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THE LOWER LUDLOW FORMATION AND ITS GRAPTOLITE-FAUNA.

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The Lower Ludlow Formation *and its* Graptolite-Fauna.

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[Plates XXV & XXVI.]

Contents.

I. Introduction.

The Lower Ludlow Shales, which form the lowest section of the Ludlow division of the Silurian System, are most typically developed in the neighbourhood of the picturesque old town of Ludlow. It was in this district that they were first defined and described by Murchison. Lithologically, they are here essentially an argillaceous group of strata, the lower and upper limits of which are well marked by two distinct calcareous beds—the Wenlock Limestone below and the Aymestry Limestone above. Palæontologically, the Lower Ludlow Shales are rich in fossils: brachiopods, cephalopods, crustacea, and graptolites.

When the Lower Ludlow Beds are followed from the Ludlow district north-eastward along their line of strike as far as the valley of the Severn, south-westward as far as Aymestry, and eastward as far as the Malverns and Mayhill, they are seen to retain their lithological characters unaltered, and the Wenlock and Aymestry Limestones are both well developed. But when these beds are traced from the typical area to the west and north-west, the limiting calcareous strata dwindle away and eventually disappear, until, finally, the Lower Ludlow Shales merge lithologically on the one hand into the Wenlock Shales below, and on the other into the Upper Ludlow Flags above. It is clearly impossible, therefore, in these westerly districts to separate, on purely lithological grounds, the Lower Ludlow Beds as a distinct group from the formations which overlie and underlie them.

The proofs that the Lower Ludlow Beds of Britain contain a characteristic graptolite-fauna have been gradually accumulated by the researches of Hopkinson, Lapworth, Watts, Marr, and Lake (see pp. 418–19); and the evidences of the existence of a similar

fauna at a corresponding horizon in Europe have long been known from the discoveries of Continental geologists. But little or nothing has hitherto been worked out with respect to the vertical range of the individual graptolite-species within the limits of the formation itself, or with regard to their geographical distribution in the equivalent strata of Wales and the West of England.

During the last few years I have devoted much of my leisure-time to the study of the graptolitic fauna, the rock-sequence, and the vertical distribution of the various graptolite-species in the recognizable subdivisions of the Lower Ludlow Shales of the typical Ludlow district and of their equivalents along the Welsh Border, in order to ascertain (1) what are the truly characteristic graptolites of Lower Ludlow age as distinct from those of the Wenlock formation, and (2) to what extent the Lower Ludlow Beds are capable of subdivision into graptolite-zones. My results and conclusions are embodied in the present paper.

It is now generally acknowledged that graptolites are among the most reliable fossils for purposes of correlation in the Lower Palæozoic rocks. And the graptolite-fauna of the Lower Ludlow Shales is of more than ordinary interest, for it is the last distinct assemblage of these fossils presented to us before the extinction of the group. Notwithstanding the interest of this particular assemblage of graptolites, it has hitherto received but little attention in Britain. The reason for this neglect is evident. Most of the species of graptolites hitherto recorded from the British Lower Ludlow Beds belonged to forms originally described by Barrande in his famous work on the 'Graptolites de Bohême,' as early as the year 1850; but in some cases he included more than one species under a single specific name, and consequently correct identifications of the British forms were impossible until a thorough revision of Barrande's Bohemian type-specimens had been made. This revision has now been carried out by Dr. Jaroslav Perner ('Études sur les Graptolites de Bohême' pt. iii), and through his kindness I have also been enabled to examine Barrande's type-specimens for myself on the occasion of a recent visit to Bohemia.

Much of the present paper is necessarily palæontological, and consists of descriptions and figures of the more important species of Lower Ludlow graptolites. I have endeavoured to limit the number of species and varieties as much as possible, and have restricted myself mainly to the description of such forms as are of greatest value for stratigraphical purposes.

In working out the stratigraphy of the Lower Ludlow I have studied three districts in some detail, namely:—

(1) The Ludlow District, where the defining limits of the formation are well marked by calcareous beds of considerable thickness;

(2) The Builth District, where the calcareous limiting-beds are still faintly indicated, but the lithological boundaries are more or less indefinite;

(3) The Long Mountain District, where the calcareous limits are absent, and no definite lithological boundaries exist.

I have also collected or examined graptolites from other areas of Ludlow rocks in Britain in addition to these three main districts, as for example from the Dee Valley, the Lake District, Dudley, Abberley, etc. In the present paper I propose first to deal with the succession, lithology, and graptolitic fauna of each of the three main districts; and afterwards to deal briefly with the supplementary districts, and show to what extent the results arrived at accord with those worked out in the more typical areas. The last part of the paper is devoted to the description of the Lower Ludlow graptolites themselves.

II. Literature.

In reviewing the history of stratigraphical research I confine myself as much as possible to that in Great Britain, but when considering the purely palæontological literature on the graptolites of the Lower Ludlow Beds I briefly summarize some of the more important results arrived at abroad.

(1) Stratigraphical.

In the year 1839 Murchison first described and defined these beds in the typical area of Ludlow. In his 'Silurian System' he showed that 'they constitute a great argillaceous mass .... of mudstone .... more argillaceous, less sandy and calcareous' (pp. 204–207) than the Upper Ludlow rocks. He pointed out that they are rich in fossil organisms, and are limited both at their base and summit by well-marked calcareous beds. He also noted the presence of these rocks in other areas along the Welsh Border, as in the undulating country between the Vale of Radnor and the Wye, and in the Long Mountain, etc. He gave a complete section through the Wenlock and Ludlow Beds in the neighbourhood of Builth, noting especially 'the thin band of impure limestone' (*op. cit.* p. 315), made up almost exclusively of the small *Terebratula navicula*, which he believed to be the representative of the Aymestry Limestone.

In 1846 appeared the first volume of the Memoirs of H.M. Geological Survey.[1] In this the Survey officers, referring to the Lower Ludlow rocks of the Builth district, grouped the beds in descending order as follows:—

> '(*a*) Argillo-arenaceous rocks, with much oblique bedding and other evidence of irregular accumulation. Many of the beds are arranged in large irregular concretions. 210 feet.
> (*b*) Thin limestone-beds. 10 feet.
> (*c*) Same rocks as at (*a*). 300 feet.'

These Lower Ludlow Beds are described as being limited at their base by nodules and interrupted beds of limestone (Wenlock Limestone), and at their summit by a thin and interrupted band of limestone composed of little else than the remains of *Pentamerus Knightii* (Aymestry Limestone).

[1] Mem. Geol. Surv. vol. i: 'Formation of the Rocks of S. Wales & S.W. England' p. 23.

In 1880 Prof. Lapworth, in his brilliant paper on the 'Geological Distribution of the Rhabdophora,'[1] grouped the Lower Ludlow as his 'zone of *Monograptus Nilssoni*' and described it as the 'highest and most important graptolitic zone of the Wenlock-Ludlow formation.' He noted that its collective fauna is 'specifically very distinct from that of the Wenlock Shales,' and suggested that the formation 'will probably in the future be found divisible into several distinct zones.'

In 1883 Tullberg,[2] in the great work embodying his researches on the graptolites and graptolite-bearing rocks of Scania, recognized the *Cardiola*-Skiffer as his highest graptolitic zone and correlated them with the Lower Ludlow Beds of Britain.

In 1885 Prof. Watts[3] recorded the occurrence of graptolites of a Lower Ludlow type in the strata of the Long Mountain. Five years later[4] he gave a broad zonal subdivision of these beds by means of their graptolites. His paper marks an important advance in our knowledge of the Lower Ludlow Beds in general, since he recognized two lithological horizons above the Wenlock Shales, each characterized by some distinctive graptolites, namely:—

(2) An Upper Group of hard thick flags with occasional shales, yielding *Monograptus leintwardinensis, M. Salweyi,* and *M. Rœmeri.*
(1) A Lower Group of thin muddy shales with rare flaggy ribs, containing *M. colonus, M. Nilssoni,* and *Cardiola interrupta.*

In 1892 Mr. Marr[5] published the results of his investigations on the Ludlow rocks of the Lake District. In this paper, as in that on the Stockdale Shales, he utilized graptolites as his characteristic zonal fossils. As this is the most important piece of research hitherto attempted in the zonal division of rocks comparable with the Lower Ludlow Beds, it may be as well to tabulate here his succession in descending order:—

(5) Bannisdale Slates = zone of *Monograptus leintwardinensis* and containing *M. colonus* and *M. Salweyi.*
(4) Coniston Grits = zone of *M. bohemicus* (upper part) with two interesting fossil horizons:—
  (2) Sheerbate Flags with *M. colonus, M. bohemicus,* and *M. Rœmeri.*
  (1) Winder Grit.
(3) Upper Coldwell Beds = zone of *M. bohemicus* (lower part) with *M. colonus, M. Rœmeri,* and *M. bohemicus.*
(2) Middle Coldwell Beds = zone of *Phacops obtusicaudatus.*
(1) Lower Coldwell Beds = zone of *Monograptus Nilssoni.*

He considered that the Wharfe Grits represent the Lower or Middle Coldwell Beds or both, and that the Moughton Whetstones occurring below them and containing *M. dubius, M. Nilssoni,* and *M. uncinatus?* belong probably to the Lower Coldwell horizon.

In the same year Dr. Barrois published his memoir on the 'Distribution des Graptolites en France.'[6] He recorded many species, now

[1] Ann. & Mag. Nat. Hist. ser. 5, vol. vi, p. 201.
[2] 'Skånes Graptoliter' pt. ii, Sver. Geol. Undersökn. ser. C, no. 55.
[3] Quart. Journ. Geol. Soc. vol. xli, p. 532.
[4] Brit. Assoc. Rep. 1890 (Leeds) p. 817.
[5] Geol. Mag. pp. 536 *et seqq.*
[6] Ann. Soc. Géol. Nord, vol. xx, p. 75.

known to be of Lower Ludlow age, from beds in Languedoc, the Pyrenees, the Ardennes, and Normandy. Of several of the species he gave descriptions, but no figures.

In 1895 Lake,[1] in his paper on the 'Denbighshire Series of South Denbighshire,' referred three of his local groups to the period of time intervening between the Wenlock and Aymestry Limestones, and he recognized two distinct graptolitic horizons. His divisions are as follows, in descending order:—

(3) '*Leintwardinensis*-beds.'
(2) Upper gritty beds, unfossiliferous.
(1) Nantglyn Flags, containing *M. Nilssoni* and *M. colonus*.

(2) Palæontological. (Graptolites.)

In 1839 Murchison[2] noted one species of graptolite as being very characteristic of the Upper Silurian strata, and abundant in the Lower Ludlow Beds. This he figured as *Graptolithus ludensis*, but gave no description of it.

In 1850 Barrande, in the 'Graptolites de Bohême,' described and figured five new species now known to be confined to beds of Lower Ludlow age, namely *Monograptus colonus*, *M. Rœmeri*, *M. Nilssoni*, *M. bohemicus*, and *M. chimæra*. Barrande's memoir gave a great impetus to graptolitic research abroad, and during the next thirty years or so various authorities described and figured graptolites from corresponding beds in Central Europe, as, for example, Suess,[3] Geinitz,[4] Heidenhain,[5] Haupt,[6] Kayser,[7] etc.

In 1855 M'Coy, in his 'British Palæozoic Fossils,' pp. 4–5, described what he believed to be Murchison's species *ludensis*, together with a new form (variety) of this which he named *Graptolites minor*.

In 1868 Nicholson, in his paper 'On the Graptolites of the Coniston Flags,'[8] recorded three of Barrande's species from the Lake District, namely, *M. Nilssoni*, *M. colonus*, and *M. bohemicus*, and figured and described each of them. He also figured a specimen of *M. colonus* from the Lower Ludlow Shales of Ludlow.

In 1873 Mr. Hopkinson,[9] who had collected and studied the graptolites from the Lower Ludlow Shales in the typical Ludlow district, recorded several species of Rhabdophora from these beds, but his new species remained undescribed for some years.

In 1880 Prof. Lapworth[10] described and figured five species of graptolites from the Lower Ludlow Shales of the typical Ludlow

[1] Quart. Journ. Geol. Soc. vol. li, p. 22.
[2] 'Silurian System' pl. xxvi, fig. 2.
[3] 'Ueber Böhmische Graptolithen' Haidinger's Abhandl. vol. iv (1851) pt. iv, p. 87.
[4] 'Die Graptolithen ... der Grauwackenformation in Sachsen' 1852.
[5] Zeitschr. d. Deutsch. Geol. Gesellsch. vol. xxi (1869) p. 143.
[6] 'Die Fauna des Graptolithengesteines' Neues Lausitz. Mag. vol. liv (1876).
[7] 'Die Fauna der ältesten Devon-Ablagerungen des Harzes' Abhandl. geol. Specialkarte v. Preussen, vol. ii (1878) pt. iv.
[8] Quart. Journ. Geol. Soc. vol. xxiv, pl. xx, figs. 9–11, 18–19 & 22–24.
[9] Brit. Assoc. Rep. (Bradford) p. 83.
[10] Ann. & Mag. Nat. Hist. ser. 5, vol. v, p. 149.

district. Three of these were species previously noted and named by Mr. Hopkinson in manuscript, namely *M. leintwardinensis*, *M. Salweyi*, and *M. serra*, and two belonged to forms which were referred to *M. colonus* and *M. Rœmeri*.

In his paper on the 'Geological Distribution of the Rhabdophora,' published about the same time, Prof. Lapworth recorded *M. scanicus*, Tullb. from the English Lower Ludlow Beds; and paralleled for the first time with the Lower Ludlow of Britain the beds *Ee* 2 of Bohemia, containing *M. bohemicus*, *M. chimæra*, *M. colonus*, *M. Rœmeri*, and *M. priodon*; and also the *M. colonus*-zone of Scania with *M. bohemicus*, *M. colonus*, *M. Nilssoni*, and *M. scanicus*.

In 1883 Tullberg,[1] besides completing the stratigraphical work mentioned on p. 418, thoroughly revised the species of graptolites found in the *Cardiola*-Skiffer of Scania. He figured and described the species which had been previously recorded from these beds, and also two new forms, *M. scanicus* and *M. uncinatus*.

In 1884 J. D. La Touche, in his 'Handbook of the Geology of Shropshire,' figured and described several species of graptolites from the Lower Ludlow Beds of Ludlow. Among these were three of Mr. Hopkinson's species, *M. clavicula*, *M. capula*, and *M. retusus*, previously named only in manuscript.

In 1889 Jækel[2] cited several graptolite-species from the 'Graptolithengestein' (Drift) of Northern Germany. From his list it is clear that the fauna of these beds is mainly of Lower Ludlow age. Two new species, *M. frequens* and *M. micropoma*, together with other forms, were described and figured.

In 1897 appeared Prof. Frech's monograph on the graptolites.[3] In this work he figured and described most of the species of graptolites previously recorded from beds of Lower Ludlow age.

The latest addition to our knowledge of the Lower Ludlow graptolite-fauna was made in 1899 by Dr. Perner,[4] who figured and described all Barrande's type-specimens, and thus helped to remove many of the difficulties which previously hindered correct identifications of the English forms with the Bohemian species. Several new species and varieties are recorded by him from the upper beds of Étage *Ee* 1 and *Ee* 2, the collective fauna of which corresponds remarkably with that of the Lower Ludlow Beds of Britain.

III. General Stratigraphy of the Lower Ludlow Formation.

Before describing the several districts which I have examined in detail, I may here state briefly the main stratigraphical problems offered by a study of the Lower Ludlow Group. Two of these problems are of special importance, namely:—

(1) The determination of the stratigraphical lower and upper limits of the Lower Ludlow Group; and

(2) The natural zonal divisions of the group.

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[1] 'Skånes Graptoliter' pt. ii, Sver. Geol. Undersökn. ser. C, no. 55.

[2] 'Ueber das Alter des sog. Graptolithengesteins' Zeitschr. d. Deutsch. Geol. Gesellsch. vol. xli, p. 653.

[3] 'Lethæa Geognostica' vol. ii, pts. ii–iii.

[4] 'Etudes sur les Graptolites de Bohême' pt. iii.

(1) The Lower and Upper Limits of the Lower Ludlow Formation.

The Silurian system of Murchison in the typical area of Shropshire and Herefordshire consists mainly of a great thickness of mudstones, of which the Wenlock Shales and Lower Ludlow Shales form part. Murchison drew the line of division between the Wenlock and Ludlow formations at the Wenlock Limestone, but admitted that the 'Lower Ludlow was simply an upward prolongation of the Wenlock Shale,' and that in some districts 'it was impracticable to endeavour to separate them.' Prof. Lapworth suggested that [1] such a division was made probably 'less from a palæontological than from an æsthetic point of view, and mainly for the sake of physical symmetry'; and urged that the Lower Ludlow was best united with the Wenlock to form the middle division (Salopian) of the Silurian system, the natural horizon of demarcation above it running 'generally along the line of the Aymestry Limestone.'

My study of the graptolitic fauna of the Lower Ludlow rocks entirely bears out the views of both these authorities. In those areas where there is a lithological transition between the Wenlock and Ludlow Beds there is also a palæontological transition, and the one group passes gradually into the other.

The Lower Ludlow graptolite-fauna, although having distinctive characters of its own, yet possesses many marked affinities with that of the Wenlock Shales; and, as I shall point out in the second part of this paper, most of the groups of graptolites characteristic of the Wenlock Beds find their representatives in the Ludlow.

Considered as a whole, however, the graptolite-fauna of the Lower Ludlow is sufficiently distinct from that of the Wenlock to admit of the two formations being separated one from the other, and such a palæontological line of division is of considerable stratigraphical and practical value. In ascertaining the most natural horizon for this zonal line, I have worked in company with my friend Miss G. L. Elles, and the following is the generalized result of our joint observations:—The Wenlock Shales are everywhere characterized by the presence of *Cyrtograptus* and by the *Flemingii*-type of *Monograptus*. In the Lower Ludlow Shales neither of these occurs, but instead the *colonus*- and spinose forms of *Monograptus*, such as *M. chimæra*, are abundant. This may be more readily shown in the following tabular comparison:—

Wenlock Beds.	Lower Ludlow Beds.
Presence of *Cyrtograptus*.	Absence of *Cyrtograptus*.
Presence of the *Flemingii*-type of *Monograptus*.	Absence of the *Flemingii*-type of *Monograptus*.
Absence of the *colonus*-type of *Monograptus*.	Presence of the *colonus*-type of *Monograptus*.
Absence of spinose forms of *Monograptus*, such as *M. chimæra*, etc.	Presence of the spinose forms of *Monograptus*, such as *M. chimæra*, etc.

[1] 'Geological Distribution of the Rhabdophora,' Ann. & Mag. Nat. Hist. ser. 5, vol. v (1880) p. 48.

It will be seen, therefore, that the typical Lower Ludlow fauna is distinct from that of the typical Wenlock, yet so imperceptibly does the one merge into the other that it is difficult to fix the exact horizon of separation. At the horizon of the *Monograptus-Nilssoni* zone one is undoubtedly in Ludlow ground, and the horizon of the *Cyrtograptus-Lundgreni* zone is as certainly Wenlock. Between these horizons intervenes the zone of *M. vulgaris*, sp. nov.; this, where well developed, consists of very thick, hard, calcareous, flaggy shales, and generally makes a feature in the landscape. The palæontological character of this zone allies it more closely with the Ludlow than with the Wenlock, and therefore we have regarded the base of the *M.-vulgaris* zone as the dividing-line between the Wenlock and the Ludlow formations.

The determination of the upper boundary of the Lower Ludlow is also a matter of some difficulty. No graptolites have been found hitherto in the Upper Ludlow Beds of Britain. The majority of the species die out in the Lower Ludlow Shales, but one species characteristic of the highest zone of these beds, namely, *M. leintwardinensis*, Hopk. certainly ranges up into the Aymestry Limestone. So far, then, as the graptolitic evidence goes, the limit between the Lower and Upper Ludlow Beds must be drawn at the top of the Aymestry Limestone, for obviously it would be unadvisable to draw the boundary in the middle of a graptolitic zone. In those areas where the Aymestry Limestone is well developed, as in the Ludlow district, or even where it is but slightly represented, as in the Builth district, there is little difficulty in fixing this upper boundary more or less exactly. But in those areas, such as the Long Mountain, where there is no calcareous representative of the Aymestry Limestone, it becomes practically impossible to draw the line between the Lower and Upper Ludlow on graptolitic evidence alone, the graptolites dying out so gradually that one is unable to determine where they cease altogether. In such cases the lithological characters of the rocks must to a large extent supplement, or indeed entirely replace, the palæontological evidence.

(2) The Zonal Divisions of the Lower Ludlow.

The limited vertical range of the individual species of graptolites in general, together with their wide distribution in space, make them peculiarly suited for zonal fossils; and most of the Lower Palæozoic rocks which contain graptolites, up to and including the Wenlock Shale, have already been variously divided into zones, each of which has a distinctive name. These zones have been found to follow each other invariably in the same order both in Britain and in Western Europe, and it was inferred long since by graptolithologists, such as Mr. Hopkinson and Prof. Lapworth, that detailed work on the graptolites of the Lower Ludlow Shales would demonstrate a corresponding zonal distribution of the species in these beds.

In those districts which I have studied in detail, I have found

that the Lower Ludlow Beds are capable of being grouped into at least four graptolitic zones, but these are apparently less persistent geographically than are the zones worked out in other Silurian formations. Indeed, speaking generally, the Lower Ludlow graptolites (with some notable exceptions which are of well nigh world-wide distribution) have for the most part an extended vertical range and a limited geographical distribution. When, however, we consider the rapid rate of accumulation of the Lower Ludlow strata as compared with that of the Birkhill Shales, for example; and when we remember that the graptolites as a family were dying out at this period, the somewhat imperfect nature of the zonal divisions of the Lower Ludlow Beds is hardly a matter for surprise. Again, owing to the fact that graptolites are of extremely rare occurrence (in Britain) in limestones, and indeed in some cases for a certain distance both above and below them, the graptolitic succession is naturally more incomplete in those areas where the more calcareous development of the Lower Ludlow exists than it is where the purely argillaceous mudstone-facies occurs.

If we consider the evidence derived from all the districts examined, it may be said that the Lower Ludlow Beds (including the Aymestry Limestone) are, broadly speaking, divisible into five main zones, as follows :—

(5) Zone of *Monograptus leintwardinensis*, Hopk.
(4) „ *M. tumescens*, sp. nov.
(3) „ *M. scanicus*, Tullb.
(2) „ *M. Nilssoni* (Barr.).
(1) „ *M. vulgaris*, sp. nov. (at the base).

These zones are not all equally well developed, or even present in every area, but their limitations will be considered when each district is described in detail.

IV. Description of Typical Districts.

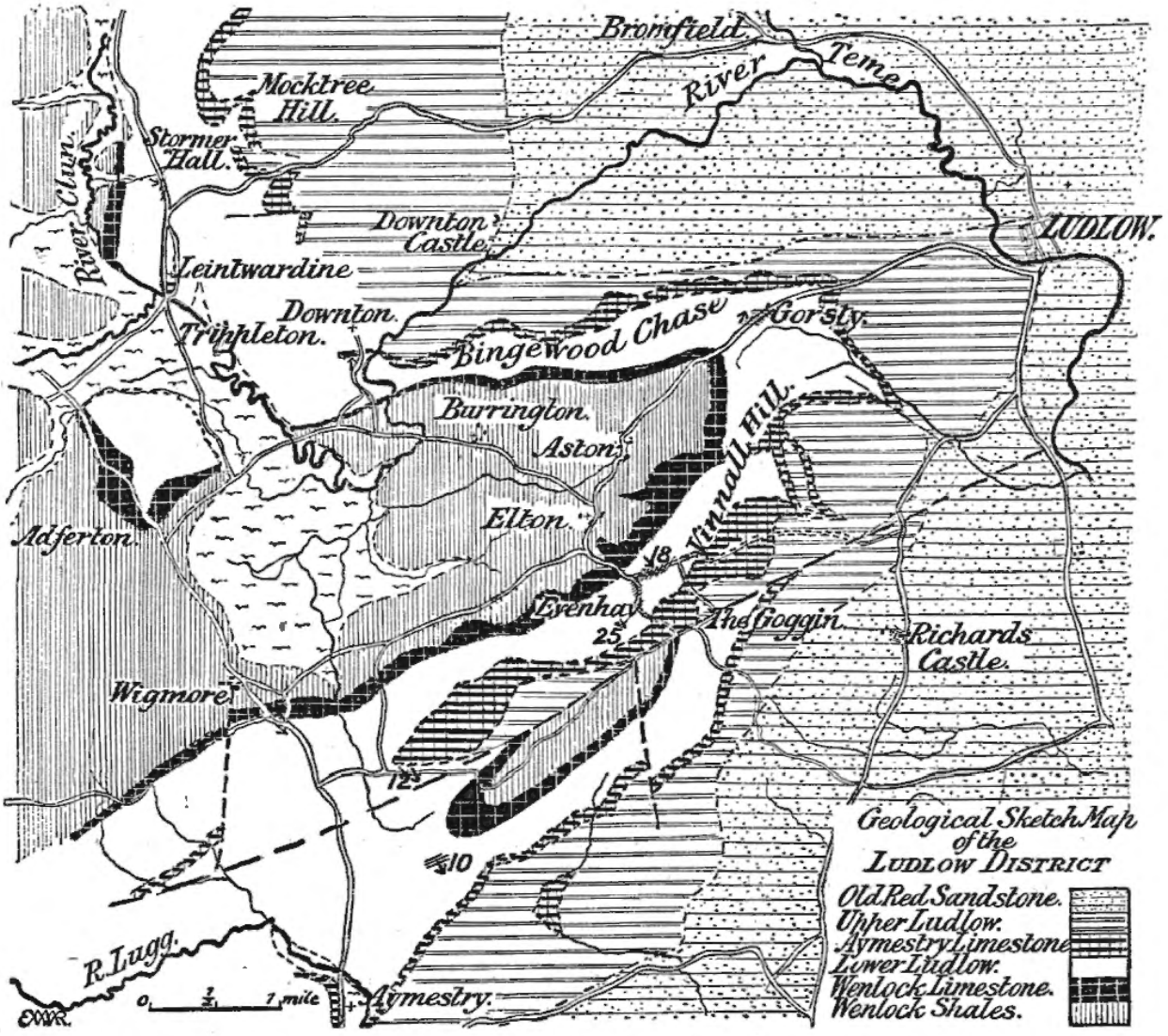
(A) The Ludlow District.

(1) Physical Features and Structure.

The typical district of Ludlow is so well known to geologists that only a very brief notice of its structure and physical features will be necessary. All along the Welsh Borderland the various beds of the Wenlock and Ludlow formations strike in a general north-north-easterly and south-south-westerly direction; but near Downton, some 5 or 6 miles west of Ludlow, the direction of strike changes abruptly to almost due west and east, owing to the fact that the beds are folded into an anticline, the axis of which runs north-east and south-west. On the Upper Ludlow Beds at the extreme north-eastern end of this anticlinal fold is situated the town of Ludlow.

The Wenlock and Ludlow formations are each composed of a calcareous and of a shaly group, and to the alternating occurrence of beds with such different powers of resistance to the agents of denudation are owing the striking scenic features of the district.

Fig. 1.



The Aymestry Limestone forms, generally speaking, the highest ground in the neighbourhood, and gives rise to the ranges of well-wooded hills, with bold and rolling outlines, such as Bingewood Chase, Mocktree Hill, the Vinnalls, etc. The Wenlock Limestone forms a much lower and less conspicuous ridge, while the intervening steep scarp-face is occupied by the Lower Ludlow Shales. The Wenlock Shales which form the core of the anticline, and occur in the neighbourhood of Wigmore, Burrington, etc., occupy the lowest ground in the district.

The Lower Ludlow Shales are exposed in numerous sections, but in no case have I found one in which the complete succession from the top of the Wenlock Limestone to the base of the Aymestry Limestone is laid bare.

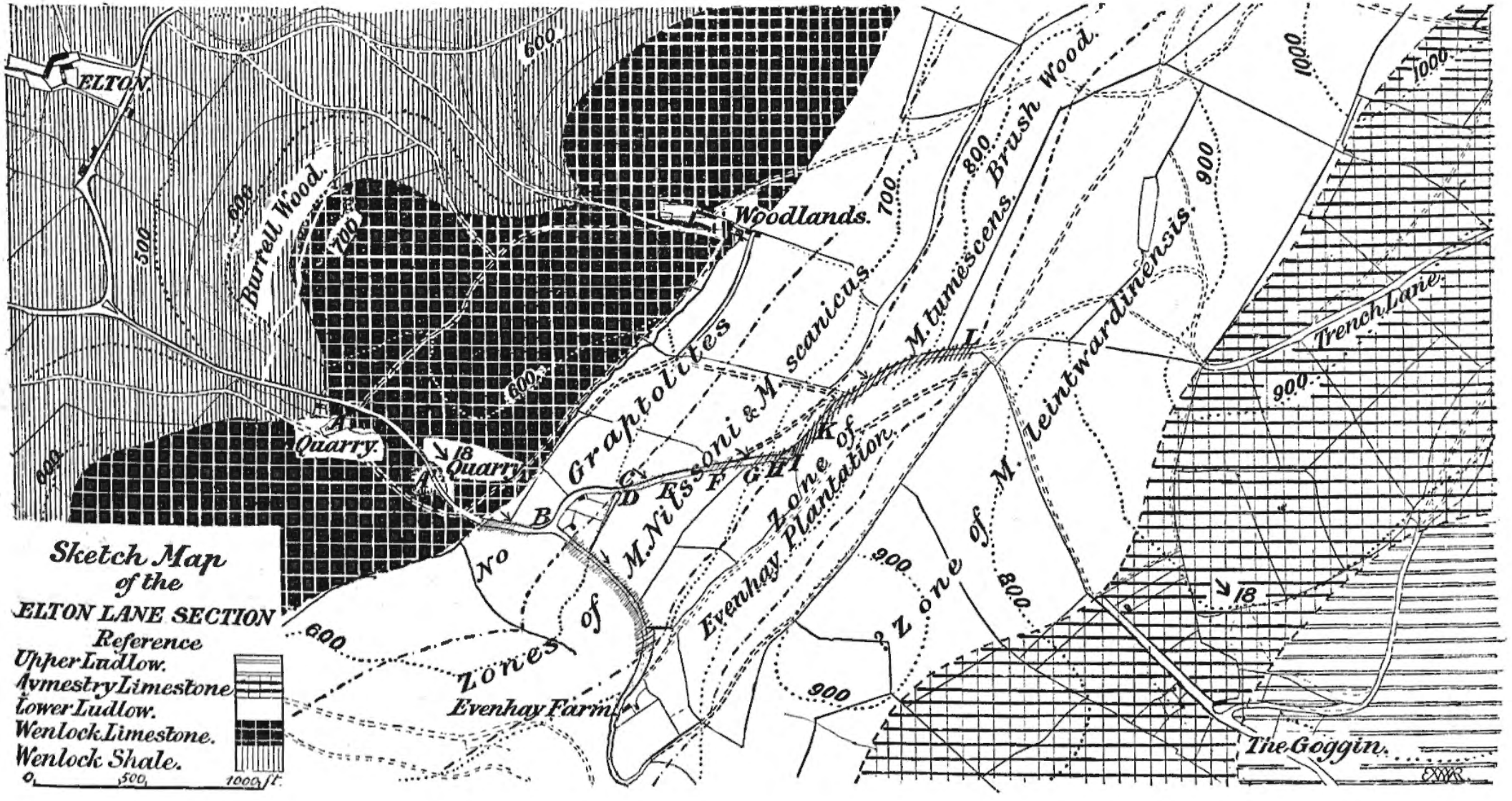
(2) Description of Sections.

(*a*) Elton-Lane Section (Lane running in a general easterly-and-westerly direction from Elton through Evenhay Plantation to Hanway Common).—This lane affords on the whole the most complete section in the Ludlow District, especially of the Middle Shales, which are here remarkably rich in graptolites. I have therefore made a detailed traverse of it, collecting graptolites from every few yards, and I give here a sketch-map of the locality (fig. 2, p. 426). The beds dip about 30° east of south, at an angle varying from 15° to 18°, and the ground rises steeply in the same direction, so that continuously higher beds are exposed as one ascends the slope.

The Wenlock Limestone at the base is well exposed in two quarries, A and A′ (see map), along the side of the road, west of a small stream which here marks the boundary between the Wenlock Limestone and the Lower Ludlow Shales. Between this stream and the place where the road bifurcates (B, 120 paces), small exposures of shale occur, but these are crowded with fragments of brachiopods, corals, trilobites, etc., to the complete exclusion of graptolites. There are no exposures along the left road for about 145 yards beyond B, so that I have been unable to obtain graptolites from the lowest parts of the Ludlow Shales. At the next exposure (C) graptolites are rare, but *M. colonus* var. *compactus* was identified. A few yards higher up (D, 161 paces), however, graptolites occur in abundance, the recognizable species being *M. bohemicus* (Barr.) very common; *M. Nilssoni* (Barr.) very common; *M. scanicus*, Tullb. (rare); *M. uncinatus* var. *micropoma* (Jækel); *M. varians* var. *pumilus* (very common); *M. vulgaris* var. *β (?)*; *M. dubius* (Suess), etc.

At E (249 paces) *M. Nilssoni*, *M. varians* var. *β*, *M. varians* var. *pumilus*, *M. colonus* var. *compactus*, etc. occur. At F (281) the beds become harder and more flaggy, graptolites are less abundant on the whole, occurring rather in bands. *M. scanicus* and *M. chimæra* (Barr.) become the dominant forms, while *M. Nilssoni* appears to die out gradually. At G (341) is a thin bed of shale about 1 inch thick, crowded with *M. varians* var. *pumilus* to the exclusion of other graptolites, while the beds immediately above and below this band are comparatively barren. Just above the point where the 700-foot contour crosses the road (H) occur *M. scanicus*, *M. bohemicus*, *M. varians* var. *pumilus*, *M. tumescens*, sp. nov., and *M. chimæra*. At I (405), where the Evenhay Plantation commences on the right, the graptolites which were so abundant in the lower beds appear to have died out almost entirely, and their places are taken by *M. tumescens*, which occurs here in great abundance. From the commencement of the wood (I) to the end of the lane (L), the strata grow more and more flaggy and individually thicker-bedded. The graptolites decrease in proportion as the arenaceous matter increases, so that in the highest exposures there are practically none. Throughout the whole of this distance *M. tumescens* is the prevailing species, and its only

Fig. 2.


ELTON
Burrell Wood.
Quarry.
18
Quarry.
Woodlands.
Brush Wood.
Trench Lane.
Evenhay Plantation.
Evenhay Farm
The Goggin.
Zones of M. Nilssoni & M. scanicus
Zone of M. tumescens
Zone of M. leintwardinensis
A
B
C
D
E
F
G
H
I
K
600
700
800
900
1000
500
Sketch Map
of the
ELTON LANE SECTION
Reference
Upper Ludlow.
Aymestry Limestone
Lower Ludlow.
Wenlock Limestone.
Wenlock Shale.
0
500
1000 ft.

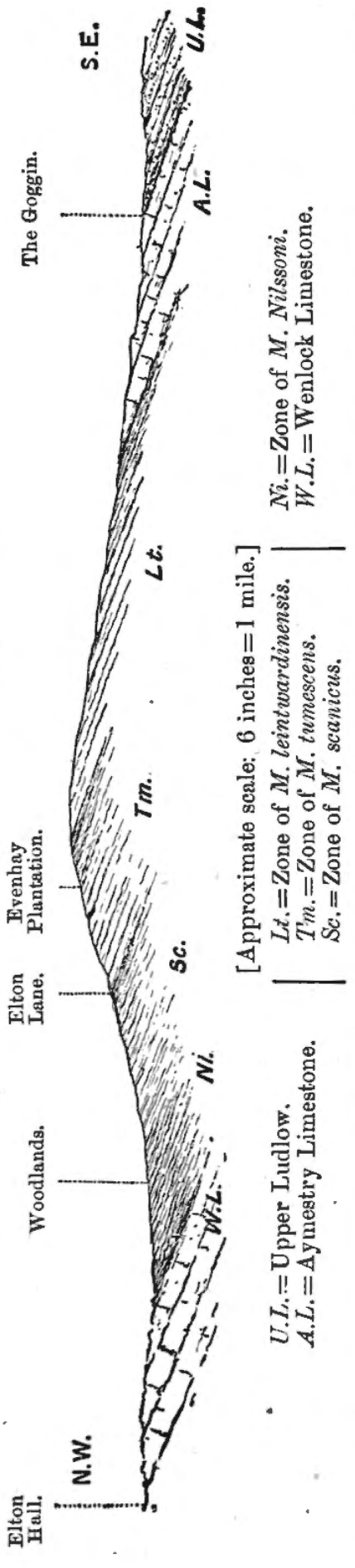


Fig. 3.—*Section from Elton Hall to the Goggin across Elton Lane.*

associates that I have found are a small fragment of *M. bohemicus* and one of *M. chimœra (?)* which occurred at K (457 paces). Beyond the gate (L) all exposures cease, so that this section affords no opportunity of examining the yet higher beds intervening between this point and the Aymestry Limestone.

In the shales especially, the graptolites are for the most part well preserved, but even there they show evidence of having been somewhat squeezed, and in the upper and flaggier beds of the section they have suffered considerably from the effects of pressure. The accompanying section (fig. 3) from Elton Hall to the Goggin illustrates the general succession of the beds in this part of the district.

(*b*) Elton–Evenhay Farm Section.—A section similar to the foregoing is seen in the lane which branches off from the first road at the foot of the hill and winds past Evenhay Farm. Along this lane also I have collected graptolites from every few yards. Seeing, however, that the general assemblage and sequence of fossils is practically the same as in the former sections, it is unnecessary to describe the section and its fauna in detail. Here the lower richly graptolitiferous beds are especially well seen.

(*c*) Elton–Ludlow Road Section.—The road from Elton to Ludlow cuts through both the Wenlock and Aymestry Limestones, and exposes a fairly good section through the middle part of the Lower Ludlow Shales. Here, as in the Elton Lane section, the beds for some distance above and

below the limestones are not laid bare. The lowest beds seen, which are about one-eighth of the way up in the succession, have yielded *M. bohemicus*, *M. Nilssoni*, *M. scanicus*, *M. chimæra*, *M. dubius*, etc. In a small quarry in the hard flaggy shales near Gorsty Farm, at the top of the hill, *M. tumescens* and *M. tumescens* var. *minor* occur in abundance and to the exclusion of other species. These beds are identical with those in the Elton Lane section between I and L.

(*d*) Leintwardine–Stormer Hall Road Section.—A small but richly fossiliferous exposure of the Lower Ludlow Shales is exhibited along the roadside south of Stormer Hall ('Stanner Hall' of Lapworth, etc.). This locality is of especial interest as being the type-locality for *M. Salweyi*, Hopk. The typical form occurs here in great abundance, but is seldom met with anywhere else in the district. It is associated with *M. dubius*, *M. uncinatus* var. *micropoma*, *M. colonus* var. *compactus*, and *M. varians* var. *a*. The slender curved graptolites, such as *M. scanicus* and *M. Nilssoni*, are conspicuous by their absence, and it is possible that these beds represent a somewhat lower horizon than those seen in the other sections just described, but as there are no other exposures near by it is impossible to speak with certainty.

(*e*) Church Hill Quarry, Leintwardine.—This quarry, now overgrown and practically inaccessible, was made in the hard flags, known as 'Leintwardine Flags,' which occur at the top of the Lower Ludlow Shales immediately below the Aymestry Limestone. It was from this locality that the type-specimens of *M. leintwardinensis*, the highest British graptolite yet known, were obtained. The only other localities in the district where I have found this characteristic species are in the hard flags at the top of Mocktree Hill and at Aymestry. In the large quarry at Aymestry I obtained a few fragments, occurring in calcareous beds crowded with brachiopods, trilobites, etc., which belong undoubtedly to the Aymestry Limestone.[1]

(3) Summary.

Judging from the field-evidence adduced in the foregoing pages, it would appear that the graptolitiferous members of the Lower Ludlow Shales and Aymestry Limestone in the typical area may be grouped into four zones:—

4.	Zone of *M. leintwardinensis*	485 feet (including the Aymestry Limestone, 275 feet).
3.	„ *M. tumescens*	220 feet.
2.	„ *M. scanicus*	350 feet (including the 130 feet at the base which have yielded no graptolites) in the Elton-Lane section.
1.	„ *M. Nilssoni* (at the base)...	

[1] In the Woodwardian Museum, Cambridge, there is a well-preserved specimen of *M. leintwardinensis* occurring in a limestone, labelled 'Upper Ludlow, Brocton & Burton.' Unfortunately the exact horizon is unknown, but it is probably that of the Aymestry Limestone. The graptolite is associated with *Strophomena depressa*, *Chonetes lata*, and *Rhynchonella nucula*.

These zones are not all equally rich in graptolites, for nearly the whole of the abundant graptolitic fauna of the Lower Ludlow occurs in the zones of *Monograptus Nilssoni* and *M. scanicus*, while the two highest zones—those of *M. tumescens* and *M. leintwardinensis*—each contain practically only one species. Again, the two lower zones yield numerous graptolites throughout their whole extent, while in the two upper zones graptolites are for the most part rare, occurring abundantly only in certain bands.

The zones of *M. Nilssoni* and *M. scanicus* are perhaps less clearly defined than the higher zones, and it is a matter of some difficulty to decide which are the best graptolites to select for the zonal forms. The three most characteristic graptolites of these beds are undoubtedly *M. bohemicus*, *M. Nilssoni*, and *M. scanicus*. *M. bohemicus* is very abundant in the lowest beds; owing, however, to the long range of this graptolite, it is not advisable to select it for the zonal form. *M. Nilssoni* and *M. scanicus* occur in association; but, as was well seen in the Elton-Lane section, *M. Nilssoni* is more abundant in the lower beds, and *M. scanicus* more characteristic of the upper. It is convenient, therefore, to group the lower 350 feet of Lower Ludlow Shales, so rich in graptolites, into two zones—a lower zone, that of *M. Nilssoni*, containing *M. bohemicus*, *M. colonus* var. *compactus*, *M. uncinatus* var. *micropoma*, *M. varians*, *M. dubius*, etc.; and an upper zone, that of *M. scanicus*, with *M. Rœmeri* and *M. chimæra* as the characteristic graptolites.

The zones of *M. tumescens* and *M. leintwardinensis* are well marked, both lithologically and palæontologically. *M. leintwardinensis* clearly ranges up into the Aymestry Limestone, above which no graptolites are known, and therefore the Aymestry Limestone should be included in the zone of *M. leintwardinensis*.

(B) The Builth District.

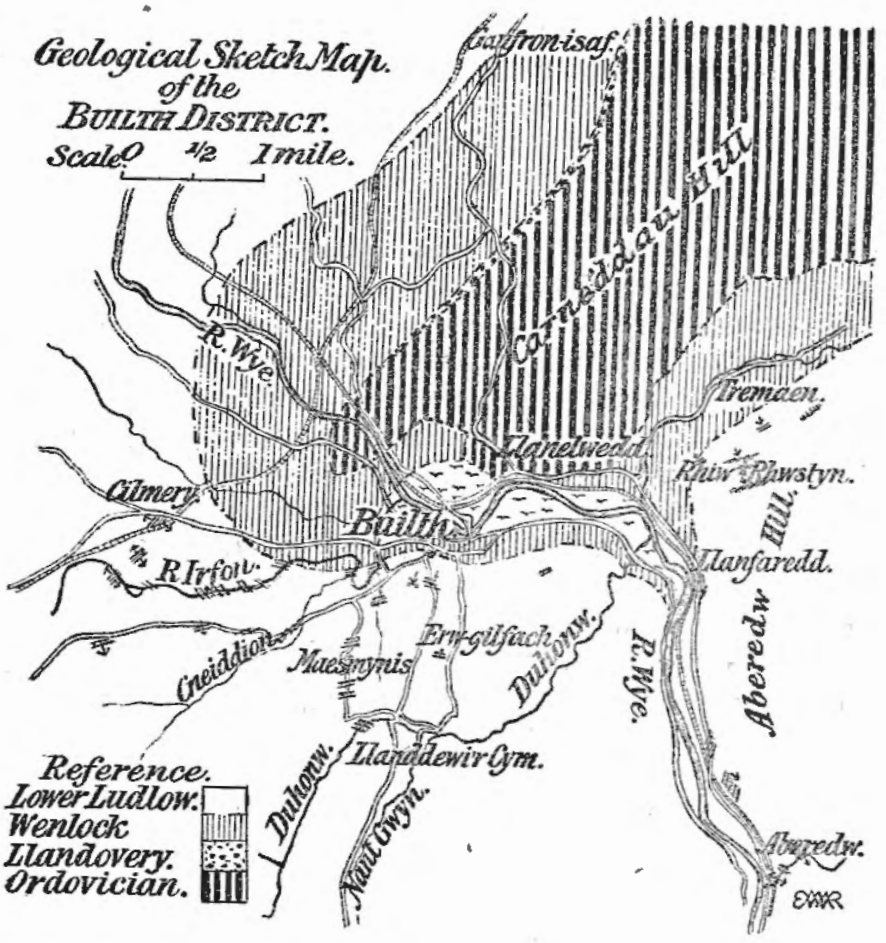
(1) Physical Features and Structure.

The Builth district, as examined by me, includes the range of the Aberedw Hills from Rhiw Rhwstyn on the north to Aberedw on the south, and also the area lying immediately south and south-west of the town of Builth. The Carneddau Hills, which form part of a buried mountain-range composed of Ordovician rocks, rise up as an anticline, the axis of which runs north-east and south-west, and occupies the central part of the area. Resting unconformably upon them is a thin band of Llandovery Grit, and above this come the various zones of the Wenlock Shales. These are folded into a broad syncline on the west of the Carneddau Hills, in the centre of which occur the lowest members of the Ludlow Shales. The Wenlock Shales pass up conformably into the Lower Ludlow without any marked lithological change.

The Lower Ludlow Beds occupy the rising ground between the valley of the Wye and the high hills of Mynydd Eppynt on the south and Aberedw on the east, which attain an elevation of

1400 to 1500 feet. The higher slopes of these are formed of Upper Ludlow strata, capped by Old Red Sandstone, the scenery of which is somewhat bare and desolate. The ground occupied by the Lower Ludlow Beds, on the other hand, is for the most part cultivated or well wooded; though on the steep slopes of the Aberedw Hills the scenic features produced by the Lower and Upper Ludlow rocks are practically indistinguishable.

Fig. 4.



These hills give birth to many small streams which cut their way in deep gorges through the hard flaggy rocks, while in the shaly beds the valleys are more open. Many of the deepest gorges, such as those of the Edw and Duhonw, are richly wooded and form picturesque scenery.

(2) Lithological Characters.

The Lower Ludlow rocks in the Builth district are somewhat varied in their lithological characters, which on the whole differ but little from those of the underlying Wenlock formation. They consist mainly of dark shales, flags, and mudstones, of varying degrees of hardness. The shales are of a dark greyish-brown, occasionally very thin and papery, but for the most part hard and

fairly thick-bedded. The majority of the rocks are of the nature of mudstones or mudstone-flags. The typical mudstones usually weather to a rather light brown, while some of the flaggier and more calcareous beds retain their original dark-grey coloration. These rocks frequently show concretionary structure, some of the concretions measuring several feet in diameter. Typical flags breaking with a splintery fracture are less common, and are found mainly in the highest beds of the formation. All the rocks contain flakes of mica more or less abundantly. At certain horizons thin bands or nodules of limestone occur in the shales; these generally weather more deeply than the strata with which they are interbedded, and thus their position may be readily detected in a section.

The rocks are for the most part richly fossiliferous. Graptolites, however, are practically confined to the shales, limestones, and micaceous flags, while the mudstones yield abundant brachiopods, trilobites, corals, etc. Unfortunately all the beds have been subjected to considerable earth-movement, and in consequence the fossils, especially the graptolites, have been deformed.

The local development of the Lower Ludlow rocks in this area is of peculiar interest, for not only do the rocks combine the lithological characters of the Ludlow sub-calcareous facies already described with those of the purely mudstone-facies of the areas farther north to be noticed later, but the graptolitic fauna shows a similar intermediate character. The lower limits of the Lower Ludlow formation can be suggested on palæontological grounds alone, while, on the other hand, the most natural upper boundary may be best fixed by lithological considerations. The Builth district is exceptionally rich in exposures, and therefore sections can be traced right through the formation from base to summit.

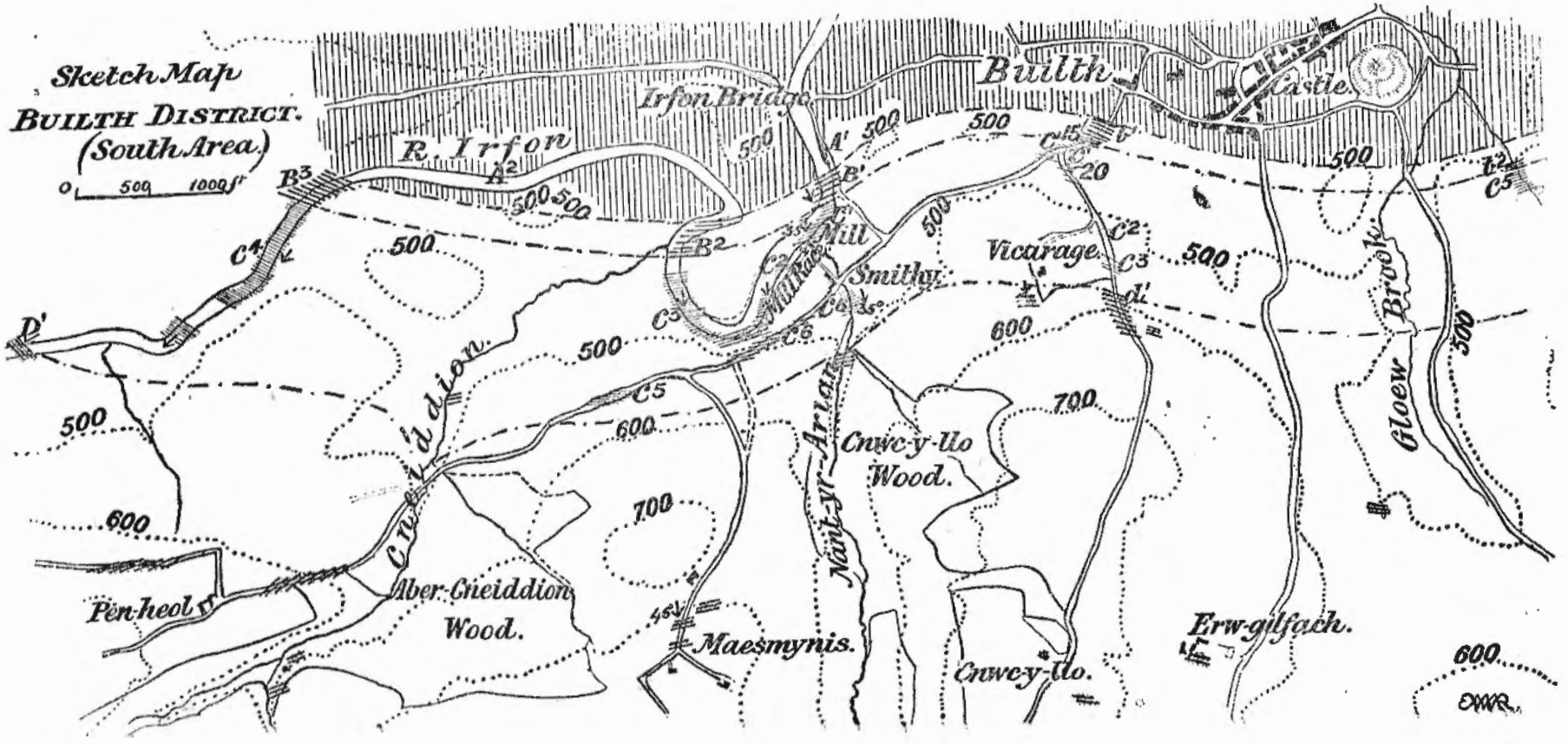
(3) Area lying South of the Wye.

(*a*) River-Irfon Section. (See map, fig. 5, p. 432.)—A complete section is exposed along the banks of the Irfon, from the upper zones of the Wenlock Shales into the Lower Ludlow Shales, and the beds are rich in graptolites throughout.

Starting from Irfon Bridge, the first beds (A^1) which are exposed along the right bank consist of black shales and harder beds with large limestone-nodules, dipping at an angle of about 35°. They have yielded *Monograptus Flemingii* var. δ and *M. dubius*. These must undoubtedly be grouped with the Wenlock Shales, and form the highest zone of that formation.

They are succeeded by a band of dark, thickly-bedded, hard calcareous flags (B^1), breaking with irregular fracture and forming a conspicuous feature, which projects into the stream and narrows its bed considerably. Graptolites are rare in the flags, and even when they do occur they are distorted almost beyond recognition. *M. vulgaris* probably occurs, and from analogy with other exposures

Fig. 5.


Sketch Map
BUILTH DISTRICT.
(South Area.)
0 500 1000 ft.
R. Irfon
Irfon Bridge
Builth
Castle
Mill
Vicarage
Smithy
Gloew Brook
Cnwc-y-llo Wood.
Aber-Cneiddion Wood.
Pen-heol
Maesmynis.
Cnwc-y-llo.
Erw-gilfach.
500
600
700

I think that these flags, which are about 100 feet thick, should be regarded as the basement-bed of the Ludlow formation.

Above these again comes a thick series of brownish-grey flaggy shales with thin beds of limestone (C). These are well exposed in the bed of the stream, and at C^1 have yielded *Monograptus colonus* (Barr.), *M. bohemicus*, and *M. Nilssoni*. At the Mill Race (C^2) the shales are especially rich in the same graptolites. The right bank of the river at this point, and for some distance up stream, rises almost precipitously to a height of 60 or 70 feet; and similar beds, containing the same graptolites, occur all up the cliff, so that they must be of considerable thickness, probably about 500 or 600 feet. At C^3 the shales yield *M. colonus* and *Retiolites spinosus*, sp. nov. in great abundance, the surfaces of the rock being almost hidden from sight by the graptolites; the specimens, however, are much squeezed.

Farther up hard flaggy beds (B^2) are again exposed at the curve which the river makes at this spot. Still higher up, the hard concretionary flags of A and B are again seen in the bed of the river (A^2, B^3), and the graptolitiferous shales (C^4) containing *M. colonus*, *M. Nilssoni*, *Retiolites spinosus*, etc., forms identical with those seen at C^2 and C^3, are re-entered. They are succeeded by hard flags (D^1) which are much contorted and folded. The dip of the beds varies considerably both in amount and direction in the higher reaches of the river, while their strike bends gradually round until, in the centre of the syncline of Wenlock Shales west of the Carneddau Hills, it runs in a north-north-easterly and south-south-westerly direction. This graptolite-bearing bed is easily recognized in the field, and forms an important zone almost at the base of the Lower Ludlow Shales. I have also recognized it in the country west of Builth, near Glan Irfon, and at Cilmery Station; and Miss Elles has traced it farther north near Gaufron-isaf, etc., but graptolites are rare at the last-named locality.

In the Irfon section two distinct horizons in these Lower Ludlow Beds are, therefore, recognizable:—

(2) Flaggy shales and thin limestones rich in graptolites: *M. colonus*, *M. bohemicus*, *M. Nilssoni*, and *Retiolites spinosus*. 500 to 600 feet.
(1) Hard calcareous flags with *M. vulgaris*. 100 feet.

(*b*) Builth-Llanddewi'r Cwm Road-Section.—An excellent section, confirmatory in every way of the foregoing, is seen along the road from Builth past the Vicarage to Llanddewi'r Cwm. At the base come the hard flags (b^1) which have yielded *M. vulgaris* and *M. dubius*; the graptolites, however, are badly preserved, and any identifications must be somewhat doubtful. Owing to their hardness, their outcrop forms a scarp, and thus they are easily mapped: they pass up gradually into the shaly graptolitiferous zone (*c*). The detailed succession of these beds is particularly well seen for some 40 or 50 yards along the Vicarage road, which here joins the main road (c^1). The beds dip at an angle of 20°, and strike 10° to 20° south of east.

The following is the succession in descending order :—

(5) Light-brown flaggy shales with *Monograptus bohemicus*, *M. Nilssoni*, *M. colonus*, and *Retiolites spinosus* (rare). 4½ feet.
(4) Thin reddish-brown limestone, containing *M. colonus* in abundance and numerous fragments of shells, etc. 3 to 4 inches.
(3) Shales (same as 5) with *M. bohemicus*, *M. Nilssoni*, *M. colonus*, and *Retiolites spinosus* (abundant). 8½ feet.
(2) Thin limestone, made up of fragments of trilobites, brachiopods, crinoid-stems, etc., and containing *M. colonus*. ½ inch.
(1) Alternating dark flaggy and fissile shales containing *M. Nilssoni*, *M. colonus*, and *Retiolites spinosus* in bands. 12 feet.

This section is prolonged without much interruption for 40 or 50 yards; the paler shales predominate, some beds being of the nature of mudstones, others more shaly. The same graptolites occur, but are for the most part fragmentary and rare. There are no more exposures for 150 yards; then at c^2 occur thin, light-brown, papery shales with limestone-nodules, and flaggier beds containing a few badly-preserved graptolites, *M. colonus (?)*, and various mollusca. At c^3 the ground rises steeply, owing to the increasingly flaggy nature of the beds and the decrease of argillaceous material, while the graptolites *(M. colonus, Retiolites?)* are relatively few, and finally seem to disappear altogether. At *d* the beds are flaggy, yellowish-brown mudstones, breaking with conchoidal fracture: they have yielded no graptolites, and only a few small brachiopods.

The rich graptolite-bearing shales (c^5) with the underlying flags (b^2) are exposed east of Gloew Brook, near the Oaklands, but I have not traced them farther eastward.

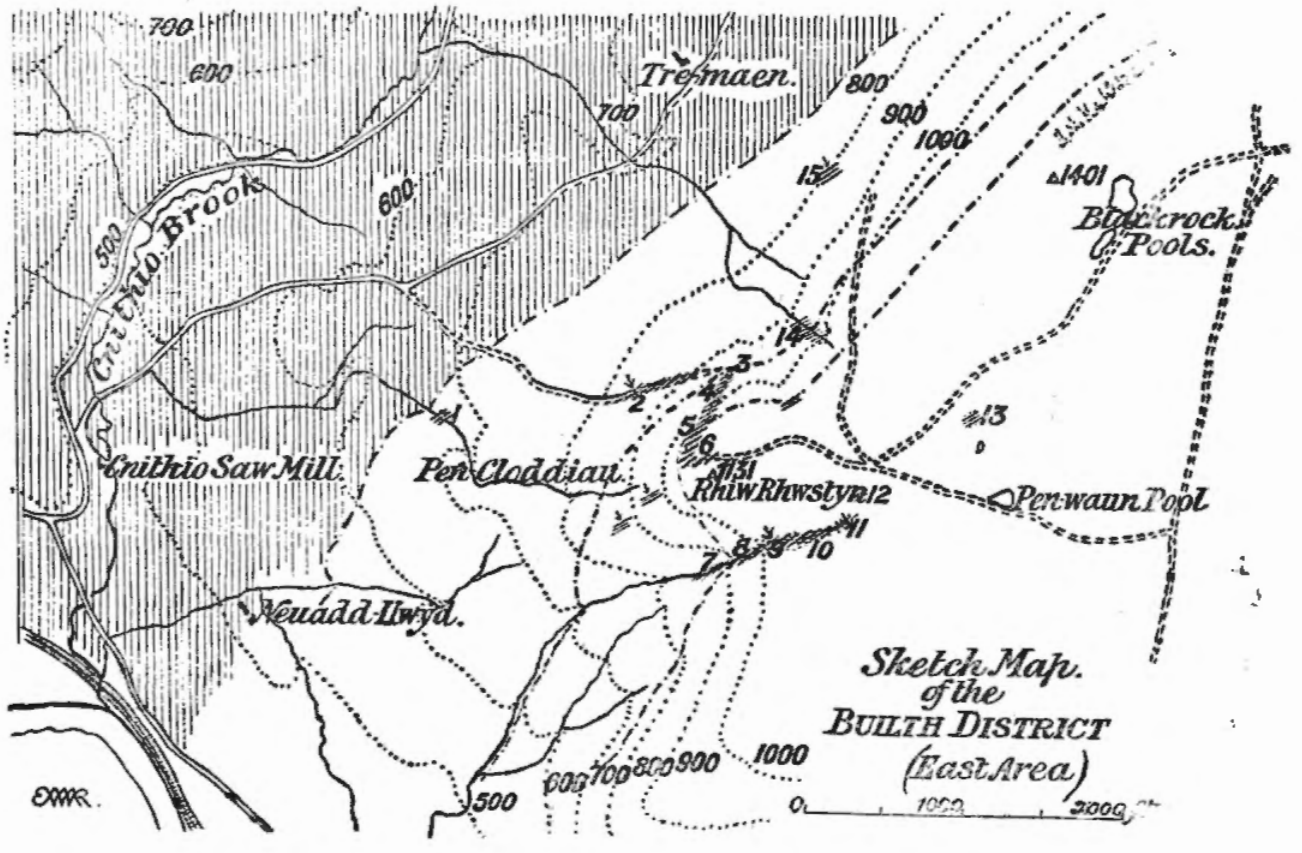
The thin papery shales seen at c^2 and c^3 at the base of the arenaceous series are also exposed in the Maesmynis road, beyond the Smithy, and in the Nant-yr-Arian (c^6), but graptolites are for the most part rare and indifferently preserved, and I have identified only *M. dubius* and *M. colonus*. The succeeding mudstones and flags are seen in various quarries and exposures farther south (see maps, figs. 4 & 5, pp. 430 & 432); but search for graptolites in any of these higher Ludlow Beds in the district south of Builth has so far proved practically fruitless, and therefore it would seem impossible in the meanwhile to fix the upper limit of this formation by means of graptolites. Everywhere the beds are mudstones and calcareous flags, rich in brachiopods, with here and there traces of graptolites showing that they had not altogether died out; thus, in a small quarry along the roadside, about ⅓ mile south of Maesmynis, I found a few fragments which probably may be referred to *M. leintwardinensis*. Still farther south, along the banks of the Duhonw, the rocks are dark micaceous flags with splintery fracture; these higher beds, however, though apparently well adapted for the preservation of graptolites, have, so far, yielded none. Judging from the evidence obtained at Aberedw, which lies to the south-east, I believe that these flags belong to the *M.-leintwardinensis* zone; and as that species occurs only in certain bands among a great thickness of unfossiliferous beds, it is possible that it may yet be found here.

As I have already mentioned, these upper flags and mudstones are rich in brachiopods, especially certain calcareous bands. One bed composed largely of casts of *Dayia navicula* is well seen in a quarry at Erw-gilfach, about 1 mile south of Builth, in association with *Spirifera crispa* and *Scenidium Lewisi* (kindly identified by Mr. F. R. C. Reed). The first-named brachiopod occurs in great abundance in the higher beds of the Lower Ludlow, in the area lying east of the Wye, and does not seem to be confined to any one horizon. I have not traced it for any distance in the south-western area.

(*c*) Summary.—Reviewing the whole of the evidence obtained from this area, the Lower Ludlow formation would seem to be divisible into three groups :—

(3) Mudstones and calcareous flags. Zone of *Monograptus leintwardinensis.*
(2) Shales and thin beds of limestone rich in graptolites. Zone of *Monograptus Nilssoni.* 500 to 600 feet.
(1) Hard flags. Zone of *Monograptus vulgaris.* 100 feet.

Fig. 6.



(4) Area lying East of the Wye. (See map, fig. 6.)

Coming now to the area of Lower Ludlow Shales which lies east of the Wye and occupies the slopes of the Aberedw Hills, one finds that the beds present certain differences from the Builth area proper. The richly fossiliferous band of the Irfon, etc. is but poorly represented ; while, on the other hand, the upper horizons,

which were practically ungraptolitiferous in the district lying south of the Wye, here contain abundant graptolites.

(*a*) Section from Cnithio Brook to Rhiw Rhwstyn.—In the brook at Cnithio Sawmill undoubted Wenlock Shales occur, belonging to the zone of *Cyrtograptus Lundgreni*. From the brook the ground rises somewhat rapidly, the beds becoming increasingly flaggy, but no good exposures are seen for some distance up the hill. In an old quarry (1 in fig. 6, p. 435), however, below Pen-Cloddiau Farm, hard bluish-grey flags occur which contain abundant graptolites, species of *Orthoceras*, and brachiopods. The graptolites belong to the species *Monograptus vulgaris* and *M. dubius*, but they are badly preserved and much distorted, owing to the cleavage that the rocks have undergone. I class these beds unhesitatingly with the Lower Ludlow, but the exact position of the base of this formation cannot be determined with certainty.

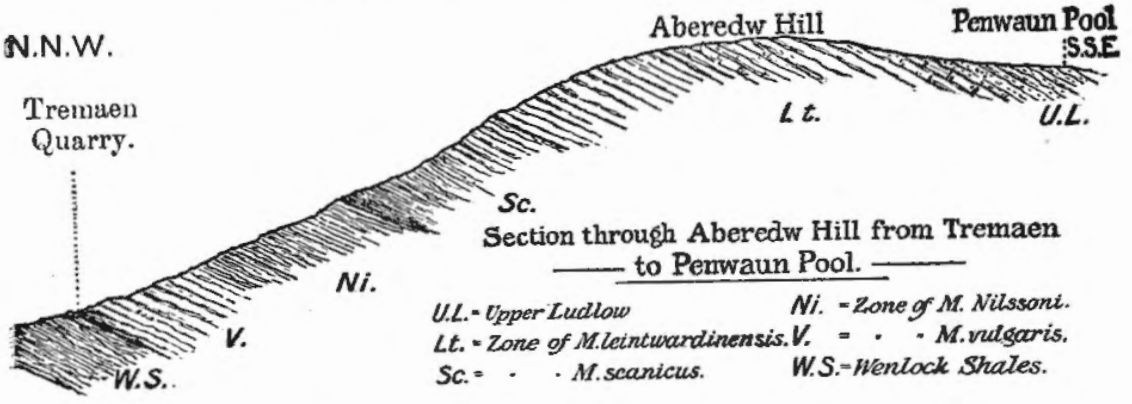
The next exposure is some distance farther up the hill, in a small quarry on the right of the road (2). Here occur two narrow limestone-bands, about 5 or 6 inches thick, separated by 18 inches of shale. The lowest limestone-band has yielded no fossils, but the upper one, which is yellowish-brown and thoroughly rotten, is crowded with *M. colonus* and *Orthoceras*, similar to the rotten limestones seen in the Vicarage road-section. It probably, therefore, represents the zone of *M. Nilssoni*, but this is the only locality where I have detected it, and I have not hitherto found either *M. Nilssoni* or *M. bohemicus* in this eastern area.

As we ascend the section the shales become more micaceous and graptolites are rare, and I have only identified *M. dubius* with certainty. The beds dip 10° east of south at an angle of about 16°. At (3), where the road bends sharply and the slope of the hill increases rapidly, graptolites occur in abundance, and a complete section is seen up to the top of the hill. For the first 75 yards the beds consist of greyish-brown shales which have yielded *M. scanicus* (common), *M. chimæra* (common), *M. dubius*, etc. As the beds become increasingly flaggy, *M. Rœmeri* and *M. bohemicus* appear together with *M. scanicus* and *M. chimæra*. At (5), about 150 yards from the bottom, light-brown, micaceous, flaggy mudstones have almost entirely replaced the shales, and a thin calcareous band, composed largely of the casts of *Dayia navicula*, intervenes. It was apparently at this horizon that the officers of the Geological Survey drew the boundary between the Wenlock and Ludlow formations. Immediately above it come a few feet of a shale which has yielded several specimens of *M. bohemicus*. The occurrence of this graptolite so high up in the Lower Ludlow is of interest, as it bears out the evidence obtained in the Ludlow district of the long range of the species. The shale is followed by a considerable thickness of flaggy mudstones (6) which, however, have yielded no graptolites.

(*b*) Confirmatory Aberedw Hill-Sections.—A section confirmatory of the foregoing is seen in the small stream-course immediately south of Rhiw Rhwstyn. Here only the uppermost

graptolitiferous beds are seen, and at (7) they have yielded *Monograptus scanicus*, *M. chimæra*, *M. Rœmeri*, and *M. dubius*. Above these come hard, dark, calcareous flags, slightly micaceous, and with a concretionary structure (8), which give rise to a waterfall 12 feet high. They are a continuation of the flaggy mudstones (6) above the *M.-bohemicus* shales seen in the road-section, and form a marked feature all along the hill-range. They contain no graptolites and but few fossils of any kind. These flags are succeeded by slightly less flaggy beds, but still destitute of graptolites. Above the 1000-foot contour (9) the stream-course rises more rapidly, and at (10)

Fig. 7.—*(Approximate scale: 6 inches = 1 mile.)*



occurs a band crowded with casts of *Pentamerus Knightii*. This is followed by greyish-brown micaceous flags, splitting readily, which have yielded several specimens of *M. leintwardinensis*. At (11) dark calcareous flags come in, as at (8), barren of fossils, interstratified with calcareous bands crowded with brachiopods (mainly *Dayia navicula*), corals, crinoid-stems, etc. At (12), farther north, are dark calcareous flaggy beds with abundant fossils, and on one slab *Pentamerus Knightii* occurs in association with *Monograptus leintwardinensis*. At (13) light-brown mudstones contain bands almost entirely composed of the casts of *Pentamerus Knightii*, *Dayia navicula*, corals, polyzoa, etc.

It would appear, therefore, from this section that it is impossible to draw any palæontological line between the Lower Ludlow Beds and the representatives of the Aymestry Limestone, for the graptolite (*M. leintwardinensis*) characteristic of the highest zone of the Lower Ludlow occurs in association with brachiopods, such as *Pentamerus Knightii*, which are typical elsewhere of the Aymestry Limestone. Consequently, the evidence obtained in this Aberedw area confirms the conclusion previously arrived at from a study of the corresponding rocks in the typical district of Ludlow, namely, that the Aymestry Limestone should be regarded as part of the Lower Ludlow formation.

Other small exposures are seen at various points along the hill-side. One good section through the lower beds of the *M.-scanicus* zone and the comparatively unfossiliferous shales below is visible in a

small gully (14 in fig. 6, p. 435) north-east of the main road-section. Still farther north-east, in an old quarry south-east of Tremaen Farm (15), dark flaggy mudstones, weathering into minute fragments, yield abundant fossils:—brachiopods, trilobites, cephalopods, etc. It is difficult to say what is the exact horizon of these beds; they may possibly represent the Wenlock Limestone.

In a quarry near Llanfaredd Church, 1 mile south of Rhiw Rhwstyn, hard calcareous flags occur, with limestone-bands and nodules crowded with *Pentamerus* and other brachiopods. This no doubt represents the Wenlock Limestone, and thus marks the base of the Lower Ludlow Beds.

(*c*) Section in the River Edw, Aberedw.—I have not examined the various exposures seen along the hillside south of Llanfaredd, but at Aberedw itself I have found the typical *Monograptus leintwardinensis* in considerable abundance. It occurs, associated with small specimens of *Lingula lata*, in the craggy cliffs of the River Edw. Owing to the steepness of the banks, the beds have slipped down from above in large masses, and it is often difficult to say with certainty whether the beds are *in situ* or not. The beds here too are much folded, and the strike changes every few yards. The graptolites occur at one or two horizons among a considerable thickness of dark micaceous and calcareous unfossiliferous flags. Unfortunately I have been unable here to determine the relations of this zone to the graptolite-zones below, for the beds appear to be, on the whole, barren of fossils.

(*d*) Summary.—The succession, then, of the Lower Ludlow Beds in the area east of the Wye is, in descending order, as follows:—

(4) Hard calcareous flags and mudstones with bands rich in brachiopods: *Pentamerus Knightii*, *Dayia navicula*, etc. Zone of *Monograptus leintwardinensis*. 400 feet?

(3) Light-coloured shales passing up into flaggy mudstones. Zone of *Monograptus scanicus*. 250 feet.

(2) Shales and thin limestone-bands. Zone of *Monograptus Nilssoni* probably. The upper beds are more micaceous and flaggy, and less fossiliferous.

(1) Dark calcareous flags. Zone of *Monograptus vulgaris*.

} 400 to 450 feet?

The upper limit of the Lower Ludlow Beds has not been determined in this area.

(5) Comparison of the two Areas.

In the eastern part of the Builth district, therefore, one richly graptolitiferous zone occurs, that of *M. scanicus*, which would seem to be unrepresented in the area lying south and south-west of Builth, while at the same time the zone of *M. Nilssoni* is less richly fossiliferous. As regards the comparatively poor development of the *M.-Nilssoni* zone, it may be possibly due to the lack of exposures at the right horizon; but at all events it is certainly not so thick as it is in the Irfon and Vicarage-road sections. There is no doubt, however, that the *M.-scanicus* zone is absent as

such in the southern and south-western parts of the district. The highest zone, that of *Monograptus leintwardinensis*, as developed at Aberedw and at Rhiw Rhwstyn, agrees lithologically with the beds which I have referred to the same zone in the valley of the Duhonw, and would seem to be of considerable thickness.

In attempting to offer an explanation for the variations in the palæontological characters of the rocks in areas so nearly adjacent, it is first of all necessary to consider briefly the conditions favourable to the existence and preservation of graptolites in general. As Prof. Lapworth has maintained, it is probable that the graptolites were not entirely free-swimming animals, but were attached to various floating bodies, such as seaweeds, which would tend to accumulate in dense masses in still waters such as those of the Sargasso Sea. A quiet though not necessarily deep sea, in which slow sedimentation would take place, would appear therefore to be the best condition for the existence of graptolites, while at the same time the fine-grained sediments thus formed would be most favourable for their preservation. It is clear, then, that coarse-grained and rapidly accumulated sediments, pointing as they do to the proximity of land and to the existence of current-swept seas, would be unfavourable both for the occurrence and for the preservation of graptolites. Such conditions seem to have largely prevailed during the deposition of the Ludlow Beds, comparatively fine-bedded argillaceous shales alternating rapidly with coarse-grained arenaceous and calcareous flags and mudstones. The upper beds, especially, of the Lower Ludlow Group were probably formed under more or less continuous shore-conditions, with occasional pauses in the rapid sedimentation. Graptolites are everywhere abundant in the shales, while they are almost entirely absent from the coarser sediments. It is, therefore, possible that while the shales containing *Monograptus scanicus* were being laid down in comparatively quiet waters in the south-eastern area, the more rapidly moving waters of the southern and south-western portions of the district which lay too near the shore-line were unfavourable for the existence of graptolites. The fact that the beds belonging to the *M.-Nilssoni* zone south of Builth are of about the same thickness as the *M.-Nilssoni* and *M.-scanicus* beds combined in the eastern area, seems to lend support to this view. But against it, on the other hand, is the fact that the uppermost horizons of the *M.-Nilssoni* zone near Builth, though graptolitiferous, have yielded no forms of the *M.-scanicus* or *M.-chimæra* type. The thickness, too, of the beds in adjacent areas cannot be relied upon, for the strata in the west, lying as they do nearer the old coast-line, would naturally be thicker than those farther east.

Another explanation suggests itself, but its application in this case could be ascertained only after a detailed mapping of the country. According to Miss Elles, in the Wenlock Shales of this district there has been an overlap of some of the higher zones on to the lower zones, and a glance at the geological map of the area

lying south and south-west of Builth shows that this phenomenon is well marked in the succeeding beds. Each formation in turn overlaps on to the one beneath it, so that at Llangadock the Upper Wenlock (? Lower Ludlow) Beds rest on the Llandovery, the former are overlapped by the Ludlow Beds, which in their turn are almost concealed by the Old Red Sandstone. Still farther south the Wenlock and Ludlow Beds are completely overlapped, and the Old Red Sandstone rests upon the Ordovician rocks. Similar conditions, too, prevailed in the Llandovery period, as Mr. H. Lapworth has clearly shown in the Rhayader district. It would seem, then, not unlikely that what happens in the case of the formation as a whole will be found to occur in the various minor subdivisions of that formation; and I think that this has probably taken place here, thus accounting for the absence of the *Monograptus-scanicus* zone in the southern and south-western portions of the Builth district.

(6) General Summary.

Summing up, we see that in the Builth district there are four main graptolite-zones, the succession being as follows, in descending order :—

(4) Zone of *Monograptus leintwardinensis*, including the probable representatives of the Aymestry Limestone.
(3) Zone of *Monograptus scanicus*.
(2) Zone of *Monograptus Nilssoni*.
(1) Zone of *Monograptus vulgaris*.

(C) The Long Mountain District. (Map, Pl. XXVI.)

(1) Structure and General Features.

The Long Mountain lies directly east of Welshpool, and is formed of a broad syncline of Silurian rocks, ranging from the middle of the Wenlock Shales, through the Lower and Upper Ludlow, to the base of the Old Red Sandstone, a few of the lower beds of which form a shallow outlier on its summit. The area is well defined on all sides: on the north by the Breidden Hills; on the west by the valley of the Severn; and on the south by the Ordovician ground of the Shelve district. On the east the Lower Palæozoic rocks are unconformably overlain by the Carboniferous and Permian formations.

On the Geological Survey maps, a considerable thickness of Wenlock Beds is represented occupying the lower slopes all round the district, while the Ludlows are confined to the high ground near the centre, the small patch of Old Red Sandstone occurring towards the north-eastern extremity. It has long been known, however, since the researches of Prof. Watts, that much of the area mapped as Wenlock Shales belongs rather to the Lower Ludlow formation, but the exact boundary between the two has not hitherto been definitely fixed. My own work in this district has confirmed and extended his research, and his large collection of graptolites, so kindly placed at my disposal, and supplemented by my own, together

with those whose sequence I worked out in the typical Ludlow area, have enabled me to bring the graptolites of the two districts into still greater harmony.

Continuous sections through the Wenlock and Ludlow Beds are fairly numerous in this district, especially on the northern flanks of the mountain, and graptolites are abundant. It is easy, therefore, to fix the position of such graptolitic zones as are recognizable, while the boundary of the Wenlock and Ludlow formations may be mapped with some degree of accuracy.

The rocks are lithologically very similar to those in the Builth district, but in the Long Mountain there is an entire absence of limestones, and the sediments range from thin papery shales on the one hand to hard, sandy, flaggy mudstones on the other.

(2) Northern Area of the Long Mountain.

(*a*) Trefnant-to-Middletown Stream Section. — The most complete section on the north side of the Long Mountain occurs in the brook which flows from Upper Trefnant on the south to near Middletown Railway-station on the north.

As we ascend the section from that station, greyish-black shales containing *Cyrtograptus Lundgreni*, *Monograptus Flemingii* var. δ, etc., occur in the stream-course where it runs parallel with the railway (1 in the map, Pl. XXVI), thus fixing the stratigraphical position of the beds as the highest zone of the Wenlock Shales. There are few exposures until (2) is reached, where a small tributary brook from Glyn Common enters the main stream. Here the beds consist of harder and more flaggy shales, slightly calcareous, giving rise to a well-marked feature. They contain various brachiopods and trilobites, but relatively few graptolites: such as occur being assignable almost exclusively to *M. dubius* and *M. vulgaris*. Similar shales are exposed for a considerable distance up stream, but become increasingly massive and flaggy, and occasionally show concretionary structure (3). *M. vulgaris* is by far the most abundant graptolite, but species of *Orthoceras* and trilobites, etc., are numerous. The graptolites are, on the whole, badly preserved, being rarely seen in true profile, so that it is difficult to be certain of all identifications, and other species may occur besides *M. vulgaris*.

At (4) the main stream follows the general strike of the beds for some distance, but the section is continued along the tributary stream which rises near Upper Trefnant. The shales with *M. vulgaris* are shown along the stream for some distance farther. The direction of dip of the beds varies from south 60° east to south 20° west, but the amount of dip is small and fairly constant.

At (5) the graptolitic fauna becomes more varied, and the beds have yielded *M. bohemicus*, *M. Nilssoni*, *M. uncinatus* var. *orbatus* nov., *M. varians*, *M. dubius*, and *M. vulgaris* var. *a*. The beds consist of dark grey shales which weather to a light brown. The main stream here bends abruptly to the left, and follows the strike of the beds; but a small tributary brook joins it on the right, and

at (6) occur numerous specimens of the typical *M. Rœmeri*. A few yards higher up (at 7 in the map, Pl. XXVI), a bed is exposed, crowded with specimens of *Monograptus varians*, *M. Nilssoni*, and *Retiolites spinosus*. This is the only locality in the Long Mountain area at which I have obtained *R. spinosus*, a form so abundant in the Builth district. Finally we have light-brown mudstones containing *M. leintwardinensis* var. *incipiens* nov.

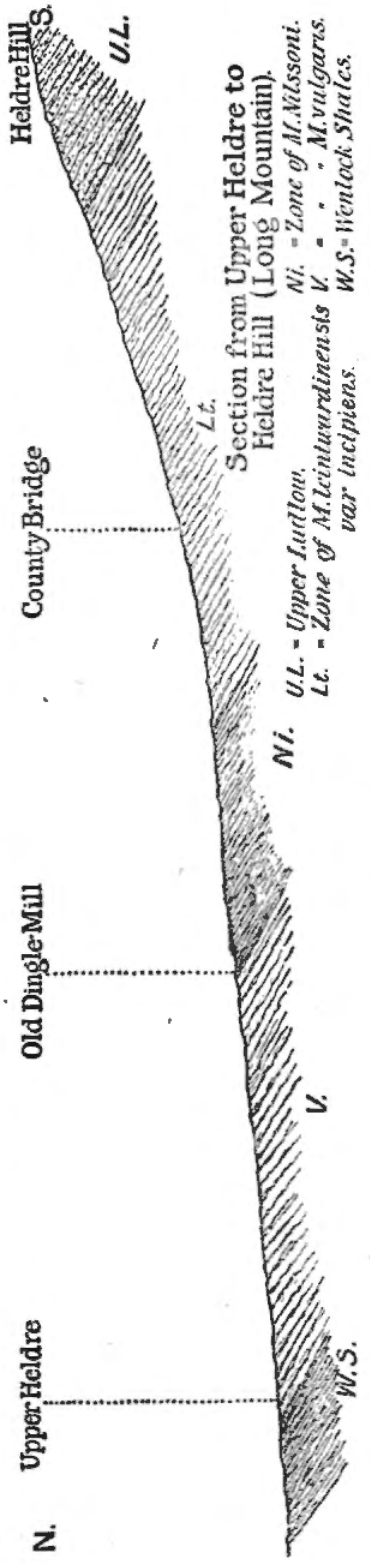


Fig. 8.—(*Approximate scale: 12 inches = 1 mile.*)

(*b*) Lower Winnington Lane Section.—About ½ mile east of the section just described, a good confirmatory section is shown in the lane near Lower Winnington Farm, but only the middle and upper beds of the Lower Ludlow above the zone of *M. vulgaris* are here laid bare.

The lowest (10) visible consist of thinly-bedded, somewhat papery shales, yielding *M. bohemicus*, *M. dubius*, etc. A few yards higher up (11) the shales contain *M. varians*, *M. Nilssoni*, and *M. crinitus*, sp. nov. in abundance, the graptolites almost completely covering the surface of the rock. Above this graptolites are rarer, but *M. varians*, *M. chimæra*, and *M. uncinatus* var. *micropoma* occur (12). Immediately below the farm the pale flaggy mudstones characteristic of the *M.-leintwardinensis* var. *incipiens* zone come on (13). These are exposed as far as the main road, and their thickness must be at least 300 feet. The succeeding beds become more arenaceous and graptolites practically disappear, their place being taken by brachiopods, trilobites, etc.

The *M.-incipiens* beds are also well seen in an exposure near the Rose & Crown Inn, about ⅓ mile north-east of Winnington Lane. They form the highest prolific graptolitiferous horizon in the district; I have, however, found a few fragments of graptolites at a considerably higher level, showing that the group of the Rhabdophora certainly lingered on in this area for some time longer. The locality

is on the steep hill-slope above Frochas and the County Bridge (14). The graptolites occur in hard micaceous flags, and the specimens are much distorted and fragmentary, so that their identification is uncertain. There is no doubt, however, that they belong to the *Monograptus-leintwardinensis* type, but whether they belong to the typical form or to the *incipiens*-variety is dubious.

(*c*) Confirmatory Sections.—Several other good sections of the Lower Ludlow Beds occur farther west and south-west, and the same general succession of rocks and fossils can be recognized in each. One section, ranging from Dingle Mill to the County Bridge, passes completely through the graptolite-bearing Lower Ludlow Beds from the base of the *M.-vulgaris* zone to the top of the zone of *M. leintwardinensis* var. *incipiens* nov. The *M.-Nilssoni* bed is well shown at the Old Mill. (See fig. 8, p. 442.)

Another complete section is visible in the stream from Trewern Bridge to Ucheldre. I have not personally studied it in detail, but I have examined the various graptolites collected from this section by Prof. Watts, and the sequence is the same as in the Dingle-Mill section. Along the road between Ucheldre and the County Bridge the beds containing *M. leintwardinensis* var. *incipiens* are well exposed, and at one locality (15) *M. ultimus*, Perner, is associated with it.

Still farther south-west another section is exposed along the road from Garbett's Hall to Black Bank. Here the beds immediately succeeding the *M.-vulgaris* zone are relatively poor in graptolites. I have, however, collected from them *M. bohemicus*, *M. Nilssoni*, *M. varians*, *M. uncinatus* var. *micropoma*, and *M. scanicus?*

(*d*) Conclusions.—It is clear from the evidence afforded by the sections exhibited on the northern side of the Long Mountain that the Lower Ludlow formation here presents much the same general palæontological features as in the Builth district. It shows, nevertheless, certain peculiarities of its own. Firstly, the species *M. scanicus*, so characteristic of a special palæontological zone on the Aberedw Hills, is practically absent: I have obtained, it is true, one doubtful specimen from the Garbett's-Hall section. One also occurs in Prof. Watts's collection, but the locality from which it was obtained is unfortunately not certain. The species is, at all events, extremely rare, and is useless, therefore, as a zonal fossil in this district. Secondly, the typical *M. leintwardinensis* has not as yet been found in this area, but its place would seem to be taken by the *incipiens*-variety. 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. Thirdly, two new forms, namely, *M. uncinatus* var. *orbatus* and *M. crinitus*, are practically confined to this district, and each of them has been detected at a single locality only. The first of these graptolites has also been found in the Lower Ludlow Beds of Dudley.

With regard to the zonal divisions of the Lower Ludlow formation

in this area, three at any rate of those recognizable near Builth are well developed: that is, the zones of *Monograptus vulgaris*, *M. Nilssoni*, and *M. leintwardinensis*. It may be found convenient in any future mapping of the area to divide the second of these into two sub-zones: (*a*) sub-zone of *M. Nilssoni* and (*b*) sub-zone of *M. Rœmeri*; but the evidence for this division is at present not quite conclusive. The succession is, broadly speaking, as follows:—

(3) Light-coloured flaggy mudstones. Zone of *Monograptus leintwardinensis* var. *incipiens* nov. 900 feet.
(2) Light-coloured thinly-bedded shales.
(*b*) Zone of *Monograptus Rœmeri*.
(*a*) Zone of *Monograptus Nilssoni*. } 350 to 400 feet.
(1) Massive flaggy shales. Zone of *Monograptus vulgaris*. 600 to 700 feet.

In the typical Long-Mountain section from Middletown to Upper Trefnant, however, beds containing *M. varians*, *M. Nilssoni*, and *Retiolites spinosus* occur above the *M.-Rœmeri* beds and a short distance below the *M.-incipiens* zone. The presence of these species at so high an horizon is peculiar, and if further research should verify it, then the sub-zone of *M. Rœmeri* can no longer be distinguished. It is possible that the beds are here folded or faulted (as they certainly are locally in other parts of the district), and that the visible succession is consequently not the true one, for I have failed to find these species elsewhere in the district, except at what seems to be a much lower horizon.

The palæontological boundary between the Wenlock and Ludlow formations is marked here, as at Builth, by a change in the lithological characters of the beds, and therefore its exact position in the field can be mapped with considerable accuracy. The upper limit of the Lower Ludlow Beds, on the other hand, cannot be determined on palæontological evidence alone, as the graptolites appear to die out very gradually. But there is a lithological change near the horizon where the graptolites disappear, which coincides fairly well with the boundary drawn by the officers of the Geological Survey between their local Wenlock and Ludlow formations previous to the working out of the graptolites; and this line may be looked upon very naturally as the boundary between the Lower and Upper Ludlow.

(3) Southern Area of the Long Mountain.

The evidence obtained from an examination of the Lower Ludlow graptolites of the southern side of the Long Mountain is by no means so satisfactory as that derived from the study of those of the northern side. The rocks in the southern area on the whole are coarser and more arenaceous, and the graptolites are rarer and more indifferently preserved. So far, however, as I have examined the sections in this southern area, the graptolitic succession agrees well with that in the northern part of the district.

(*a*) Northern Sections.—In this sub-area the lowest horizons of the Ludlow, namely those of the *M.-vulgaris* zone, are well developed in the neighbourhood of Aston Rogers and Aston

Pigot, and at the Workhouse Dingle near Little Worthen. In the beds of the Workhouse Dingle *Monograptus vulgaris* is abundant and is associated with *Retiolites nassa*, Holm, which has not hitherto been recognized elsewhere in Britain. A good section through the Upper Wenlock and Lower Ludlow is exposed along the Brockton Brook, but graptolites are scarce and badly preserved. I have not worked out the section in complete detail, and it may therefore be passed over.

(*b*) Ackley-Llettygynfach Section.—A fairly good section through the Upper Wenlock and Lower Ludlow is exposed along the lane from Lleyn on the south, past Ackley to Llettygynfach, but here again the graptolites are for the most part indifferently preserved and a zonal division of the rocks is at present impossible. The beds for some distance above the Wenlock are not exposed: the lowest visible horizons of the Ludlow contain *M. chimæra* or its variety *Salweyi*, *M. tumescens* and its variety *minor*, and *M. dubius?* The exposure at Llettygynfach Farm is one of the type-localities for *M. tumescens*: it is here the most abundant form, and so far as is known at present occurs only here and at Ludlow. The highest beds in this section have yielded one specimen of *M. leintwardinensis*.

(4) Montgomery-Road Section.

South and west of the Long Mountain itself, but forming practically its longitudinal extension, lies a large area coloured on the Geological Survey maps as Wenlock. I have not worked the country in detail, but a section seen along the road from Montgomery Railway-station to Montgomery Town is worthy of notice.

The beds are much disturbed and are repeated by folds, so that it is difficult to be sure of the order of succession, but two zones are rich in graptolites. The lowest is that of *M. Nilssoni*, with which are associated *M. dubius*, *M. varians*, and fragments of *Retiolites* sp. The higher zone is that of *M. leintwardinensis* var. *incipiens*. The intervening beds are so crushed that it is impossible to obtain any identifiable graptolites from them.

The Ackley-Llettygynfach and Montgomery-road sections were first worked out by Prof. Lapworth, who pointed them out to me when I began to study the graptolite-fauna of the Lower Ludlow Beds, and kindly placed his collections from those localities at my disposal.

(D) Supplementary Districts.

In addition to working over the three areas just described, I have had an opportunity of examining graptolites from the Lower Ludlow Beds of several other districts in Great Britain. Before concluding my remarks on the stratigraphy of the Lower Ludlow formation I will briefly point out to what extent the graptolitic evidence obtained from these supplementary districts confirms the conclusions already arrived at in the Ludlow, Builth, and Long Mountain districts.

(1) The Dee Valley.—My friend and colleague Miss Elles, who visited this district in 1899, has kindly placed her notes and specimens in my hands. She recognized two well-marked graptolite-zones in the Nantglyn Flags, which Mr. P. Lake correlates with the Lower Ludlow Shales, while the zone of *Monograptus leintwardinensis* (typical form) occurs at a considerably higher horizon. The succession is as follows :—

(3) Zone of *Monograptus leintwardinensis*.
(2) Upper Gritty Beds, unfossiliferous.
(1) Nantglyn Flags.
(*b*) Zone of *Monograptus Nilssoni*.
(*a*) Zone of *Monograptus vulgaris*.

M. vulgaris occurs in various exposures south of Nant Arddau, while *M. bohemicus* and *M. Nilssoni* are seen in abundance in the gritty bands exposed in the Deeside slate-quarries. The rocks are for the most part too cleaved to make it possible to determine what form of *M. colonus* it is that occurs in association with *M. bohemicus* and *M. Nilssoni* in this zone. It is interesting to find that *M. leintwardinensis* here is the typical form of this species ; I have examined specimens from the Llantisilio Road and from Pen-y-Vivod.

(2) The Lake District.—Mr. Marr has kindly permitted me to examine the specimens of Wenlock and Ludlow graptolites collected by himself from the Lake District. At the time when his paper 'On the Wenlock & Ludlow Strata of the Lake District' [1] was published, Barrande's type-forms were uncertain and the Upper Wenlock and Lower Ludlow Beds of the West of England had not been zonally separated, nor had their graptolite-species been clearly defined. Judging from the results now obtained, I should be inclined to group the Ludlow Beds of the Lake District as follows :—

Lower Ludlow	5. Bannisdale Slates.	Zone of *M. leintwardinensis* var. *incipiens*.
	4. Coniston Grits.	Zone of *Monograptus Nilssoni*.
	3. Upper Coldwell Beds.	
	2. Middle Coldwell Beds.	? Zone of *Monograptus vulgaris*.
Upper Wenlock	1. Lower Coldwell Beds.	Zone of *Monograptus Nilssoni*= ? *Cyrtograptus Carruthersi*.

The Middle Coldwell Beds have not hitherto yielded graptolites, and therefore their exact horizon is uncertain. They may possibly represent the zone of *M. vulgaris*, or that species may eventually be detected in the lower part of the Upper Coldwell Beds. The examples of *M. colonus* collected from the Upper Coldwell Beds and Coniston Grits agree more closely than any other British examples known to me with Barrande's most typical form. The specimens of *M. leintwardinensis* from the Bannisdale Slates belong to the variety which I call *incipiens*, and its horizon is the same here as in the Long Mountain district.

[1] Geol. Mag. 1892, pp. 534 *et seqq.*

(3) Southern Scotland.—So far as is known at present the Lower Ludlow Beds of Southern Scotland are non-graptolitic. *Monograptus colonus* has, it is true, been recorded from the Riccarton Beds,[1] and from the Pentland Hills at Habbie's Howe,[2] but its identity with Barrande's *M. colonus* is as yet uncertain.

(4) Dudley.—The Lower Ludlow Shales of the Midlands, intervening between the Dudley and Sedgley Limestones, are not prolific in graptolites. A few, however, have been obtained from time to time by the workmen, and, through the kindness of Dr. Fraser of Wolverhampton, I have been enabled to examine several specimens. Only two species are recognizable:—namely, *M. uncinatus* var. *orbatus* nov. and *M. Rœmeri*; but both are exceptionally well preserved. The exact locality at which the specimens were collected is unfortunately not known.

Some good specimens of *M. Rœmeri* from Dudley are in the Natural History Museum, South Kensington. They probably came from the beds overlying the Dudley Limestone, at one time grouped popularly as Wenlock, but now known to be the representatives of the Lower Ludlow.

(5) The Abberley Hills.—Mr. Wickham King has sent me several specimens of graptolites from the Lower Ludlow of th Abberley Hills for identification: they are all typical Lower Ludlow species. *M. varians* var. *pumilus* is abundant; *M. scanicus* and *M. chimæra* also occur.

V. General Summary.

The Lower Ludlow Shales in Britain, when traced from one district to another, exhibit many variations, not only in lithological characters, but more especially in the thickness of their deposits. Considered as a whole, the beds consist of calcareous mudstones and flags, weathering to a characteristic light-brown; but the sediments become coarser and more arenaceous as they are traced from the south and south-east to the west and north-west, and whereas in the typical Ludlow district the whole thickness of the Lower Ludlow (including the Aymestry Limestone) is only about 1000 feet, in the Lake District it has apparently increased to 10,000 feet.

In spite of the marked variation in vertical extent, however, there is a striking constancy in the sequence of lithological characters of the sediments which distinguish the individual zones, at any rate in the three districts which I have examined in most detail, namely those of Ludlow, Builth, and the Long Mountain. Thus the zone of *M. vulgaris* consists of hard flaggy shales, the zones of *M. Nilssoni* and *M. scanicus* of softer and more shaly material, while that of *M. leintwardinensis* is made up for the most part of hard calcareous

[1] 'Scottish Monograptidæ,' Geol. Mag. 1876, p. 505 & pl. xx, fig. 9.
[2] Mem. Geol. Surv. 'Silur. Rocks of Britain: vol. i, Scotland' (1899) p. 604.

TABLE I, SHOWING THE GEOGRAPHICAL VARIATION IN LITHOLOGY AND THICKNESS OF THE ZONES OF THE LOWER LUDLOW ROCKS.

ZONES.	LUDLOW DISTRICT.	BUILTH DISTRICT.		LONG MOUNTAIN DISTRICT.	DEE VALLEY.	LAKE DISTRICT.
		EASTERN AREA.	SOUTH-WESTERN AREA.			
Zone of *Monograptus leintwardinensis.*	Aymestry Limestone (275 feet). Calcareous laminated flags, passing down into light-brown flaggy mudstones (210 feet).	Thin calcareous bands and micaceous laminated flags, passing gradually into Light flaggy mudstones and darker calcareous flags (400 to 500 feet).	Dark micaceous and calcareous flags, well laminated, passing gradually into Light flaggy mudstones.	Micaceous flags passing into Light flaggy mudstones. (900 feet ?)	'*Leintwardinensis*-Flags.'	Bannisdale Slates: [Upper parts calcareous.] (5000 feet.)
Zone of *M. tumescens*, sp. nov.	Light flaggy mudstones (220 feet).				Upper Gritty Beds.	Coniston Grits.
Zone of *M. scanicus.*	Light flaggy mudstones and shales (100 feet).	Greyish-brown shales, with some flaggy mudstones (250 feet).	Unknown.	Greyish-brown thinly-bedded shales (350 feet).	[No fossils.]	
Zone of *M. Nilssoni.*	More thinly bedded mudstones and shales (120 feet).	Greyish-brown shales, with thin calcareous bands.	Greyish-brown shales, with thin calcareous bands (550 feet).		Nantglyn Flags.	Upper Coldwell Flags.
Zone of *M. vulgaris*, sp. nov.	Thinly bedded shales. No graptolites. (130 feet.)	Dark-grey calcareous shaly flags. (300 feet.)	Dark-grey calcareous flags, with conchoidal fracture (100 feet).	Dark-grey calcareous flaggy shales (600 to 700 feet ?).		Middle Coldwell (?). (5000 feet.)
	Wenlock Limestone.	Wenlock Shales. (Zone of *Cyrtograptus Lundgreni.*)	Wenlock Shales.	Wenlock Shales.	Moel Ferna Slates.	Lower Coldwell (?).

splintery flags. Speaking generally, there is a gradual decrease of argillaceous material as the beds are followed from base to summit of the series (for detailed comparison see Table I, p. 448).

With regard to the distribution of the Lower Ludlow graptolites, it may be pointed out that some forms, as, for instance, *Monograptus Nilssoni* and *M. bohemicus*, are very widely distributed over Britain and Europe. Some appear to be associated only with sediments of a particular lithological character, as, for example, *M. scanicus*, which occurs in Scania and the southern and south-eastern districts of Britain, but is rare or absent in the northern and north-western areas. Some forms again seem to be quite local, as, for instance, *M. crinitus*, which is practically confined to the Long Mountain district.

It is hardly surprising, therefore, to find that of the five graptolitic zones which may be recognized in one or other of the several British districts, only two, those of *M. Nilssoni* and *M. leintwardinensis*, are common to them all. The zone marked by *M. vulgaris*, although persistent in those areas where there is a little or no development of purely calcareous sediments, is unknown in the Ludlow district. The zone marked by *M. scanicus* is well shown in two districts, namely, those of Ludlow and Builth (eastern area), but in other districts it is either wanting in graptolites or else the zone-fossil is absent. The zone of *M. tumescens* is confined to two areas, namely, those of Ludlow and the south side of the Long Mountain, but in these it occurs in great abundance.

As respects the distribution of the graptolites in these several ones, an examination of Table III (p. 450) shows clearly that the great majority occur in association in the zones of *M. Nilssoni* and *M. scanicus*, while all the other zones yield only a few species.

Regarding the limits of the Lower Ludlow Shales, we have seen that the boundaries based on purely lithological characters are artificial, for the Wenlock and Aymestry Limestones are confined to special areas. Any natural and universally applicable division must be determined by palæontological considerations. Such a division necessitates, in my opinion, the inclusion of the Aymestry Limestone in the Lower Ludlow formation.

No detailed comparison with the Lower Ludlow deposits of Europe is at present possible, as no zonal work has been done in these beds outside Britain. A glance at Table II (facing p. 450), however, will show that many of the species of Lower Ludlow graptolites found in Britain occur in Scania, Bohemia, Germany, and France. One awaits with interest the forthcoming section of Perner's 'Études sur les Graptolites de Bohême,' dealing with the zonal divisions of the graptolitic rocks of Bohemia, the graptolites of which seem to be so closely allied to those of Britain.

TABLE III, SHOWING THE ORDER OF APPEARANCE OF THE GRAPTOLITES OF THE LOWER LUDLOW BEDS OF BRITAIN.

[C=Very common; c=common; r=rare.] SPECIES.	Zone of *M. vulgaris*.	Zone of *M. Nilssoni*.	Zone of *M. scanicus*.	Zone of *M. tumescens*.	Zone of *M. leintwardinensis*.
Monograptus leintwardinensis, Hopk.	...	...	...	...	c
—— —— var. *incipiens* nov.	...	...	...	...	c
M. ultimus, Perner	...	...	...	...	r
M. tumescens, sp. nov.	...	...	c	c	
—— —— var. *minor* (M'Coy)	...	...	c	c	
M. bohemicus (Barr.)	...	C	c	r	
M. chimæra (Barr.)	...	c	C	r	
—— —— var. *a*	...	?	c		
M. Rœmeri (Barr.)	...	r	c		
M. scanicus, Tullb.	...	c	c		
M. varians var. *pumilus* nov.	...	C	C		
M. chimæra var. *Salweyi* (Hopk.)	...	c			
M. colonus (Barr.)	...	C			
—— —— var. *compactus* nov.	...	r			
M. comis, sp. nov.	...	r			
M. crinitus, sp. nov.	...	r			
M. gotlandicus, Perner	...	r			
M. Nilssoni (Barr.)	...	C			
M. uncinatus var. *micropoma*, (Jækel)	...	r			
M. uncinatus var. *orbatus* nov.	...	r			
M. varians, sp. nov.	...	c			
—— —— var. *a*	...	r			
—— —— var. *β*	...	c			
M. vulgaris var. *a* nov.	...	c			
—— —— var. *β* nov.	...	r			
Retiolites spinosus, sp. nov.	...	C			
M. dubius (Suess)	C	c	c		
M. vulgaris, sp. nov.	C				
Retiolites nassa, Holm	r				

VI. PALÆONTOLOGY.

(A) General Characters of the Graptolite-Fauna of the Lower Ludlow Formation.

Some of the more typical species of graptolites now known to be characteristic of beds of Lower Ludlow age have long since been described and figured by Murchison, Barrande, Suess, and others; but owing to the imperfect state of knowledge of graptolites in general, at the time when the original type-specimens were named, many of the subsequent identifications were necessarily provisional,

[*To face* p. 450.

TABLE II, SHOWING THE DISTRIBUTION OF GRAPTOLITES IN THE LOWER LUDLOW BEDS OF BRITAIN AND EUROPE.

SPECIES.	LUDLOW DISTRICT.				BUILTH DISTRICT.				LONG MT. DISTRICT. North side.			S. side.	MONTGOMERYSHIRE.	DEE VALLEY.		LAKE DISTRICT.		ABBERLEY HILLS.	DUDLEY.	SCANIA.	BOHEMIA.	FRANCE.	GERMANY.
	Zone of *M. Nilssoni.*	Zone of *M. scanicus.*	Zone of *M. tumescens.*	Zone of *M. leintwardinensis.*	Zone of *M. vulgaris.*	Zone of *M. Nilssoni.*	Zone of *M. scanicus.*	Zone of *M. leintwardinensis.*	Zone of *M. vulgaris.*	{ Sub-zone of *M. Nilssoni.* Sub-zone of *M. Rœmeri.*	Zone of *M. leintwardinensis* var. *incipiens.*	Llettygynfach and Worthen District.	Montgomery Road and Llanfair.	Nantglyn Flags.	'*Leintwardinensis*'-Beds.	Coldwell Beds.	Bannisdale Slates.	Ludlow Shales.	Sedgley Shales.	*Cardiola*-Skiffer.	Étage E*e* 1 ? E*e* 2 or Colonies.	Languedoc, Bretagne, etc.	Graptolithengestein (Drift).
Genus *Monograptus.*																							
Group I. Type *M. dubius.*																							
Monograptus comis, sp. nov.	*																						
— *dubius* (Suess)	*	*	...	...	*	*	*	...	*	*	...	*	*	*	...	*	...	...	...	*	*		
— *gotlandicus*, Perner	...	...	...	...	...	...	...	...	...	*	...	...	...	...	...	...	...	...	...	*	*		
— *tumescens*, sp. nov.	...	*	*	...	...	...	...	...	...	...	...	*											
— — var. *minor* (M'Coy)	...	...	*	...	...	...	...	...	...	...	...	*											
— *ultimus*, Perner	...	...	...	...	...	...	...	...	..	...	*	...	...	...	...	...	*	...	...	...	*		
— *vulgaris*, sp. nov.	...	...	...	...	*	...	...	...	*	...	...	*	...	...	...	...	...	...	...	...	*		
— — var. *α*	*	...	...	...	...	...	...	...	...	*	...												
— — var. *β*	...	...	...	...	...	...	...	...	...	*	...												
Group II. Type *M. colonus.*																							
M. colonus (Barr.)	*	...	...	...	...	*	...	...	...	...	...	...	...	?	...	*	...	...	...	...	*	*	
— — var. *compactus* nov.	*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*	...	...	...		
— — var. *ludensis* (Murch.)	...	...	...	...	...	...	...	...	...	...	...	...	*										
— *Rœmeri* (Barr.)	*	*	...	...	...	...	*	...	...	*	...	...		...	...	?	...	...	*	?	*	*	
— *varians*, sp. nov.	...	...	...	...	...	...	...	...	...	*	...	...	*										
— — var. *α*	*																						
— — var. *β*	*																						
— — var. *pumilus* nov.	*	*	...	...	...	...	...	...	..	...	...	...	...	...	...	...	...	*	...	...	...		
Group III. Type *M. chimæra.*																							
M. chimæra (Barr.)	*	*	*	...	...	...	*	...	...	*	...	...	...	...	...	...	...	?	...	...	...	*	?
— — var. *α*	...	*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*	...		
— — var. *Salweyi*, Hopk.	*	...	...	...	...	...	...	..	...	...	...	...	...	...	...	...	...	...	...	...	...		?
— *leintwardinensis*, Hopk.	..	...	...	*	...	...	...	*	...	...	...	...	...	...	*	...	...	...	...	*	...		
— — var. *incipiens* nov.	...	...	...	...	...	...	...	...	...	...	*	...	*	...	...	...	*	...	...	...	*		
Group IV. Type *M. uncinatus.*																							
M. uncinatus var. *micropoma*, Jækel.	*	...	...	...	...	...	...	...	...	*	...	...	...	...	...	...	...	...	...	...	...		*
— — var. *orbatus* nov.	...	...	...	..	...	...	...	...	...	*	...	?	...	...	...	...	...	...	*	...	...		
Group V. Type *M. scanicus.*																							
M. crinitus, sp. nov.	...	...	...	...	...	...	...	...	...	*	...	...	...	...	...	...	...	...	...	...	...		?
— *scanicus*, Tullb.	*	*	...	...	...	...	*	...	...	?	...	...	...	...	...	...	...	*	...	*	...		*
Group VI. Type *M. Nilssoni.*																							
M. bohemicus (Barr.)	*	*	*	...	...	*	*	...	...	*	...	...	...	*	...	*	...	...	...	*	*	*	*
— *Nilssoni* (Barr.)	*	*	...	...	...	*	...	...	...	*	...	...	...	*	...	?	...	...	...	*	*	*	*
Genus *Retiolites.*																							
R. nassa, Holm	...	...	...	...	...	...	...	...	...	...	...	*	...	...	...	...	...	...	...	*	*		
R. spinosus, sp. nov.	...	...	...	...	...	*	...	...	...	*	...	...	*	...	...	...	...	...	...	...	*		

and, as we are now aware, frequently incorrect. Consequently the graptolite-fauna of the formation stands greatly in need of revision.

The graptolitic species of the Lower Ludlow Beds show many resemblances among themselves, and the graptolite-fauna as a whole presents certain peculiarities of its own. In the first place, the polypary, in the large majority of the forms, is straight for the greater part of its length, but is distinctly curved inward at the proximal extremity. This shape of the polypary is almost peculiar to the Lower Ludlow graptolites, and stands in marked contrast to that of the Wenlock-Shales graptolites, which as a rule is curved outward proximally.

Secondly, the shape of the thecæ is strangely similar in most Lower Ludlow species. The apertures are either spinose, or they are wholly destitute of ornamentation. The development of the apertural spines appears to have been gradual and also subject to variations, for not only is there every gradation between species which possess only a single apertural spine and those that have all their thecæ spinose, but even in the same species the number of spines is variable. The development of spines would seem to be the expression of an instinct of preservation, and it is interesting to note that the later forms of trilobites show similar characters. This leads one to infer that the extermination of both graptolites and trilobites may have been due not merely to unfavourable physical conditions but also to the existence of powerful enemies.

In spite, however, of the general similarity in form of the Lower Ludlow graptolites, a further and more complete examination of the fauna reveals the existence of a large number of species and varieties. The separation of these is difficult, for as the number of specimens examined is increased, the more is one induced to accept the views of those who assert that species and varieties merge the one into the other by almost imperceptible gradations. It would be useless for the purposes of this paper to describe all the various transitional forms, and I shall therefore confine myself to describing and naming (*a*) those which are of zonal value in working out the stratigraphy of the Lower Ludlow Beds; and (*b*) those of special palæontological interest.

As regards the classification of the species and varieties, it is found to be most convenient to group them round special types. The character which I consider to be of most value for the purposes of such grouping is undoubtedly that of the proximal extremity, for it is more constant than any other and appears to be less liable to variations. In the present general state of our knowledge, however, other characters, such as the form of the polypary and the shape of the thecæ, must still in many cases be the main guide in classification, for we must assume provisionally that the general morphology of the form is the best index of phylogenetic relationship.

The Lower Ludlow graptolite-fauna includes two families and two genera, namely *Monograptus* and *Retiolites*, while two families and three genera are contained in that of the Wenlock Shales below.

The genus *Monograptus* is represented in the Lower Ludlow by fifteen well-marked species and thirteen varieties, while of the genus *Retiolites* there are only two species. The following is a list of the species and varieties described in this paper :—

Genus Monograptus. Group I. Type *M. dubius* (Suess).
M. dubius (Suess), *M. vulgaris*, sp. nov., *M. vulgaris* var. *a*, *M. vulgaris* var. *β*, *M. tumescens*, sp. nov., *M. tumescens* var. *minor* (M'Coy), *M. gotlandicus*, Perner, *M. comis*, sp. nov., and *M. ultimus*, Perner.

Group II. Type *M. colonus* (Barr.).
M. colonus (Barr.), *M. colonus* var. *ludensis* (Murch.), *M. colonus* var. *compactus* nov., *M. varians*, sp. nov., *M. varians* var. *a*, *M. varians* var. *β*, *M. varians* var. *pumilus* nov., and *M. Rœmeri* (Barr.).

Group III. Type *M. chimæra* (Barr.).
M. chimæra (Barr.), *M. chimæra* var. *Salweyi* (Hopk.), *M. chimæra* var. *a*, *M. leintwardinensis*, Hopk., and *M. leintwardinensis* var. *incipiens* nov.

Group IV. Type *M. uncinatus*, Tullb.
M. uncinatus var. *orbatus* nov., and *M. uncinatus* var. *micropoma* (Jækel).

Group V. Type *M. scanicus*, Tullb. [sub-group of *M. lobiferus* (M'Coy)].
M. scanicus, Tullb., and *M. crinitus*, sp. nov.

Group VI. Type *M. Nilssoni* (Barr.).
M. Nilssoni (Barr.) and *M. bohemicus* (Barr.).

Genus Retiolites. *R. nassa*, Holm, and *R. spinosus*, sp. nov.

Of the six groups of *Monograptus* enumerated in the foregoing list, the first two, those of *M. dubius* and *M. colonus*, are by far the most important, and both are rich in species and varieties. The separation of these two groups has been almost entirely determined by the character of the proximal extremity, for the general form of the polypary and the shape of the thecæ are much the same in both groups. Although the group typified by *M. colonus* is the more characteristic of the Lower Ludlow Shales, being entirely confined to them, yet I place the group of *M. dubius* first, as it is the more primitive of the two and is well represented in the underlying Wenlock Shales.

The separation of the group of *M. chimæra* as distinct from that of *M. colonus* must be regarded as provisional: for the presence or absence of thecal spines, as I have already pointed out, seems to be in many forms dependent on external conditions, and therefore can hardly be considered of great classificatory value.

The remaining three groups, those of *M. uncinatus*, *M. scanicus*, and *M. Nilssoni*, are individualized almost entirely by the character of the thecæ and the form of the polypary. Such grouping is admittedly unsatisfactory and provisional, but these groups are so poorly represented in the Lower Ludlow Beds that there is not sufficient evidence available for a more complete and exact classification. I am of opinion, however, that further research will show the advantage of placing species with such distinct proximal extremities as *M. Nilssoni* and *M. bohemicus* in separate groups; and possibly of uniting *M. scanicus* and *M. Nilssoni* in the same group on account of the similarity of their siculæ.

When we compare the graptolite-fauna of the Lower Ludlow as now worked out, with that of the Wenlock Shales below, the sup-

posed great palæontological break between them all but disappears. It is true that only one or two species are common to both, but most of the groups of graptolites occurring in the Lower Ludlow Beds are met with in the Wenlock Shales, and the remainder appear to represent the natural and gradual development of allied Wenlock groups. Thus the group of *Monograptus dubius*, already occurring in the Wenlock, survives undiminished in the Ludlow, and the groups of *M. scanicus* and *M. uncinatus* are also represented in both formations. The groups of *M. colonus* and *M. chimæra* are probably only developments of that of *M. dubius*. Even *Retiolites* is common to both the Wenlock and Ludlow formations. *Cyrtograptus*, as such, is unknown in the Lower Ludlow, yet this genus, so valuable for stratigraphical purposes in the Wenlock, may perhaps be regarded rather as a temporary reversion than as a constant biological genus, seeing that in one instance at least—namely that of *Cyrtograptus Carruthersi* and *Monograptus Nilssoni*—the two forms appear to be identical in all respects, except in the matter of branching.

Notes on Terminology, etc.

The following notes have been drawn up for the purpose of making clear the exact meaning of the various terms and measurements used in the description of the species:—

1. Owing to the difficulty of observing the exact point of origin of the first theca from the sicula in compressed specimens, its position as here stated is the apparent one only. Thus, in those species which belong to the group of *M. dubius*, the first theca probably arises above the aperture of the sicula; but its outer wall invariably grows downward, and so appears to arise from the base.

2. In most species it is found that the number of thecæ per inch in the proximal part of the polypary is greater than that in the distal part. Two numbers therefore are given throughout, the first referring to the proximal and the second to the distal end. The first number is obtained by doubling the numbers counted in the proximal half-inch, and similarly with the second.

3. The length of the theca as given is that of the lower thecal wall, but the amount of overlap is (according to general practice) measured from the upper thecal wall.

4. The various measurements tabulated in the description of a species are the average of those taken from one or two typical specimens; thus although the actual numbers may not hold for other specimens, yet the relative proportions are the same for all.

5. The associates of a species, as here enumerated, are those which have been actually found with it on the same slab.

(B) Description of the Graptolite-Species.

1. Genus *Monograptus*.

(a) Group 1. Type *M. dubius* (Suess).

1. Thecæ of one type only.
2. Outer wall of first theca extending down to the aperture of the sicula and inclined to it at a small angle (20° to 30°).
3. Length of adult theca, as a rule, 2 or 3 times the width.

The first two characters are by far the most important for the

purposes of separating the species belonging to the groups of *Monograptus dubius* and *M. colonus*. The relative width and length of the thecæ vary considerably in different species, and are in some cases the same in the one group as in the other. It is impossible to identify a species belonging to either of these groups without a careful examination of the proximal end of its polypary.

Monograptus dubius (Suess). (Pl. XXV, figs. 1 A & 1 B.)

1851. *Graptolithus dubius*, Suess, 'Ueber Böhmische Graptolithen' Haidinger's Abhandl. vol. iv, pt. iv, p. 115 & pl. ix, figs. 5 *a–b*.

(Note.—The synonymy of the several species will be found on p. 487.)

This is typically a Wenlock form, but as it ranges up into the Ludlow Beds I here give a brief description of it, drawn from specimens found in the *M.-Nilssoni* zone of the Montgomery-road section and in the Ludlow district.

Polypary.—Attains a length of 10 cm. (4 inches). Straight for the greater part of its length, but for the first five or six thecæ slightly curved inward. Width at proximal end = about ·76 mm. (·03 inch); maximum width = only 2 mm. (·08 inch); increase in width gradual throughout the polypary, but rather more rapid for the first few thecæ. Distal prolongation of the virgula rarely seen, owing to the great length of the polypary.

Proximal Extremity.—Sicula 1·77 mm. (·07 inch) long and ·42 mm. (·017 inch) in diameter at the apertures, hence $4\frac{1}{2}$ times as long as wide. Aperture concave and slightly contracted, with a short curved ventral spine. Apex of the sicula extending to just below the aperture of the second theca, and the outer wall of the first theca reaching to the base of the sicula and inclined to it at a low angle of 20°.

Fig. 9.—M. dubius, *proximal extremity showing the sicula.* (×5.)

Enlargement of fig. 1 A in Pl. XXV.]

Thecæ.—Twenty-five to twenty in the inch (ten to eight in 1 cm.), inclined to the axis at an angle of 30° to 35°. All of the same type; fairly long and broad tubes, 2 or 3 times as long as wide, and overlapping for from a third to a quarter of their length. Length of an adult theca = 2·54 mm. (·1 inch). Thecal apertures round or slightly oval, provided with a blunt denticle, generally ornamented with a small spine.

M. dubius is readily recognized by the shape and number of its thecæ, but it often varies considerably in the general form of the polypary. At some horizons in the Wenlock Shales it rarely exceeds 2·54 to 3·8 cm. (1 to 1·5 inches) in length, and has a long distal prolongation of the virgula; at others again, it reaches a length of

8·9 to 10 cm. (3½ to 4 inches) and is somewhat broader. In all cases, however, the shape of the thecæ is the same, and it seems impossible to separate the extreme types in the present state of our knowledge.

One form belonging to the group typified by *Monograptus dubius*, from the Lower Ludlow Beds of the Ludlow district, has been figured as *M. serra*, Hopk.; but, after a careful examination of numerous specimens, I find that I am unable to separate it from *M. dubius*, even as a distinct variety. This may possibly be done when the characters of *M. dubius* are more clearly defined. The slightly spinose apertural denticle so characteristic of *M. serra* is equally well marked in specimens of *M. dubius* from the Wenlock Shales of Builth. The Bohemian form figured by Dr. Perner as *M. dubius*[1] also exhibits this character quite as distinctly. The original figure of *M. dubius* given by Suess is a very indifferent one, but in spite of this the graptolite appears to have been as a rule correctly identified by British geologists. Dr. Perner has recently refigured and described Suess's type-specimen, and the British forms agree well with it.

Foreign Localities.—Bohemia (Vyskočilka, Kuchelbad, Kozel, Borek, etc.); Sweden (Röstånga, Tomarp, Tibaröd); Harz Mountains, etc.

British Localities.—Ludlow district (Elton Lane, Stormer Hall, Elton-Ludlow Road, etc.); Builth (Aberedw Hill, etc.); Long Mountain (Glyn Brook, etc.); Lake District (Moughton); Southern Scotland (Riccarton and Hindhope).

Horizon.—Lower Ludlow Shales (zones of *M. vulgaris*, *M. Nilssoni*, and *M. scanicus*). It also occurs in the Wenlock Shales.

Associates.—*M. Nilssoni*, *M. bohemicus*, *M. scanicus*, *M. chimæra* var. *Salweyi*, *M. uncinatus* var. *micropoma*, *M. varians* and its variety *pumilus*, *M. vulgaris*.

Monograptus vulgaris, sp. nov. (Pl. XXV, fig. 2.)

Polypary attaining a length of 5 to 10 cm. (2 to 4 inches) or even exceeding that length. Straight at the proximal end, except for a slight incurve of the first three or four thecæ; when about half the length is reached the polypary curves gently, so that the outer margin is slightly concave. Form of the polypary very characteristic, recalling that of *M. Rœmeri*. Virgula prolonged for a short distance distally. Width at the proximal end = about ·76 mm. (·03 inch), increasing to a maximum width of 2·54 mm. (·1 inch) at the distal end. Increase in width most rapid for the first 12·7 or 19 mm. (·5 or ·75 inch), at the rate of about ·127 mm. (·005 inch) for each theca; after this the increase is more gradual until the distal extremity is reached.

Proximal Extremity.—Most characteristic, serving to distinguish this species readily from all others related to it. Sicula about 2 mm. (·08 inch) long, ·5 mm. (·02 inch) wide at the aperture, hence only 4 times as long as wide; inner wall of the

[1] 'Études sur les Graptolites de Bohême' pt. iii, sect. *b* (1899) pl. xiv, fig. 11.

sicula prolonged as a coarse curved spine about 5 mm. (·02 inch) in length. The first theca, 1 mm. (·04 inch) long, arises distinctly above the aperture of the sicula, being inclined to it at an angle of about 30°. The sicula extends to the level of the lower edge of the aperture of the second theca.

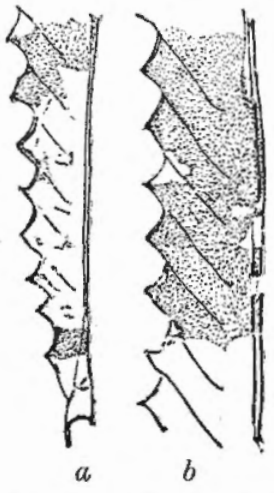


Fig. 10.—M. vulgaris, *sp. nov. from Trefnant-Middletown Brook, Long Mountain. (×5.)*

[*a*=Proximal extremity, with sicula.
b=Distal thecæ.]

Thecæ.—Twenty-eight to twenty-four in the inch (eleven to nine in 1 cm.), inclined to the axis at angles of 35° to 40°. They vary considerably in shape according to the manner of preservation, but appear to be midway between those of *M. dubius* and *M. colonus*. The more proximal thecæ are short and wide tubes not quite twice as long as wide, with widened apertures of the typical *M.-dubius* type. Adult thecæ considerably longer, measuring 2·75 mm. (·11 inch), and 4 times as long as wide. Increase of length and relative decrease of width of the thecæ very gradual. Amount of overlap nearly one half (in the distal thecæ).

Affinities.—*M. vulgaris* may be readily distinguished by

(*a*) Its comparatively large size;
(*b*) The general shape of the polypary;
(*c*) The character of the proximal end; and
(*d*) The character of the thecæ.

The only species to which it is allied and with which it might be confused is *M. largus*, Perner. It is somewhat difficult to determine correctly the characters of this Bohemian species, as the figures are not quite in agreement with Dr. Perner's brief description. Thus he states the width at the proximal end to be 1·7 mm., whereas the width, as measured from his fig. 23 (*op. cit.* pl. xiv), is ·85 mm., and none of his figures show a width exceeding 2·8 mm. (5 mm. in description). The Bohemian species appears, however, to be considerably larger than the English form. Again, the polypary is said to be straight, except at the proximal end, which shows a greater incurve than do the English specimens, and the adult thecæ are relatively shorter and broader. Dr. Perner, unfortunately, does not figure the sicula complete, which would enable one to determine the identity or otherwise of these two forms. *M. vulgaris* approximates closely to the form figured by Dr. Perner (*op. cit.* pl. xvii, fig. 17), and provisionally referred to *M. dubius*, in general form and shape. The sicula also appears to be somewhat similar, but there are only twenty or nineteen thecæ in the inch as against twenty-eight to twenty-four (eleven to nine in 1 cm.). It is easily distinguishable from all other English forms.

Monograptus vulgaris is of considerable palæontological interest, for it possesses characters which ally it both with the *M.-dubius* and the *M.-colonus* groups. This is well seen, not only in the shape of the thecæ, but also in the character of the proximal end: the first theca being inclined to the sicula at a low angle as in *M. dubius*, yet arising above the aperture as in *M. colonus*.

Localities.—This species occurs most abundantly in the Long Mountain district, but I have also found it at Builth, and Miss Elles has recognized it in the Dee Valley.

Horizon.—*M. vulgaris* is the characteristic graptolite of the lowest zone of the Lower Ludlow.

Associates.—*M. dubius* and *Retiolites nassa*.

M. vulgaris has a considerable range in time, and undergoes certain modifications as we follow it higher up the succession. If the specimens of *M. vulgaris* were in a more satisfactory state of preservation, I believe that it would be possible to trace the gradual stages in the evolution of this species, from the type-form at the base of the succession, through the various horizons of the Ludlow Shales, to the well-marked varietal forms at the top. Two distinct varieties characteristic of the higher horizons may be here distinguished.

Var. α nov. (Pl. XXV, fig. 3.)

This variety is distinguished from the typical form by

(1) The shape of the adult thecæ, which are relatively broader and only 3 times as long as wide, and therefore more distant;
(2) The general shape of the polypary, which is straight distally and more incurved proximally, and seldom, if ever, exceeds 5 cm. (2 inches) in length.

Localities.—Long Mountain (Trefnant-Middletown Brook, etc.); Ludlow district (Elton Lane ?).

Horizon.—Zone of *M. Nilssoni*.

Associates.—*M. Nilssoni*, *M. uncinatus* var. *orbatus*, *M. colonus* var. *compactus*, *M. varians*.

Var. β nov. (Pl. XXV, fig. 4.)

This variety is distinguished from the typical form by

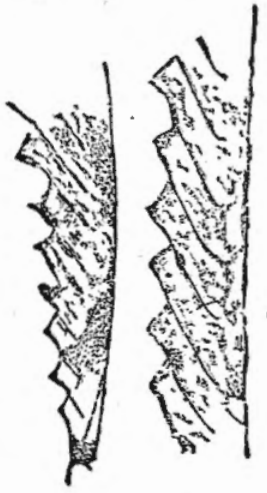
(1) Its greater narrowness, the maximum width rarely attaining 2 mm. (·08 inch);
(2) The general form of the polypary, which has a strong proximal curvature and straight distal portion;
(3) The character of the proximal end: the sicula is nearly 5 times as long as wide, and the first theca appears to arise rather nearer the sicular aperture;
(4) The form of the thecæ: they are shorter and narrower, and their apertures appear to be slightly oblique to the direction of the thecæ.

It occurs on the north side of the Long Mountain, at Lane Farm, in association with *M. bohemicus*, in the zone of *M. Nilssoni*, or possibly in the sub-zone of *M. Rœmeri*.

Monograptus tumescens, sp. nov. (Pl. XXV, figs. 5A & 5B.)

Polypary from 2·5 to 3·8 cm. (1 to 1·5 inch) long, straight for the distal four-fifths of its length, but the proximal one-fifth is strongly incurved, making an angle of 10° or more with the general direction of the polypary. Width at the aperture of the first theca =about ·76 mm. (·03 inch), increasing rapidly for the first three or four thecæ, at the rate of ·38 mm. (·015 inch) for each theca, then more gradually, the maximum width of 2 mm. (·08 inch) being attained from the seventh to the tenth theca. From that point the width decreases slightly, so that throughout the distal part the width is only 1·77 mm. (·07 inch), thus giving the polypary a characteristic form. The virgula, is so far as I have observed, not prolonged beyond the distal extremity.

Fig. 11.—M. tumescens, *sp. nov.* (×5).



a b

[*a* = Enlargement of proximal extremity of fig. 5A in Pl. XXV.
b = Distal thecæ of a specimen from Llettygynfach.]

Proximal Extremity.—Sicula about 1·9 mm. (·075 inch) long and ·38 mm. (·015 inch) wide at the aperture, hence it is 5 times as long as wide. Aperture concave, somewhat contracted, and provided with a long ventral spine. Proximal extremity in other respects similar to that of *M. dubius*.

Thecæ.—Twenty-eight to twenty-four in one inch (eleven to nine and a half in 1 cm.), inclined to the axis at an average angle of about 30°; proximal thecæ less highly inclined than the distal. All approximately similar in form, being long and wide tubes with straight or slightly concave apertures at right angles to the direction of the thecæ, with an acute denticle, but devoid of spines. Adult thecæ about 2·54 mm. (·1 inch) long, and 4 times as long as wide; the first theca is only about 3 times as long as wide. The adult thecæ overlap for from one-third to one-half of their length.

This form is one of the many which have been assigned to *M. colonus* (Barr.). It will be evident, however, when the foregoing characteristics are taken into consideration, that it is quite distinct from all other species: its general form, and the disposition and general characters of the thecæ distinguishing it readily. In the shape of the polypary it approaches somewhat closely to *M. subcolonus*, Perner, though it differs in the number and shape of the thecæ. It bears some resemblance to *M. frequens*, Jækel, but the identity of that species is doubtful.

Localities.—Long Mountain (south side at Llettygynfach); Montgomery Road; Ludlow district (Elton Lane and Elton–Ludlow Road).

Horizon.—It is the characteristic fossil of the *M.-tumescens* zone near the top of the Lower Ludlow Shales. Forms almost identical with it, however, occur in the lower zones of the Ludlow.

Associates.—*Monograptus tumescens* var. *minor*, *M. chimœra* (very rare), *M. bohemicus* (very rare).

Var. *MINOR* (M'Coy), non *Monograptus ludensis*. (Pl. XXV, figs. 6 A & 6 B.)

1855. *Graptolites ludensis* var. *minor*, M'Coy, 'Brit. Palæoz. Foss.' p. 5.

M'Coy described under this name a 'species resembling' *M. ludensis*, 'but of only half the width, yet having from four to five denticles in a space of two lines.' I have been unable to obtain specimens from M'Coy's type-locality at Llangynyw Rectory (Montgomeryshire), but from specimens formerly in Nicholson's collection, and now in Prof. Lapworth's possession, I am inclined to the opinion that the form here described is identical with M'Coy's variety.

M. tumescens var. *minor* agrees with the typical *M. tumescens* in

(1) The character of the proximal extremity; and
(2) The shape of the thecæ.

It differs from it in

(1) Its small size, never exceeding 12·7 mm. (·5 inch) in length, and measuring generally less;
(2) The form of the polypary.

Localities.—Long Mountain (Llettygynfach); Ludlow district (Elton-Ludlow Road, Elton Lane); Llangynyw Rectory (Montgomeryshire).

Associate.—*M. tumescens*.

I have had the opportunity of examining only one of the specimens which Nicholson collected from the Lake District, and described as *M. colonus*. This is now in Prof. Lapworth's collection at Mason University College, Birmingham. Unfortunately, it is by no means well preserved. I have, however, found others very similar in the Ludlow district (Elton Lane, etc.), and the form is evidently closely allied to, if not identical with, the species which I have described as *M. tumescens*. The Lake District form is shorter and stouter than the typical *M. tumescens*, and the thecæ are more close-set, thirty-three to thirty in the inch (thirteen to twelve in 1 cm.). They may all belong to a distinct variety of *M. tumescens*, but at present there is not sufficient evidence to decide this point.

MONOGRAPTUS COMIS, sp. nov. (Pl. XXV, figs. 8 A & 8 B.)

Polypary barely 2·5 cm. (·07 inch) in length. Straight for the distal half of its length, curving inward distinctly in the proximal half. Increase in width, from ·5 mm. (·02 inch) to 1·27 mm. (·05 inch), gradual throughout the polypary. In the only specimen that shows the distal end, the virgula is slightly produced beyond the terminal theca.

Proximal Extremity.—Sicula probably about 1·77 (·07 inch) long, and its apertural width =·38 mm. (·015 inch). The first theca arises distinctly above the aperture of the sicula, but grows down so as almost to reach the aperture.

Fig.12.—Monograptus comis, *sp. nov.* (×5).

[Enlargement of the proximal extremity of fig. 8 A in Pl. XXV.]

Thecæ.—Twenty-nine or twenty-eight in 1 inch (eleven and a half to eleven in 1 cm.), inclined to the axis at an angle of 25° to 30°; straight tubes, uniform in width throughout; the adult thecæ are 1·77 mm. (·07 inch) long, and from 3 to 4 times as long as wide. Proximal thecæ in contact merely, or with a slight overlap in the distal thecæ. Lower free wall concave or straight. Apertures concave, the lower wall prolonged into a pointed denticle bending outward and slightly downward, but with no actual spine.

This graceful species is readily distinguished by (*a*) its general form and (*b*) by the character of the thecæ. The proximal extremity shows that it belongs to the group of *M. dubius*. In other respects *M. comis* has no marked resemblance to any other species.

Localities.—Ludlow district (Elton–Evenhay Lane).

Horizon.—Zone of *M. Nilssoni*.

Monograptus gotlandicus, Perner. (Pl. XXV, fig. 7.)

1890. *Monograptus* sp., Holm, 'Gotlands Graptoliter' Bihang till K. Svensk. Vet.-Akad. Handl. vol. xvi, pt. iv, no. 7, p. 17 & pl. i, figs 27–30.

1899. *Monograptus gotlandicus*, Perner, 'Études sur les Graptolites de Bohême' pt. iii, sect. *b*, p. 12 & pl. xiv, fig. 22.

Hitherto only small fragments of this species have been figured, and these only of the distal end; the proximal extremity has never been either described or figured, nor has the general form of the polypary been given. Any identification with this species must be, therefore, a matter of doubt, and it is with some hesitation that I identify the following form with the fragmentary specimens figured by Holm and Perner.

Polypary.—3·2 mm. (1·25 inch) long, and straight distally, but with a slight incurve at the proximal end. Width at the proximal end = ·76 mm. (·035 inch), increasing gradually to a maximum width of 2·03 mm. (·08 inch) at the rate of ·01 mm. (·004 inch) for each theca. Distal end incomplete.

Proximal Extremity.—Exact length of sicula not seen, but it is probably about 2·03 mm. (·08 inch) long and ·35 (·014 inch) wide at the aperture, which is strongly concave and has a long curved ventral spine. The first theca seems to extend nearly to

the base of the sicula, being inclined to it at an angle of 25° approximately.

Thecæ.—Twenty-three to twenty in 1 inch (nine or eight in 1 cm.), and inclined to the polypary at an angle of 25° to 35°. Thecæ characterized by long and flexuous walls which bend inward so as to be almost at right angles to the virgula. Adult thecæ 3 mm. (·12 inch) long and 4½ times as long as wide, overlapping for a third to a half of their length. Aperture concave, apparently oblique to the direction of the thecæ: it has a sharp denticle which is curved downward, but no spine. From Holm's figures it appears that the apertures are round or slightly oval.

Monograptus gotlandicus is allied to *M. dubius*

(1) In the character of its proximal extremity; and
(2) In the number of thecæ;

but is distinguished from it by

(1) The greater width of the polypary;
(2) The greater length of the thecæ, and the relative proportions of their length to their width.

The English form is sufficiently similar to the Swedish and Bohemian forms to make it clear that they are at any rate closely allied. The English graptolite appears to differ somewhat in the amount of overlap of its thecæ, this being greater than that measured by Holm (one-fifth), but not much more than appears from his figures. The angle of inclination of the thecæ is somewhat less, too, in the English specimens.

A specimen now in the Prague Museum from Colonie Krejci, of which I took a drawing in Bohemia, is very similar in shape to the English specimen.

Foreign Localities.—Bohemia (Konĕprus and Colonie Krejci?); Gotland (*Pterygotus*-beds near Visby).

British Locality.—Only one specimen has been found hitherto, It was obtained by Prof. Watts from the Old Dingle Mill in the Long Mountain district, and is now in his collection.

Horizon.—Zone of *M. Nilssoni*.

Associates.—*M. Nilssoni* and *M. varians*.

Monograptus ultimus, Perner. (Pl. XXV, figs. 9 A & 9 B.)

1899. *Monograptus ultimus*, Perner, 'Études sur les Graptolites de Bohême' pt. iii, sect. *b*, pp. 13–14, text-figs. 14 *a–b* & pl. xvi, figs. 4, 5, 11 *a–b*.

The collection of graptolites from the Long Mountain, made by Prof. Watts, contains a few indifferently-preserved specimens of a small graptolite which is almost certainly the British representative of the Bohemian species *M. ultimus*, Perner. The English specimens are not sufficiently perfect for complete description, so that the following account is drawn mainly from Dr. Perner's original diagnosis and from my own drawings of some Bohemian specimens from Kosor presented to Prof. Lapworth by Dr. Perner. A few specimens of this species from the Lake District are to be found in the Natural History Museum, South Kensington.

Polypary never exceeding 2 cm. (·8 inch) in length, generally less than 1·27 cm. (·5 inch). Width at the proximal end = about ·63 mm. (·025 inch), increasing gradually to a maximum of 1·6 mm. (·06 inch).[1] Polypary slightly curved, especially at the proximal end.

Proximal Extremity.—Sicula long and curved, extending nearly to the level of the aperture of the second theca; about 1·9 mm. (·075 inch) long and 5 times as long as wide. Ventral wall of aperture prolonged into a spine. The first theca arises distinctly above the aperture of the sicula.

Fig. 13.—Monograptus ultimus (× 5). *Enlargement of fig.* 9 B *in Pl. XXV.*

Thecæ thirty to twenty-eight in the inch (twelve to eleven[2] in 1 cm.), inclined to the axis at an angle of 30° to 40°. In specimens in relief the thecæ are of the *M.-colonus* type, but Dr. Perner states that in compressed specimens they are rather of the type of *M. vomerinus* or *M. crenulatus*. Adult thecæ 1·6 mm. (·06 inch) long, and from 3 to 4 times as long as wide, in contact only or with slight overlap. Outer free wall straight or slightly concavo-convex. Dr. Perner states that the aperture is perpendicular to the axis of the polypary; but in all the Bohemian specimens preserved in relief in true profile, that I have examined, the aperture is at right angles to the axis of the theca: this is the case also with the English examples.

This species is readily distinguished by

(1) Its small size;
(2) Its narrowness;
(3) The number of thecæ to the inch; and
(4) The form of the thecæ.

The affinities of the species are by no means clear. I have placed it, however, in the group of *M. dubius* provisionally because

(1) It has only one type of thecæ; and
(2) The first theca is inclined to the sicula at a fairly low angle.

On the other hand, the thecæ possess characters which ally it to *M. vomerinus* and *M. colonus* rather than to *M. dubius*, and the relation of the first theca to the sicula is in some respects similar to that in *M. colonus*.

Foreign Localities.—Bohemia (Kosoř, Lochkov, Dlouhá Hora, Kozel, Dvoretz).

British Localities.—Long Mountain (north side, near Frochas); Lake District (Helm Knot).

Horizon.—Zone of *M. leintwardinensis* var. *incipiens*.

Associate.—*M. leintwardinensis* var. *incipiens*.

[1] Dr. Perner states the width at 2 mm., but no specimens figured measure more than 1·6 mm.

[2] Dr. Perner says 'six,' but this is obviously a misprint.

(b) Group 2. Type *Monograptus colonus* (Barr.).

1. Two types of thecæ are present, the proximal thecæ possessing recurved apertures.

2. The outer wall of the first theca arises above the aperture of the sicula, and is inclined to it at a considerable angle (40° to 45°).

3. The length of the adult theca is, as a rule, 4 or more times the width.

Different species belonging to this group vary considerably in the form of the thecæ, but in all, the first two characteristics noted above are invariable.

Monograptus colonus (Barr.). (Pl. XXV, figs. 10 A–10 D and text-fig. 14, p. 464.)

1850. *Graptolithus colonus*, Barrande, 'Grapt. de Bohême' p. 42 & pl. ii, figs. 2–3.

There are probably few species that have been so frequently quoted by graptolithologists as this form, and few whose identification has been so uncertain. This is largely due to the fact that Barrande, under the name of *colonus*, figured three obviously different species (*op. cit.* pl. ii, figs. 1–5). Even when it became the general practice to regard Barrande's figs. 2 & 3 as the type-specimen, the difficulties of identification were by no means all removed, for doubt was still felt as to the accuracy of the figure. We now know that such doubts were well founded, for the artist's figure is not a reproduction of a complete specimen, but rather an inaccurate restoration in which the thecæ are drawn as if they were all of the form of those at the proximal extremity.

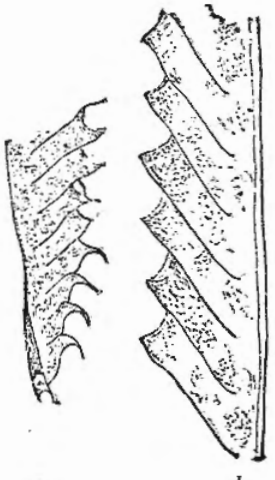
Fortunately there is now no room for doubt as to the true characters and form, not only of the proximal, but also of the distal thecæ of Barrande's original specimens on which he founded this species. Dr. Perner has refigured and redescribed these specimens, and through his kindness I was enabled to examine and draw them for myself. The following description, however, is drawn mainly from English specimens from the Lake District and from Builth, supplemented, where necessary, from these Bohemian forms.

Polypary.—3·8 to 5·8 cm. (1·5 to 2 inches) long, occasionally exceeding the latter limit. Straight distally, but possessing a distinct dorsal curvature in the proximal 6·3 mm. (·25 inch) or so of its length. Width at the proximal end = about ·84 mm. (·033 inch), exclusive of the apertural spine. Increase in width at the rate of about ·127 mm. (·005 inch) for each theca for the first six or eight thecæ, then much more gradual, and for the distal third or half of the length of the polypary the width is uniform. Maximum width = 2·3 mm. (·09 inch). Virgula slightly prolonged distally, rarely seen.

Proximal Extremity.—Sicula generally conspicuous, rather less than 1·9 mm. (·077 inch) long, and about ·32 mm. (·012 inch) wide at the aperture, so that it is 6 times as long as wide. Aperture provided with a long slender ventral spine. First theca

arising slightly above the aperture of the sicula, being inclined to it at an angle of about 45°. Sicula extending to the level of the second thecal aperture.

Fig. 14.—Monograptus colonus *(Barr.)*.



a *b*

a=proximal extremity, showing the sicula and the form of the proximal thecæ; from Vicarage Road, Builth. (×5.)

b=Distal thecæ of fig. 10 B in Pl. XXV, partly restored. (×5.)

Thecæ.—Thirty-two to twenty-six in the inch (twelve to ten in 1 cm.[1]), inclined to the axis at angles varying from 35° to 45°, generally about 40°. They are of two distinct types: the proximal four or five thecæ have their apertures strongly recurved, and possess a distinct spine which is bent downward. The succeeding thecæ have no such distinct spines, the apertures being concave, at right angles to the direction of the theca, and possessing only a somewhat pointed denticle to the lower apertural margin. According to Dr. Perner, in some Bohemian specimens preserved in full relief, the apertures are slightly convex and recurved in some of the more distal thecæ, but this character is not observed in ordinary compressed specimens preserved in shale. Proximal thecæ only $2\frac{1}{2}$ to 3 times as long as wide, the proportion gradually increasing until the adult thecæ are 4 times[2] (or even more) as long as wide. The amount of overlap varies from one quarter in the proximal thecæ to a third or a half in the adult thecæ. The length of an adult theca exceeds 2·6 mm. (·1 inch).

M. colonus has been almost universally quoted correctly as marking the horizon of the Lower Ludlow Shales in Britain and Europe. The species, however, as now defined, is by no means so common, in Britain at any rate, as has been generally supposed. In the Lower Ludlow Shales of Ludlow itself *M. colonus* is rare, and the only specimens that can be identified with it are those figured by Prof. Lapworth as *M. Rœmeri*: these are perhaps hardly typical, as I shall subsequently point out. Where the mudstone-facies of the Lower Ludlow is developed, as at Builth, *M. colonus* occurs in great abundance, and is one of the most characteristic graptolites of the *M.-Nilssoni* zone.

Although the foregoing description is significant of the typical form of *M. colonus* as found in Bohemia, yet in each British locality where this species occurs it is met with under certain slight variations; these local variations I do not, however, consider

[1] Dr. Perner reckons ten to eight in 1 cm., but this is undoubtedly a misprint.

[2] See Perner, 'Études sur les Graptolites de Bohême' pt. iii, sect. *b* (1899) pl. xiv, fig. 3.

to be worthy of varietal names. Helm Knot in Cumberland affords examples of *Monograptus colonus* (Pl. XXV, fig. 10 B) which, of all the British forms, bear the closest resemblance to the Bohemian type.

In the examples found at Adferton (Pl. XXV, fig. 10 D) in the Ludlow district (type-specimen *M. Rœmeri*, Lapw.), the polypary appears to widen out rather more rapidly than usual, and the adult thecæ are somewhat longer in proportion to their width, being 5 times as long as wide. At Builth, where the species occurs in great abundance, associated with *M. Nilssoni*, *M. bohemicus*, and *Retiolites spinosus*, it seems rarely to exceed 3·1 cm. (1·25 inch) in length, and the incurve at the proximal extremity is conspicuous. The thecæ are close-set, thirty-four to thirty in 1 inch (thirteen and a half to twelve in 1 cm.), and are long and narrow. Occasionally, however, at Builth (Pl. XXV, fig. 10 C), specimens differing but little from the typical form may be found. In the Long Mountain district the place of *M. colonus* is taken by another form, which I think is sufficiently distinct to be described as a new species.

Foreign Localities.—Bohemia (Vyskočilka, Kuchelbad, Kozel, Litohlav, Slavik, Butowitz, Borek, etc.; Colonies Krejci, Tachlowitz, d'Archiac, etc.); Scandinavia; Saxony; Thuringia; Harz Mountains; Polnisches Mittelgebirge; Graptolithengestein; France (Ardennes, Languedoc, Normandy, and Britanny).

British Localities.—Ludlow district (Elton Lane, Adferton); Builth (River Irfon, etc.); Lake District (Helm Knot, etc.); Dee Valley?

Horizon.—Zone of *M. Nilssoni*.

Associates.—*M. Nilssoni*, *M. bohemicus*, and *Retiolites spinosus*.

Var. *LUDENSIS* (Murch.). (Pl. XXV, fig. 11.)

1839. *Graptolithus ludensis*, Murchison, 'The Silurian System' p. 694 & pl. xxvi, fig. 2.

M. ludensis was originally figured by Murchison, but no description was appended. Beck, to whom Sir Roderick sent his specimens, identified them with Swedish forms which he intended to name *Graptolithus virgulatus*; but Murchison adhered to his own name of *Gr. ludensis*. M'Coy, in his 'British Palæozoic Fossils' (1855, p. 4), described *M. ludensis* in terms which make it evident that he was referring to *M. priodon*, and since that time *M. ludensis* has generally been considered as synonymous with *M. priodon*. Since the adoption of Bronn's earlier specific name *priodon*, the name *ludensis* has gradually disappeared from use.

It seemed clear, however, from Murchison's fig. 2, pl. xxvi, that his specimens did not belong to the *priodon*-group at all, and when I was enabled to examine and draw Murchison's original specimens in the Geological Society's Museum it was evident that they belonged to a form closely allied to *M. colonus*. Since the type-specimens were not well enough preserved to enable me to

make out all the characters, I went to Llanfair, and was fortunate enough to find the locality from which Murchison had evidently collected his type-specimens. Moreover, in addition to those which I myself collected, Dr. Humphreys, to whom my best thanks are due, kindly lent me a very fine slab crowded with examples.

All the Llanfair specimens are preserved in a hard calcareous sandstone which weathers deeply, and it is only on this weathered surface that the graptolites can be seen. Owing to this circumstance the apertures of the thecæ are generally imperfectly preserved, especially near the proximal end, where the apertures are somewhat turned underneath, and consequently half hidden from view. I have been unable, therefore, to determine with certainty whether the first thecæ are spinose: that is to say, whether they are identical in their characters with those of Barrande's *Monograptus colonus* or not. I believe that the first theca is spinose, but the succeeding thecæ are unprovided with spines. I have thought it best, therefore, to separate *M. ludensis* from *M. colonus* as a distinct variety. It agrees closely with *M. colonus* in general form and type of thecæ, but differs from it in the following particulars:—

(1) The proximal three or four thecæ are not recurved;
(2) The adult thecæ are 6 instead of 4 times as long as wide; and
(3) They overlap for a distance of more than one-half of their length.

Even if it were proved that one of the species included under Murchison's *Gr. ludensis* is identical with Barrande's *Gr. colonus*, I think that it would not be advisable, even for the sake of priority of nomenclature, to replace the well-known name of *colonus* by the old and unfamiliar designation *ludensis*: one, too, which was given with a most imperfect knowledge of the characters of the species, and was published without a description and with an inadequate drawing.

Locality.—Llanfair (Montgomeryshire).
Horizon.—Uncertain, but almost undoubtedly Lower Ludlow.
Associate.—*M. dubius*.

Var. *COMPACTUS* nov. (Pl. XXV, fig. 12.)

This well-marked variety agrees with the typical *M. colonus* in the shape of the thecæ and character of the proximal extremity, but is distinguished from it by the following characters:—

(1) Polypary dorsally curved throughout, and never exceeding 25·4 cm. (1 inch) in length;
(2) Maximum width of polypary attained about the thirteenth theca, the width decreasing towards both extremities;
(3) Virgula stout, and prolonged distally;
(4) There are forty-two to thirty-seven thecæ in 1 inch (sixteen and a half to fourteen and a half in 1 cm.); and
(5) The proximal thecæ are 3 times as long as wide, the adult 4½ times as long as wide.

Only a few specimens of this form have been found, but the type is in an excellent state of preservation.

British Localities.—Ludlow district (Elton–Evenhay Lane, Elton Lane, and Stormer Hall); Abberley Hills?

Horizon.—Zone of *Monograptus Nilssoni*.

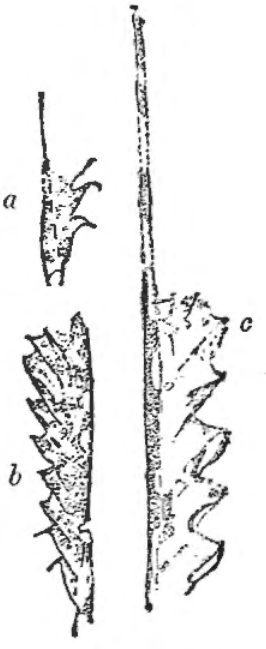
Associates.—*M. chimœra* var. *Salweyi*, *M. serra*, *M. varians* var. *pumilus*, and *M. Nilssoni*.

Monograptus varians, sp. nov. (Pl. XXV, figs. 14 A & 14 B.)

Polypary rarely exceeding 25·4 mm. (1 inch) in length, and generally only about 19 mm. (·75 inch) long. Straight distally, but with a distinct incurve at the proximal end. Width at proximal end = about ·76 mm. (·05 inch), the maximum width usually attained at the distal end being 1·77 mm. (·07 inch). Width increasing throughout the polypary, but most marked at the proximal end, where the rate of increase is approximately ·084 mm. (·003 inch) for each theca. Distal prolongation of the virgula very characteristic, being often as much as 12·7 mm. (·5 inch).

Proximal Extremity.—Sicula 1·77 mm. (·07 inch) long, and about ·32 mm. (·012 inch) wide, hence 5½ times as long as wide. Its relation to the first theca is the same as in *M. colonus*. Apex of sicula slightly above the aperture of the second theca.

Fig. 15.—M. varians, *sp. nov.* (×5).



a & *b* = Proximal extremity, showing the sicula; from the road above Garbett's Hall.

c = Distal thecæ of the reverse side of fig. 14 A in Pl. XXV.

Thecæ.—Thirty-two to twenty-six in the inch (thirteen to ten in 1 cm.), inclined to the axis at an angle of 30° to 35° (in exact profile). Proximal three thecæ with distinct apertural spines, the remainder having a concave aperture of the usual type. Proximal thecæ about twice as long as wide, the adult thecæ from 3½ to 4 times. Free for nearly three-quarters of their length, the outer and lower free wall being convex just below the aperture, and then becoming distinctly concave close to the aperture of the theca below, thus presenting the appearance of a marked excavation at that point. When preserved in true profile, this is not so conspicuous. The length of an adult theca is 2·2 mm. (·08 inch).

Localities. — Long Mountain (Lower Winnington, Dingle Mill, etc.); Montgomery Road; Ludlow district (Stormer Hall, etc.).

Horizon.—Zone of *M. Nilssoni*.

Associates.—*M. Nilssoni*, *M. dubius*, *M. uncinatus* var. *orbatus*, *Retiolites spinosus*, *M. crinitus*, and *M. chimœra* var. *Salweyi*.

Affinities, etc.—At first sight this form appears to be closely

allied to *Monograptus colonus*, but on examination it presents so many differences that I am of opinion that it should be regarded as a distinct species rather than merely as a variety of that form. It differs from *M. colonus* in the following particulars:—

(1) The polypary is shorter and narrower;
(2) Width of the polypary increasing more uniformly throughout;
(3) Distal prolongation of the virgula more persistent and conspicuous;
(4) The thecæ present a smaller amount of overlap; and
(5) The excavation at the base of the free part of the theca is peculiar.

It agrees with *M. colonus* in general form, and in possessing two types of thecæ; and it occurs in abundance at the same horizon as that at which one would expect to find *M. colonus* in the Long Mountain district.

M. varians is remarkable in presenting certain variations even in the same limited area, and, so far as can be judged, at the same horizon. It occurs at several localities in large numbers, in association with *M. Nilssoni*, on the north side of the Long Mountain; at the easternmost locality, namely at Winnington Green, it is usually only 12·7 to 19 mm. (·5 to ·75 inch) long, and the first two thecæ are spinose. At the Old Dingle Mill, 1½ miles farther west, it occurs also in great abundance in association with *M. Nilssoni*, but is longer, and the first theca alone is spinose. Some 2½ miles still farther west, above Garbett's Hall, it is still long, but has the first two thecæ spinose. These variations are quite constant for each locality. Between Winnington Green and Old Dingle Mill in the Trefnant–Middletown Brook *M. varians* occurs in association with *Retiolites spinosus* and *M. Nilssoni*, but is broader and coarser-looking, and the first three thecæ possess strong spines. As already mentioned in the first part of this paper, it is uncertain whether these graptolites occur here at a higher horizon than usual. The foregoing facts are interesting, as showing how readily small variations may take place even within so limited an area.

Var. *a* nov. (Pl. XXV, figs. 16 A & 16 B.)

1880. *Monograptus colonus* (Barr.) Lapworth, Ann. & Mag. Nat. Hist. ser. 5, vol. v, p. 152 & pl. iv, figs. 3 *b*–3 *d*.

This form was figured by Prof. Lapworth from a specimen found at Mary Knoll, Ludlow, and belonging to Mr. Hopkinson, as *M. colonus* (Barr.). Other examples have been collected by me from Stormer Hall, and I regard it as a variety of *M. varians*. It resembles the typical *M. varians* in

(1) The form of the thecæ;
(2) The long distally-produced virgula; and
(3) The character of the proximal extremity.

It differs from it in:—

(1) Its greater width of 2·1 mm. (·08 inch), which is attained more rapidly in *M. varians*;
(2) Its higher angle of inclination of the thecæ, namely 40°; and
(3) The greater number of thecæ in the inch (thirty-five to twenty-eight).

Horizon.—Zone of *M. Nilssoni*.

Associates.—*M. Nilssoni*, *M. chimæra* var. *Salweyi*, and *M. dubius*.

Var. β nov. (Pl. XXV, fig. 15.)

A second variety found in the Ludlow district is of interest as forming a connecting-link between the typical *Monograptus varians* and the variety next to be described, namely, *M. varians* var. *pumilus* nov. It agrees with *M. varians* in

(1) The general form of the polypary; and
(2) The shape of the thecæ.

It is distinguished from *M. varians* by the following characters:—

(1) The polypary is rather longer;
(2) The sicula is intermediate in length between that of *M. varians* and its variety *pumilus*, and extends midway between the apertures of the second and third thecæ.
(3) There are from thirty-six to thirty thecæ in the inch (fourteen to twelve in 1 cm.).

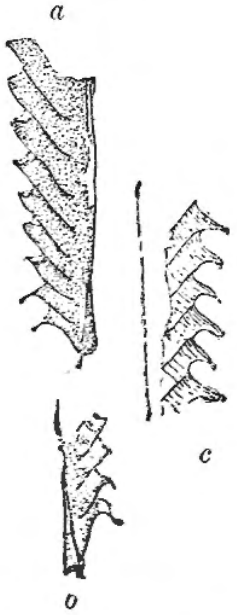
Locality.—Ludlow district (Elton Lane).
Horizon.—Zone of *M. Nilssoni*.
Associates.—*M. varians* var. *pumilus*, *M. Nilssoni*, and *M. dubius*.

Var. *PUMILUS* nov. (Pl. XXV, figs. 17 A & 17 B.)

This variety agrees with the typical *M. varians* in the shape of the thecæ. It is readily distinguished from it by the following characters:—

(1) Polypary seldom attaining a greater length than 12·7 mm. (·5 inch);
(2) Polypary straight, except for a very slight dorsal curvature;
(3) Sicula 1·9 mm. (·075 inch) in length and ·32 mm. (·012 inch) wide, hence 6 times as long as wide, extending to nearly the level of the aperture of the third theca. Dorsal wall of sicula very straight;
(4) There are forty-two to thirty-six thecæ in 1 inch (sixteen and a half to fourteen and a half in 1 cm.); and
(5) The thecal growth-lines are well marked.

Fig. 16.—M. varians *var.* pumilus *nov.* (×5).



a=Proximal extremity; from the Abberley Hills, coll. Wickham King.
b=Proximal extremity; from Elton Lane.
c=Cast of distal thecæ, showing growth-lines. From Round Hill, Abberley; coll. Wickham King.

British Localities.—Ludlow district (Elton Lane, Elton-Evenhay Lane, Stormer Hall); Abberley Hills. It occurs in great abundance at these localities.

Horizon.—Zones of *M. Nilssoni* and *M. scanicus*.

Associates.—*M. Nilssoni*, *M. colonus* var. *compactus*, *M. dubius*, *M. varians* var. β, *M. scanicus*, *M. chimæra* and its variety *Salweyi*.

Monograptus Rœmeri (Barr.). (Pl. XXV, figs. 13 A & 13 B.)

1850. *Graptolithus Rœmeri*, Barrande, 'Grapt. de Bohême' p. 41 & pl. ii, figs. 9–11.

Polypary.—3·8 to 7·3 cm. (1·5 to 2·5 inches) long, with a characteristic form, the dorsal margin being slightly convex at the proximal extremity, then concave for the greater part of its length, and again convex at the distal end. The width at the first theca is ·89 mm. (·035 inch), increasing for the first four thecæ at the rate of ·19 mm. (·0075 inch). After that increase it is more gradual, the maximum width, 2·9 mm. (·115 inch), being attained at about the fourteenth theca. Some examples, however, measure as much as 3·6 to 4·2 mm. (·14 to ·17 inch). Frequently the polypary appears to narrow towards the distal end. Distal prolongation of virgula short, and rarely seen in British specimens, but it may be as long as 2 cm. in Bohemian forms.

Proximal Extremity.—Sicula about 1·8 mm. (·07 inch) long, and ·32 mm. (·012 inch) wide, hence more than 5 times as long as wide, and extending to about the apertures of the second theca. Aperture provided with a long ventral spine. First theca the same as in *M. colonus*.

Fig. 17.—M. Rœmeri (*Barr.*) ×5.

[Proximal extremity, showing the sicula: enlargement of the reverse side of fig. 13 A in Pl. XXV.]

Thecæ.—Thirty-four to twenty-eight in the inch (thirteen and a half to eleven in 1 cm.), inclined to the axis at an angle of 40° to 45°. Thecæ long, narrow tubes, the adult thecæ being 5 or $5\frac{1}{2}$ times as long as wide, and overlapping for two-thirds of their length. Aperture wide and concave (somewhat convex in relief) and at right angles to the direction of the theca. Proximal three or four thecæ only about 3 times as long as wide, inclined to the axis at a high angle, overlapping for half their length, and with the aperture recurved.

M. Rœmeri is a well-marked species characterized by (1) its peculiar double curvature, (2) its rapid increase in width, and (3) the amount of thecal overlap. This species has not been correctly identified in England hitherto, owing probably to its rarity. It does not seem to have been yet recognized in Sweden, unless Tullberg's *M. colonus*[1] is referable to it, but Dr. Barrois records it from France, and an isolated specimen was figured by Heidenhain from the Graptolithengestein. Nowhere, however, does it occur so abundantly and characteristically as in Bohemia. This species is quite distinct from *M. colonus*, though Prof. Frech seems to regard its separation from *M. colonus* as 'at least doubtful.'

Foreign Localities.—Bohemia (Butowitz, Borek, Slavik, etc.), Graptolithengestein; France (Languedoc, Britanny, etc.); Scania? (Knashufvud).

[1] 'Skånes Graptoliter' pt. ii (1883) Sver. Geol. Undersökn. ser. C, no. 55, pl. i, fig. 21.

British Localities.—Ludlow district (Elton Lane, Elton–Ludlow Road?; Adferton?; Dudley (Sedgley Shales); Long Mountain (Trefnant–Middletown Brook); Builth (Aberedw Hill).

Horizon.—In Bohemia it occurs in the Limestone Ee 2, and belongs, therefore, characteristically to the Lower Ludlow. In Britain it is found in the zones of *Monograptus Nilssoni* and *M. scanicus*, characteristically in the latter.

Associates.—*M. scanicus*, *M. chimæra*, and *M. Nilssoni*.

(c) Group 3. Type *M. chimæra* (Barr.).

1. Proximal extremity of the form of that of the *M.-colonus* type.
2. Thecal apertures provided with long spines.

Monograptus chimæra (Barr.). (Pl. XXV, figs. 18 A–18 D.)

1850. *Graptolithus chimæra*, Barrande, 'Graptolites de Bohême' p. 52 & pl. iv, figs. 34–35.

Polypary.—2·54 to 3·8 cm. (1 to 1·5 inch) long, straight distally, but with a distinct dorsal curvature for the first 5 mm. (·2 inch) of its length. Increase in width most rapid for the first five or six thecæ, but generally slight throughout the whole length. Width at the aperture of the first theca (exclusive of spines)= generally about ·89 mm. (·035 inch), while the maximum width of the distal end (exclusive of spines) is 1·9 mm. (·075 inch). Virgula produced slightly beyond the distal end.

Proximal Extremity.—Sicula approximately 1·7 mm. (·066 inch) long, extending to about midway between the apertures of the second and third thecæ. Width at the aperture=·34 mm. (·013 inch), hence the sicula is approximately 5 times as long as wide.

Thecæ.—Thirty-two to twenty-eight in the inch (thirteen to eleven in 1 cm.), inclined to the axis at an angle of about 40° to 50°. Straight broad tubes, fairly uniform in width throughout, provided with a stout blunt spine arising from the aperture. This spine has a maximum length of ·63 mm. (·025 inch), and arises slightly above the centre of the lateral wall of the aperture, though the apparent position varies considerably in compressed specimens. The proximal thecæ are twice, and the distal thecæ 4 times as long as wide. The amount of overlap is about half of the whole length.

I have referred this species provisionally to *M. chimæra* (Barr.), since the type of thecæ and position of the spine are similar in the Bohemian and British forms. The Bohemian type-specimen, however, is small, only 12·7 mm. (·5 inch) long, and is not well preserved, and possibly a further study of more perfect specimens may prove that the British form is a variety of it. No other species resembles this closely, except *M. Salweyi* (Hopk.) and *M. colonus*, Jækel, and its affinities to these will be considered later. Numerous small specimens occur in association with the adult forms at the Elton-Ludlow Road locality (Pl. XXV, fig. 18 D), which differ somewhat in their general shape, but they may be only young forms, and are not worthy of a varietal distinction.

I have examined a large number of specimens in the hope of

detecting the true form of the theca and the position of the apertural spine, but the English examples are so indifferently preserved that it is only possible to infer their characters. When the thecæ are preserved in true profile, the spine arises slightly above the centre of the lateral wall of the aperture, and is not a prolongation of the interthecal wall (see fig. 18 *a*, p. 473), as is the case in *Monograptus leintwardinensis*. This, then, would probably be the true position of the spine if the theca were in relief, and might produce a certain angularity in the form of the theca; indeed, in one specimen, preserved so that the apertures face the observer, one or two of the thecæ appeared to be hexagonal in shape. The spines of the proximal three or four thecæ are seldom seen in true profile, and present much the same appearance as those of *M. colonus*; but it is probable that there is no essential difference between their original position in the proximal and that in the distal parts of the polypary. The various positions that the spine assumes under different conditions of preservation may be best seen from the figures.

Foreign Localities.—Bohemia (Hinter-Kopanina). (Ee 2.)

British Localities.—Ludlow district (Elton-Ludlow Road, Elton Lane); Builth district (Aberedw Hill); the Long Mountain (north side).

Horizon.—It occurs typically in the *M.-scanicus* zone, but is also found in the *M.-Nilssoni* zone.

Associates.—*M. scanicus*, *M. Rœmeri*, *M. dubius*, *M. bohemicus*, and *M. Nilssoni*.

Var. *Salweyi* (Hopk. MS.). (Pl. XXV, figs. 19 A & 19 B and text-fig. 18, p. 473.)

1880. *Monograptus Salweyi* (Hopk. MS.) Lapworth, Ann. & Mag. Nat. Hist. ser. 5, vol. v, p. 150 & pl. iv, figs. 2 *a–b*.

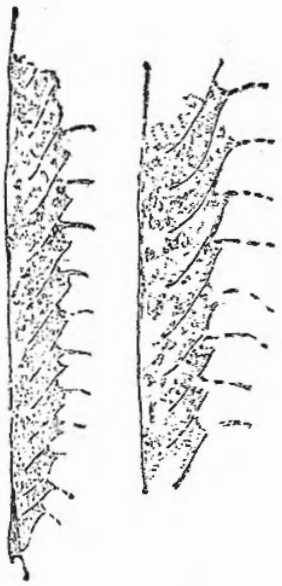
M. chimæra var. *Salweyi* was originally named by Mr. Hopkinson as a distinct species, and his type-specimen, which shows the distal end only, was figured by Prof. Lapworth. From numerous specimens of this form, collected by me from Mr. Hopkinson's type-locality of Stormer Hall, near Leintwardine, I have been able to complete the description of the whole polypary.

Although no other specimen was found showing the extremely long distal prolongation of the virgula, so characteristic of Mr. Hopkinson's type-specimen, there is no doubt as to its identity, for it is the dominant species at this locality. *M. Salweyi* in its typical form is a well-marked variety of *M. chimæra* (Barr.), and is distinguished from it by the following peculiarities:—

(1) Polypary seldom exceeding 12·7 mm. (·5 inch) in length, and attaining a maximum width of 1·6 mm. (·06 inch);
(2) Margins of polypary parallel except at the proximal extremity, the increase in width taking place within the length occupied by the first five or six thecæ;
(3) Polypary straight throughout;
(4) Virgula prolonged distally for a considerable length; and
(5) Thecal apertural spines longer and more slender.

But although the extreme forms of *Monograptus chimæra* and *M. Salweyi* are readily distinguished, there are so many intermediate shapes linking the two together that it is often impossible to separate them.

Fig. 18. — M. chimæra, *var.* Salweyi *(Hopk.) from Stormer Hall (×5).*



a *b*

a=Complete specimen, showing sicula.
b=Distal thecæ, with long curved spines.

The only other *Monograptus* with which this variety *Salweyi* can be confused is *M. colonus*, Jækel. That form belongs undoubtedly to the group of *M. chimæra*, but whether it should be referred to *M. chimæra* or to its variety *Salweyi* is uncertain. One fragment found at the Stormer Hall locality, if referable to that variety, must have been of abnormal size. It is 25·4 mm. (1 inch) long, and about 2·1 mm. (·08 inch) wide, while the virgula, which is extremely broad, is produced distally for 10 mm. (·4 inch). The entire polypary, however, is not preserved, and consequently its identification with *M. chimæra* var. *Salweyi* is doubtful.

Prof. Frech identifies [1] *M. uncinatus*, Tullb., with *M. Salweyi*, but he himself figures (*op. cit.* fig. 213) as an example of *M. uncinatus* a fragment from Djurröd (Scania), which in my opinion belongs to *M. leintwardinensis*. I have been unable to examine Tullberg's types, but I have found his drawings, as respects other species, so accurate that I have no reason to regard them in this case as incorrect.

Foreign Localities.—Unknown abroad unless *M. colonus*, Jækel, may be referred to it, and this occurs in the Graptolithengestein of the German Drift.

British Localities.—It occurs in abundance at Stormer Hall near Leintwardine; it has also been found at Elton–Evenhay Lane, and at Llettygynfach, south-west of the Long Mountain.

Horizon.—Zone of *M. Nilssoni*.

Associates.—*M. dubius*, *M. colonus* var. *compactus*, and *M. varians* var. *a*.

Var. *a* nov. (Pl. XXV, fig. 20.)

This interesting form, although undoubtedly a variety of *M. chimæra*, presents peculiarities at various stages of its growth which give parts of the polypary a remarkable resemblance to *M. colonus*, or at any rate to species belonging to that group.

[1] 'Lethæa Geognostica' vol. i, pt. iii (1897) p. 658.

It agrees with the typical *Monograptus chimæra* in :—

(1) The character of the proximal extremity;
(2) The spinose nature of some of the thecæ; and
(3) The number of thecæ to the inch.

It is distinguished by the following peculiarities :—

(1) The form of the polypary is that of a broad *M. colonus*. Length =2·54 to 3·8 cm. (1 to 1·5 inch), and the maximum width of 2·5 mm. (·1 inch) is attained rapidly;
(2) All the thecæ, except the first six or seven, either have very short blunt spines, or are destitute of them altogether.

The foregoing description is based partly on British specimens and partly on Swedish forms in the possession of Prof. Lapworth, the latter being better preserved and agreeing with the British forms in most particulars.

Localities.—Ludlow district (Elton Lane, Elton-Ludlow Road).

Horizon.—Zone of *M. scanicus*.

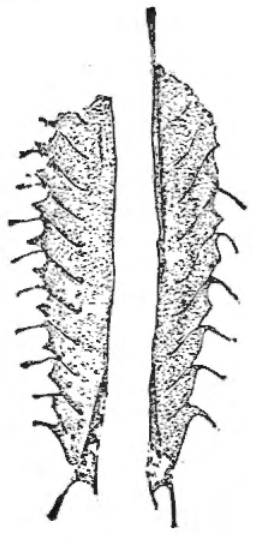
Associates.—*M. varians* var. *pumilus* and *M. scanicus*.

Monograptus leintwardinensis, Hopk. MS. (Pl. XXV, figs. 21 A & 21 B.)

1880. *Monograptus leintwardinensis*, Hopk. MS. Lapworth, Ann. & Mag. Nat. Hist. ser. 5, vol. v, p. 149 & pl. iv, figs. 1 *a*–1 *d*.

Polypary short, seldom exceeding 12·7 mm. (·5 inch) in length. Straight distally, with a slight curvature at the proximal end. Width at the aperture of the first theca (exclusive of spine) = about ·85 to 1 mm. (·03 to ·04 inch). Increase in width gradual for the first five or six thecæ, until the maximum width of 1·6 mm. (·06 inch) is attained. Virgula generally produced somewhat beyond the distal end of the polypary.

Fig. 19.—M. leintwardinensis, *Hopk., from Church Hill Quarry (×5).*



a *b*

a=Enlargement of fig. 21 A in Pl. XXV.
b=Specimen showing different positions of the thecal spines.

Proximal Extremity. — Sicula conspicuous, long, and narrow. About 2·1 mm. (·08 inch) in length, extending to midway between the apertures of the second and third thecæ. Width at the aperture =·38 mm. (·015 inch), so that the length is almost 6 times the width. Aperture provided with a long ventral spine, and a shorter incurved dorsal one. The sicula gives origin to the first theca at a distance of about one-fifth of its length above the aperture.

Thecæ.—Fourteen to eleven in the whole polypary, giving an average of thirty-eight to thirty-six thecæ in the inch (fifteen to fourteen in 1 cm.). Fairly short and narrow

tubes, adult ones 1·7 mm. (·07 inch) in length and $3\frac{1}{2}$ times as long as wide. At the proximal end the thecæ are merely in contact; distally they overlap for not quite half their length. They are inclined to the axis at an angle of 35° to 45°. Outer free wall rather deeply excavated just above the aperture of the theca below, then expanding somewhat, and again contracting slightly at the aperture, which is markedly concave. The upper interthecal wall of each theca is continued as a long flexible spine ·63 mm. (·025 inch) long, generally curving slightly over the aperture.

This species is very characteristic of the Lower Ludlow, and is readily recognized by its (*a*) small size, (*b*) thecal spines, and (*c*) gregarious habit, occurring as it does in great numbers on a slab unassociated with other species. As in all other spinose forms, the position of the spine varies considerably under different conditions of preservation. In forms preserved in perfect profile it is clear that the spine arises from the upper interthecal wall. In compressed forms it seems to arise some little distance up the outer wall of the theca next above, but this appearance is deceptive. Sometimes the aperture appears very narrow, and then the position of the spine does not differ in any way from that of the spine of *Monograptus chimæra* var. *Salweyi* in a similar aspect.

M. leintwardinensis has not been described from abroad, but, as was pointed out on p. 473, Prof. Frech's figure of *M. uncinatus* from Scania may be that of a Swedish form referable to this species.

Foreign Localities.—Djurröd in Scania?

British Localities.—Ludlow district (Leintwardine, Church Hill, Adferton? Trippleton? Aymestry, Vinnall); Broxton and Burton; Long Mountain (Llettygynfach); Builth district (Aberedw); Presteign, Old Radnor; Dee Valley (Llantisilio Road and Pen-y-Vivod); Lake District?

Horizon.—*M. leintwardinensis* is the characteristic zone-fossil of the highest beds of the Lower Ludlow, and ranges up into the Aymestry Limestone.

Associates.—It has not yet been found in association with any other graptolite.

Var. *INCIPIENS*, nov. (Pl. XXV, figs. 22 A & 22 B.)

This variety agrees with the typical *M. leintwardinensis* in

(1) The presence of the typical apertural spines in some of the thecæ; and
(2) The number of thecæ to the inch.

It is distinguished from it by the following peculiarities:—

(1) Polypary wider, the maximum width being 2 to 2·3 mm. (·08 to ·09 inch) and somewhat longer;
(2) Sicula broader, being ·42 mm. (·016 inch) in diameter, and rarely more than $4\frac{1}{2}$ times as long as wide;
(3) The proximal thecæ are provided with spines similar to those of *M. leintwardinensis*, but the distal thecæ have no spines, and are at least 4 times as long as wide; and
(4) The adult thecæ overlap for a half to three quarters of their length.

This form is abundant in certain localities, and may be merely a local variety of the typical *Monograptus leintwardinensis*, the two not being found in association. It seems to occur at a somewhat lower horizon, and may possibly represent the form from which *M. leintwardinensis* was eventually developed.

The form figured by Dr. Perner[1] as *Monograptus* sp. from Hviždalka is probably referable to this variety.

British Localities.—Montgomery Road; Long Mountain (various localities, such as Rose & Crown Inn, Lower Winnington, etc.); Lake District (Tebay Gill, Bannisdale).

Horizon.—Near the top of the Lower Ludlow Beds.

Associate.—*M. ultimus*.

(d) Group 4. Type *M. uncinatus*, Tullb.

1. Thecæ short broad tubes; apertures circular, upper wall prolonged into a spinose claw.

2. Polypary of the general type of *M. colonus*.

The typical Swedish form *M. uncinatus* has not hitherto been found in Britain, but the group which it typifies is represented by two varieties.

Monograptus uncinatus var. *orbatus* nov. (Pl. XXV, figs. 23A & 23B.)

Polypary from 2·54 to 5·08 cm. (1 to 2 inches) long, and increasing gradually from a width of ·76 mm. (·03 inch) at the proximal end to a maximum width of 1·9 mm. (·08 inch) at the distal end, the increase being at the rate of about ·13 mm. (·025 inch) for each theca; somewhat irregularly curved, the dorsal margin of the proximal third convex, then distinctly concave, and finally in the distal third of its length becoming straight or slightly convex. This 'broken-back' appearance (Pl. XXV, fig. 23A), though less marked in some specimens than in others, is characteristic, and reminds one of *M. riccartonensis*, Lapw. Virgula slightly produced distally.

Fig. 20.—M. uncinatus *var.* orbatus *nov.*

a *b*

a=Proximal extremity, showing sicula; from Trefnant-Middletown Brook.
b=Distal thecæ, from Dudley; coll. Dr. Fraser.

Proximal Extremity.—Sicula = about 1·6 mm. (·06 inch) in length, and ·32 mm. (·012 inch) wide at the aperture, hence it is five times as long as wide. Outer wall of sicula convex, especially near the aperture, and with a short spine. The first theca arises from the sicula above the aperture, being inclined to it at an angle of 30°. The

[1] 'Études sur les Graptolites de Bohême' pt. iii, sect. *b* (1899) pl. xvii, fig. 14.

sicula appears to extend to about the level of the aperture of the second theca.

Thecæ.—Thirty to twenty-four in the inch (twelve to nine in 1 cm.), inclined to the axis at an angle of 30° to 35°. Original shape of the thecæ somewhat difficult to determine, as it varies considerably in different aspects. In some views the thecal aperture appears to be circular, as in *Monograptus vomerinus*, and the upper wall is prolonged into a long curved spine (text-fig. 20 *b*, p. 476). In other views the aperture is not so well seen, the upper thecal wall curving over it as a short claw which is prolonged into a spine directed downward, reminding one of *M. riccartonensis*, Lapw. (text-fig. 20 *a*). There are also appearances intermediate between these extremes. The various aspects of the thecæ are shown in the figures. Lobe-like projections of the thecæ occupy only about a quarter of the total width of the polypary. The adult thecæ are about 1·27 mm. (·05 inch) long, rather more than ·63 mm. (·025 inch) wide, being therefore barely twice as long as wide. Thecæ in contact only, or with slight overlap.

The occurrence of *M. uncinatus* var. *orbatus* in the Lower Ludlow Shales is of particular interest, since the variety forms a connecting-link between the graptolitic fauna of the Wenlock and Ludlow. It combines some of the characters of the *M.-colonus* group, so characteristic of the Ludlow, with some of those of the *M.-priodon* and *M.-vomerinus* groups of the Wenlock, for it resembles the former (1) in its general shape, (2) in the character of the proximal extremity, and (3) in the distally-produced virgula, while it is allied to the latter in the shape and form of the thecæ.

It may be readily distinguished from all other Ludlow graptolites, except those of the group of *M. uncinatus*, by:—

(1) The generally irregular form of the polypary; and
(2) The character of the thecæ.

It is undoubtedly closely allied to *M. uncinatus*, Tullb., of which it must be regarded as a variety. The English form may be distinguished from the Swedish species by:—

(1) Its irregular form (*M. uncinatus* is nearly straight);
(2) The form of the sicula;
(3) The larger number of thecæ to the inch (thirty as against twenty-four);
(4) The spinose termination of the apertural claw of the theca.

Localities.—Long Mountain (Trefnant–Middletown Brook).

Horizon.—Zone of *M. Nilssoni*.

Associates.—*M. bohemicus*, *M. Nilssoni*, *M. vulgaris* var. α, and *M. varians*.

Var. *MICROPOMA* (Jækel). (Pl. XXV, figs. 24 A & 24 B and text-fig. 21, p. 478.)

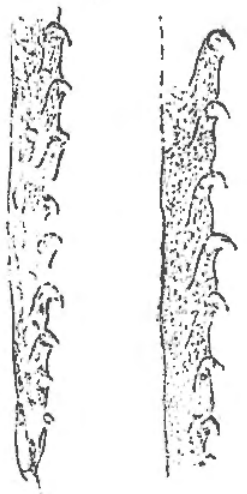
1889. *Pomatograptus micropoma*, Jækel, Zeitschr. d. Deutsch. Geol. Gesellsch. vol. xli, pl. xxix, figs. 4–6.

I have found only a few British specimens of this form, and these are somewhat indifferently preserved. I have no doubt, however,

that the thecæ are of the same type as those of *Monograptus uncinatus*, and that this should be regarded as a variety of the species distinguished by the following peculiarities:—

(1) Polypary almost straight, except for a slight dorsal curve at the proximal end;
(2) Maximum width of 1·27 mm. (·05 inch) attained very gradually and uniformly;
(3) Thecæ twenty-six to twenty-two in the inch (ten to nine in 1 cm.);
(4) Apertural claw shorter and narrower, and form of theca resembling that of *M. vomerinus* more closely than it does that of *M. riccartonensis*.

Fig. 21.—M. uncinatus, *var.* micropoma *(Jækel)* ×5.



a *b*

a=Proximal extremity, with sicula; from Elton–Ludlow Road.
b=Distal thecæ; from Stormer Hall.

The above characters will serve to distinguish it from *M. uncinatus* var. *orbatus*.

I believe that the English form is identical with Jækel's species *micropoma*, though I have been unable, on account of the scarcity of specimens and the consequent lack of good material, to investigate all those structural details necessary for a thoroughly satisfactory identification. The German specimens appear to be in a better state of preservation than the English examples, and Jækel considers that the apertural spine is rather of the nature of a lobe than a spine proper. This view coincides with my own opinion. Jækel holds that his species is identical with *Monograptus* sp. of Heidenhain, and I have therefore used Heidenhain's description to supplement his own.

The English and German specimens of this variety agree in the following characters:—

(1) The general form of the polypary;
(2) The number of thecæ to the inch;
(3) The general shape of the thecæ and the nature of the aperture.

The angle of inclination of the thecæ to the axis is greater in the German specimens (45° against 25° to 30°), but this may be due merely to the conditions of preservation; indeed, in the proximal part of fig. 5 of Jækel, the angle of inclination is only 30°. The spine in Jækel's figures is shorter than in the English specimens.

Foreign Localities.—Graptolithengestein at Kunzendorf; doubtfully from Röstånga in Scania.

British Localities.—Ludlow district (Elton Lane, Elton–Ludlow Road, and Stormer Hall); Long Mountain (Lower Winnington and Garbett's Hall).

Horizon.—In England this variety occurs in the zones of

Monograptus Nilssoni and *M. scanicus*, more especially in the former. In Germany it is found in the Graptolithengestein, in association with other Lower Ludlow forms.

Associates.—*M. bohemicus*, *M. Nilssoni*, *M. varians* and its variety *pumilus*, *M. dubius*, and *M. chimæra* var. *Salweyi*.

(e) Group 5. Type *M. scanicus*, Tullb.

1. Thecæ without overlap; apertures concave, with the upper wall bent into a claw.
2. Polypary slender, curved.

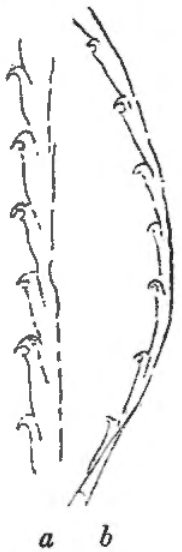
Monograptus scanicus, Tullb. (Pl. XXV, figs. 25 A & 25 B.)

1883. 'Skånes Graptoliter' pt. ii, Sver. Geol. Undersökn. ser. C, no. 55, p. 26 & pl. ii, fig. 38.

Polypary slender, slightly curved, very flexible, so that the general form varies constantly. Length of whole polypary not seen; the longest fragments measure 10·1 cm. (4 inches). It is extremely slender at the proximal end, about ·254 mm. (·01 inch) in width, widening very gradually, and attaining a maximum width of about 1 mm. (·04 inch) at the distal end.

Proximal Extremity.—Sicula rarely preserved, but it has been seen in a few specimens; about 1·5 mm. (·06 inch) in length, while the width at the aperture is about one-sixth to one-seventh of the length. Aperture concave, dorsal wall provided with a fairly long, slender spine. The first theca arises at a distance of about one-third of the length of the sicula from the aperture of the sicula.

Fig. 22.—M. scanicus, *Tullb., from Aberedw Hill (×5).*



a *b*

a=Distal thecæ.
b=Proximal extremity, with sicula.

Thecæ.—Twenty to twenty-three in the inch (eight to nine in 10 mm.), being more distant at the proximal extremity and inclined to the axis at an angle of 10° to 20°; generally arranged on the concave side of the polypary, though occasionally at the proximal extremity they occur on the convex side. Thecæ long narrow tubes, of equal width throughout; aperture concave, the upper wall curving over it in the form of a claw, which is bent outward and downward. The aperture resembles that of *M. uncinatus* in shape, but differs markedly in size. At the proximal extremity the proportion between the length and width of the thecæ is about 7 to 1; distally it is only 5 to 1. Thecæ in contact merely, no overlap; the median wall of the proximal thecæ is much shorter than that of the more distal thecæ.

The curves of the polypary vary greatly in different fragments, some showing the proximal extremity with a double curvature like that of *Monograptus Nilssoni*, while others are concavely curved throughout and bear the thecæ on the concave side. The more distal fragments are first gently curved, and finally straight. Perfectly straight fragments 7·6 cm. (3 inches) long have been found, showing that the complete polypary was probably some 12·7 to 15·2 cm. (5 to 6 inches) long.

Affinities.—This form is clearly identical with Tullberg's Swedish species, and although it has never previously been described and figured in England, it was recorded by Prof. Lapworth as early as 1880.[1] It is a very clearly defined species, and there is little difficulty in its correct identification. Jækel's *Pomatograptus Becki* is most probably referable to this species, and he himself says that it is known as *M. scanicus* in Sweden. Prof. Frech's view [2] that Jækel's species is referable rather to *M. cygneus*, Törnq., which he regards as a synonym of *M. scanicus* conditioned by stratigraphical differences only, may here be mentioned.

Foreign Localities.—Sweden (Knashufvud, Ask, Röfvarekulan, Djurröd, and many places in South-eastern Scania); Graptolithengestein (Brandenburg, Rostock, Königsberg, etc.); Polnisches Mittelgebirge; Northern France.

British Localities.—Ludlow district (Elton Lane, Elton-Evenhay Lane, Elton–Ludlow Road, etc.); Builth (Aberedw Hill); Abberley Hills; Long Mountain?

Horizon.—In Britain *M. scanicus* occurs in the *M.-Nilssoni* and *M.-scanicus* zones. In Sweden it is found in the *Cardiola*-Skiffer, and in France in beds containing *Cardiola interrupta*.

Associates.—*M. bohemicus*, *M. Nilssoni*, *M. dubius*, *M. chimæra* and its var. *α*, *M. Rœmeri*, and *M. varians* var. *pumilus*, etc.

Monograptus crinitus, sp. nov. (Pl. XXV, figs. 26 A & 26 B and text-fig. 23, p. 481.)

Polypary probably reached many inches in length, but is only preserved in a fragmentary condition, some of the fragments, however, being 5 to 7·5 cm. (2 to 3 inches) long. Occurs covering the surface of the rock like a thick mass of hairs. Maximum width of the hair-like polypary, even at the aperture of the theca = only ·38 mm. (·015 inch), while it may be as little as ·19 mm. (·007 inch). Between the apertures of the thecæ the width is considerably less. Polypary curved in various directions, some fragments being nearly straight, others concavely curved ventrally; but as a rule there is a distinct convex curvature, the thecæ occurring on the concave side.

Proximal Extremity.—The polypary becomes so extremely slender at the proximal extremity that it is very difficult to identify the sicula with certainty; it appears, however, to be similar to

[1] 'Geological Distribution of the Rhabdophora' Ann. & Mag. Nat. Hist. ser. 5, vol. v, p. 369.

[2] 'Lethæa Geognostica' vol. i, pt. iii (1897) p. 644.

that of *M. scanicus*, as is also its relation to the first theca. It is about 1·4 mm. (·055 inch) long, and 6 or 6½ times as long as wide Aperture concave, with spines. The first theca arises at a distance of from a half to a third of the length of the sicula from the aperture of the sicula.

Fig. 23. — Monograptus crinitus, *sp. nov., from Lower Winnington Lane, Long Mountain (×5).*

a = Enlargement of fig. 26 A in Pl. XXV.
b = Proximal extremity.
c, *d* = More distal thecæ.

Thecæ.—Fourteen to eighteen in the inch (five and a half to seven in 1 cm.), inclined to the axis at an angle of 5° to 10°. Long narrow tubes, expanding gradually towards the aperture, the upper wall of which bends over like a small hook or claw. In the distal thecæ this claw-like portion is blunter and less hook-like. Length of proximal thecæ = 1·9 mm. (·063 inch), whereas that of the more distal is 1·6 mm. (·055 inch). Thecæ in contact only.

Affinities, etc. — This species seems to be quite distinct from any other Lower Ludlow graptolite yet described. It may be readily distinguished by:—

(1) Its delicate thread-like form;
(2) The hook-like shape of the thecæ; and
(3) The distance apart of the thecæ.

It is a matter of considerable difficulty to distinguish species with such very slender forms one from the other, owing to the impossibility of making out the necessary minute details; hence the general form of the polypary in these cases must be the main guide. It is mainly on this ground that I consider this species distinct from *M. Barrandei* (Suess), though it resembles that species in its slender shape and number of thecæ to the inch. *M. Barrandei*, however, is straight or very slightly curved distally, while *M. crinitus* is markedly flexuous and curved throughout. The type of theca, too, is rather different in the two forms, so far as one can judge in such minute cells: the apertures in *M. Barrandei* are (according to Prof. Lapworth) blunt, and the apertures of the proximal thecæ hardly project at all from the ventral margin; whereas in *M. crinitus* the apertures are prolonged into a pointed claw or hook, and those of the proximal thecæ project almost as much from the ventral margin as do those of the adult thecæ. It is possible that *M. Barrandei* of Jækel may be referable to this species, but the description and figures are too meagre to afford sufficient evidence.

Locality.—Lower Winnington, on the north side of the Long Mountain.

Horizon.—Zone of *M. Nilssoni*.

Associates.—*M. varians*, *M. Nilssoni*, and *Retiolites* sp.

(f) Group 6. Type *M. Nilssoni* (Barr.).

1. Thecæ in contact or with slight overlap, apertures simple.
2. Polypary narrow and curved.

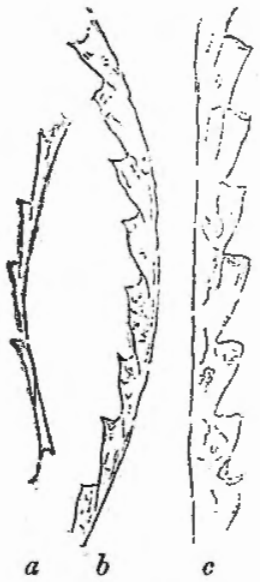
Monograptus Nilssoni (Barr.). (Pl. XXV, figs. 28 A & 28 B.)

1850. *Graptolithus Nilssoni*, Barrande, 'Grapt. de Bohême' p. 51 & pl. ii, fig. 16.

Polypary several inches in length, bent into a double curve proximally, almost straight distally. The width increases gradually from ·21 mm. (·008 inch) at the proximal extremity to a maximum width of 1 mm. (·04 inch) in the adult portions.

Proximal Extremity.—Sicula small but distinct, length= about 1·27 mm. (·05 inch); width at the aperture one-fifth to one-sixth of the length. Aperture concave, ventral edge produced into a long slender spine. The sicula gives origin to the first theca towards its apex, so that the apertures of the sicula and first theca are about 2 mm. (·08 inch) distant.

Fig. 24.—M. Nilssoni (*Barr.*) ×5.



a=Proximal extremity, with sicula; from Montgomery Road.
b=Enlargement of part of fig. 28 A in Pl. XXV.
c=Enlargement of the distal thecæ of fig. 28 B in Pl. XXV.

Thecæ linear, twenty to twenty-two in the inch (eight to nine in 1 cm.), arranged on the concave side of the polypary, except at the extreme proximal end, where for a short distance they are on the convex side. Thecæ in contact only, and inclined at an angle of 10° to 25°. Outer wall slightly curved, concavo-convex; aperture concave, at right angles to the direction of the thecæ; length of thecæ=4 to 5 times the width.

The double curvature of the polypary in its proximal portion is very characteristic, and, where this part is preserved, renders the species easily recognizable. Unfortunately, however, the adult forms generally occur in fragments, many of which, 5 to 7·6 cm. (2 to 3 inches) long, are quite straight, and show that the complete polypary must have been of considerable length. It has been generally regarded as characteristic of this species that the apertures of the thecæ are at right angles to the line of the virgula; such, however, I do not hold to be the case, that appearance being due partly to the very low inclination of the thecæ to the axis of the polypary, and partly to the special method of preservation. The sicula and its relation to the first theca as given above have not hitherto been described, and are characteristic of the species.

I have examined Barrande's type-specimen, and have had the

opportunity of collecting many specimens from his type-locality of Borek, and I feel no doubt that our English species agrees in every particular with the Bohemian form. It is probably also identical with the Swedish form *Monograptus Nilssoni*, described by Tullberg,[1] though in his plate the whole polypary is not figured and the thecæ are shown as rather more closely set.

The nearest relation of *M. Nilssoni* is undoubtedly the so-called *Cyrtograptus Carruthersi* of the Upper Wenlock Beds, fragments of which are indistinguishable from similar fragments of *M. Nilssoni* when both are similarly preserved.

Range.—In Britain there is little doubt that *M. Nilssoni*, in its characteristic form, is confined to the Lower Ludlow Beds, outside of which I have myself never found it. I have collected it at Borek (Bohemia) in association with the Ludlow forms *M. colonus* var. and *Retiolites spinosus*.

Foreign Localities.—Bohemia (Borek, Vyskočilka, etc.); Scandinavia (Hjontaröd, Knutsdorp, Tibaröd, etc.); Saxony; Thuringia; Harz Mountains; Graptolithengestein (Ronneburg and Gräfenwerth); France (Languedoc, Normandy, Britanny, etc.).

British Localities.—Ludlow district (Elton Lane, Elton-Ludlow Road, Adferton, etc.); Builth (R. Irfon, etc.); Long Mountain (Old Dingle Mill, etc.); Montgomery Road; Lake District.

Associates.—*M. bohemicus*, *M. colonus* and its variety *compactus*, *M. varians* and its variety *pumilus*, *M. Rœmeri*, *M. dubius*, *M. uncinatus* var. *orbatus* and var. *micropoma*, etc.

Monograptus bohemicus (Barr.). (Pl. XXV, figs. 27 A & 27 B and text-fig. 25, p. 484.)

1850. *Graptolithus bohemicus*, Barrande, 'Graptolites de Bohême' p. 40 & pl. i, figs. 15–18.

Polypary gracefully bent, the proximal part being curved almost into a semicircle, while the distal end has a broader sweep, becoming eventually almost straight. Fragments 7·5 to 10 cm. (3 to 4 inches) long are found, so that the polypary must have reached a considerable length. The width increases gradually from ·36 mm. (·014 inch) at the proximal end to 2 mm. (·08 inch) distally. The virgula projects slightly at the distal end.

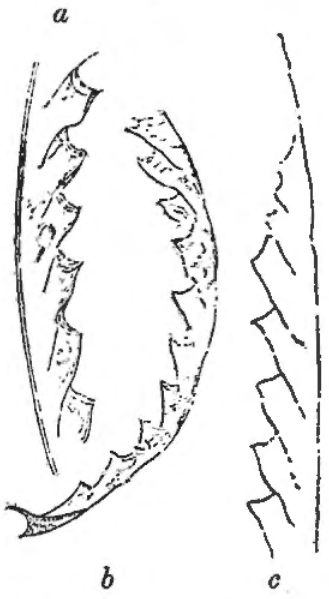
Proximal Extremity.—Sicula very characteristic, about ·85 to 1 mm. (·03 to ·04 inch) long, and ·32 mm. (·012 inch) wide at the aperture, so that it is only $2\frac{1}{2}$ to 3 times as long as wide. The apex does not quite extend to the level of the aperture of the first theca, which is inclined to the sicula at an angle of about 45°. Aperture furnished with a long and stout spine.

Thecæ.—Twenty-seven to twenty-three in the inch (eleven to nine in 1 cm.), occurring on the concave side of the polypary. Thecæ in contact merely, or with a slight overlap in the more distal thecæ, inclined to the axis at an angle of about 30° to 35°. They

[1] 'Skånes Graptoliter' pt. ii (1883) Sver. Geol. Undersökn. ser. C, no. 55, p. 17 & pl. i, figs. 31–32.

are short broad tubes, only about 2 to 3 times as long as wide; the outer wall is constricted where it is in contact with the theca below, but convex above, the aperture being concave and fairly wide, and provided with a small denticle.

Fig. 25.—M. bohemicus (*Barr.*) ×5.



a=Distal thecæ; from the River Irfon, Builth.
b=Proximal extremity, with sicula; from the Elton-Ludlow Road.
c=Distal extremity; from the Elton-Ludlow Road.

There are few species so readily recognizable as this one, and it has been correctly identified by most observers. Nicholson, however, confused it with a Llandovery species which has a strong convex curvature. Prof. Frech regards *Monograptus bohemicus* as a 'doubtful species' resembling his *Linograptus Nilssoni*. Barrande reckons only twenty thecæ to the inch in his description of *M. bohemicus* (though in his figures there are twenty-three), but in all the English specimens there are as many as twenty-seven at the proximal end, and in none are there so few as twenty, even in the adult parts. The sicula and its position with regard to the first theca were first figured by Tullberg, and are very characteristic of this species, being quite different from that of *M. Nilssoni*. The general form of the polypary varies somewhat at different localities: thus, in the Ludlow district the specimens are small and strongly curved; while at Builth they often reach a considerable length, and the distal part is almost straight; in the Dee Valley they are long, but curved throughout. I do not consider, however, that these variations in shape are worthy of varietal names.

Foreign Localities.—Scania (Röstånga, Ask, Billinge, Pugerup, Röfvarekulan, Harlösa, Heinge, Djurröd, Tosterup, Tolonga); Bohemia (Butowitz, Vyskočilka, Kozel, Kosoř, Kuchelbad, etc.); Thuringia; Harz Mountains; Graptolithengestein (Kunzendorf, Rexdorf, Gräfenwerth); Polnisches Mittelgebirge; France (Languedoc, Ardennes, Normandy, and Britanny).

British Localities.—Ludlow district (Elton Lane, Elton–Evenhay Lane, Elton–Ludlow Road, etc.); Long Mountain (north side); Builth district (Aberedw Hill, River Irfon, etc.); Lake District (Helm Knot).

Horizon.—*M. bohemicus* ranges throughout the greater part of the Lower Ludlow, but is most characteristic of the zone of *M. Nilssoni*. In Sweden, Bohemia, etc., it occurs in the *Cardiola*-beds.

Associates.—*M. Nilssoni*, *M. scanicus*, *M. chimæra*, *M. colonus*, *M. varians*, *M. tumescens*, *M. uncinatus* var. *micropoma*, and *Retiolites spinosus*.

2. Genus *Retiolites*.

Retiolites spinosus, sp. nov. (Pl. XXV, figs. 29 A & 29 B.)

Polypary diprionidian, straight, from 12·7 to 19 mm. (·5 to ·75 inch) long. Virgula straight, produced beyond the distal end. Width at proximal extremity = about ·89 mm. (·035 inch), increasing gradually and uniformly to a maximum diameter of 1·78 mm. (·07 inch), exclusive of thecal spines.

Proximal Extremity.—I have not been able to determine with certainty the details of the proximal extremity. The aperture of the first theca is ·6 mm. (·024 inch) above the base, so that the initial canal, if existent, must be very short. There appears, however, to be a true sicula with a continuous periderm ·5 mm. (·03 inch) long, extending halfway between the first and second thecæ, and continuous with the virgula (text-fig. 26*a*).

Fig. 26.—Retiolites spinosus, *sp. nov., from Vicarage Road, Builth* (×5).

a *b*

a=Proximal extremity.
b=Enlargement of fig. 29 A in Pl. XXV.

Thecæ.—Twenty-eight to twenty-six in 1 inch (eleven to ten in 1 cm.). The apertures appear to be at right angles to the axis of the polypary, and are each provided with one or two long spines, 1·01 mm. (·04 inch) and more in length, which are generally straight and directed at right angles to the polypary. In the British specimens one spine alone is usually visible, arising from the aperture of each theca; but in Bohemian specimens collected from Borek the polypary has not been compressed quite symmetrically, and there are two spines visible. Consequently it is probable that there are two in the English forms. It is difficult, in the compressed state of the specimens, to make out the details of the network. Main threads would seem to arise from the virgula and outline the apertures of the thecæ. The outer walls between the apertures are angular and concave, giving to the outer edge of the polypary a zigzag appearance. Straight threads at right angles to the polypary connect these angles with the virgula. The details of the network, however, will be best seen from the figures.

Affinities.—*Retiolites spinosus* may be readily distinguished from all other species of the genus by (*a*) the general shape of the polypary, and (*b*) the long thecal spines. It is one of the most characteristic forms that occur in the zone of *Monograptus Nilssoni*, especially in the Builth district, where it is found covering large

surfaces of rock with a delicate network of threads. In Bohemia I have obtained it at a similar, and also at a slightly lower horizon. At one locality it was associated with *Monograptus Nilssoni* and a variety of *M. colonus*; at another it occurred together with *Cyrtograptus Lundgreni*, *Monograptus testis*, *Retiolites nassa*, etc.

Foreign Localities.—Bohemia (Borek).

British Localities.—Builth (River Irfon, etc.); Long Mountain (Trefnant–Middletown Brook); Montgomery Road.

Horizon.—Zone of *M. Nilssoni*.

Associates.—*M. Nilssoni*, *M. bohemicus*, *M. colonus*, *M. varians*, and *M. dubius*.

Retiolites nassa, Holm (*Gothograptus*, Frech). (Pl. XXV, fig. 30.)

1890. *Retiolites nassa*, Holm, 'Gotlands Graptoliter' Bihang till K. Svenska Vet.-Akad. Handling. vol. xvi, pt. iv, no. 7, p. 25 & pl. ii, figs. 12–14.

This characteristic little species has hitherto been obtained from but one locality in Britain, and there only in a fragmentary condition. The species has been so fully diagnosed by Holm and Wiman that a complete description here is unnecessary. It can be readily recognized by the following characters:—

Fig. 27. — Retiolites nassa, *Holm* (×5).

[Enlargement of fig. 30 in Pl. XXV.]

(1) Polypary seldom exceeding 6 or 7 mm. (·025 to ·03 inch) in length;
(2) Margin of polypary entire;
(3) Long initial canal present, terminating proximally in a spine; and
(4) Thecal apertures resembling those of *Climacograptus*.

Foreign Localities. — Gotland; Bohemia (Borek).

British Locality.—South side of the Long Mountain, near Worthen.

Horizon.—*M.-vulgaris* zone in Britain. Abroad it occurs in the highest zone of the Wenlock, that of *M. testis*, and at the base of the Lower Ludlow Beds in association with *M. Nilssoni*.

Associate.—*M. vulgaris*.

In conclusion, I should like to express my sincere thanks to Prof. Watts, M.A., Sec.G.S., for generously placing at my disposal his collection of graptolites from the Long Mountain and his field-maps of the country; to Mr. Marr, F.R.S., for his kind permission to examine his graptolites from the Lake District; to my colleague and friend, Miss G. L. Elles, in whose company much of my work in the field was done, and with whom many points have been freely

[*To face* p. 486.

Table IV.—Distinctive Characters of the Lower Ludlow Graptolites.

Species.	Polypary.					Proximal Extremity.					Thecæ.						
	Length in cm.	Maximum width in mm.	Minimum width in mm.	General shape.	Distal prolongation of virgula.	Length of sicula.	Width of sicula.	Angle of inclination of first theca to sicula.	Apparent point of origin of first theca and sicula.	Level of apex of sicula.	Number to the inch.	Angle of inclination.	Length of adult thecæ.	Proportion of length to width.	Amount of overlap in adult thecæ.	Number of types of thecæ.	Character of apertures.
								°				°					
Monograptus dubius (Suess)	3–10	2	·76	Straight distally, incurved proximally.	None.	1·77–2	·31	20	At aperture.	2nd thecal aperture.	25–20	30	2·54	2½–3	½–⅓	1	Pointed denticle.
M. vulgaris, sp. nov.	5–10	2·54	·76	Double curvature.	Slight.	2	·5	30	Above aperture.	2nd thecal aperture.	28–24	35–40	2·75	4	½	1	Simple, or with denticle as in *M. dubius*.
—— —— var. *α* nov.	5	2·54	·76	Straight distally, incurved proximally.	?	Same as in *M. vulgaris*.					26–22	„	2·40	3	⅓	1	„
—— —— var. *β* nov.	6	2	·76	Straight distally, strong proximal curvature.	...	2	·5	30	Slightly above aperture.	2nd thecal aperture.	30–26	„	2·27	4	⅓–½	1	Simple.
M. tumescens, sp. nov.	2·5–3·8	2	·76	As in *M. dubius*.	None.	1·9	·38	20	At aperture.	Second theca.	28–24	30	2·54	4	⅓–½	1	Simple, or with blunt denticle.
—— —— var. *minor* nov.	1·25	1·6	·76	Curved throughout.	None.	Same as in *M. tumescens*.					28–30			Same as in *M. tumescens*.			
M. gotlandicus, Perner	3·2	2·03	·76	As in *M. dubius*.	?	2·03	·35	25	At aperture.	?	23–20	25–35	3—	4½	½–⅓+	1	Long blunt denticle.
M. comis, sp. nov.	2·5	1·27	·51	„ „	Slight.	1·77	·38	25	Near aperture.	?	29–28	25–30	1·77	3–4	Very slight.	1	Pointed denticle.
M. ultimus, Perner	1·27–2·0	1·6	·63	„ „	None.	1·9	·38	30–35	Distinctly above aperture.	Second theca.	30–28	30–40	1·6	3–4	In contact only or slight overlap.	1	Simple.
M. colonus (Barr.)	3·8–5·8	2·3	·84	„ „	Slight.	1·9	·32	45	Slightly above aperture.	„	32–26	40	2·6	4+	⅓–½	2	Recurved proximally, simple distally.
—— —— var. *ludensis* (Murch.)	2·5–5·0	2·5	1	„ „	6·3 mm. long.	2	·36	40	„	„	34–26	30–35	2·9	5–6	½+	2?	Distal apertures simple.
—— —— var. *compactus* nov.	1·9–2·5	2	·76	Curved throughout.	Stout and well marked.	1·27	·25	40	„	„	42–37	40–50	2·4	4½	½–⅔	2	As in *M. colonus*.
M. Rœmeri (Barr.)	3–7	3·6–4·2	·89	Double curvature.	2 cm. or more.	1·8	·32	40–45	„	„	34–28	40–45	3·8	5–5½	⅔	2	„
M. varians, sp. nov.	2·5	1·77	·76	As in *M. dubius*.	12·7 mm.	2	·36	40	„	Above second theca.	32–26	30–35	2·2	3½–4	¼	2	„
—— —— var. *α* nov.	2·5	2·1	·76	„ „	Long.	2	·36	40	„	„	35–28	40	2	3½	¼+	2	„
—— —— var. *β* nov.	3·8	1·7	·76	„ „	Slight.	2	·36	40	„	Between second & third thecæ.	36–30	35–40	2	3½–4	¼	2	„
—— —— var. *pumilus* nov.	1·27	1·6	·76	Nearly straight throughout.	Very slight.	1·9	·32	35–40	·25 mm. above aperture.	Near third theca.	42–36	35–40	1·6	3½	⅓–½	2	„
M. chimæra (Barr.)	2·5–3·8	1·9	·89	As in *M. dubius*.	Slight.	1·7	·34	35–40	Above aperture.	Between second & third thecæ.	32–28	40–50	2+	2–4	½	1	Stout spines.
—— —— var. *Salweyi* (Hopk.)	1·27	1·6	·72	Straight throughout.	Very long.	1·9	·32	35–40	Above aperture.	Above second theca.	34–30	35–40	2	4	⅓–½	1	Long slender spines.
—— —— var. *α*	2·5–3·8	2·5	·72	As in *M. dubius*.	...	Same as in *M. chimæra*.					36–28	40–45	2·5	3½	⅓–⅔	2	Stout spines proximally, simple distally.
M. leintwardinensis, Hopk.	1·27	1·6	·85–1	„ „	Slight.	2·1	·38	35–40	·4 mm. above aperture.	Between 2nd & 3rd thecæ.	38–36	35–45	1·7	3½	½—	1	Long curved spines.
—— —— var. *incipiens* nov.	1·27	1·9–2·1	·72	„ „	Very long.	1·9	·42	35–40	·3 mm. above aperture.	Above second theca.	40–37	40–50	2·54	4	½–⅔	2	Long spines in proximal thecæ.
M. uncinatus, var. *orbatus* nov.	2·5–5·0	1·9	·76	Double curvature.	Slight.	1·6	·32	30	Slightly above aperture.	Second theca.	30–24	30–35	1·27	2—	In contact or with slight overlap.	1	Spinose claw.
—— —— var. *micropoma* (Jækel)	2·54	1·27	·5	Nearly straight.	Slight.	1·27	·25	25–30	Near aperture.	Between 1st & 2nd thecæ.	26–22	25–30	1·27	2–3	„	1	Small spinose claw.
M. scanicus, Tullb.	10–15	1	·25	Strongly curved.	None.	1·5	·23	10	·5 mm. above aperture.	First theca.	20–23	10–20	2	7–8	In contact.	1	Small claw.
M. crinitus, sp. nov.	7·5+	·38	·19	Flexuous.	None.	1·4	·21	10	·6 mm. above aperture.	Near first theca.	14–18	5–10	1·6	8–6	„	1	„
M. Nilssoni (Barr.)	8–12?	1	·21	Strong double curve.	None.	1·27	·23	10	·76 mm. above aperture.	Considerably below first theca.	20–22	10–25	2	5–4	„	1	Simple concave aperture.
M. bohemicus (Barr.)	10–15?	2	·36	Semicircular curve at the proximal end.	Slight.	·85–1	·32	45	·25 mm. above aperture.	„	27–23	30–35	1·8	2–3	In contact or with slight overlap.	1	Widely concave, with slight denticle.

discussed; and above all, my gratitude to Prof. Lapworth, F.R.S., who has granted me every facility for my work, and has helped me throughout with advice and sympathy.

[Note.—All the figures of graptolites were drawn by me with the Parkes-Lapworth microscope in the Research Section of the Geological Department, Mason University College, Birmingham. Unless otherwise indicated, the specimens figured are in my own collection.]

(C) Synonymy.

Monograptus dubius (Suess).

1850. *Graptolithus colonus*, Barrande, 'Graptolites de Bohême' p. 43 & pl. ii, fig. 5.
1851. *Gr. dubius*, Suess, 'Ueber Böhmische Graptolithen' Haidinger's Abhandl. vol. iv, pt. iv, p. 115 & pl. ix, figs. 5 *a*–5 *b*.
1876. *Monograptus dubius*, Lapworth, Geol. Mag. 1876, p. 33 & pl. xx, fig. 10.
1878. *M. dubius*, Kayser, 'Die Fauna der ältesten Devon-Ablagerungen des Harzes' Abhandl. geol. Specialkarte von Preussen, vol. ii, pt. iv, p. 215 & pl. xxxi, figs. 19–22.
1880. *M. serra*, Hopkinson MS., Lapworth, 'New British Graptolites' Ann. & Mag. Nat. Hist. ser. 5, vol. v, pl. iv, figs. 6 *c* & 6 *d*.
1883. *M. dubius*, Tullberg, 'Skånes Graptoliter' pt. ii, Sver. Geol. Undersökn. ser. C, no. 55, p. 29 & pl. i, figs. 28–29; pl. ii, figs. 20–21.
1890. *M. dubius*, Holm, 'Gotlands Graptoliter' Bihang till K. Svenska Vet.-Akad. Handling. vol. xvi, pt. iv, no. 7, pp. 16, 17 & pl. i, figs. 18–26.
1893. *M. dubius*, Wiman, 'Ueber *Monograptus*' Bull. Geol. Inst. Upsala, vol. i, no. 2, p. 2 & pl. vii.

Monograptus tumescens, sp. nov.

1868. *Graptolites colonus*, Nicholson, Quart. Journ. Geol. Soc. vol. xxiv, pp. 540–41 & pl. xx, figs. 9–11.
1889. *Pristiograptus frequens?* Jækel, Zeitschr. d. Deutsch. Geol. Gesellsch. vol. xli, p. 669 & pl. xxviii, figs. 1–2.

Monograptus gotlandicus, Perner.

1890. *Monograptus* sp., Holm, 'Gotlands Graptoliter' p. 18 & pl. i, figs. 27–30.
1899. *M. gothlandicus*, Perner, 'Études sur les Graptolites de Bohême' pt. iii, sect. *b*, p. 12 & pl. xiv, fig. 22.

Monograptus colonus (Barrande).

1850. *Graptolithus colonus*, Barrande, 'Graptolites de Bohême' p. 42 & pl. ii, figs. 2–3; non 1, 4, 5.
1851. Non *Gr. colonus*, Suess, 'Ueber Böhmische Graptolithen' pp. 116–117 & pl. viii, fig. 8.
1852. *? Gr. colonus*, Geinitz, 'Die Graptolithen... der Grauwackenformation in Sachsen' p. 38 & pl. ii, figs. 33–36.
1868. Non *Gr. colonus*, Nicholson, Quart. Journ. Geol. Soc. vol. xxiv, p. 540–41 & pl. xx, figs. 9–11.
1869. *? Monograptus colonus*, Heidenhain, Zeitschr. d. Deutsch. Geol. Gesellsch. vol. xxi, p. 146.
1876. Non *M. colonus*, Lapworth, Geol. Mag. p. 505 & pl. xx, figs. 9 *a–c*.
1876. ? Non *M. colonus*, Haupt, 'Die Fauna des Graptolithengesteines' Neues Lausitz. Mag. vol. liv, pp. 19–20.
1878. *? M. colonus*, Kayser, 'Die Fauna der ältesten Devon-Ablagerungen des Harzes' pl. xxxi, figs. 17 & 18.
1880. Non *M. colonus*, Lapworth, Ann. & Mag. Nat. Hist. ser. 5, vol. v, p. 153 & pl. iv, figs. 3 *a*–3 *c*.
1880. *M. Rœmeri*, Lapworth, *ibid.* p. 151 & pl. iv, figs. 5 *a*–5 *c*.
1883. *M. colonus*, Tullberg, 'Skånes Graptoliter' pl. i, figs. 22 & 23.

1884. Non *Monograptus colonus*, J. D. La Touche, 'Handbook to the Geology of Shropshire' p. 78 & pl. xviii, fig. 577.
1889. Non *Pristiograptus colonus*, Jækel, Zeitschr. d. Deutsch. Geol. Gesellsch. vol. xli, p. 674 & pl. xxviii, fig. 7.
1890. *Monograptus colonus*, Geinitz, 'Die Graptolithen d. k. Min. Mus. in Dresden' Mitth. d. k. Min. Geol.-Prähist. Mus. Dresden, pt. ix, pp. 15, 16 & pl. A, fig. 14.
1892. *M. colonus*, Barrois, 'Distribution des Graptolites en France' Ann. Soc. Géol. Nord, vol. xx, p. 100.
1897. *Pristiograptus colonus*, Frech, 'Lethæa Geognostica' vol. i, pt. iii, pp. 655–656, fig. 209.
1899. *Monograptus colonus*, Perner, 'Études sur les Graptolites de Bohême' pt. iii, sect. *b*, p. 9, pl. xiv, figs. 3, 12, 17 & text-fig. 12.

Var. LUDENSIS (Murchison).

1839. *Graptolithus ludensis*, Murchison, 'The Silurian System' pl. xxvi, fig. 2.
1855. Non *Monograptus ludensis*, M'Coy, 'Brit. Palæoz. Foss.' p. 4.
1879. *? Graptolithus ludensis*, Quenstedt, 'Petrefactenkunde Deutschl.' vol. vi, pp. 192–93 & pl. cl, fig. 29.

MONOGRAPTUS RŒMERI (Barrande).

1850. *Graptolithus Rœmeri*, Barrande, 'Graptolites de Bohême' p. 41 & pl. ii, figs. 9–11.
1869. *Monograptus Rœmeri*, Heidenhain, Zeitschr. d. Deutsch. Geol. Gesellsch. vol. xxi, p. 150 & pl. i, fig. 5.
1879. *Graptolithus colonus*, Quenstedt, 'Petrefactenkunde Deutschl.' vol. vi, pl. cl, fig. 40.
1880. Non *Monograptus Rœmeri*, Lapworth, Ann. & Mag. Nat. Hist. ser. 5, vol. v, pl. iv, figs. 5 *a*–5 *c*.
1883. *? M. colonus*, Tullberg, 'Skånes Graptoliter,' pl. i, fig. 21.
1884. *M. Rœmeri*, J. D. La Touche, 'Handbook to the Geology of Shropshire' p. 78 & pl. xviii, fig. 578.
1897. *Pristiograptus Rœmeri*, Frech, 'Lethæa Geognostica' pt. iii, p. 656, fig. 210.
1899. *Monograptus Rœmeri*, Perner, 'Études sur les Graptolites de Bohême' pt. iii, sect. *b*, p. 8, pl. xiv, figs. 1, 7, 10, 18, 24 & text-fig. 11.

MONOGRAPTUS CHIMÆRA (Barrande).

1850. *Graptolithus chimæra*, Barrande, 'Graptolites de Bohême' p. 52 & pl. iv, figs. 34–35.
1884. Non *Monograptus chimæra*, J. D. La Touche, 'Handbook to the Geology of Shropshire' p. 77 & pl. xviii, fig. 571.
1889. *Pristiograptus colonus*, Jækel (?) Zeitschr. d. Deutsch. Geol. Gesellsch. vol. xli, p. 674 & pl. xxviii, fig. 8.
1899. *Monograptus chimæra*, Perner, 'Études sur les Graptolites de Bohême' pt. iii, sect. *b*, p. 14 & pl. xvii, figs. 15 *a*–15 *b*.

Var. SALWEYI (Hopkinson MS.).

1880. *Monograptus Salweyi*, Lapworth, Ann. & Mag. Nat. Hist. ser. 5, vol. v, p. 150 & pl. iv, figs. 2 *a*–2 *b*.
1884. *M. chimæra*, J. D. La Touche, 'Handbook to the Geology of Shropshire' p. 77 & pl. xviii, fig. 571.

MONOGRAPTUS LEINTWARDINENSIS, Hopkinson MS.

1880. *Monograptus leintwardinensis*, Lapworth, Ann. & Mag. Nat. Hist. ser. 5, vol. v, p. 149 & pl. iv, fig. 1.
1884. *M. leintwardinensis*, J. D. La Touche, 'Handbook to the Geology of Shropshire' p. 77 & pl. xviii, fig. 574.
1897. *Pristiograptus uncinatus*, Frech, 'Lethæa Geognostica' pt. iii, p. 658, fig. 213.

MONOGRAPTUS UNCINATUS var. MICROPOMA (Jækel).

1869. *Monograptus* sp., Heidenhain, Zeitschr. d. Deutsch. Geol. Gesellsch. vol. xxi, p. 151 & pl. i, fig. 6.
1889. *Pomatograptus micropoma*, Jækel, Zeitschr. d. Deutsch. Geol. Gesellsch. vol. xli, p. 682 & pl. xxix, figs. 4–6.
1897. Non *Monoclimacis spinulosa* (Tullb.) Frech, 'Lethæa Geognostica' vol. i, pt. iii, p. 623.

MONOGRAPTUS SCANICUS, Tullberg.

1869. *Monograptus distans* (Portl.) Heidenhain, Zeitschr. d. Deutsch. Geol. Gesellsch. vol. xxi, p. 147 & pl. i, fig. 1.
1876. *M. distans?* (Portl.) Haupt, 'Die Fauna des Graptolithengesteines' p. 20 & pl. iv, fig. 1.
1883. *M. scanicus*, Tullberg, 'Skånes Graptoliter' p. 26 & pl. ii, figs. 38–44.
1884. *M. clavicula*, Hopk. MS.? see J. D. La Touche, 'Handbook to the Geology of Shropshire' p. 78 & pl. xviii, fig. 575.
1889. *Pomatograptus Becki*, Jækel, Zeitschr. d. Deutsch. Geol. Gesellsch. vol. xli, p. 683 & pl. xxix, figs. 7–9.
1897. *M. cygneus*, Frech, 'Lethæa Geognostica' vol. i, pt. iii, p. 644, fig. 199.

MONOGRAPTUS NILSSONI (Barrande).

1850. *Graptolithus Nilssoni*, Barrande, 'Grapt. de Bohême' p. 51 & pl. ii, fig. 16.
1851. *Gr. Nilssoni*, Suess, 'Ueber Böhmische Graptolithen' p. 119.
1851. Non *Gr. Nilssoni*, Harkness, Quart. Journ. Geol. Soc. vol. vii, p. 61 & pl. i, figs. 7 *a*–7 *d*.
1852. *Monograptus Nilssoni*, Geinitz, 'Die Graptolithen ... der Grauwackenformation in Sachsen' p. 35 & pl. ii, figs. 17–20, 24, 25, 28–32 (?).
1867. Non *Graptolites Nilssoni*, Baily, 'Characteristic Brit. Foss.' pl. ix, figs. 2 *a*–*b*.
1868. Non *Gr. Nilssoni*, Nicholson, Quart. Journ. Geol. Soc. vol. xxiv, pl. xx, fig. 19.
1869. *Monograptus Nilssoni*, Heidenhain, Zeitschr. d. Deutsch. Geol. Gesellsch. vol. xxi, p. 147 & pl. i, fig. 2.
1876. *M. Nilssoni*, Lapworth, Geol. Mag. p. 315 & pl. x, figs. 7 *a*–*c*.
1876. *M. Nilssoni*, Haupt (?) 'Die Fauna des Graptolithengesteines' p. 21 & pl. iv, fig. 3 (?).
1878. *M. Nilssoni*, Kayser, 'Die ältesten Devon-Ablagerungen des Harzes' p. 217 & pl. xxxi, fig. 12 (fig. 25 ?).
1883. *M. Nilssoni*, Tullberg, 'Skånes Graptoliter' pl. i, figs. 31, 32.
1884. *M. Nilssoni*, J. D. La Touche, 'Handbook to the Geology of Shropshire' p. 78 & pl. xviii, fig. 576.
? 1885. *M. scanicus*, Rœmer, *non* Tullberg, 'Lethæa Erratica,' pl. ix, figs. 13 *a*, *b*.
1889. *Pristiograptus Nilssoni*, Jækel, Zeitschr. d. Deutsch. Geol. Gesellsch. vol. xli, p. 673 & pl. xxviii, fig. 7.
1890. *Monograptus Nilssoni*, Geinitz, 'Die Graptolithen d. k. Min. Mus. in Dresden' p. 13 & pl. A, fig. 7 (in part) *non* fig. 8.
1892. *M. Nilssoni*, Barrois, 'Distribution des Graptolites en France' pp. 101, 121.
1897. *Linograptus Nilssoni*, Frech, 'Lethæa Geognostica' vol. i, pt. iii, p. 662, fig. 218.
1899. *Monograptus Nilssoni*, Perner, 'Études sur les Graptolites de Bohême' pt. iii, sect. *b*, p. 7 & pl. xvii, figs. 1, 2, 7.

MONOGRAPTUS BOHEMICUS (Barrande).

1850. *Graptolithus bohemicus*, Barrande, 'Graptolites de Bohême' p. 40 & pl. i, figs. 15–18.
1851. *Gr. bohemicus*, Suess, 'Ueber Böhmische Graptolithen' pp. 110–111 & pl. viii, figs. 6 *a*–*e*.
1851. ? *Gr. Barrandei*, Scharenberg, 'Ueber Graptolithen, etc.' Inaug. Dissert. (Breslau) p. 15 & pl. i, figs. 5–5 *a*.
1852. *Monograptus bohemicus*, Geinitz, 'Die Graptolithen ... der Grauwackenformation in Sachsen' p. 36 & pl. ii, fig. 41.
1868. Non *M. bohemicus*, Nicholson, Quart. Journ. Geol. Soc. vol. xxiv, p. 539 & pl. xx, figs. 22–24.
1869. *Graptolithus bohemicus*, Heidenhain, Zeitschr. d. Deutsch. Geol. Gesellsch. vol. xxi, p. 149 & pl. i, figs. 4 *a*–*c*.
1876. *Monograptus bohemicus*, Haupt, 'Die Fauna des Graptolithengesteines' p. 19.
1881. *Graptolithus scalaris*, Quenstedt, 'Petrefactenkunde Deutschl.' vol. vi, pl. cl, fig. 44.
1883. *M. bohemicus*, Tullberg, 'Skånes Graptoliter,' pl. iii, figs. 3–5.
1884. *M. bohemicus*, J. D. La Touche, 'Handbook to the Geology of Shropshire' p. 77 & pl. xviii, fig. 573.
1889. *Pristiograptus bohemicus*, Jækel, Zeitschr. d. Deutsch. Geol. Gesellsch. vol. xli, p. 672 & pl. xxviii, figs. 3–6.
1890. *Monograptus bohemicus*, Geinitz, 'Die Graptolithen d. k. Min. Mus. in Dresden' p. 14 & pl. A, fig. 10.

1892. *Monograptus bohemicus*, Barrois, 'Distribution des Graptolites en France' p. 99.
1897. *Pristiograptus bohemicus*, Frech, 'Lethæa Geognostica,' vol. i, pt. iii, p. 664.

RETIOLITES NASSA, Holm.

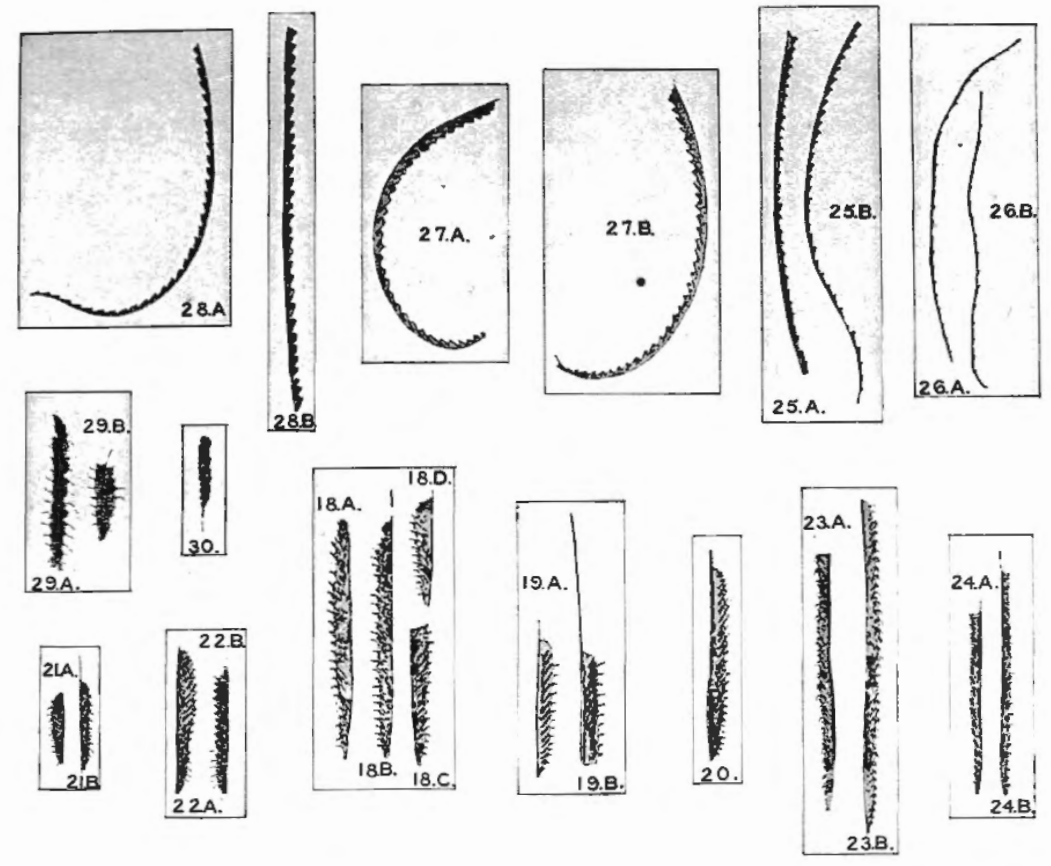
1890. *Retiolites nassa*, Holm, 'Gotlands Graptoliter' p. 25 & pl. ii, figs. 12–14.
1895. *R. nassa*, Wiman, 'Ueber die Graptolithen' Bull. Geol. Inst. Upsala, vol. ii, no. 2, pls. ii & xi.
1899. *R. nassa*, Perner, 'Études sur les Graptolites de Bohême' pt. iii, sect. *b*, p. 23, text-figs. 32 *a*–32 *b* & pl. xvii, figs. 20–21.

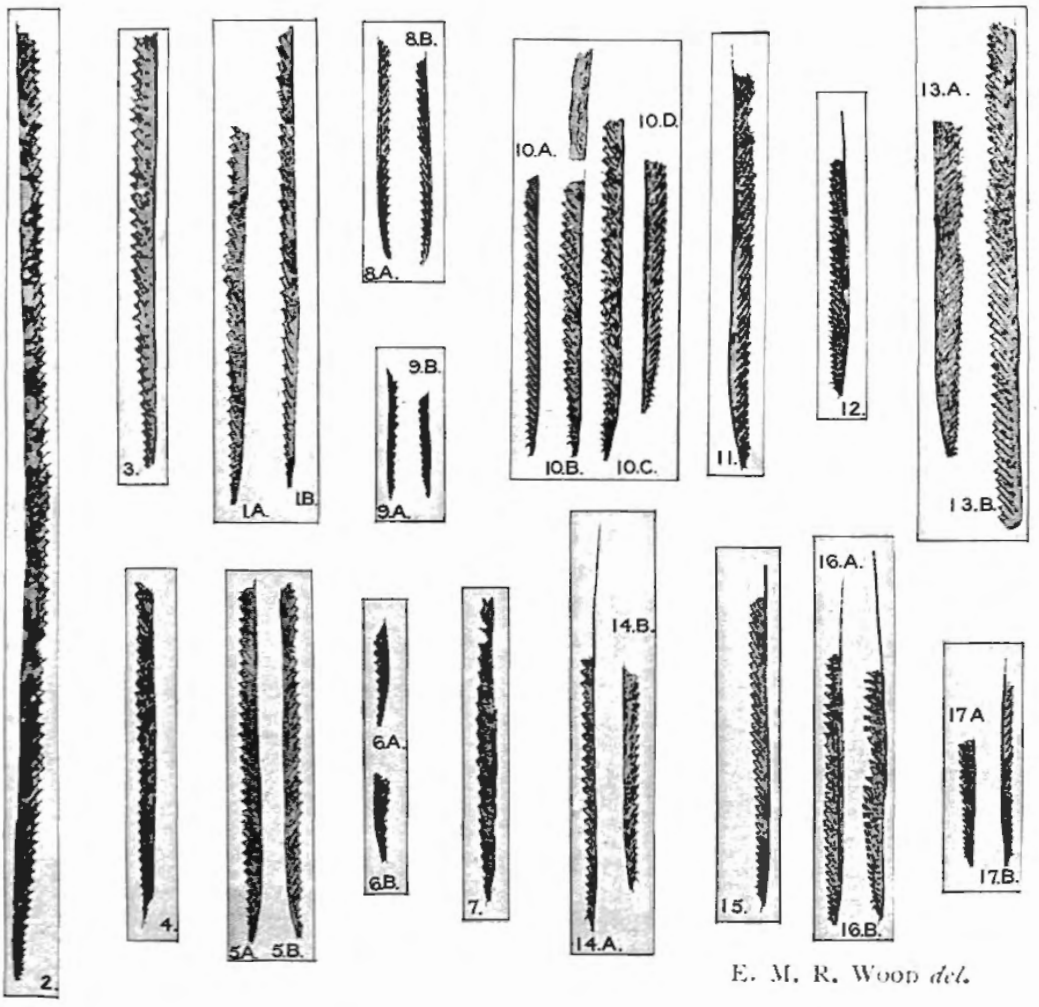
EXPLANATION OF PLATES XXV & XXVI.

PLATE XXV.

[All the figures are of the natural size.]

Fig. 1. *Monograptus dubius* (Suess). 1 A. Elton Lane (*M. serra* of Mr. Hopkinson's collection); 1 B. Stormer Hall.
Figs. 2–4. *M. vulgaris*, sp. nov. Trefnant–Middletown Brook, Long Mountain (Loc. 3 in Pl. XXVI).
3. Var. *α* nov. Trefnant–Middletown Brook, Long Mountain (Loc. 5 in Pl. XXVI).
4. Var. *β* nov. Lane Farm, Long Mountain.
5 & 6. *M. tumescens*, sp. nov. 5 A. Llettygynfach, Long Mountain. Coll. C. Lapworth. 5 B. Elton–Ludlow Road, Gorsty Farm.
6. Var. *minor* (M'Coy). 6 A. Elton–Ludlow Road. 6 B. Elton Lane.
Fig. 7. *M. gotlandicus*, Perner. Old Dingle Mill, Long Mountain. Coll. W. W. Watts.
8. *M. comis*, sp. nov. 8 A. Elton–Ludlow Road. 8 B. Reverse side of 8 A.
9. *M. ultimus*, Perner. 9 A. Road between County Bridge and Ucheldre, Long Mountain (Loc. 15 in Pl. XXVI). Coll. W. W. Watts. 9 B. Kosor, Bohemia. Coll. C. Lapworth.
Figs. 10–12. *M. colonus* (Barrande). 10 A. Butowitz, Bohemia. Coll. C. Lapworth. 10 B. Helm Knot, Lake District. Coll. Nat. Hist. Mus. S. Kensington. 10 C. R. Irfon, Builth (Loc. *C'* in fig. 5, p. 432). 10 D. Adferton. Coll. J. Hopkinson.
11. Var. *ludensis* (Murch.). Llanfair, Montgomeryshire. Coll. Dr. Humphreys, Llanfair.
12. Var. *compactus* nov. Elton–Evenhay Lane.
Fig. 13. *M. Rœmeri* (Barr.). A & B. Trefnant–Middletown Brook, Long Mountain (Loc. 6 in Pl. XXVI).
Figs. 14–16. *M. varians*, sp. nov. 14 A. Old Dingle Mill, Long Mountain. 14 B. Road above Garbett's Hall, Long Mountain.
15. Var. *β* nov. Elton Lane.
16. Var. *α* nov. 16 A. Stormer Hall. 16 B. Mary Knoll, near Ludlow. Coll. J. Hopkinson. Figured in Ann. & Mag. Nat. Hist. ser. 5, vol. v (1880) pl. iv, figs. 3 *b* & 3 *d*.
17. Var. *pumilus* nov. 17 A. Elton Lane (Loc. D in fig. 2, p. 426). 17 B. *Ibid.* (Loc. G in fig. 2).
18–20. *M. chimæra* (Barr.). 18 A, C, D. Elton–Ludlow Road. 18 B. Stream from Ucheldre to Trewern Bridge, Long Mountain. Coll. W. W. Watts.
19. Var. *Salweyi* (Hopk.). 19 A. Stormer Hall. 19 B. *Ibid.* Coll. J. Hopkinson. Figured in Ann. & Mag. Nat. Hist. ser. 5, vol. v. (1880) pl. iv, figs. 2 *a* & 2 *b*.
20. Var. *α* nov. Elton–Ludlow Road.
21 & 22. *M. leintwardinensis*, Hopk. 21 A, B. Church Hill Quarry, near Leintwardine. Coll. J. Hopkinson.
22. Var. *incipiens* nov. 22 A. Montgomery Road. 22 B. Long Mountain. Coll. W. W. Watts.





E. M. R. WOOD *del.*

LOWER LUDLOW GRAPTOLITES.

Figs. 23 & 24. *M. uncinatus*, var. *orbatus* nov. 23 A, B. Trefnant-Middletown Brook (Loc. 5 in Pl. XXVI).
24. Var. *micropoma* (Jækel). 24 A. Elton–Ludlow Road. 24 B. Road above Garbett's Hall, Long Mountain.
Fig. 25. *M. scanicus*, Tullb. 25 A. Aberedw Hill (Loc. 7 in fig. 6, p. 435). 25 B. Aberedw Hill (Loc. 3 in fig. 6).
26. *M. crinitus*, sp. nov. Lower Winnington Lane, Long Mountain.
27. *M. bohemicus* (Barr.). 27 A. River Irfon, Builth. 27 B. Aberedw Hill.
28. *M. Nilssoni* (Barr.). 28 A. Adferton. Coll. J. Hopkinson. 28 B. Elton–Evenhay Lane.
29. *Retiolites spinosus*, sp. nov. Vicarage Road, Builth (Loc. c' in fig. 5, p. 432).
30. *Retiolites (Gothograptus) nassa*, Holm. Borek, Bohemia.

PLATE XXVI.

Geological Sketch-map of the Long Mountain District (Northern Area) on the scale of 3 inches to the mile.

DISCUSSION.

Mr. HOPKINSON said that, although he had worked out the zonal distribution of the graptolites of the Lower Ludlow rocks in the neighbourhood of Ludlow, and had communicated two papers on the subject to the British Association, also describing and figuring several new species in La Touche's 'Geology of Shropshire,' he had not been able, in the few short visits which he had paid to the district, to arrive at results which he considered worthy of being brought before the Society; and he was pleased to find that what he had failed to do was accomplished by the Authoress. He could assign an approximate position in the Ludlow mudstones to a few species wherever collected in that area, but there were certain difficulties which he had been unable to overcome. In the first place, it was necessary to confirm the results from this area by working out the zonal distribution in other areas; then there was the difficulty of being certain as to the identification of some of Barrande's species, which could only be overcome, as it had been by the Authoress, by an actual examination of Barrande's specimens; and, lastly, he had been unable to determine the precise horizon of the Cladophora found at Bow Bridge near Downton, and, so far as he knew, nowhere else in the Lower Ludlow rocks in this country. It was stated in the paper that *Monograptus* was the only genus represented, but that was the case only so far as the Rhabdophora are concerned, for here were found species of *Callograptus*, *Dendrograptus*, and *Ptilograptus*. He thought that this Cladophora-bed was just below the zone of *Monograptus leintwardinensis*—that is, nearly at the top of the Lower Ludlow. He had found a fragment of a graptolite above Aymestry Limestone, but he could not be certain that it was above the Aymestry Limestone, for the shale in which he found it may have been between the two beds of limestone, the upper bed not showing. It was certainly the fact that the beds became more calcareous as the summit of the

mudstone was approached, but their more arenaceous character was equally well marked.

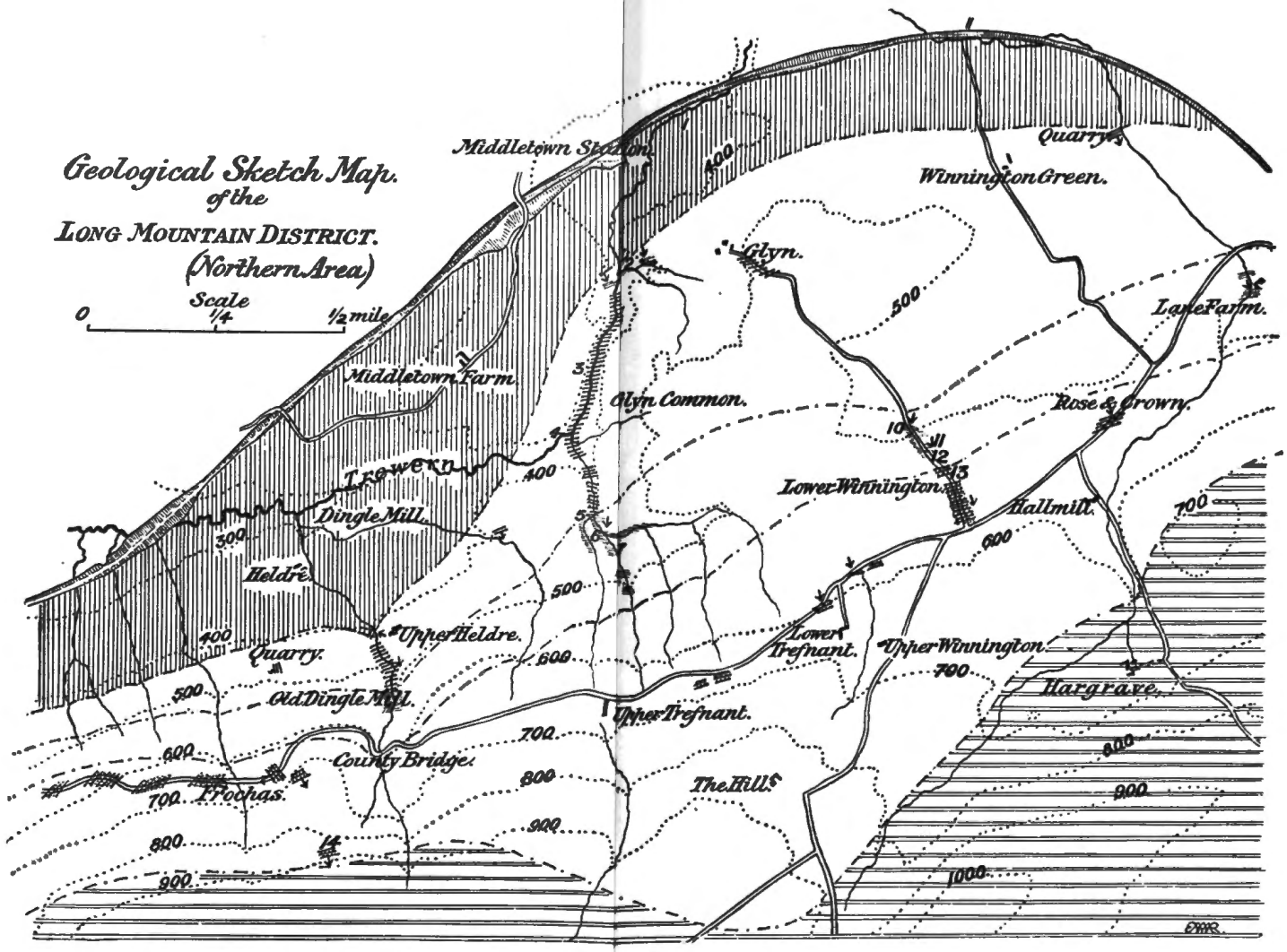
The Rev. J. F. Blake said that he was convinced of the extreme importance of the subdivision of the great unvarying masses of the Lower Ludlow, particularly in the typical districts; but he could not help being somewhat sceptical as to the naming of graptolites in general. They preserved so few characters, and these appeared to be so liable to be masked by accidents of preservation, while the writers on the group did not seem to have made up their minds as to the relative value of the characters.

Prof. Watts congratulated the Authoress on the good work done. As he had previously worked in one of the districts alluded to, the Long Mountain, he believed that the Authoress was right in her classification. He drew attention to the admirable illustrations which accompanied the paper.

Mr. C. D. Sherborn also spoke.

Prof. Lapworth pointed out the great interest of this paper, as showing for the first time that the principle of zonal mapping by means of graptolites is applicable even in the very latest formation in which the Rhabdophora have hitherto been certainly recognized; and, further, that this zonal method of stratigraphy not only enables us to correct the previously published maps of the Silurian rocks of the Welsh Borderland, but affords us a means of mapping the monotonous flaggy and mudstone series of all Eastern Wales in detail in the future, and of bringing them into direct comparison with the corresponding strata of other districts. The main obstacle which had formerly stood in the way of the graptolithologist who attempted the study of these Lower Ludlow graptolites, was the uncertainty of the identity of many of our British forms with the Bohemian species originally described in the classical works of Barrande. Thanks to the detailed revision of the Bohemian graptolites recently published by Dr. Perner, and to the fact that the Authoress and Miss Elles, previous to the commencement of their investigations, paid a visit to Bohemia, examined Barrande's types in the Prague Museum, and, guided by Dr. Perner, collected many of the critical forms in the field, we have now a guarantee that the identifications may be regarded as reliable. Mr. Hopkinson's work among the Ludlow graptolites had long been recognized as the most important hitherto accomplished among these rocks. The Authoress had found it of the highest value in her own work, and had described and figured specimens of the Rhabdophora from his collection among her types. Too little is as yet known of the Cladophora to make them available for zonal purposes.

As respects Prof. Blake's observations on the ammonites and graptolites, it was but natural that the students of the one group should find themselves unable to appreciate the minute distinctions relied upon by the students of the other, or the necessity for the very detailed classifications insisted upon. But the specific forms in both groups are certainly of high stratigraphical value, and no doubt all disputes and difficulties will disappear in the course of time.


Geological Sketch Map.
of the
LONG MOUNTAIN DISTRICT.
(Northern Area)
Scale
0
1/4
1/2 mile
Middletown Station.
Middletown Farm.
Trewern.
Dingle Mill.
Heldre.
Upper Heldre.
Quarry.
Old Dingle Mill.
County Bridge.
Trochas.
Glyn.
Glyn Common.
Lower Trefnant.
Upper Trefnant.
The Hills.
Quarry.
Winnington Green.
Lane Farm.
Rose & Crown.
Lower Winnington.
Hallmill.
Upper Winnington.
Hargrave.
100
200
300
400
500
600
700
800
900
1000