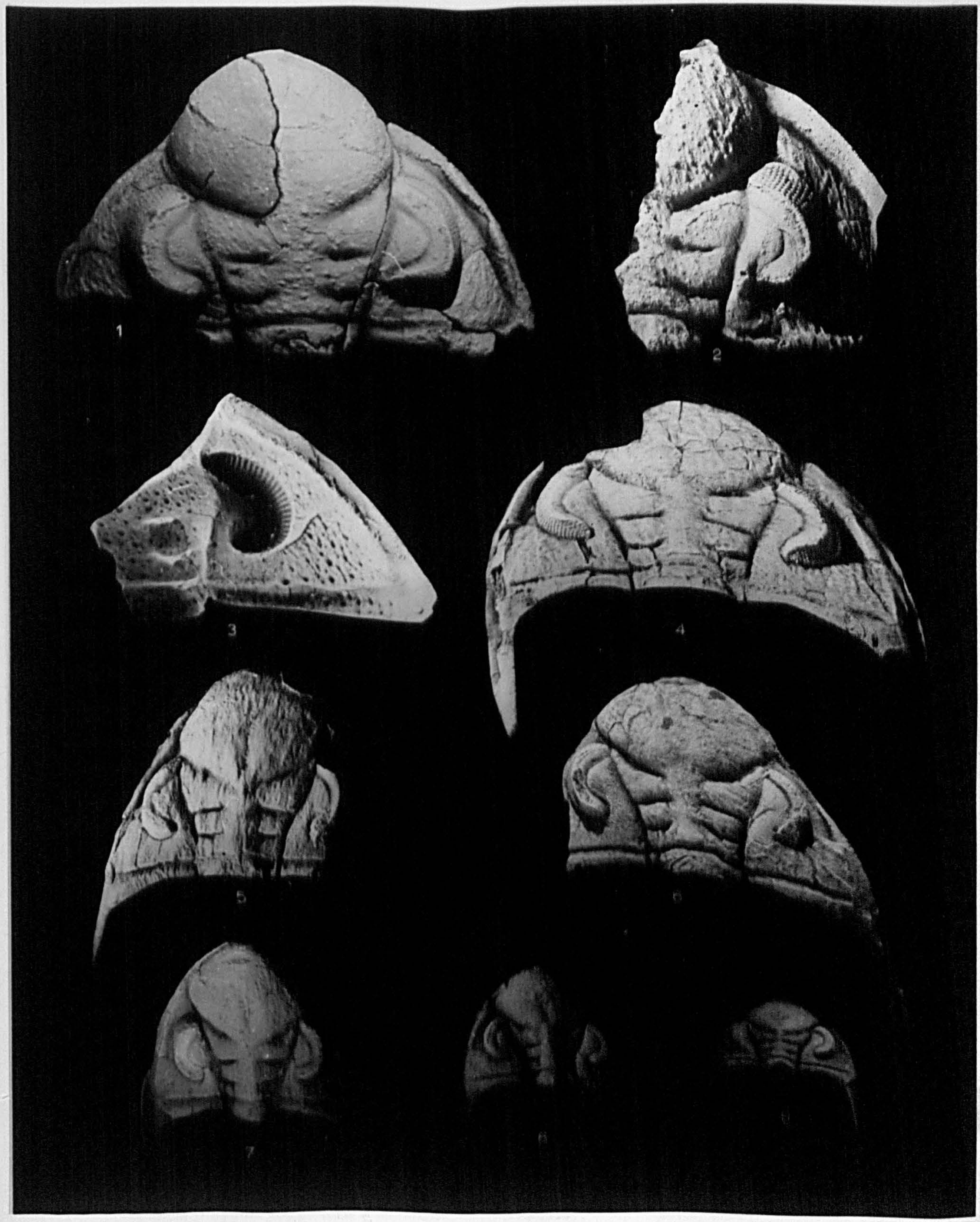
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PLATE 42

Fig.1 Odontopleura hughesi (Lake), HUR./1C/1; internal mould of complete specimen; nilssoni-scanicus Zone, Clough River; x 2½ (p.360)

Fig.2 Odontopleura hughesi (Lake), S.M. A35521 (counterpart of A373,66); internal mould of glabella showing pair posterior spines. x 2½ (p.360)

Fig.3 Odontopleura hughesi (Lake), S.M. A35519a; internal mould of thorax. x 2½ (p.360)

Fig.4 Odontopleura hughesi (Lake), lectotype, S.M. A37135a; badly preserved internal mould figured by Lake (1896) pl.8,fig.4. x 2½ (p.360)

Fig.5,6. Delops o. howgillensis gen. et subsp. nov. HUR./1D/19; young specimen, internal mould of cephalon; fig.5 dorsal view; fig.6 anterio-lateral view showing manner in which frontal lobe transgresses frontal margin. x 2½ (p.354)

Fig.7 Odontopleura hughesi (Lake), S.M. A35516a; internal mould of almost complete specimen showing an abnormal pygidium in which a thoracic pleural segment is developed. x 2½ (p.360)

Fig.8 Delops o. howgillensis gen. et subsp. nov. HUR./1D/7; young specimen showing glabellar tuberculation, latex cast of external mould. x 2½ (p.354)

Fig.9 Struveria torvus gen. et sp. nov. HUR./1D/3; young specimen showing typical glabellar furrows. x 2½ (p.357)

Fig.10 Delops o. howgillensis gen. et subsp. nov. HUR./1D/258; latex cast of external mould of young pygidium. x 2½ (p.354)

Fig.11 Delops o. howgillensis gen. et subsp. nov. HUR./1D/18; glabella of

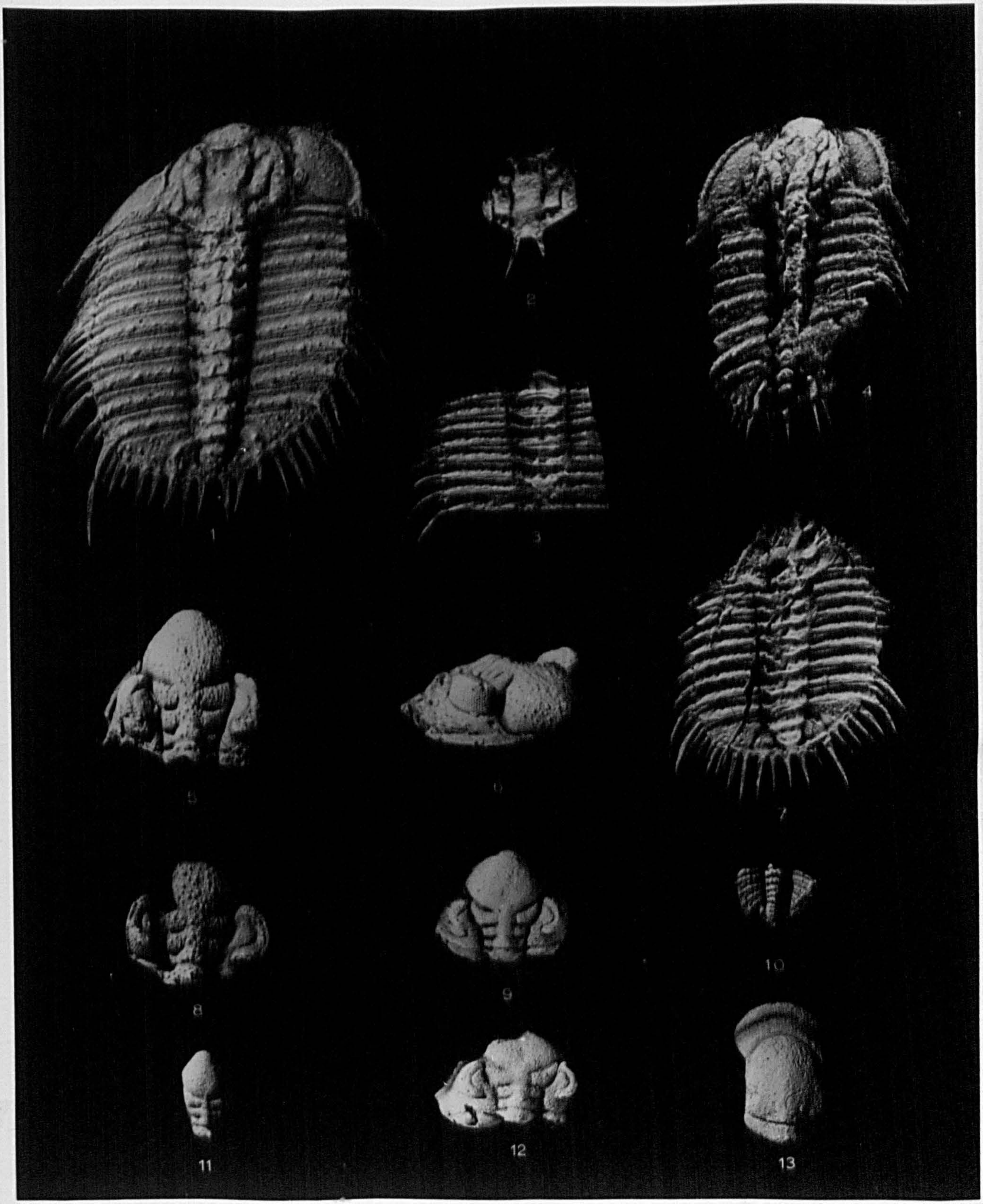
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Fig.11 young specimen, latex cast of external mould; tuberculation may be contrasted with fig.8. x2½ (p.354)

Fig.12 *Struveria torvus* gen. et sp. nov. HUR./1D/35; latex cast of external mould of young individual showing fine tuberculation. x 2½ (p.357)

Fig.13 *Decoroproetus sp.* HUR./1D/305, not described; internal mould of glabella. x 2½

PLATE 43

Figs.1-5,9 Decoroproetus sp. (not described), 1-5 are internal moulds, 8 an external mould of 5; specimens are, respectively, HUR./1D/386; HUR./1D/387; HUR./1D/388; HUR./1D/389 & a; HUR./1D/390 and 390a.

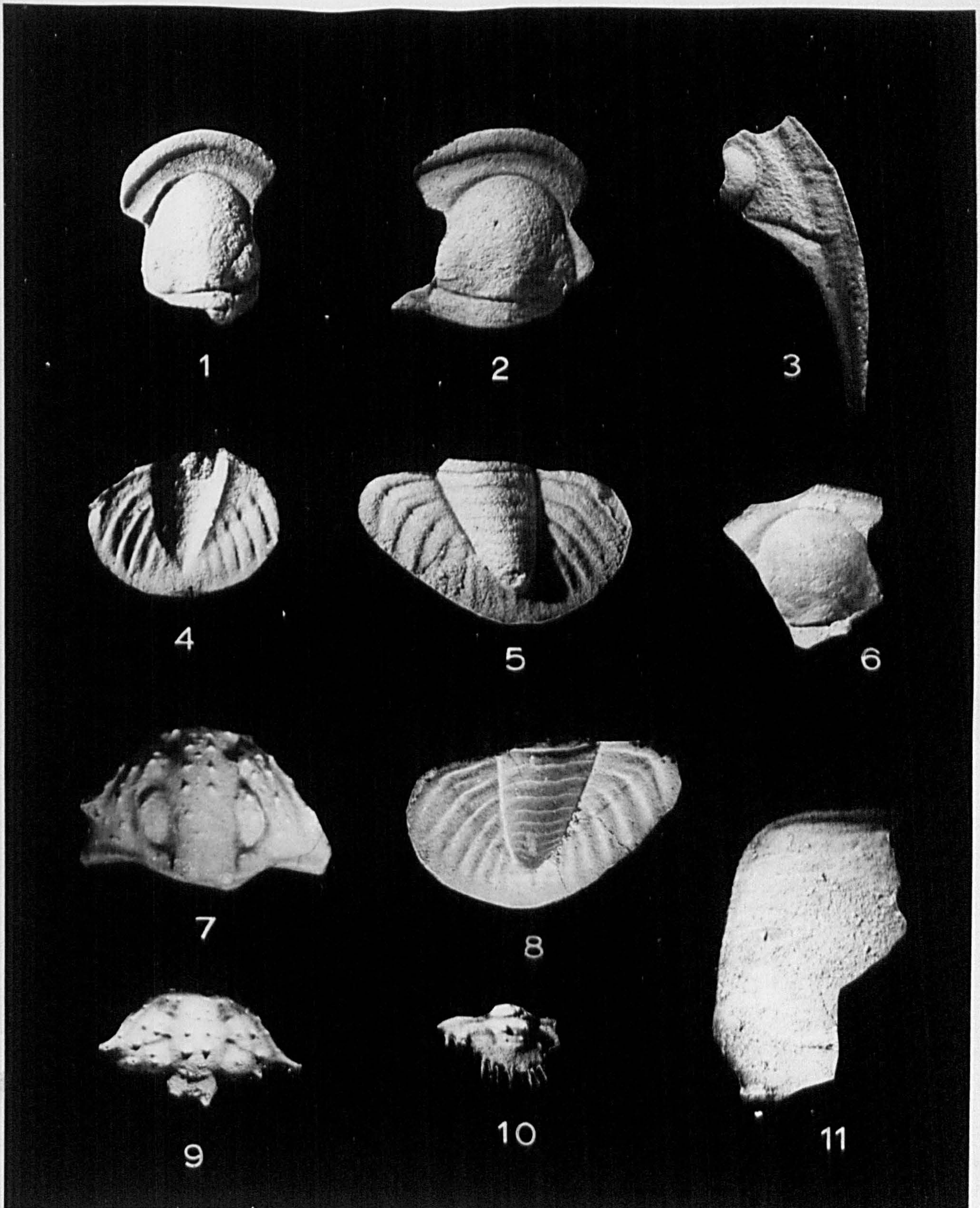
Fig.6 ?Decoroproetus sp. HUR./1D/97; internal mould x5.

Fig.7 Miraspis sp. HUR./1D/391; internal mould. x 5

Fig.9 Miraspis sp. HUR./1D/392; internal mould showing eye stalks. x 5.

Fig.10 Miraspis sp. HUR./1D/393; internal mould of pygidium. x 5

Fig.11 ??Homalonotus sp. HUR./1D/394; ?glabella, internal mould.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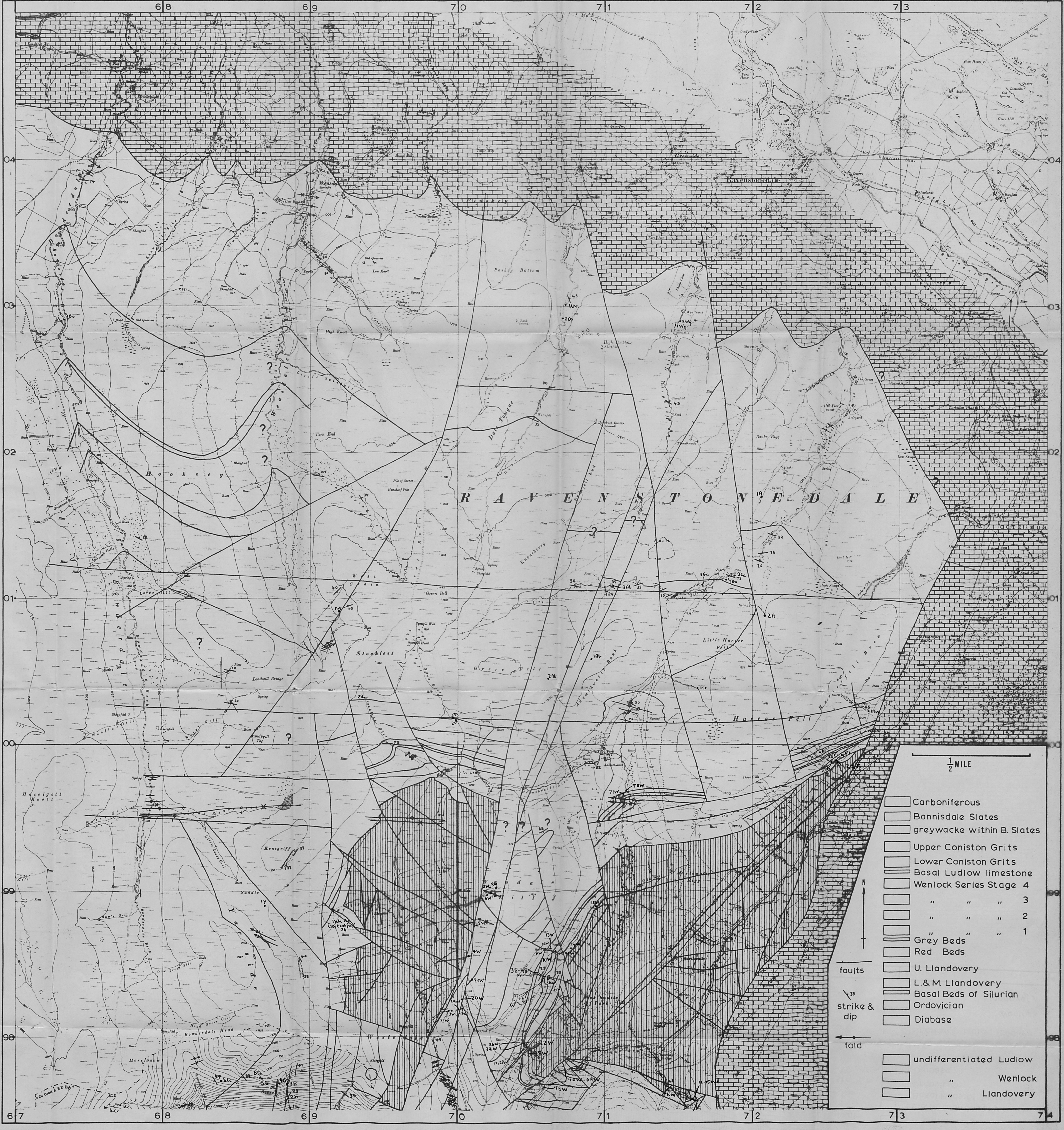
R A V E N S T O N E D A L E
H o o k s e y
Harter Fell
Stockless
Green Bell
Little Harter Fell
Leathgill Bridge
Posken Bottom
High Knott
Turn End
Hazelgill Knott
Bowderdale Head
½ MILE
Carboniferous
Bannisdale Slates
greywacke within B. Slates
Upper Coniston Grits
Lower Coniston Grits
Basal Ludlow limestone
Wenlock Series Stage 4
" " " 3
" " " 2
" " " 1
Grey Beds
Red Beds
U. Llandovery
L.& M. Llandovery
Basal Beds of Silurian
Ordovician
Diabase
faults
strike & dip
fold
undifferentiated Ludlow
" Wenlock
" Llandovery
N
67
68
69
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72
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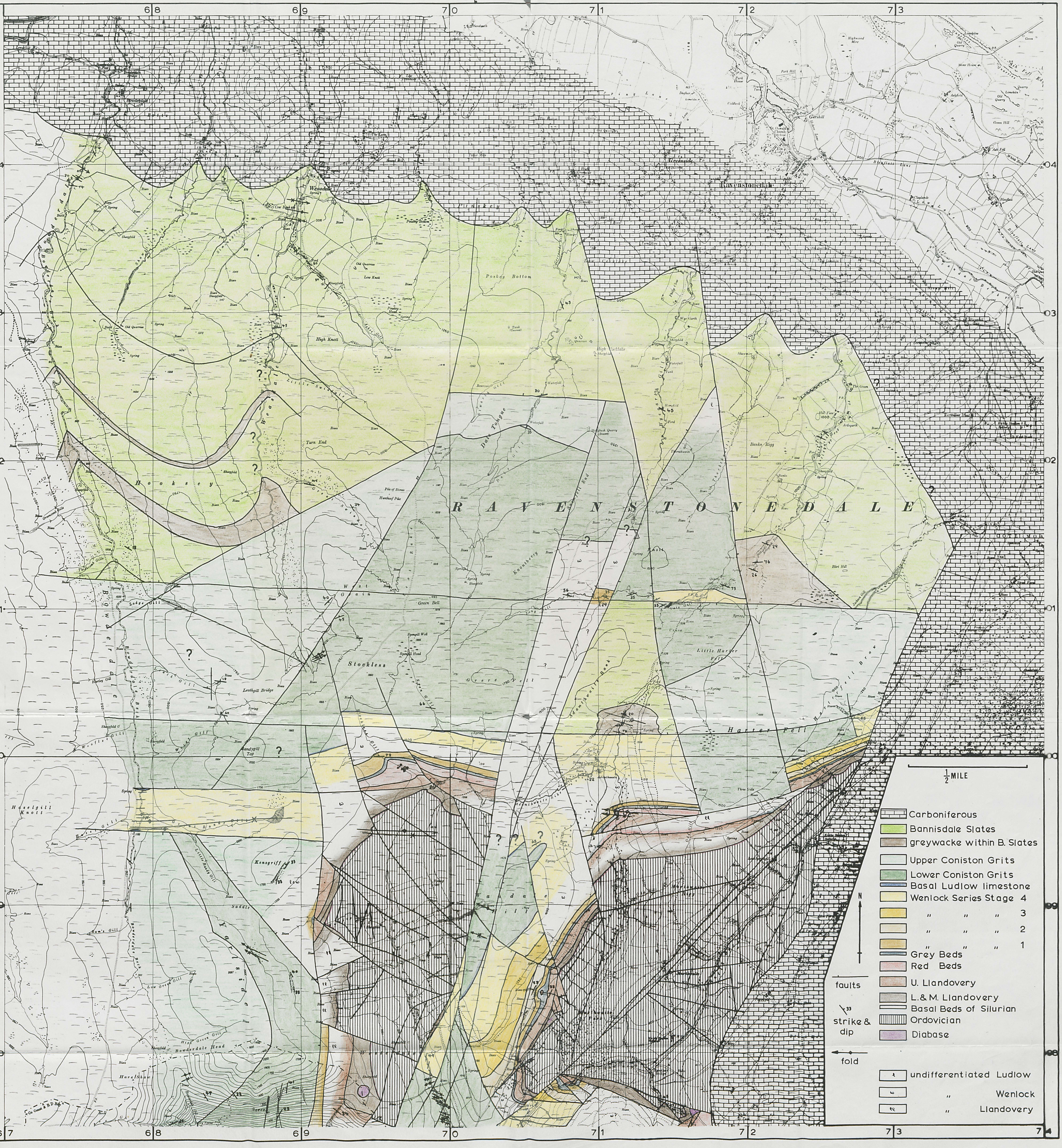
LOCALITY MAP, SOUTH

Carboniferous
?Carboniferous conglomerate
Bannisdale Slates
a leintwardinensis Zone, base
greywacke within B. Slates
b nilssoni-scanicus Zone, top
Upper Coniston Grit
Lower Coniston Grit
Basal Ludlow limestone
Wenlock Series Stage 4
" " Stage 3
" " Stage 2
" " Stage 1
Grey Beds
Red Beds
U. Llandovery
L. & M. Llandovery
Basal Beds of Silurian
Ordovician
Felsite
Diabase
undifferentiated Ludlow
" Wenlock
" Llandovery
1/2 MILE
faults
strike & dip
plunging fold
? doubtful relationships
N
BRANT FELL
Bland
SEDBERGH
BLUECASTER
sedbergh fault
rawthey fault
dent fault
White Fell
The Calf
Cautley Crag
Great Dummacks
Little Dummacks
Bram Rigg Top
Little Force Gill Rigg
Great Force Gill Rigg
Middle Tongue
Swarth Greaves
Eller Mire
Sickers Fell
Crook
Winder
Green Mea
Bluecaster Side
Ben End


R A V E N S T O N E D A L E
Hooksey
Bowderdale
Stockless
Green Bell
Harter Fell
Little Harter Fell
N
1/2 MILE
Carboniferous
Bannisdale Slates
greywacke within B. Slates
Upper Coniston Grits
Lower Coniston Grits
Basal Ludlow limestone
Wenlock Series Stage 4
" " " 3
" " " 2
" " " 1
Grey Beds
Red Beds
U. Llandovery
L. & M. Llandovery
Basal Beds of Silurian
Ordovician
Diabase
faults
strike & dip
fold
undifferentiated Ludlow
" Wenlock
" Llandovery

Note: To avoid complexity all boundaries, including inferred boundarie are drawn in solid lines. In cases where doubt exists this is indicated by means of question marks.