

THE WENLOCK GRAPTOLITES OF THE LUDLOW DISTRICT, SHROPSHIRE, AND THEIR STRATIGRAPHICAL SIGNIFICANCE

by C. H. HOLLAND, R. B. RICKARDS, and P. T. WARREN

ABSTRACT. *Monograptus ludensis* (Murchison 1839) *sensu* Wood 1900 (with its synonyms *M. gotlandicus* Perner 1899 and *M. vulgaris* Wood 1900) is fully described together with a new species *Pristiograptus jaegeri*, the two having been frequently confused with *M. vulgaris*. A second new species described from the Wenlock rocks of the Ludlow district, Shropshire, is *Holoretiolites (Balticograptus) lawsoni*, and another form *Pristiograptus* sp. 1 is left under open nomenclature. *M. deubeli* Jaeger 1959 is recorded for the first time in the British Isles. The stratigraphical distribution of the graptolite fauna of the Wenlock and lowest Ludlow of the Ludlow district is discussed and comparisons made particularly with North Wales. A poorly developed 'nassa/dubius Interregnum' (Jaeger 1959) separates the *C. lundgreni* Zone, with its abundant *M. flemingii* (Salter), from the *M. ludensis* Zone with its association of *P. jaegeri* sp. nov. and the index species. The problem of the correlation of the Wenlock/Ludlow boundary is discussed and it is recommended that in the graptolite sequence the horizon best correlated with this boundary is the base of the *P. nilssoni* Zone.

IN their revision of the stratigraphy of the Silurian rocks of the Ludlow district, Holland, Lawson, and Walmsley (1963) defined the Ludlow Series and its four component stages by means of standard sections for the boundaries between these and adjacent stratigraphical units. The higher Wenlock rocks cropping out in the south-western part of the district were given detailed description in terms of lithology and fauna though, naturally, no attempt was made at a definitive classification of the Wenlock Series. The boundary between the Wenlock and Ludlow was, however, effectively designated by the choice and accurate description of a standard section for the base of the Ludlow Series and its lowest Eltonian Stage. At this standard locality, in an old quarry in Pitch Coppice on the south side of the Ludlow-Wigmore road, nearly 5 m. of Wenlock Limestone are followed by 1 or 2 m. of Lower Elton Beds. Conscious that they were stabilizing rather than completely solving the problem of the Wenlock/Ludlow boundary, Holland *et al.* (1963, p. 141) referred to the remaining difficulty, viz. that the position of the base of the *Monograptus vulgaris* Zone in relation to the Wenlock Limestone was not known. 'The problem of the graptolite sequence in areas where the Wenlock Limestone is developed might be solved by prolonged collecting throughout the Welsh Borderland but the rarity of graptolites at this level in the shelf facies would make this a most difficult task. In any event, it is desirable that at the standard locality the Wenlock Limestone should be within the Wenlockian and the Ludlovian (Eltonian) should begin above it.'

Subsequently, two of the present authors (C. H. H. and R. B. R.) decided to attempt a revision of the Wenlock graptolites of the Ludlow district, the available background of carefully documented localities permitting the possibility of rigorous collection from all exposed Wenlock and basal Ludlow. The third author (P. T. W.) was in the meantime concerned with the precise revision of the graptolite sequence at the same level in the geosynclinal area of North Wales and had encountered a nomenclatural question concerning the species *M. vulgaris*. Thus, the present paper sets out not only to describe the

graptolite fauna of the Wenlock rocks of the Ludlow district but also to attempt to solve the taxonomic and stratigraphical problems associated with *M. vulgaris*, the zone of that name, and the Wenlock/Ludlow boundary. Two preliminary notes on these matters have already been published (Warren, Rickards, and Holland 1966; Holland, Rickards, and Warren 1967).

Localities within the Ludlow district are numbered as in Holland *et al.* (1963), where grid references and other topographical details are given. Where it has proved necessary to subdivide these localities the relevant information is provided herein. Our graptolite collection from the Ludlow district has been deposited in the Geological Museum of Trinity College, Dublin, and TCD numbers are given. Other material described herein is in possession of the Sedgwick Museum, Cambridge [SM], Birmingham University [BU], and the Institute of Geological Sciences [GSM GSC (Geological Society of London Collection), GSM Zp (Boswell Collection)].

Acknowledgements. One of us (P. T. W.) thanks Dr. A. G. Brighton (Cambridge) and Dr. I. Strachan (Birmingham) for the loan of specimens in their care and also Dr. H. Jaeger (Berlin) for helpful discussions on the *ludensis* Zone faunas of both North Wales and Germany. Both C. H. H. and P. T. W. are grateful to Dr. L. Teller (Warsaw) for affording them the opportunity individually to see and collect from the Pragowiec section in the Holy Cross Mountains. C. H. H. has had the benefit of a visit to sections in the German Democratic Republic under Dr. Jaeger's expert and hospitable guidance. C. H. H. and R. B. R. thank Dr. T. R. Lister, Christine Rickards, and Dr. J. H. Shergold, for assistance in collecting from the Ludlow district. Dr. Warren's contribution is published by permission of the Director, Institute of Geological Sciences.

THE 'VULGARIS' PROBLEM

In the systematic descriptions below it will be shown that *Monograptus ludensis* (*sensu* Wood 1900), *M. gotlandicus* Perner 1899, and *M. vulgaris* Wood 1900 are conspecific. We have already indicated our preference for usage of the name *ludensis* (Warren *et al.* 1966, Holland *et al.* 1967) and our views have been accepted by Martinsson (1967). In addition we have received a number of personal communications variously advocating the usage of *ludensis*, *gotlandicus*, or *vulgaris*. It would seem that several workers have more or less concurrently concluded that these forms are conspecific.

Of these three the earliest published name is *ludensis* Murchison 1839, and subsequent to Wood's (1900) description of this species nothing has been added to its diagnosis. Although it has been but rarely recorded, Wood's concept of *ludensis* has not been changed or abused. Largely because of her definitive work *ludensis* cannot be considered a confused species. Nevertheless, although she clearly interpreted the species by reference to fig. 2 of Murchison's original illustrations (Murchison 1839, pl. 26), Wood did not specify (as lectotype) a particular specimen from those shown crowded together on the slab depicted there.

It is true that earlier M'Coy (1851, p. 4) gave as 'Ref.' (i.e. synonymy) 'Sil. Syst. t. 26. f. 1, & 1^a. (Not. 2.)', thus referring to those figures depicting a *Monograptus priodon* (Bronn)-like form; but in describing fossils from the Geological Museum of the University of Cambridge he cannot be taken as 'first reviser' of *ludensis* in the sense of the Rules. There is no question of M'Coy's having selected a lectotype *from the type series* as the Rules require; he was simply assigning material to one particular previously published figure and not to another.

Murchison himself in *Siluria* (1854, pl. 12, figs. 4 and 4a) chose to repeat only figs. 1 and 1a of his original plate from the 'Silurian System' and referred to the form shown there

as 'Graptolithus priodon (Ludensis), Bronn', thus leaving outside this implied synonymy his original fig. 2. However, in *Siluria* (3rd ed., 1859) Murchison again included both original figures under the name 'Gr. priodon Bronn [Gr. ludensis, Sil. Syst.]'.

The principal objection to the use of *gotlandicus* Perner 1899 as the specific name for the graptolite in question is that the original figure is of a distal rhabdosomal fragment. However, modern Czechoslovakian and Polish workers have adequately redefined the species, and again there has been no confusion in the literature. *M. gotlandicus* has been widely recorded except in Britain (an omission explained once the conspecificity of *ludensis*, *vulgaris*, and *gotlandicus* is appreciated), and the name is well entrenched in the literature.

By contrast *M. vulgaris* Wood 1900 must be one of the most frequently misidentified species in graptolite literature. The majority of records and illustrations of the species are based upon incorrect identification. Our recent examination of the Das Gupta collection (Imperial College, London), for example, showed that some specimens labelled 'vulgaris' were referable to spinose graptolites of the *M. leintwardinensis* Lapworth type. The confusion over the identification of *vulgaris* arises partly from the fact that Wood's (1900) original description involved two distinct species. One of these, a straight, slender pristiograptid (*P. jaegeri* sp. nov. herein) has been commonly found and recorded as *vulgaris*, whereas Elles and Wood (1911) clearly designate a specimen belonging to the other form as 'type specimen'. As implied above, the true '*vulgaris*' has been widely recorded outside Britain as *gotlandicus*, whilst in Britain some specimens in Elles's and Wood's collections were referred to *ludensis* and other material, notably in the Boswell Collection, was assigned either correctly or to *M. vulgaris* cf. *curtus* Elles and Wood and *M. colonus*. Few indications of *vulgaris* in the literature are, therefore, correct and none clearly defines the morphology either of the pristiograptid or of *M. vulgaris* Wood (pars).

The true *vulgaris* we would retain in *Monograptus* since it has distinctly rounded lateral aperture margins to th 1, and does not fall readily into either *Pristiograptus* Jaekel or *Colonograptus* Přibyl. *M. ludensis* as defined by Wood is, as we now know, identical with this, and Wood's failure to notice the conspecificity reflects the poor preservation of specimens collected from the locality of the type specimen of *M. ludensis*. We are fortunate in having in our possession isolated Polish specimens of *M. gotlandicus* Perner. Comparison of these with our now extensive collections of *ludensis* and *vulgaris* indicates that the three named species are conspecific and that the pristiograptid form (common also in the Polish material) requires a new name.

The problem, therefore, is complex in that none of the three names is entirely satisfactory. Our discussions with colleagues have indicated that to choose one name will please but a fraction of the interested parties. At this point we shall state our views on the matter, and then describe the species below under our preferred name. The immediate aims are to establish the conspecificity of *ludensis*, *gotlandicus*, and *vulgaris*, and to apply our preferred name to the relevant biostratigraphical unit. It is our view that the interests of palaeontology and stratigraphy will best be served if the name *vulgaris* is *not* (by special provision) adopted. It is the most junior name and yet is shrouded in the greatest misunderstanding. Of the two remaining names we prefer properly to follow the Rules still further in adopting the senior name *ludensis*, though we appreciate that it is less well established in the literature than *gotlandicus*.

SYSTEMATIC DESCRIPTIONS

Family RETIOLITIDAE Lapworth 1873

Subfamily PLECTOGRAPTINAE Bouček and Münch 1952

Genus HOLORETIOLITES Eisenack 1951

Subgenus BALTICOGRAPTUS Bouček and Münch 1952

H. (Balticograptus) lawsoni sp. nov.

Text-figs 1a-c

Diagnosis. Rhabdosome tiny, parallel-sided; thecae inconspicuous, apertures ventrally facing and surmounted by loop-shaped processes which show, in the form of lists, traces of the graptolite fusellar structure; thecal spacing 13 in 10 mm.; clathrial elements well-developed, reticula imperfect and sparse; nema subcentral.

Holotype. The specimen illustrated as Fig. 1a, number TCD 8473.

Material. Three well-preserved specimens in low relief, and other fragmentary specimens (TCD 8473-5).

Horizon and locality. Wenlock Shale, Wenlock Series, *ludensis* Zone. Ludlow district, Burrington Farm lane. section, locality 62 of Holland *et al.* (1963): see text-fig. 4. Associates are: *Monograptus ludensis* and *Pristiograptus jaegeri* sp. nov.

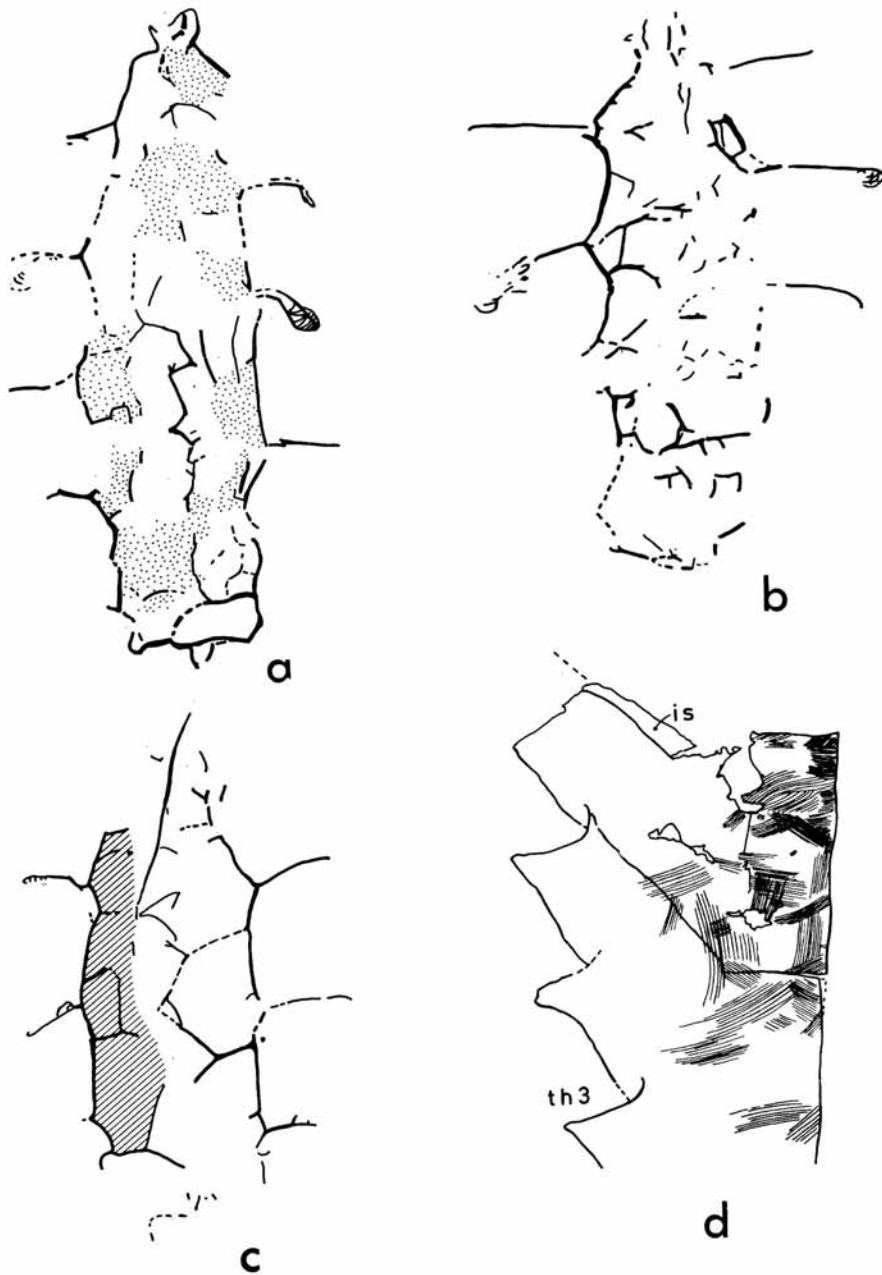
Derivation of name. After Dr. J. D. Lawson, who collected the specimens during the 1964 Ludlow Research Group meeting in the Ludlow district.

Description. The maximum observed rhabdosome length is 4.00 mm. and the dorso-ventral width (low relief) 2.70 mm. Excluding apertural processes the rhabdosome achieves a dorso-ventral width of 0.90-1.00 mm. and is more or less parallel-sided. The extreme proximal end is almost rectangular in outline and rapidly reaches the maximum dorso-ventral width. The thecal spacing is 13 in 10 mm. Text-fig. 1b depicts the apertural processes at their maximum observed length of 0.80-0.90 mm.

Clathrial elements appear to form a very approximately hexagonal mesh on the lateral walls. The free ventral thecal walls are roughly vertical or gently concave, turning outwards slightly in the region of the apertures, and are defined by quite robust paired ventral lists. An imperfect and sparse reticulum is indicated by the presence and distribution of much finer threads.

The thecal apertures are obscure, but are probably similar to those of *H. (B.) balticus* Eisenack, i.e. ventrally facing. Loop-shaped processes surmount the apertures and project ventrally, or somewhat proximally, for a distance of 0.80-0.90 mm. The loop may exhibit some transverse expansion away from the thecal aperture (text-figs. 1a, b) and is infilled with slender cross threads. The cross threads form a rough 'zigzag suture' and could possibly be homologous with the growth bands of sclerotized graptolites. One specimen (text-fig. 1c) shows a slender nema in a subcentral position. Distally there is an abbreviated appendix (text-figs. 1a, b) and a general slight tapering, clearly indicating that the rhabdosomes have reached their adult length.

Remarks. This species clearly belongs to the subgenus *Balticograptus* and is distinguished from *H. (Holoretiolites)* by the presence of a poor reticulum, and a less tapering rhabdosome. *H. (B.) lawsoni* is perhaps closest to Eisenack's species *H. (B.) balticus* but differs in having longer apertural processes, a less parallel-sided and more robust



TEXT-FIG. 1 *a-d*. *Holoretiolites (Balticograptus) lawsoni* sp. nov. *a*, TCD 8473, holotype, *ludensis* Zone, Wenlock Series, locality 62 Burrington Farm; *b*, TCD 8475, same horizon and locality as holotype; *c*, TCD 8474, same horizon and locality as holotype; *d*, *Pristiograptus* sp. 1, TCD 8654, part of specimen on Pl. 130, fig. 6, showing pattern in cortical tissue.
 Figs. 1 *a-c* $\times 20$, 1 *d* $\times 30$; is, interthecal septum; stipple indicates ferruginous staining; oblique ruling indicates nearside of rhabdosome in 1c.

rhabdosome, and more closely spaced thecae. From *Retiolites clathrospinosus* Eisenack, *H. (B.) lawsoni* differs in having loop-shaped apertural processes as opposed to paired bifurcating spines, a less well-developed reticulum, and thecae which approximate to a 'climacograptid' rather than an 'orthograptid' type. The general dimensions of the two species are similar. *Holoretiolites* Eisenack is recorded for the first time in Britain.

Family MONOGRAPTIDAE Lapworth 1873

Genus PRISTIOGRAPTUS Jaekel 1889

Pristiograptus jaegeri sp. nov.

Plate 130, fig. 1, text-figs 2*k-r*, 3*f*

- 1900 *Monograptus vulgaris* Wood, pp. 455-6 (pars), text-fig. 10*a* (non 10*b*, pl. 25, fig. 2).
 1911 *Monograptus vulgaris* Wood; Elles and Wood, pp. 378-9 (pars), text-fig. 248*a* (non 248*b*, pl. 37, figs. 10*a-e*).
 ?1935 *Monograptus vulgaris* Wood; Decker, pp. 443-4, figs. 32-4.
 ?1935*a* *Monograptus vulgaris* Wood; Decker, p. 309.
 1943 *Pristiograptus vulgaris vulgaris* (Wood); Přibyl, text-fig. 2*l* (non 2*m*), ?pars, pp. 22-3.
 ?1947 *Monograptus vulgaris* Wood; Ruedemann, p. 490, pl. 84, figs. 22-4.
 ?1948 *Pristiograptus cf. vulgaris vulgaris* (Wood 1900); Přibyl, p. 78.
 1963 *Monograptus vulgaris* Wood; Holland *et al.*, pp. 104, 136, 157.
 non 1900 *Monograptus vulgaris* var. β Wood, p. 457, pl. 25, fig. 3.
 non 1911 *Monograptus vulgaris* var. *curtus* Elles and Wood, p. 379, pl. 37, fig. 11.
 non 1960 *Monograptus vulgaris* var. *ashlandensis* Berry, p. 1163, fig. 2*H*.

Diagnosis. Rhabdosome of moderate length, relatively slender, and 'stiff', particularly at the proximal end; sicula 2 mm. long, reaching aperture of th 2; over-all thecal spacing 12-8 in 10 mm.; distal thecae inclined at 40°; maximum dorso-ventral width at 20 mm., 1.30-1.50 mm (relief).

Holotype. The specimen figured herein as Plate 130, fig. 1, and text-fig. 2*n*, TCD 8661.

Material. Many specimens flattened and in relief, numerous isolated specimens.

Horizon. *ludensis* Zone in the Ludlow district and uppermost *lundgreni* and *ludensis* Zones in North Wales; *nilssoni* Zone of Prągowiec, Bardo Syncline, Holy Cross Mountains, Poland.

Localities. See text-fig. 4 for Ludlow and Conway Valley (North Wales) areas; Holy Cross Mountains, Poland (see Tomczyk 1962, fig. 9, p. 45).

Derivation of Name. After Dr. H. Jaeger (Humboldt University, Berlin).

Description. The rhabdosome reaches several centimetres in length but is usually of the order of 20 mm., where the dorso-ventral width is approximately 1.30-1.50 mm (in relief). Flattened and compressed specimens may have a distal dorso-ventral width of up

EXPLANATION OF PLATE 130

Figs. 1-8. 1, *Pristiograptus jaegeri* sp. nov., holotype, TCD 8661, *ludensis* Zone, Wenlock Limestone locality 100A. 2, *Monograptus ludensis* (Murchison) *sensu* Wood 1900, TCD 8658, *ludensis* Zone, Wenlock Shale, locality 61. 3, *Monograptus deubeli* Jaeger, TCD 8657, *ludensis* Zone, Wenlock Limestone, locality 114D. 4, *Gothograptus nassa* (Holm), TCD 8653, *ludensis* Zone, Wenlock Shale, Locality 40. 5, 6, *Pristiograptus* sp. 1, TCD 8660, 8654, *lundgreni* Zone, Wenlock Shale, locality 91. 7, *Pristiograptus dubius* (Suess), TCD 8663, *ludensis* Zone, Wenlock Shale, locality 40. 8, *Monograptus flemingii* (Salter), TCD 8652, *lundgreni* Zone, Wenlock Shale, locality 79. Figs. 1, 2, 3, 6, and 8 $\times 10$; fig. 4 $\times 7$; figs. 5 and 7 $\times 5$. None retouched. Localities within Ludlow district as in text.



1



2



3



4



5



6



7



8

HOLLAND, RICKARDS and WARREN, Wenlock-Ludlow graptolites

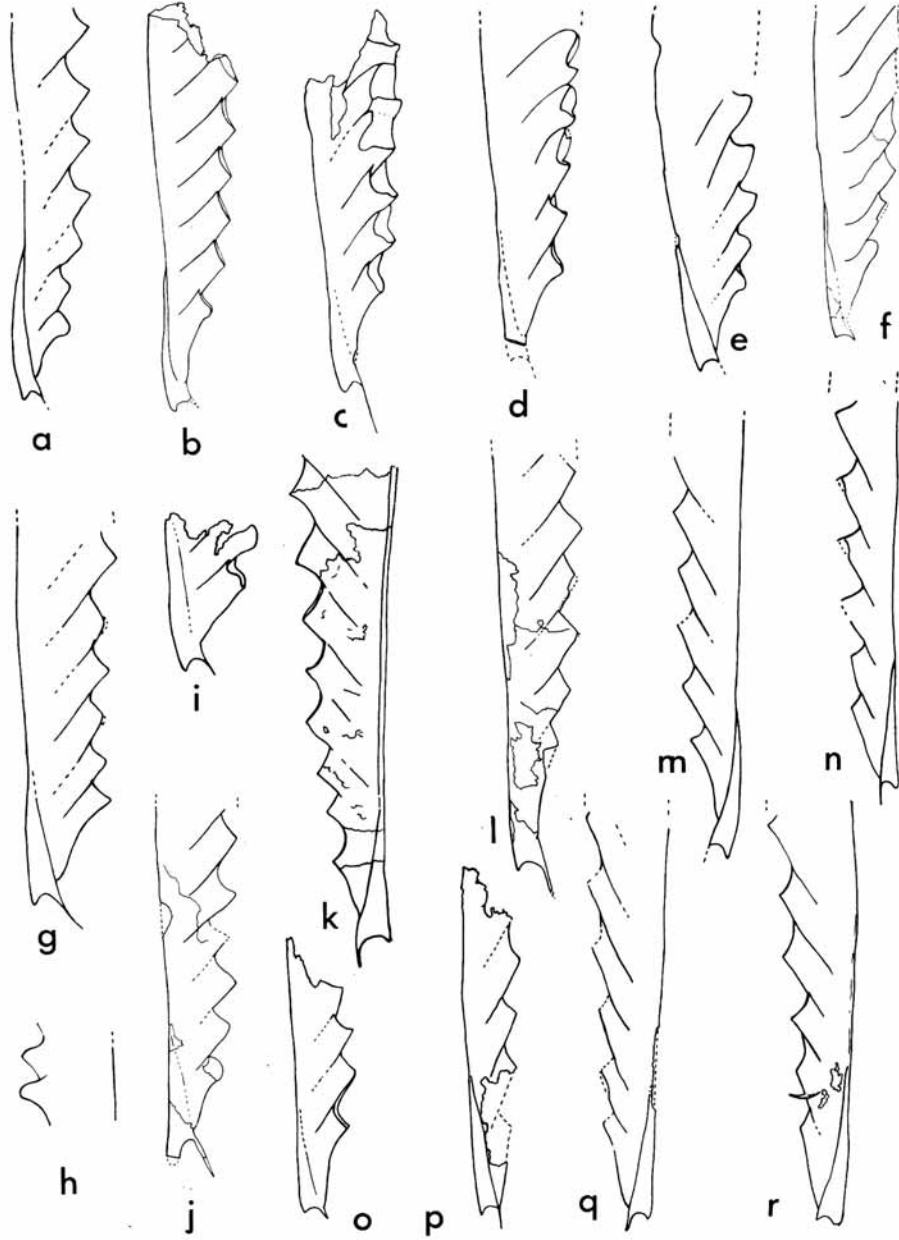
to 1.90 mm. A typical feature of the species is the 'stiff' rhabdosome, particularly at the proximal end (text-figs. 2, 3) which only occasionally shows very slight *dubius*-like curvature. The sicula has a length of at least 2.00 mm., the apex reaching to the level of the aperture of th 2. The over-all proximal thecal spacing is 12–10 in 10 mm. falling to almost 8 in 10 mm. distally in the most extreme variants. Undistorted specimens in relief usually have a thecal spacing of 11–10 in 10 mm. proximally and 10–9 in 10 mm. distally. The thecae are of simple pristiograptid type throughout the length of the rhabdosome, and are inclined to the axis at about 40°, in the distal regions. Rare specimens show a slight rounding (incipient lappets) of the apertural region of th 1 (text-fig. 2k). Such a degree of rounding of th 1 in *P. jaegeri* would be most difficult to detect in a specimen not isolated from the matrix. Thecal overlap distally is approximately two-thirds. A small number of specimens has been obtained from Ludlow in which a strange lateral thecal spine is seen on th 2 at about the level of the thecal aperture of th 1. We consider that these are probably abnormal and that the spine is not a character of specific importance.

Remarks. It is this species which has been most commonly recorded, and indifferently figured and described, by numerous authors as *M. vulgaris* Wood. Some of Das Gupta's (1933) specimens, for example, although with a 'stiff' proximal end, are referable to *M. leintwardinensis* and not to '*M. vulgaris*'. Přibyl (1948), however, selected as the lectotype of *M. vulgaris* the specimen figured by Wood (1900) as pl. 25, fig. 2 and re-figured by Elles and Wood (1911) as *Monograptus vulgaris* Wood (pl. 37, fig. 10a). It is of interest that Elles and Wood (op.cit.) had already effectively designated this specimen as 'type' (plate description of pl. 37). The species is distinct from the pristiograptid described herein as *P. jaegeri* sp. nov. *Monograptus vulgaris sensu* Elles and Wood does not merit retention in the genus *Pristiograptus*, an assignation adopted by some workers (e.g. Přibyl 1943). *M. vulgaris sensu stricto* is considered below under the description of *Monograptus ludensis* (Murchison).

Pristiograptus jaegeri sp. nov. occurs quite commonly associated with *M. ludensis*, although on evidence from North Wales its first appearance may be somewhat earlier than that of the latter. Assemblages isolated from calcareous nodules from the Holy Cross Mountains, Poland, almost invariably yield both species. The faint rounding of th 1, rarely exhibited by *P. jaegeri*, perhaps suggests an evolutionary relationship between this species and *M. ludensis* (Murchison).

Work in progress by one of us (P. T. W.) on the graptolites of North Wales suggests that *P. jaegeri* may eventually be usefully subdivided into several subspecies, and that some evolutionary connections may be unravelled. At the moment we would note that more slender forms seem to occur at lower stratigraphical levels, in *lundgreni* and basal *ludensis* Zone beds.

P. jaegeri may be distinguished from *P. dubius* (Suess) by the straight, 'stiff' proximal end and the long sicula reaching to the level of th 2. As with all pristiograptids, identification is most difficult if few specimens are at hand. There is considerable variation of such factors as dorso-ventral width, thecal spacing, etc., depending on whether the rhabdosome is flattened or in relief and, further, on whether the apparent width has been increased or decreased by compression in the strata. The North Wales specimens tend, for example, to be less well preserved than the isolated Polish or the three dimensional Ludlow specimens, and are usually flattened and often compressed. Consequently,



TEXT-FIG. 2

a greater dorso-ventral width is sometimes achieved (up to 1.90 mm.) and the thecal spacing shows a greater range of variation.

P. jaegeri differs from *M. vulgaris ashlandensis* Berry 1960 mainly in having a longer and more conspicuous sicula. We consider that Berry's form is at present best regarded as a species in its own right distinct from *M. ludensis*, probably referable to the genus *Pristiograptus*. *P. ashlandensis* is known only from flattened material and there may be some doubt about its true thecal characters.

Pristiograptus sp. 1

Plate 130, figs. 5, 6, text-fig. 1d

Material. Twenty-four specimens almost flat or in low relief.

Horizon and localities. Wenlock Shale, Wenlock Series, *lundgreni* Zone, localities 91 and 38 of Holland *et al.* (1963). Associated are: *Monograptus flemingii* and *Pristiograptus dubius*.

Description. The rhabdosome reaches a length of at least 35 mm. and a distal dorso-ventral width (low relief) of 2.40 mm. A width of 2.00 mm. is achieved quite close to the proximal end, usually at about 7 mm. above the base of the sicula or approximately the 9–th 10. The proximal thecal spacing is of the order of 13 in 10 mm., although some badly squashed specimens reach 14 in 10 mm. Distally a value of 10 in 10 mm. is the widest observed spacing.

The sicula has a length of 2.00 mm. the apex reaching the level of the second thecal aperture. In the mesial and distal parts of the rhabdosome the thecal tubes are inclined at 45–50° to the axis. Thecal overlap in the same regions is of the order of two-thirds.

TEXT-FIG. 2a–j. *Monograptus ludensis* (Murchison 1839) *sensu* Wood 1900: a, TCD 8658, specimen in relief, *ludensis* Zone, locality 61 Ludlow district (text-fig. 4); b, SM A60900, isolated specimen in full relief, nodule from Prągowiec, Bardo Syncline, Holy Cross Mountains, Poland, probably *nilssoni* Zone, presented to the Sedgwick Museum by Dr. A. Urbanek; c, d, SM A60904–5, isolated, mature specimens in moderate relief from Prągowiec, *nilssoni* Zone, showing infilling of apertural region with late tissue, nodule from Dr. A. Urbanek, specimens prepared by Dr. G. H. Packham 1960; e, SM A60901, broad, immature, isolated, specimen in full relief, nodule from Prągowiec, probably *nilssoni* Zone, angles of thecal apertures, not yet infilled with late tissue; f, GSM GSC 6584a, proximal end, in full relief, of proposed lectotype, illustrated in text-fig. 3b. *ludensis* Zone; g, TCD 8744, external mould of specimen in low relief, *ludensis* Zone, locality 41 Ludlow district (text-fig. 4); h, TCD 8744a, internal mould of th 1 and th 2 of previous specimen showing rounding of th 1 not apparent on external mould; i, SM A60906, proximal end in full relief, nodule from Prągowiec, Holy Cross Mountains, Poland, *nilssoni* Zone; j, GSM Zp 5670, abnormal development of dorsal lip of sicula, specimen almost flattened, *ludensis* Zone, Oerfa, Llanrwst, N. Wales (N.G.R. SH 8456 5950), Boswell's locality 482; k–r, *Pristiograptus jaegeri* sp. nov.: k, BU 1470, specimen originally figured by Wood (1900) as *Monograptus vulgaris*, text-fig. 10a and again by Elles and Wood (1911) as text-fig. 248a; l, GSM Zp 5720, proximal end of specimen illustrated herein as text-fig. 3f, *ludensis* Zone, Cefn-y-Fran, Llanrwst, N. Wales (SH 8280 6080) Boswell's locality 536; m, TCD 8745 specimen with unusually curved sicula, *ludensis* Zone, locality 100 Ludlow district (text-fig. 4); n, TCD 8661, holotype, a specimen in full relief, *ludensis* Zone, locality 100A, Ludlow district (text-fig. 4); o, SM A60903, isolated specimen in full relief, showing the rare slight rounding of th 1, nodule from Prągowiec, Bardo Syncline, Holy Cross Mountains, Poland, probably *nilssoni* Zone; p, SM A60902, isolated specimen in low relief, nodule from Prągowiec, probably *nilssoni* Zone; q, TCD 9218, *ludensis* Zone, locality 40, Ludlow district (text-fig. 4); r, TCD 8696 specimen in low relief with abnormal spine, *ludensis* Zone, locality 40, Ludlow district (text-fig. 4). All figures $\times 10$.

The length of the ventral thecal wall at th 10 is 2.50 mm. The thecal apertures approach the horizontal, that is they are not at right angles to the long axis of the thecal tube, and both proximal and distal thecae are strongly denticulate, almost spinose.

A single specimen (TCD 8654, text-fig. 1*d*) shows a rather curious pattern of the cortical tissue. This is composed of fine, arcuate ridges, which are mostly, but not invariably, concave towards the ventral side of the rhabdosome. The ridges are laid down over the dorsal wall of the rhabdosome and over the nema. In numerous instances earlier ridge systems can be seen beneath later ones. The exposed portion of the sicula is similarly affected, but not the interthecal septum of th 6–th 7.

Remarks. The cortical tissue on the specimen described above is clearly laid down in a somewhat irregular manner, presumably by soft parts operating from the ventral side of the rhabdosome. Dr. Berry has recently shown us electron microscope photographs of this structure which he has found on Ordovician orthograptids.

Pristiograptus sp. 1 is a relatively robust form, and is difficult to equate with the many previously described pristiograptids. In general appearance it resembles the form figured by Přibyl (1943) as *P. cf. sardous sardous* (Gortani), a *flexilis (linnarssoni)* Zone species. The Ludlow district species is, however, rather more slender and has more closely spaced thecae, whilst the thecal angle is distinctly higher. *P. kosoviensis* (Bouček), a Ludlow species, is perhaps closer to *Pristiograptus* sp. 1 in terms of general dimensions, being only slightly broader. The long-ranging *P. dubius* stock seems repeatedly to produce narrow and broad species (and subspecies), and *P. sp. 1* may reflect the latter tendency.

Genus MONOGRAPTUS Geinitz 1842
Monograptus deubeli Jaeger 1959

Plate 130, fig. 3

1959 *Monograptus deubeli* Jaeger, pp. 126–7, pl. 10, figs. 4–8.

Material. Six specimens, low to moderate relief.

Horizon and Locality. *ludensis* Zone, Wenlock Series; locality 114D, Ludlow District (see p. 676).

Description. The rhabdosome is almost straight or with gentle dorsal curvature (particularly at the proximal end), achieving a length of about 20 mm. and a distal dorso-ventral width of 1.10–1.25 mm. The thecal spacing varies from 12–13 in 10 mm. proximally to 10 in 10 mm. distally. At the level of the aperture of th 1 the dorso-ventral width is 0.90 mm.

The sicula has a length of approximately 2.00 mm. its apex reaching almost to the level of the aperture of th 2. The dorsal wall of the sicula may have dorsal curvature whilst the sicula as a whole expands rapidly towards its aperture. The sicula, therefore, appears more broadly triangular than is usual in monograptids: the aperture has a diameter of 0.50 mm. (moderate relief).

Th 1 has a distinctly rounded aperture. Subsequent thecae are of simple pristiograptid type, though a faint trace of rounding can be seen on th 2 and th 3. The rounded aperture of th 1 is already formed when th 3 is half completed. Thecal overlap is about one-half and the angle of inclination of the thecae some 30°.

Remarks. Although less well preserved our material agrees closely with that described

by Jaeger (1959) from Thuringia, particularly in the nature of the proximal end and the shape of the sicula. *M. deubeli* has not previously been recorded in Britain. Dr. Jaeger has recently obtained the species from Australia whilst one of us (R. B. R.) has identified *M. cf. deubeli* in the Hassi Bedda-1A borehole of the Compagnie Française des Pétroles d'Algérie, where it occurs in strata immediately overlying beds with *P. bohemicus* (Barande), *M. incipiens* Wood, and *M. chimaera semispinosus* Elles and Wood.

Monograptus ludensis (Murchison 1839), *sensu* Wood 1900

Plate 130, fig. 2, text-figs. 2*a-j*, 3*a-e*.

- 1839 *Graptolithus Ludensius* Murchison, p. 694, pl. 26, fig. 2 (non fig. 1).
 ?1879 *Graptolithus colonus* Barrande; Quenstedt, pp. 198–201, pl. 150, fig. 43 × (non figs. 43*f*, *p*, *y*, *z*).
 1890 *Monograptus* sp. Holm, pl. 1, figs. 27–30.
 1899 *Monograptus gotlandicus* Perner, p. 12, pl. 14, fig. 22.
 1900 *Monograptus vulgaris* Wood, pp. 455–6 (pars), text-fig. 10*b*, pl. 25, fig. 2.
 ?1900 *Monograptus gotlandicus* Perner; Wood, p. 460, pl. 25, fig. 7.
 1900 *Monograptus colonus* var. *ludensis* Murchison; Wood, p. 465, pl. 25, fig. 11.
 1911 *Monograptus vulgaris* Wood; Elles and Wood, pp. 378–9 (pars), text-fig. 248*b*, pl. 37, figs. 10*a-e*.
 ?1911 *Monograptus cf. gotlandicus* Perner; Elles and Wood, pp. 382–3, text-fig. 252, pl. 37, fig. 8.
 1911 *Monograptus colonus* (?) var. *ludensis* (Murchison); Elles and Wood, pp. 394–5, text-fig. 262, pl. 38, figs. 9*a-c*.
 ?1935 *Monograptus vulgaris* Wood; Bouček, pp. 9–10, figs. 4*i-j*.
 ?1936 *Monograptus cf. vulgaris* Wood; Bouček, p. 6, fig. 1*k*.
 1936 *Monograptus gotlandicus* Perner; Bouček, p. 6, figs. 1*a-c*.
 ?1942 *Pristiograptus gotlandicus* (Perner); Münch, p. 251, pl. 3, figs. 1–3.
 1943 *Pristiograptus gotlandicus* (Perner 1889); Příbyl, p. 26, text-fig. 38, pl. 2, fig. 5.
 ?1948 *Pristiograptus (Pristiograptus) gotlandicus* (Perner); Příbyl, p. 70.
 1956 *Pristiograptus (Pristiograptus) vulgaris vulgaris* (Wood, 1900); Tomczyk, pp. 53–54, fig. 15*a*, pl. 6, fig. 1, pl. 7, fig. 1.
 1959 *Pristiograptus gotlandicus* (Perner 1889); Urbanek, pp. 11–26, text-figs. 1–3, text-pl. 1, pls. 1 and 2.
 ?1965 *Pristiograptus gotlandicus* (Perner), 1899; Obut, Sobolevskaya, and Bondarev, pp. 67–8, pl. 11, figs. 4, 5.
 non 1879 *Graptolithus ludensis* Murchison; Quenstedt, pp. 192–3, pl. 150, figs. 29, 31, 32.
 non 1879 *Graptolithus ludensis arcuatus*; Quenstedt, p. 194, pl. 150, fig. 30 [= *M. testis* s.l.].
 non 1900 *Monograptus vulgaris* var. *β* Wood, p. 457, pl. 25, fig. 3.
 non 1900 *Monograptus vulgaris* Wood, text-fig. 10*a*.
 non 1911 *Monograptus vulgaris* Wood; Elles and Wood, text-fig. 248*a*.
 non 1911 *Monograptus vulgaris* var. *curtus* Elles and Wood, p. 379, pl. 37, fig. 11.
 non 1960 *Monograptus vulgaris* var. *ashlandensis* Berry, p. 1163, fig. 2H.

Lectotype. The type slab contains at least 80 well-preserved specimens of the species. Murchison's original figure (pl. 26, fig. 2) appears to be diagrammatic, probably composite, and shows only a portion or portions of the type slab. We have chosen GSM GSC 6584*a* as lectotype of the species. This specimen is illustrated herein as text-figs. 2*f* and 3*b*. The specimen figured by Murchison (1839) as pl. 26, fig. 1 is conspecific with *Monograptus priodon* (Bronn 1835).

Material and localities. Numerous specimens in low to moderate relief from the Ludlow District and from North Wales (text-fig. 4). Many specimens isolated from the matrix, from *nilssoni* Zone nodules, Bardo Syncline, Holy Cross Mountains, Poland.

Horizon. *ludensis* Zone in Ludlow District; *ludensis* and basal few metres of *nilssoni* Zone in North Wales; elsewhere the species ranges into the *nilssoni* Zone.

Description. The rhabdosome is characteristically large and straight, often reaching a length of 60–80 mm. and a dorso-ventral width (in relief) of over 2 mm. At 10 mm. from the proximal end the dorso-ventral width in our material varies from 1.50 to 1.70 mm.

The proximal region shows rather variable but usually ventral curvature, whilst the actual proximal end commonly has a most striking appearance (text-figs. 2*a*, *b*), often with a ventrally curved sicula and a prominent apertural region. In these specimens the ventral wall of th 1 is often concave, thus accentuating the rather claw-like appearance of the proximal end. However, there is every gradation between this 'typical' proximal end and the more robust type (text-figs. 2*e–g*), in which th 1 may have a less concave ventral wall and a higher angle of inclination and in which the sicula is less prominently curved.

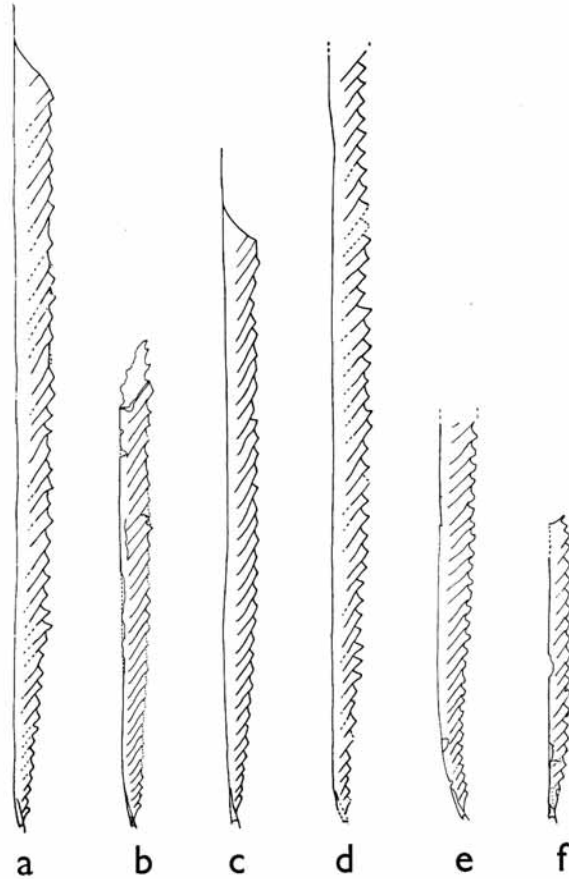
Th 1, and less often th 2, shows a distinct rounding of the apertural region (text-figs. 2*a*, *e*, *h*, *i*, *j*) due to the development of incomplete half rings resulting in incipient lappets (Urbanek 1959). The lappets are clearly visible on our British specimens. The sicula may be slightly in excess of 2 mm. in length whilst its apex reaches the level of the aperture of th 2. At th 2 the dorso-ventral width is from 0.80 to 1.10 mm. The thecal spacing changes from 13 in 10 mm. proximally, to usually 10 in 10 mm. distally, but occasionally to 8 in 10 mm.

In immature rhabdosomes (say 10–20 mm. long), thecae subsequent to th 1 or th 2 may have simple pristiograptid apertural regions, but adult specimens show a pronounced infilling with late fusellar tissue of the angle between the original even aperture and the subsequent free ventral wall (Urbanek 1959). This is clearly seen in mature Ludlow specimens and is commonly observed in the North Wales examples (text-fig 3*e*).

Thecal overlap changes from rather more than one-half and up to two-thirds proximally, to three-quarters distally. However, when infilling of the apertural angle is complete in mature specimens the rhabdosome appears almost parallel-sided and the 'serrations' of the ventral margin may be hardly visible and a free ventral wall non-existent. In such material overlap is effectively complete.

Remarks. *M. gerhardi* Kühne, 1955 is clearly very close to *M. ludensis* (Murchison), differing only in having a higher proximal thecal count (14 in 10 mm.) and a dorso-ventral width of 2.20 mm. at 10 mm. from the proximal end. Indeed, Jaeger (1959, p. 64 n.) has suggested that *gerhardi* and *vulgaris* (large form, = *ludensis*?) are conspecific and reiterating this later (1964, p. 37) he added that he believed *gotlandicus* and *gerhardi* also to be conspecific. It is possible that the variation noted above can be ascribed to astogenetic changes (see above and Jaeger 1962, p. 37), but it may equally represent geographical variation and short of a detailed study of *gerhardi* we prefer to leave open the question of its precise relation to *ludensis*.

The appreciation of the conspecificity of *M. ludensis* (Murchison) *sensu* Wood, *M. gotlandicus* Perner, and *M. vulgaris* Wood (pars) solves a number of problems concerning the geographical records of this species. Thus *M. gotlandicus* was widely recorded and common on the continent (*nilssoni* Zone) and only doubtfully recognized in Britain. The converse holds for *M. vulgaris* (pars). The latter has, however, been frequently and



TEXT-FIG. 3a-e. *Monograptus ludensis* (Murchison 1839) *sensu* Wood 1900: a, BU 1466 (a), specimen figured by Elles and Wood (1911), pl. 37, fig. 10b as *M. vulgaris* Wood on the same slab as the type specimen, pl. 37, fig. 10a; b, GSM GSC 6584a, proposed lectotype, a specimen in full relief on the type slab showing critical details of the proximal end, locality: Llanfair, Montgomeryshire; c, BU 1496, specimen figured by Elles and Wood (1911), pl. 38, fig. 9b as *M. colonus* (?) var. *ludensis* (Murchison); d, BU 1466 (b), the type specimen of *M. vulgaris* Wood, figured by Wood (1900) as pl. 25, fig. 2 and by Ellis and Wood (1911) as pl. 37, fig. 10a; e, GSM Zp 4003b, somewhat compressed specimen, *ludensis* Zone, locality Brynnyllydy, Llanrwst, N. Wales (SH 8202 6164), Boswell's locality 472; f, *Pristiograptus jaegeri* sp. nov. GSM Zp 5720, *ludensis* Zone, locality given under explanation of text-fig. 2l. All figures $\times 2\frac{1}{2}$.

widely misidentified, and is probably not as common in Britain as the literature would suggest.

The form described by Elles and Wood as *Monograptus vulgaris curtus* nom. nov. (for Wood's *M. vulgaris* var. β) would seem to be a pristiograptid, the type lacking the

rounding of th 1 so typical of *M. ludensis*. We feel unable to comment at this stage on the position of *Pristiograptus curtus* in relation to other pristiograptids.

STRATIGRAPHICAL DISTRIBUTION

The stratigraphical distribution of graptolites we have collected from the Wenlock and lowest Ludlow of the Ludlow district is indicated in text-fig. 4. The locality numbers are those of Holland *et al.* (1963), except that a few subdivisions have been made as follows:

Locality 114 (Holland *et al.* 1963, p. 165) is a track section continuing some 500 m. through Wenlock Shale. Our more precise Locality 114A refers to National Grid Reference SO 45387228, whereas Locality 114B lies about 120 m. north-eastwards at 45487232, and Locality 114C is at 45667247, some 230 m. further north-eastwards. About 160 m. beyond this an exposure within the Wenlock Limestone at Grid Reference 45817253 is referred to as Locality 114D.

The north-eastern arm of the branching track with its exposures of Wenlock Shale referred to as Locality 100 in Holland *et al.* (1963, p. 164) may be followed up slope where some exposures of the lower part of the Wenlock Limestone are available. The lowest of these, at the base of the Wenlock Limestone, is here referred to as Locality 100A (Grid Reference 44887244).

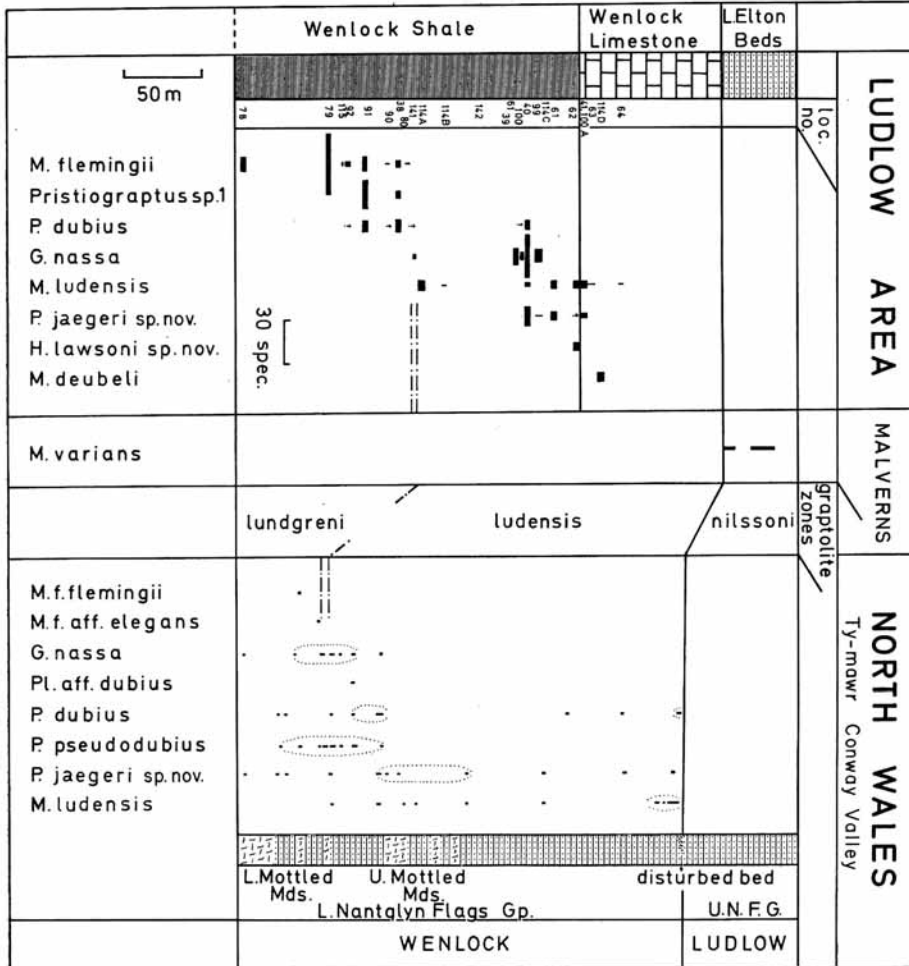
As will be appreciated from text-figure 4, some localities in the Wenlock Shale have yielded no graptolites or but a sparse record, whereas others, such as Localities 79, 91, and 40, are relatively rich. Holland *et al.* recorded no graptolites from the Wenlock Limestone but the present investigation has revealed a sparse fauna in its lower part. These same authors, (Holland *et al.* 1963, p. 108), record a graptolite fragment from the Lower Elton Beds of Locality 69, but this and other exposures within these beds were searched again with very little success. We have obtained but a further single specimen which we have identified as *Monograptus ? varians* Wood.

Approximately the lower half of the Wenlock Shale in the Ludlow district falls within the *lundgreni* Zone and is characterized by an assemblage of relatively abundant *Monograptus flemingii*, associated with *Pristiograptus dubius* and another pristiograptid here referred to as *Pristiograptus* sp. 1.

The 'nassa/dubius Interregnum' of Jaeger (1959) may be identified as a relatively thin horizon in which *M. flemingii* and *Pristiograptus* sp. 1 have disappeared; *Gothograptus nassa* is present; but *Monograptus ludensis* has not yet appeared. It is immediately succeeded by strata yielding *M. ludensis*; but between this first appearance of the species and its further occurrences there is a considerable thickness of strata from which we have recorded no graptolites at all (see text-fig. 4). The factors responsible for the impoverishment of graptolite faunas at the level of Jaeger's 'Interregnum', and marked there by the restricted fauna of *G. nassa* and *P. dubius*, may perhaps be reflected here in the absence of graptolites through the basal part of the *ludensis* Zone, which we have taken as beginning at the first appearance of the index species just over 100 m. below the base of the Wenlock Limestone.

The characteristic assemblage of the *ludensis* Zone as seen in the highest part of the Wenlock Shale is of *M. ludensis* itself together with *Pristiograptus jaegeri*. Both *G. nassa* and *M. dubius* are also present at first.

Finally, it is important to note that the *ludensis-jaegeri* association is now known to



TEXT-FIG. 4. Range chart of graptolites in the Ludlow, Malvern, and North Wales (Conway Valley) districts. The section given here is that measured at Ty-mawr Farm (N.G.R. SH 820 682), Eglwysbach, Conway Valley and the graptolite occurrences are local and hence can be directly related to this section. However, the general stratigraphy and graptolite ranges are applicable to the whole of NW. Denbighshire. In the North Wales graptolitic facies approximate peaks are indicated by fine dotted lines. Dot/dash lines indicate approximate position of the *nassa/dubius* Interregnum. Alternating lined and stippled beds are mudstones; 'bricks' are limestones; 'broken bricks' are calcareous mottled mudstones; and fine-lined beds are shales. *P. nilssoni* Zone species are omitted from the North Wales side of the chart, whereas these only are shown for the Malverns. Abbreviations: Mds. = Mudstone; Gp. and G. = Group; spec. = specimens. Details of graptolites (in the North Wales section) not referred to in the text are as follows: *M. flemingii* aff. *elegans* Elles, *Plectograptus* (?) aff. *dubius* Bouček and Münch, *Pristiograptus pseudodubius* (Bouček).

continue into the basal part of the Wenlock Limestone. Thus, we have factual evidence that the upper part of the Wenlock Shale and part at least of the Wenlock Limestone belong in the *ludensis* as distinct from the *lundgreni* Zone. The consequences of this in terms of stratigraphical nomenclature are discussed in the next section of this paper.

Also within the Wenlock Limestone, we may note the occurrence of *Monograptus deubeli* at a somewhat higher level than in Thuringia from whence Jaeger first described this species.

As mentioned above, it is unfortunate that the Lower Elton Beds of the Ludlow district have still failed to provide conclusive evidence of their position in the graptolite zonal sequence. We have, through the kindness of Mr. J. S. W. Penn, Miss J. Vinnicombe, and Mr. D. G. A. Whitten, been allowed to examine a collection of Silurian graptolites from the Malvern Hills assembled at Kingston-upon-Thames College of Technology. Mr. Penn will undoubtedly be referring to the full results of our examination elsewhere, but we note here the presence of *Monograptus varians* in the Lower Elton Beds. The number of specimens is small and, in spite of the uniformity of shelf facies Ludlow successions throughout the Welsh borderland, there remains the possibility that the Lower Elton Beds of the Malverns are not of precisely the same age as those at Ludlow. So, as *M. varians* has never been recorded in pre-*nilssoni* strata, here is slight evidence that the Lower Elton Beds belong to the *nilssoni* Zone and we have added this to our chart.

We have also been able to examine, and here report on, four graptolite specimens obtained by Professor P. J. Lespérance (University of Montreal, Canada) from the Lower Elton Beds of Millichope, Shropshire, which were forwarded to us by Dr. J. H. Shergold (Canberra, Australia). They are: an indeterminate distal fragment; the part and counterpart of a form probably referable to *P. dubius*; and a specimen referred to *Monograptus* sp. cf. *variens variens* Wood. The material is not well preserved and the last mentioned specimen does not exhibit clearly the proximal thecal 'hooks' of *variens* although the dimensions of the rhabdosome accord in every way with that species. It could possibly be assigned to *M. aff. ludensis*. Thus, whilst in no way providing of itself an unequivocal age for the Lower Elton Beds, this material adds further slim evidence to that from the Malverns.

Finally we would note the occurrence of *M. uncinatus orbatus* Wood, a *nilssoni* Zone species, from the Lower Elton Beds of the May Hill Inlier (Birmingham University, specimen no. My 82M).

Text-fig. 4 also includes a summary of uppermost Wenlock graptolite occurrences in the Denbighshire Moors in North Wales. We provide this as an illustration of a typical basin facies graptolitic sequence in contrast to that of the Ludlow district; and, moreover, a basin sequence which has been subject to modern study by the Institute of Geological Sciences. The Ludlow district is to be regarded as of shelf facies in terms of higher Silurian stratigraphy, though certainly in a position marginal to the basin or geosyncline. In the North Wales section, as in that at Ludlow, the ranges of *Monograptus ludensis* and *Pristiograptus jaegeri* replace that of the original *M. 'vulgaris'*. Although *Gothograptus nassa* is common within the basal *M. ludensis* Zone, its maximum occurrence is within a '*nassa/dubius* Interregnum', of the same order of thickness as that at Ludlow, which may be recognized immediately below the first occurrence of *M.*

ludensis. This interregnum is thus again in the same stratigraphical position as that originally described by Jaeger (1959).

It is now clear that the sequence from the *lundgreni* Zone (with its characteristic occurrence of *M. flemingii*), through a '*nassa/dubius* Interregnum', to the *ludensis* Zone (characterized by both *M. ludensis* and *Pristiograptus jaegeri*), and then into a more varied *nilssoni* Zone assemblage, can be widely recognized in Europe. The comparison with the very carefully described sequence from Thuringia is evident from Jaeger's diagram of graptolite ranges (1959, p. 39) and two of the present authors (C. H. H. and P. T. W.) have had the opportunity of seeing the same sequence in the Polish sections of the Holy Cross Mountains.

THE WENLOCK LUDLOW BOUNDARY

The question of the recognition of the boundary between the Wenlock and Ludlow in the light of the stratigraphical facts referred to above must now be considered against the historical background. A short review of the problem is given by Holland (in press).

Murchison (1833) was originally confused between the two Silurian limestones at Wenlock and Aymestrey respectively, and his Lower and Upper Ludlow Rock were at first separated by the so-called Wenlock Limestone. This confusion was eliminated the following year when the relevant part of his stratigraphical table (Murchison 1834) showed the Lower Ludlow Rock following upon the Wenlock and Dudley Limestone and succeeded by the Aymestry and Sedgley Limestone. Wood (1900), in her classical account 'The Lower Ludlow Formation and its Graptolite-Fauna', referred to Murchison's line of demarcation, but noted (p. 421) that he himself had admitted that the 'Lower Ludlow was simply an upward prolongation of the Wenlock Shale'. In some districts he thought it impracticable to separate them. She referred also to Lapworth's (1880, p. 48) comment that the division was probably made 'less from a palaeontological than from an aesthetic point of view'. Wood's own palaeontological studies had confirmed that 'where there is a lithological transition between the Wenlock and Ludlow Beds there is also a palaeontological transition' (p. 421). Nevertheless, she was able to draw a palaeontological line between the two 'of considerable stratigraphical and practical value' (p. 421). Working with Elles (1900), who had similarly described the graptolite fauna of the Wenlock, Wood (1900, p. 421) compiled a short list of the comparative graptolitic characteristics of the two divisions. Thus, the Wenlock was characterized by the presence of *Cyrtograptus* and monograptids of the *flemingii* type, both of which were absent in the Lower Ludlow. The Lower Ludlow, on the other hand, contained monograptids of the *colonus* (Barrande) type as well as spinose forms such as *M. chimaera* (Barrande), none of which was present in the Wenlock.

More significantly for the future development of Wenlock/Ludlow biostratigraphy, Wood divided the 'Lower Ludlow Beds' into five graptolite zones, of which the lowest was that of *M. vulgaris*. This last followed upon the highest of the Wenlock zones defined by Elles, that of *Cyrtograptus lundgreni* Tullberg. The *vulgaris* Zone was devoid of graptolites in the type Ludlow district, though the fauna was to be found in both the Builth and Long Mountain districts where Wood also established her detailed stratigraphy.

The *M. 'vulgaris'* [= *ludensis*] Zone has since been taken internationally as the base

of the Ludlow Series and numerous references from Central and Eastern Europe could be quoted. The authoritative and comprehensive work of Jaeger (1959) on the graptolitic Silurian of Thuringia has already been referred to above. In Britain, Boswell (1949), for example, used it (though evidently with some difficulty) in his lengthy treatment of the Silurian rocks of North Wales. In contrast, those working in the shelf facies of the higher Silurian, where the Wenlock Limestone is developed, have followed Murchison's revised stratigraphy with the Ludlow beginning immediately above that limestone. A correlation table and comprehensive reference list for the British Ludlow is given by Holland *et al.* (1963).

Nevertheless, since Watts (1925) equated the *M. 'vulgaris'* [= *ludensis*] Zone of the Long Mountain with the 'Wenlock Limestone Stage' of the Wenlock-Ludlow Area (Watts 1925, p. 346) and went on to report that above the Wenlock zones 'comes the zone of *M. vulgaris* which Miss Wood (Dame Ethel Shakespear) has shown to be equivalent of the Wenlock Limestone' (p. 394), a sense of disquiet has tended to affect those obliged to rely upon the assumed correlation of the barren beds above the Wenlock Limestone with the '*vulgaris*' [= *ludensis*] Zone of the graptolitic geosynclinal facies.

The *Summary of Progress of the Geological Survey of Great Britain for 1926*, published in 1927, referring to the Much Wenlock district, suggested (pp. 42-3) that the '*vulgaris*' [= *ludensis*] Zone extended some 60 m. below the Wenlock Limestone whilst a *P. nilssoni* zonal assemblage had been found about 18 m. above the limestone. An abundance of *Gothograptus nassa* in the 60 m. of shales below the Wenlock Limestone 'would, other things being equal, be taken as clearly indicative of the zone of *Monograptus vulgaris*. The correspondingly low position of the localities indicating the zone of *Cyrtograptus lungreni* supports this view.' Das Gupta (1933), however, found the range of *Gothograptus nassa* at Wenlock Edge and in North Wales to be 'closely comparable with its occurrence abroad, as, for example, in Bohemia, where it ranges from the highest beds of the zone of *M. testis* (= zone of *C. lungreni* in Great Britain) to the lower beds of the zone of *M. nilssoni*'. Das Gupta's comments were taken into account by the authors of the Shrewsbury memoir (Pocock *et al.* 1938), where Robertson and Stubblefield (p. 102) wrote as follows:

Subsequent . . . to the completion of the survey of the Shrewsbury Sheet, Dr. Das Gupta, working in the Long Mountain area, where there is no Wenlock Limestone, has found *M. vulgaris* in the *C. lungreni* Zone, and associated with the zone-fossil. He has also collected *M. vulgaris* from beds a short distance above the Wenlock Limestone of Wenlock Edge, at a point some 9 miles south-west of Much Wenlock. Manifestly, these discoveries are still not sufficient to establish whether the Wenlock Limestone belongs to the *C. lungreni* or the *M. vulgaris* Zone, or to both, and until that is done, it should be clearly recognized that the position of the Ludlow-Wenlock boundary in the graptolite succession remains unsettled.

At this point we may simply refer back to the introduction to this paper, where reference is made to the standard locality (Pitch Coppice) for the base of the Ludlow Series. We accept this marker point in the shelf facies for the Wenlock/Ludlow boundary (but see later). We are now in possession of new biostratigraphical facts as summarized in text-fig. 4 above and our commentary upon it in the preceding section. We now know that the *M. ludensis* Zone begins some 100 m. below the base of the Wenlock Limestone

in the Ludlow District and that some at least of that limestone is definitely to be included therein.

Consequently, a difficult situation exists. The 'vulgaris' [= *ludensis*] Zone has been widely regarded as the base of the Ludlow and yet we are convinced that the Wenlock Limestone must remain in the Wenlock Series and not the Ludlow Series. Thus, we have advocated that workers in the graptolitic facies should now take as the base of the Ludlow Series the base of the *nilssoni* Zone (Holland, Rickards, and Warren 1967). Martinsson (1967) has already found this helpful in his ostracode correlations.

But though this course of action will restore stability and allow for reasonable accuracy of correlation from one facies to another, it does not dispose of the final problem of the definition of the base of the Ludlow Series at a standard section in the Ludlow district. As explained above, we still do not know that the base of the Lower Elton Beds in that district coincides with the base of the *nilssoni* Zone. It is still possible that the whole of the Lower Elton Beds are, as was originally assumed, of 'vulgaris' [= *ludensis*] age or, again, the base of the *nilssoni* Zone may come within or even below these beds. If the first of these three possibilities obtains there will be no problem as the base of the Ludlow Series, as defined by Holland *et al.* (1963), will coincide with the biostratigraphical horizon at the base of the *nilssoni* Zone already advocated for use in correlation. We have indicated above that there is some evidence from the Malvern Hills that this is indeed the case.

If, on the other hand, fresh finds of graptolites or other aids to correlation do eventually demonstrate that the base of the *nilssoni* Zone comes at a higher level within the Lower Elton Beds, we shall be left with a Wenlock/Ludlow boundary, as at present defined, which comes within the *ludensis* Zone, though of course high in that zone. This situation may not commend itself when the inevitable progress of international stratigraphical procedure leads to a decision on this particular boundary, and it may prove necessary to accept a slight readjustment of the base of the Eltonian to coincide (if possible) with the base of the *nilssoni* Zone.

Our present study cannot contribute further to this particular problem and we can only reiterate that we recommend the acceptance of the *nilssoni* Zone as the base of the Ludlow Series in the graptolitic facies, and we are satisfied that any resulting correlations from one facies to another will then in any event be close to the truth.

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