

Isolated Silurian Graptolites from the Bollerup and Klubbudden Stages of Dalarna, Sweden

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with 3 Plates

Abstract: Graptolites isolated from Lower Silurian shales and limestone nodules have provided new information on the structure of several species. In particular, it is shown that a), some monograptids exhibit a form of prothecal folding; b), *Monograptus proteus* (BARRANDE) has asymmetrical thecal hooks; and c), an unnamed monograptid has thecae superficially resembling the dicellograptid type. In addition, the morphology is described in some species hitherto known only from flattened or pyritized material. The following are described: *Pseudoclimacograptus* (*Metaclimacograptus*) *hughesi* (NICHOLSON), *Orthograptus* sp., *Orthograptus* ? sp., *Glyptograptus tamariscus* (NICHOLSON), *Glyptograptus* aff. *G. tamariscus fastigans* HABERFELNER, *Petalograptus* sp., *Retiolites* s.l. sp., *Rhaphidograptus toernquisti* (ELLES & WOOD), *Monograptus exiguus* (NICHOLSON), *Monograptus gregarius* (LAPWORTH), *Monograptus halli* (BARRANDE), *Monograptus marri* PERNER, *Monograptus proteus* (BARRANDE), *Monograptus* cf. *M. barrandei* sensu ELLES & WOOD, *Monograptus* aff. *M. spiralis* GEINITZ, *Monograptus* sp. 1, *Monograptus* sp. 2, and *Rastrites linnaei* BARRANDE.

In several instances, comparison is made with recently-collected pyritized material from the British Lower Silurian.

Zusammenfassung: Aus untersilurischen Schiefen und konkretionären Kalksteinen Dalarnes konnte eine Anzahl von Graptolithen-Arten zum ersten Male isoliert werden. Daraus ergab sich eine Reihe neuer Beobachtungen, die in der vorliegenden Arbeit ausführlich beschrieben und diskutiert werden. Das Material stammt von zwei verschiedenen Fundorten:

1. Straßeneinschnitt am Silverb erg bei Boda, an der Ostseite der Autostraße Rättvik-Furudal (Profil beschrieben bei WAERN 1960), aus dem oberen Teil der Bollerup-Schichten, Zone des *Monograptus gregarius*. Aus den kalkigen Schiefen wurde das Material mit Salz- und Flußsäure herausgelöst. Die Graptolithen sind flachgedrückt, teilweise wurden sie bei der Behandlung durchsichtig, was mit Oxydationsmitteln noch verstärkt werden konnte.

Unter dem hier gewonnenen Material ist *Monograptus* sp. 2 von besonderem Interesse, der deutlich introvertierte Thekenöffnungen und Thekenränder mit paarigen Seitenlappen und einem median-ventralen Sattel besitzt. Das Geniculum hat eine Kappe. Silurische Graptolithen mit einwärts gerichteten Theken sind selten und *Monograptus* sp. 2 kann mit keinem der beschriebenen identifiziert werden. Wegen der Form des Geniculums bestehen Beziehungen zu den Dicellograptiden, die aber keinen median-ventralen Sattel und noch stärker introvertierte Theken haben. Die beachtliche Zeitlücke und die fehlenden Verbindungsglieder lassen phylogenetische Verbindungen voreilig erscheinen. Wenn sich aber bestätigt, daß die Monograptiden zur Entwicklung einwärts gerichteter Theken tendieren, so ist trotzdem der Grad der Ähnlichkeit mit den Dicellograptiden bemerkenswert.

Monograptus gregarius rechnet noch zur Gattung *Pristiograptus* JAEKEL, die sonst einfachen Theken haben ein hervorragendes, gerundetes Geniculum. Bei einigen zeigen die Öffnungen eine gewisse Tendenz zur Isolierung. Vielleicht sind frühsilurische Monograptiden mit einfacheren, oft eversen oder mit geniculaten Theken die Wurzel der *Pristiograptus*.

Orthograptus ? sp. zeigt zusätzlich zu normalen orthograptiden Theken eine reich verzweigte Virgella, die dazu neigt, wie ein Netzwerk um das Rhabdosom zu wachsen. Gespaltene Virgellen kommen auch sonst vor, wachsen aber im allgemeinen von der Sricula weg und nicht als kompliziertes Netzwerk. Im Oberordovicium von Australien und in der Kanadischen Arktis gibt es Ähnliches.

Möglicherweise sind einige „Retioliten“ von solchen Graptolithen abzuleiten unter Reduktion des normalen Theken-Periderms. Einige ordovicische Graptolithen, die ein wohlentwickeltes Lacinien-Netzwerk besitzen, haben möglicherweise dieselbe Grundstruktur wie *Orthograptus* ? sp. Man sollte nicht auf Grund von gewöhnlichem, verdrücktem Material Schlüsse über die Natur dieses Merkmals ziehen.

2. Westabhang des Osmunds-Berges. Dort liegt diskordant auf oberordovicischem Boda-Kalkstein eine untersilurische Folge mit einem basalen Kalkkonglomerat und darüber Schiefer und konkretionäre Kalksteine. (Beschrieben bei THORSLUND & JAANUSSON 1960.) Die Aufsammlungen entstammen der *Monograptus turriculatus*-Zone. Aus den Kalkknollen konnte mit Hilfe von Salzsäure dreidimensionales Material isoliert werden.

Die sonst nicht immer zutreffende Meinung von ELLES & WOOD über asymmetrische Entwicklung der Apertur der Theken bestätigte sich bei *Monograptus proteus*, der stark verdrehte Theken-Haken besitzt. Die Asymmetrie wird durch Verdrehung der Thekenachse entlang der Zigzag-Sutur erreicht, nicht durch verschiedene Entwicklung der Seitenwände.

Retiolites sp. läßt sich trotz ausgezeichneter Erhaltung nicht in ein beschriebenes Genus einordnen. Wahrscheinlich werden die Retioliten in der heutigen Literatur viel zu stark aufgegliedert. *Retiolites* sp. nähert sich *Orthoretiolites*, aber es gibt auch Unterschiede. Für die Gründung eines neuen Retioliten-Genus reichen die Merkmale nicht aus.

Zwischen *Monograptus halli* und *Monograptus sedgwicki* bestehen enge Beziehungen; offenbar ist *M. halli* trotz jüngeren Alters ein weniger fortschrittlicher Typ aus gleicher Wurzel. Damit wird es allerdings schwierig, die *priodon*-Gruppe hier anzuschließen. Statt dessen zeigen sich eher Beziehungen zu Formen wie *Monograptus marri*, und die *marri-priodon*-Gruppe ist von der *halli-sedgwicki*-Gruppe zu unterscheiden.

Bei einigen Monograptiden des schwedischen Materials gibt es prothekale Falten (*M. exiguus*, *M. cf. barrandei*), außerdem gibt es noch zwei Arten mit Protheken-Falten (*M. nodifer* und *M. sartorius*). *M. nodifer* ist der Typus von *Streptograptus* YIN und mit *M. cf. barrandei* und *M. sartorius* durch gemeinsame Merkmale verbunden. *M. exiguus* fällt durch seine Thekenstruktur so aus dem Rahmen, daß er nicht mehr zu *Streptograptus* gestellt werden kann. Die Tatsache prothekaler Faltung tritt in verschiedenen Gruppen auf und kann nicht als taxonomisches Kriterium verwendet werden.

Aus alledem ergibt sich auch, daß viele Arten noch in der Sammelgattung *Monograptus* bleiben müssen, bis man mehr über ihre Thekenform weiß.

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I. Introduction

This paper records the results of a study of the remains of graptolites etched from Lower Silurian shales and concretionary limestones collected by the writers in the summer of 1965 from two localities in Dalarna (Dalecarlia), south-central Sweden. Isolation of the graptolites from the rock matrix has revealed morphological details, not otherwise observable, which are considered to be of sufficient interest and importance to merit a full description. None of the species described herein has been previously available isolated from the matrix.

The stratigraphically older of the two collections is from Silvberg, a road-cut near the town of Boda, on the east side of the highway between Rättvik and Furudal. A detailed account of the section exposed there has been given by WAERN (1960: 127–129 and Fig. 1), who records the presence of the Zones of *Monograptus revolutus*, *M. gregarius*, *Petalograptus folium*, *Cephalograptus cometa*, *M. sedgwicki*, and *M. runcinatus*, in a thickness of 16.2 m; the graptolites recovered from this locality by the writers came from the *M. gregarius* Zone (uppermost part of the Bollerup Stage of WAERN, 1960) and the following species are represented in their collection: *Pseudoclimacograptus hughesi* (NICHOLSON), *Orthograptus* ? sp., *Glyptograptus tamariscus* (NICHOLSON), *Rhaphidograptus toernquisti* (ELLES & WOOD), *Monograptus gregarius* (LAPWORTH), *Monograptus* sp. 1, and *Monograptus* sp. 2.

The second collection was obtained from the western flank of the Osmunds Hill (Osmundsberget), where a Lower Silurian succession, comprised of a basal limestone conglomerate followed by shales and concretionary limestones, is seen to lie unconformably upon Upper Ordovician Boda Limestone. THORSLUND & JAANUSSON (1960: 32–33 and Fig. 13) note the occurrence of the Zones of *Monograptus sedgwicki*, *M. turriculatus* (= *M. runcinatus* Zone of WAERN, 1960), and *M. discus* (= *M. crispus* + *M. griestoniensis* Zones of WAERN, 1960), at this locality. The writers' collection was made from beds referable to the *M. turriculatus* Zone (lowermost part of the Klubbudden Stage of WAERN, 1960) and contains the following species: *Orthograptus* sp., *Glyptograptus* aff. *tamariscus fastigans* HABERFELNER, *Petalograptus* sp., *Retiolites* sp., *Monograptus exiguus* (NICHOLSON), *Monograptus halli* (BARRANDE), *Monograptus marri* PERNER, *Monograptus proteus* (BARRANDE), *Monograptus* cf. *M. barrandei* sensu ELLES & WOOD, *Monograptus* aff. *M. spiralis* GEINITZ, and *Rastrites linnaei* BARRANDE.

Terminology

Measurement of thecal spacing accords with the technique adopted by PACKHAM (1962) and RICKARDS (1965): spacing is measured for a small number of thecae and is then converted to thecae per cm. It is considered that this mode of presentation gives a better idea of the change in thecal size along the rhabdosome.

Acknowledgements

We are deeply indebted to Professor Per THORSLUND and Dr. J. H. McD. WHITAKER, who led the Leicester University geological excursion to Sweden in 1965 and with whose help the material was collected. Dr. Bertil WAERN and Dr. Roland SKOGLUND have very kindly given us permission to publish information on part of their general field of research. Work on the material has been carried out at the University of Cambridge, University College London, Trinity College Dublin, and the British Museum (Natural History).

The figured specimens from Sweden have been deposited in Naturhistoriska Riksmuseet, Stockholm, and have received the catalogue numbers Cn 54882 to Cn 54948. Figured comparative material from the British Isles is housed in the Department of Geology, Trinity College, Dublin (TCD 8271A, B: fig. 55; TCD 8272A,B: fig. 7); the Sedgwick Museum, Cambridge (SM A60408: fig. 68); and in the Institute of Geological Sciences, Leeds (PJ 9870: fig. 29).

Please note that figure numbers are used without reference to plate numbers, the figures being all on the plates and numbered in through sequence.

II. Systematic Section

Several features of special interest and importance are discussed in sections II a) & II b) below, prior to the formal systematic descriptions given in section II c).

a) The Silvberg material

The calcareous shales of the *gregarius* Zone yielded numerous short lengths of graptolite rhabdosome when treated successively with HCl and HF acids. Most of the specimens are almost flattened, whilst many were at least partially transparent on isolation and could sometimes be further cleared by the usual oxidising agents.

Among the most interesting species recovered is *Monograptus* sp. 2, a form whose thecae bear a striking, but probably superficial, resemblance to those of some dicellograptids. In *Monograptus* sp. 2 the thecal apertures are essentially introverted, the margin possesses paired, lateral lappets (and a median, ventral saddle), and the geniculum is hooded. Silurian graptolites exhibiting introverted thecal apertures are rare and introversion appears to be restricted to the barrandeograptids described by LAURSEN (1940) and BOUČEK & PŘIBYL (1954) and to species of the *M. incommodus* TÖRNQUIST group (RICKARDS & RUSHTON, 1968). The Silvberg species cannot be referred to any described graptolite, though it is doubtful whether the features illustrated and described below would be detectable in the usual flattened shale material. Dicellograptids occasionally have genicular hoods (JAMES, 1965), and the genicular "spines" of some monoclismacids can be shown to be hoods when well-preserved material is at hand. Because of the presence of a median, ventral saddle in the apertural lip of *Monograptus* sp. 2, the degree of thecal introversion is, as a whole, less than in most dicellograptids. It would be premature, however, to postulate a direct line of evolution from dicellograptids to these *gregarius* Zone monograptids since they are separated by a considerable time gap which is, as yet, unbridged by like genera or species. In spite of the above remarks it should be emphasized that the degree of similarity between the two groups is all the more remarkable when it is realised that the general trend in the evolution of monograptids at this time was towards the development of thecal retroversion.

Associated with *Monograptus* sp. 2 is a considerable number well-preserved specimens of *Monograptus gregarius* LAPWORTH. Two points of interest emerge with respect to *M. gregarius*. In the first place, it is clear that it has only a borderline claim for inclusion in the genus *Pristiograptus* JAEKEL (as conceived by present day workers) since the thecae, although rather simple, do have a prominent, rounded geniculum. In some pyritised specimens, the thecal aperture has a slight tendency towards isolation, and this occurs when the thecal tube grows a little way over the geniculum (compare herein Figs. 63 and 64 with Fig. 68). Early Silurian monograptids which lack thecal hooks are broadly and loosely divisible into two groups, the one with introverted thecae (*incommodus* TÖRNQUIST, etc.) and the other with simpler, often everted or geniculate thecae (*atavus*, *cyphus*, *gregarius*, etc.). It is possible that the pristiograptids had their roots in the latter group, but this has not been established.

The species described below as *Orthograptus* ? sp. is represented by three early growth stages having, in addition to normal orthograptid thecae, a much-divided virgella which tends to grow as a network around the rhabdosome. Division of the virgella is a not uncommon phenomenon and has been recorded, for example, in the following Silurian graptolites: *Climacograptus indivisus* (DAVIES), *Climacograptus trifilis* MANCK, *Akidograptus acuminatus* (NICHOLSON) and *A. ascensus* DAVIES. Except in the last-named species, however, the divided virgella is directed away from the sicula aperture and there is little sign of the formation of a complicated network. A form possibly more closely allied to the present material, with respect to subdivision of the virgella, is the Australian species *Climacograptus baragwanathi* from the Upper Ordovician (Eastonian) of Victoria. Finally, Dr. THORSTEINSSON has isolated specimens from the Canadian Arctic, possibly referable to *Orthograptus insectiformis* NICHOLSON, in which a similar network surrounds quite mature rhabdosomes (pers. comm. Professor O. M. B. BULMAN).

The possibility now exists that some "retiolitids" have arisen from such graptolites, as well as by reduction of the normal thecal periderm. Some of the Ordovician graptolites possessing a pronounced lacinial network might have the same basic structure as that present in *Orthograptus* ? sp. At least it is certain that deductions as to the nature of "lacinial" networks should not be made from ordinarily flattened material.

b) The Osmundsberg material

The calcareous nodules from this locality yielded three-dimensional graptolites when subjected to treatment with dilute HCl. As with the Silbyberg collection, the isolated specimens illustrate several points of importance concerning graptolite morphology.

ELLES & WOOD (1901-18) repeatedly consider the possibility of asymmetrical development of the thecal aperture. While it is now known that many such observations were based upon the incorrect interpretation of indifferently preserved material, the present material shows that *Monograptus proteus* (BARRANDE) has strongly twisted thecal hooks. The only other instances of asymmetrical development of monograptid thecae are those recorded by URBANEK in the cucullograptids of the Ludlow Series. The Swedish material differs in that the asymmetry is achieved by actual twisting of the thecal axis (that is, torsion along the line of the zig-zag suture) and not by differential development of the lateral

walls of the thecal tube. At the present time the significance of this discovery is without explanation, and torsion of the thecal axis in *M. proteus* would seem to be an unique structure.

From the description which follows, it is clear that the form *Retiolites* sp. cannot be readily accommodated in any of the described genera, in spite of its excellent preservation. The question must be raised as to whether the retiolitids might not be excessively sub-divided at the present time. The Swedish species differs from the members of genus *Paraplectograptus* BOUČEK & MÜNCH (1948) in having strongly spinose thecae with distinct apertural regions. The present species seems to be closest to the Ordovician genus *Orthoretiolites* WHITTINGTON, but differs in having a single ventral list, in the lack of an early sclerotized portion, and in the degree of spinosity. This does not seem to be sufficient basis, however, for the erection of yet another retiolitid genus. It seems reasonable to expect that, of necessity, retiolitid genera will eventually become more broadly based.

Monograptus halli, which succeeds *M. sedgwicki* in time, exhibits a retreat of the dorsal wall of the thecal hook and a reduction in the length of the thecal spines: the apertures of the distal thecae face essentially in a ventral direction. The species, *halli* and *sedgwicki*, are otherwise similar and it would be reasonable to suppose that they are related. However, such a relationship between *halli* and *sedgwicki* makes it difficult to envisage *priodon*-like monograptids arising from this line. The *priodon* group is more likely to have evolved through a line including the form described herein as *M. marri* PERNER. This *marri-priodon* line appears to be distinct, and with different roots, from the *sedgwicki-halli* line. Further discussion follows below.

The last point to be discussed, at this stage, concerns the presence of prothecal folds in some monograptids. In the Osmundsberg material, two species, *M. exiguus* (NICHOLSON) and *Monograptus* cf. *M. barrandei* sensu ELLES & WOOD, exhibit a form of prothecal folding. Since a nema is present the prothecal folding is not expressed by dorsal expansion of the protheca, but by lateral expansion on both sides of the stipe. In addition to the isolated Swedish specimens prothecal folding occurs in two other monograptid species; the four fall into two distinct thecal groups:

1. *Monograptus exiguus* (NICHOLSON), and
2. *Monograptus* cf. *M. barrandei* sensu ELLES & WOOD, *M. nodifer* TÖRNQUIST, and *M. sartorius* sensu WILSON 1954. *M. nodifer* TÖRNQUIST is the type species of the genus *Streptograptus* YIN. Well-preserved pyritised material from Sweden (pers. comm. B. WAERN) and Norway shows that the thecal lobe structure of *M. nodifer* as interpreted by ELLES & WOOD (1913) and BOUČEK & PŘIBYL (1942) is incorrect. *M. nodifer* s.s. has a peculiar flangelike apertural expansion which abuts against the late prothecal portion of the same theca. *M. sartorius* sensu WILSON and *Monograptus* cf. *M. barrandei* sensu ELLES & WOOD appear to be very similar, though simpler, whilst the latter shows a slight mesial upturning of the dorsal wall of the hook. These three species are the only ones which can reasonably be retained in the genus *Streptograptus* since the detailed form of the thecal "lobe" in other streptograptids (see BOUČEK & PŘIBYL, 1942) is unknown.

M. exiguus (NICHOLSON) must also be removed from *Streptograptus* since the isolated material described below reveals that its thecal structure, at the time of writing, is unique. The existence of prothecal folds in *M. exiguus* suggests that this feature cannot at present be used in taxonomy. As in Ordovician graptolites, prothecal folding is probably present in a number of groups.

The above paragraphs again emphasize the necessity of retaining numerous species in the genus *Monograptus* until the thecal form is known in some detail.

c) Systematic descriptions

Order *Graptoloidea* LAPWORTH, 1875

Suborder *Diplograptina* LAPWORTH, 1880,
emend. BULMAN, 1963

Family *Diplograptidae* LAPWORTH, 1873

Genus *Pseudoclimacograptus* PRIBYL, 1947,
emend. BULMAN & RICKARDS, 1968

P. (Metaclimacograptus) hughesi (NICHOLSON, 1869)

Pl. 1, Figs. 1–4

Subgenus *P. (Metaclimacograptus)* BULMAN & RICKARDS,
1968

- 1869 *Diplograptus Hughesi* n. sp. – NICHOLSON, p. 235, pl. 11, figs. 9, 10.
1906 *Climacograptus Hughesi* (NICHOLSON) – ELLES & WOOD, pp. 208–10, text-figs. 140 a–d; pl. 27, figs. 11 a–e.
? 1924 *Climacograptus hughesi* (NICHOLSON) – HUNDT, pl. 1, figs. 8–10.
? 1934 *Climacograptus hughesi* (NICHOLSON) – HSÜ p. 67, pl. 5, figs. 7 a–c.
? 1937 *Climacograptus hughesi* (NICHOLSON) – HARRIS & THOMAS, pp. 69–70, pl. 1, fig. 1.
1945 *Climacograptus hughesi* (NICHOLSON) – WATERLOT, pl. 8, fig. 130.
? 1947 *Climacograptus hughesi* (NICHOLSON) – RUEDEMANN, p. 428, pl. 73, figs. 30, 31.
? 1965 *Climacograptus hughesi* (NICHOLSON) – STEIN, pp. 167–8, fig. 14 i.
1968 *P. (Metaclimacograptus) hughesi* (NICHOLSON) – BULMAN & RICKARDS, pp. 3–6, text-figs. 1 a–c.

Material. Several specimens; flattened and carbonized, but otherwise well preserved.

Horizon. *gregarius* Zone, Silvberg.

Description. The prosicula has a length of 0.20 mm and a flattened width of 0.10 mm. At least five longitudinal threads are present (Fig. 1), which coalesce to form a very slender and short nema. The metasicula has a length of 0.60 to 0.70 mm, excluding the virgella; this latter is up to 0.30 mm long and is incurved across the sicula aperture. The growth lines on the metasicula are very closely spaced (in Fig. 1, five growth lines are present in each 0.10 mm of metasicula) and the virgella seems to be strongly developed at an early stage (in Fig. 1, it has a length of 0.15 mm).

Th¹ originates 0.25 mm above the sicula aperture and grows downwards, past the aperture and along the virgella, for 0.10 mm before turning upwards (Fig. 2). The total length of th¹ in the available material is 0.85 mm.

At the level of th¹ the flattened rhabdosome has a dorso-ventral width of 0.60 mm; distally, it reaches 0.85 mm. The thecae are spaced at 20 per 10 mm proximally, and about 15 per 10 mm distally. The thecal excavations are short and deep and the thecal aperture is slightly introverted. Faint traces of genicular hoods are sometimes present (Fig. 3), but otherwise both the apertural rim and the geniculum appear to be thickened. In these flattened specimens the supragenicular wall, though almost straight, slopes slightly inwards (Fig. 4). About ten growth lines are present on the supragenicular portion of each theca.

The median septum is not clearly seen, but is undulating rather than angular. The nema can be seen “pressed through” (Fig. 4).

Remarks. These specimens resemble *P. (M.) undulatus* (KURCK) in respect of thecal spacing, but otherwise they have the characteristics of *P. (M.) hughesi* (NICHOLSON). The inward-sloping (though straight) supragenicular wall is probably a reflection of the transverse apertural narrowing of the theca in this species: that part of the theca in the region of the geniculum becomes broader upon flattening, in the same way that the mouth of a cone becomes wider when the cone is flattened.

The sicula of *P. (M.) hughesi* was estimated to be about 1.00 mm in length by BULMAN & RICKARDS (1968), a figure which agrees closely with the observed value of up to 0.90 mm in the present material. The prosicula is unusually small and would have a maximum diameter in relief of the order of 0.06 mm.

In the dorso-ventral width of the rhabdosome, the length of th¹, the degree of thecal overlap, and the nature of the median septum, the present material compares closely with that described by BULMAN & RICKARDS (1968).

Genus *Orthograptus* LAPWORTH, 1873

Orthograptus sp.

Pl. 1, Figs. 5–7

Material. Six well-preserved, semi-transparent specimens in full relief.

Horizon. *turriculatus* Zone; nodule no: 2, Osmundsberg.

Description. The rhabdosome has a maximum observed length of 3.30 mm and a dorso-ventral width distally of 1.00–1.10 mm. The lateral width reaches 0.50 mm in the mature part of the rhabdosome, so that the cross section is rectangular. In lateral (profile) view, the thecae may not be clearly visible, since the thecal apertures are strongly everted; this would be particularly true in the case of flattened specimens where detail usually becomes less discernible. Flattened specimens might be expected to have a dorso-ventral width of approximately 1.50 mm (1.00 mm + 0.50 mm) in the case of true profile flattening (it would be unreasonable to expect the free ventral wall to bend inwards since it is gently convex outwards).

The sicula is about 1.00 mm in length and reaches to the level of the aperture of th². The prosicula has not been observed. In reverse aspect the sicula is visible in mature specimens for 0.30 mm, whilst the sicula aperture has a diameter of 0.15 mm. The virgella has a maximum observed length of 0.30 mm. In observe aspect the sicula is visible for up to 0.50 mm of its length.

The point of origin of th¹ on the sicula has not been seen, but th¹ grows downwards to a level slightly below that of the sicula aperture before turning upwards. Th¹ has a visible length of 0.60–0.80 mm (excluding the everted portion). Distally, the thecae all appear to be of similar length.

The thecae are slightly alternating and overlap is rather more than one-half. A median septum is absent. Each theca has a maximum dorso-ventral width of about 0.30 mm. In ventral view the aperture is almost circular and distally it occupies almost the full lateral width of the rhabdosome. The apertural diameter of th¹ is 0.20 mm, and in this case the aperture does occupy the full lateral width. The thecae number approximately 13 in 10 mm.

The thecal apertures are strongly everted so that they face ventrally rather than distally. This is particularly true of the

most proximal thecae. Eversion of the thecal aperture is achieved as illustrated in Fig. 5 a. As far as can be ascertained (the material is only semi-transparent), incomplete rings are rarely developed in the dorsal part of the aperture. The ventral apertural lip is slightly thickened. In some specimens (Fig. 6), the eversion may be sufficiently strong to produce an incipient thecal hook.

The early part of the intertheical septum appears to be formed of the dorsal thecal wall; the actual base of the septum is somewhat thickened (Fig. 5 b). At the growing end of the rhabdosome three thecae grow simultaneously. In Fig. 5 b, the base of the inter-theical septum between $th3^1$ and $th4^1$ appears to be formed of the dorsal margin of $th3^1$. The thickened base to the intertheical septum is already formed at this stage (i.e., it is not a late-formed thickening) and further addition of growth bands is made from $th3^1$. Presumably, as the level of the free ventral wall of $th4^1$ is approached, the deposition of growth rings forming the intertheical septum is taken over by the zooid of $th4^1$. This would coincide roughly with the level at which $th4^1$ gives rise to $th4^2$.

R e m a r k s. *Orthograptus* sp. is one of the youngest members of the genus, occurring as it does fairly high in the *turriculatus* Zone. ELLES & WOOD (1907) record *Orthograptus bellulus* TÖRNQUIST from as high as the *sedgwicki* Zone and a small *Orthograptus* species (Fig. 7) has recently been obtained from the upper part of the *turriculatus* Zone of Balbriggan (Eire) which closely resembles the form described herein, though the thecal apertures may be slightly less everted in the Irish specimens. A tiny *Climacograptus* ranges above the *turriculatus* Zone in the Howgill Fells (Northern England).

The only species of comparable size to *Orthograptus* sp. is *O. cyperoides* TÖRNQUIST, but this latter species is typified by a long sicula and longer thecae, whilst apertural eversion is lacking. The degree of apertural eversion, with the dorsal thecal wall becoming free of the succeeding theca in extreme instances (Fig. 6), is closely comparable with that observed in *Pseudoclimacograptus* (*Clinoclimacograptus*) *retroversus* BULMAN & RICKARDS (1968, fig. 5).

When flattened, *Orthograptus* sp. might conceivably be confused with small petalograptids such as *P. tenuis* (BARRANDE), although it lacks the typical petalograptid aspect and particularly the concave ventral thecal walls as seen in profile view. However, this argument might also be applied to some of the small, later petalograptids described by BOUČEK & PŘIBYL (1941). Some petalograptids do have a tendency towards eversion of the apertural margin, but apparently not to the extent exhibited by this species.

Orthograptus? sp.

Pl. 1, Figs. 8–10

Material. Three well-preserved and transparent early growth stages.

Horizon. *gregarius* Zone, Silvberg.

Description. The nature of the mature rhabdosome is unknown; the most fully-developed specimen extends only to $th1^1$ – $th2^1$. In each specimen the prosicula is damaged but some 0.30 mm is seen in the specimen illustrated as Fig. 8. The length achieved by the prosicula is probably of the order of 0.40–0.50 mm and at least seven longitudinal, thickened threads are present (Fig. 10). The metasacula has a length of 1.80 mm (Figs. 9, 10) giving a total sicular length of more than 2.00 mm. In this flattened material, the sicula aperture has a diameter of 0.30 mm and is provided with a robust virgella. There is no dorsal process on the sicula aperture. $Th1^1$ originates some 0.20 mm above the sicula aperture. In

one specimen, $th1^1$ grows downwards slightly below the level of the sicula aperture, but in another it turns upwards rather earlier (Fig. 10). In this latter, the downward-growing portion of $th1^1$ must be extremely short, and approximately 0.15 mm. $Th1^2$ originates 0.40 mm above the sicula aperture and grows across the sicula (Fig. 10) leaving the sicula clearly visible for one-third of its length. The beginning of $th2^1$ is visible in Fig. 10, but the rhabdosome is developed no further in this specimen. As far as can be ascertained $th1^1$ is of simple orthograptid type. The dorso-ventral width of the rhabdosome at the level of the aperture of $th1^1$ is probably of the order of 1.00 mm, to judge from the generally robust beginnings of this species.

The most interesting feature of the species is the strongly divided virgella. The specimen depicted as Fig. 8 shows that the virgella begins to divide before the sicula is fully formed. This particular stage superficially resembles the ancora stage in the development of some retiolitids (KÜHNE, 1953; MU, 1963). When the sicula is completed (Figs. 9, 10) the length of virgella between the sicula aperture and the first virgellar splitting is approximately 0.15 mm. At this stage the virgella exhibits complex divisions and ramifications lacking any apparent order. In general it seems that the network grows upwards, and if developed further would envelope the rhabdosome.

R e m a r k s. *Orthograptus?* sp. is certainly a diplograptid and is probably referable to the genus *Orthograptus*. $Th1^1$ seems to be of simple orthograptid type. Dr. THORSTEINSSON has detected a structure similar to the above virgella network in an orthograptid from the Silurian of the Canadian Arctic (pers. comm. Professor O. M. B. BULMAN). In this case the orthograptid was thought possibly to belong in *O. insectiformis*. The Swedish specimens, young stages though they are, agree with ELLES & WOOD's description of *O. insectiformis* in that the sicula is fully 2.00 mm in length and is clearly visible for one-third of its length in profile view. Unfortunately, the present material does not permit further comparison.

Genus *Glyptograptus* LAPWORTH, 1873, emend. BULMAN & RICKARDS, 1968

Glyptograptus tamariscus tamariscus

(NICHOLSON, 1868)

Pl. 1, Figs. 11–13

- 1868 *Diplograptus tamariscus* n.sp. – NICHOLSON, p. 526, pl. 19, figs. 10, 11, 13 (n o n fig. 12).
- ? 1897 *Diplograptus tamariscus* NICHOLSON – PERNER, p. 4, pl. 9, fig. 16.
- 1907 *Diplograptus* (*Glyptograptus*) *tamariscus* NICHOLSON – ELLES & WOOD, p. 247, text-figs. 167 a–c; pl. 30, fig. 8 a (n o n text-fig. 167 d; pl. 30, figs. 8 b–d).
- ? 1924 *Diplograptus tamariscus* NICHOLSON – HUNDT, pl. 1, figs. 38–40.
- ? 1945 *Glyptograptus tamariscus* (NICHOLSON) – WATERLOT, p. 59, pl. 14, fig. 185.
- ? 1949 *Diplograptus* (*Glyptograptus*) *tamariscus* (NICHOLSON) – OBUT, pp. 14–15, pl. 1, figs. 6 a, b.
- 1962 *Glyptograptus tamariscus tamariscus* (NICHOLSON) – PACKHAM, pp. 504–6, text-figs. 1 g–j, m–u; pl. 71, figs. 1–4, 11, 13.
- ? 1963 *Glyptograptus* cf. *tamariscus* (NICHOLSON) – WILLEFERT, p. 18, text-fig. 15 a.
- ? 1965 *Glyptograptus tamariscus* (NICHOLSON) – OBUT & SOBOLEVSKAYA, pp. 31–32, pl. 1, fig. 13.

Material. Six proximal ends, flattened and more or less transparent, and other fragmentary distal specimens.

Horizon. *gregarius* Zone, Silvberg.

Description. No early growth stages of this species are available, but it is clear from the transparent proximal end specimens that the sicula is very small (Fig. 13). Excluding the short, robust virgella, the length of the sicula cannot exceed 0.50–0.60 mm, and its apex reaches to about the level of the apertures of $th1^1$ and $th1^2$.

The upward-growing portion of $th1^1$ has a length of 0.50 mm. The proximal thecal spacing is of the order of 16 in 10 mm, falling to 10 in 10 mm distally. At the level of the aperture of the $th1^1$ the dorso-ventral width is 0.70–0.80 mm, and in the most distal portion available the width reaches 1.00 mm. A robust nema is visible “pressed through” in some specimens, but the presence of a median septum cannot be ascertained.

The thecae alternate and have only a small amount of overlap (approximately one-third). Each geniculum is rounded rather than angular, and the supragenicular walls are composed of seven to nine growth bands. The apertural lip is even and very slightly thickened.

Remarks. An unusual feature of these specimens is the very small sicula. None of the species studied by PACKHAM (1962) has a sicula much shorter than 1.00 mm. Whilst these Swedish specimens clearly fit into the *tamariscus* complex, and are closest to *tamariscus* s.s., they are rather broad at the level of $th1^1$. The short total length of $th1^1$ suggests affinity with PACKHAM's *G.t. tamariscus* form B, although $th1^2$ seems also to be quite short; the thecal spacing (16–10 in 10 mm) supports this suggestion.

A further interesting feature of the preservation is that some specimens (Fig. 12) are subventral views and in carbonized, flattened specimens these would be not unlike small orthograptids.

Glyptograptus* aff. *G. tamariscus fastigans

HABERFELNER, 1931

Pl. 1, Fig. 14

aff. 1931 *Glyptograptus tamariscus* mut. *fastigans* n. subsp. – HABERFELNER, p. 105, pl. 3, figs. 17 a–e.

1962 *Glyptograptus* sp. cf. *G. tamariscus fastigans* HABERFELNER – PACKHAM, pp. 512–3, text-fig. 3 f; pl. 71, fig. 5.

Material. Numerous specimens, rather carbonized, in full relief and unaffected by compression. Some early growth stages.

Horizon. *turriculatus* Zone; nodule no. 1, Osmundsberg.

Description. The longest complete rhabdosome is 3.70 mm in length and has a dorso-ventral width (in full relief) of 0.80 mm. A few, more distally derived, fragments indicate that a width of 1.00 mm is achieved. The proximal specimens are characteristically thorn-shaped with a very prominent sicula, alternating early thecae, and a dorso-ventral width at the level of $th1^1$ of approximately 0.40 mm.

The sicula is 1.30 mm in length and has an apertural diameter of 0.20 mm. A short, robust virgella (up to 0.20 mm long) is present, but otherwise the sicula aperture is quite even and circular. The prosicula cannot be discerned.

The downward-growing portion of $th1^1$ is approximately 0.30–0.40 mm long and it turns upwards fractionally below the level of the sicula aperture (fig. 14). The upward-growing portion of $th1^1$ has a length of 0.80–1.00 mm, and a width in profile of the order of 0.20 mm. The thecal aperture of

$th1^1$ is even to very slightly everted and occupies the full lateral width of the rhabdosome (in ventral view).

$Th1^2$ grows across the sicula at a low angle to the axis of the rhabdosome, leaving 0.50–0.70 mm of the sicula clearly exposed, and opens 1.10–1.50 mm above the sicula aperture. The total length of the $th1^2$ may be as much as 1.30 mm. The thecae are, therefore, very strongly alternating at the proximal end, where the thecal spacing is 10–11 in 10 mm. Subsequent thecae continue to alternate; as the rhabdosome widens, however, the thecae become rather less conspicuous since they retain a uniform profile width. The apertures of the distal thecae are even to slightly everted, more commonly the latter, and the thecal spacing is 10 in 10 mm. Thecal overlap is about one-half.

None of the specimens has a median septum.

Remarks. The Swedish specimens are very close to the specimen described by PACKHAM (1962) as *Glyptograptus* sp. cf. *G. tamariscus fastigans* HABERFELNER, from the *turriculatus* Zone of Swindale Beck, Knock. This latter specimen was flattened, but allowing for this the Swedish specimens compare closely in size, taper, degree of sicular exposure, thecal spacing, apertural eversion, and profile width of the thecae. Thecal overlap is not easily determinable in either the Knock specimen or in the Osmundsberg material; the latter has no median septum. The isolated Swedish specimens add considerably more information on the early development of this form, which is recorded from Sweden for the first time and which must be one of the last known glyptograptids.

Genus *Petalograptus* SUESS, 1851

***Petalograptus* sp.**

Pl. 1, Figs. 15–18

Material. Four early growth stages in full relief.

Horizon. *turriculatus* Zone; nodule no. 2, Osmundsberg.

Description. The present material shows only the development of $th1^1$ – $th2^1$. It can be estimated that the dorso-ventral width at the level of the aperture of $th1^1$ is approximately 1.50 mm. The rhabdosome is tabular in cross section. The sicula has a total length of 1.30–1.50 mm of which about 0.30 mm consists of the prosicula. Initially, the sicula is rather narrow, but expands halfway along its length to a diameter of 0.20 mm. The later part of the metasacula is slightly curved ventrally (Fig. 15) and the aperture has a short dorsal process. A slender virgella, 0.40 mm long, is present on one specimen (Fig. 15). The sicula aperture has a diameter of 0.20–0.30 mm.

$Th1^1$ originates quite low down on the sicula, approximately 0.20 mm above the aperture (Fig. 18), and then grows downwards to a point slightly below the level of the sicula aperture. Thereafter, it grows upwards giving rise almost immediately to the initial portion of $th1^2$. The ventral walls of $th1^1$ are gently concave (Figs. 15, 16) and are inclined at a high angle to the axis of the rhabdosome (30° – 50°). None of the growth stages is developed as far as the aperture of $th1^1$.

The specimen depicted in Fig 17 shows the beginning of the intertheical septum between $th1^1$ and $th2^1$. At this stage three narrow growth bands have been deposited to form the base of $th2^1$, whilst the intertheical septum, already slightly thickened, is composed of a single growth band deposited by the zooid of $th1^1$. The growth of the intertheical septum at this stage is, like $th1^1$, slightly ahead of the growth of $th2^1$.

The zooid of $th2^1$ must take over deposition of the median septum just before, or at the time, $th1^1$ is completed (i.e., when the zooid of $th1^1$ is approaching maturity, and when the free ventral wall of $th2^1$ needs to be laid down). This initial stage of the interthecal septum appears as a thickened loop slightly above the general level of development (Fig. 17).
R e m a r k s. The interthecal septum in *Petalograptus* sp. is formed in a similar manner to that in *Orthograptus* sp., as described above. Both genera confirm the general interpretation of BULMAN (1955), and add to the rather small number of forms in which some indication of its formation can be deduced.

The whole of the early development, and in particular the tabular cross section of the rhabdosome, indicates the genus *Petalograptus*, whilst the probable early rhabdosomal width suggests that these specimens belong in the *P. palmens* group.

Family *Retiolitidae* LAPWORTH, 1873

Genus *Retiolites* BARRANDE, 1850

Retiolites sensu lato sp.

Pl. 1, Figs. 19, 20

M a t e r i a l. A single specimen preserved in three dimensions.

H o r i z o n. — *turriculatus* Zone; nodule no. 1, Osmundsberg.

D e s c r i p t i o n. The rhabdosome has a length of 3.20 mm, and at the level of $th3^1$ or $th3^2$ would have a dorso-ventral width of 2.00 mm. At this level, however, the specimen is damaged though the width can be estimated with some certainty (Fig. 19).

The initial ancora is recognisable and has a maximum dorso-ventral width of about 0.80 mm. The lateral width of the rhabdosome is less than 0.30 mm, although this value could have been reduced somewhat by partial flattening. There is no reticula. The thecae number 13 in 10 mm.

Neither the prosicula nor the metasacula are sclerotized or recognisable, but the most proximal parts of the rhabdosome closely resemble the ancora described by KÜHNE (1953). A single vertical thread, probably connected with the nema, divides proximally into four lists which quickly define four roughly quadrangular areas. Thecal details cannot be discerned, but distally the thecae are strongly alternating and have well-defined apertural regions.

The nema is incorporated in the obverse wall, so that one of the above-mentioned quadrangular meshes probably corresponds approximately with the sicula aperture. There is no virgella or other sicular spines. The reverse lateral wall of the rhabdosome is characterised by a pronounced zig-zag list (see below).

Identification of the list structures roughly defining the thecal tubes can only be done with difficulty (Fig. 20). The free ventral wall of each theca is marked by a single, mesial list (herein termed a ventral list following WHITTINGTON, 1954, and SKEVINGTON, 1960). Horizontally-directed parietal lists connect with the nema on the obverse side and with a dorsal list on the reverse side. The dorsal lists form a pronounced zig-zag along the reverse side of the rhabdosome. The thecal apertures seem to be clearly defined by an oval list which would suggest quite strongly everted apertures. The apertural list connects with the obverse and reverse parietal lists, and also forms a short cross bar between them. The apertural list also connects in a ventro-mesial position with the ventral list.

A long mesial spine is directed downwards from the ventral list of each theca subsequent to $th1^1$. $Th1^1$ appears to have at

least two such spines, and possibly three, although the most proximal seems to be part of the ancora.

The thecal aperture has two spines which are paired in the sense that they originate in a similar position on the obverse and reverse sides of the aperture and nearer the dorsal than the ventral apertural margin. However, the apertural spines on the reverse side of the rhabdosome are directed distally, whilst those on the obverse side droop proximally. The distinction does not seem to be the result of preservation.

R e m a r k s. This species clearly has some affinity with the genera *Retiolites*, *Paraplectograptus*, and *Orthoretiolites*. From the first, it differs in its total lack of a reticula and in the presence of both paired and unpaired thecal spines. *Paraplectograptus* BOUČEK & MÜNCH lacks thecal spines and has less clearly defined thecae and thecal apertures. From both *Paraplectograptus* and *Orthoretiolites*, the Swedish form is distinct in having a single mesial ventral list, but nevertheless it bears a remarkable resemblance to the more distal parts of the latter genus (the earliest parts of *Orthoretiolites* are sclerotized). If fig. 19 herein is compared with text-fig. 4 of SKEVINGTON (1960) the only fundamental difference is the early sclerotized portion of *Orthoretiolites*. Otherwise they differ in the degree and nature of the spinosity and in the number of ventral lists. *Retiolites* sensu lato sp. would seem to be morphologically closer to *Orthoretiolites* than to any other described genus.

Spinosity and number of ventral lists might possibly be regarded as features of importance at the specific level, whilst sclerotization of the early part of the rhabdosome may be useful at higher taxonomic levels. It is difficult to avoid the conclusion that the retiolitids might be excessively subdivided at present and for this reason a new genus is not erected for the Swedish specimen. Some of the characters used to distinguish retiolitid genera, namely spinosity and the nature of the reticula, may prove to be quite variable at the specific level. The nature of the clathria, which at least roughly defines the thecal and rhabdosomal form, is perhaps the most useful tool for classification of the retiolitids.

Family *Dimorphograptidae* ELLES & WOOD, 1908

Genus *Rhaphidograptus* BULMAN, 1936

Rhaphidograptus toernquisti (ELLES & WOOD, 1906)

Pl. 1, Figs. 21, 22

- 1876 *Climacograptus rectangularis* (M'COY) — LAPWORTH, pl. 2, fig. 50.
 1877 *Climacograptus scalaris* var. *rectangularis* (M'COY) — LAPWORTH, p. 138, pl. 4, fig. 32.
 1897 *Climacograptus rectangularis* (M'COY) — TÖRNQUIST, p. 8, pl. 1, figs. 16–21.
 1906 *Climacograptus Törnquisti* n.sp. — ELLES & WOOD, pp. 190 to 191, text-figs. 123 a–b; pl. 26, figs. 6 a–f.
 1920 *Climacograptus toernquisti* ELLES & WOOD — GORTANI, pp. 15–16, pl. 1, figs. 17–19 (n o n fig. 16).
 1924 *Climacograptus toernquisti* ELLES & WOOD — HUNDT, pl. 1, figs. 32–34.
 1929 *Climacograptus toernquisti* ELLES & WOOD — DAVIES, text-fig. 32, 5.
 1936 *Rhaphidograptus toernquisti* (ELLES & WOOD) — BULMAN, p. 19 et seq., text-figs. 1 a–e, 2 a.
 1945 *Climacograptus Törnquisti* ELLES & WOOD — WATERLOT, pl. 6, fig. 112.
 1948 *Rhaphidograptus toernquisti* (ELLES & WOOD) — PŘIBYL, p. 20.

- ? 1949 *Climacograptus törnquisti* ELLES & WOOD – OBUT, p. 13, pl. 1, figs. 4 a–b.
 1955 *Rhaphidograptus toernquisti* (ELLES & WOOD) – BULMAN, p. 91, fig. 67, 3 a.
 1965 *Rhaphidograptus toernquisti* (ELLES & WOOD) – STEIN, pp. 180–182, figs. 16 i, 26 a–d; tables 14–16.

Material. About twenty early growth stages, flattened and semi-transparent, and a few more distally derived fragments.

Horizon. *gregarius* Zone, Silvberg.

Description. The sicula (Fig. 21) is of the order of 1.50 to 1.70 mm in length, of which 0.30 mm comprises the prosicula. The metasicula has an apertural diameter (flattened) of 0.30 mm. When the sicula is complete, and when little of th1¹ has developed, a slender nema projects distally for almost 1.50 mm in some specimens. A robust virgella is present at an early stage of growth; when the first theca is fully developed a length of more than 1.00 mm may be achieved. None of the specimens shows the distal thickening of the virgella typical of mature rhabdosomes. The sicula aperture is even except ventrally, where it is drawn down into the base of the virgella.

Th1¹ originates some 0.20–0.30 mm above the sicula aperture and grows downwards to the level of the sicula aperture or slightly below before turning upwards. The thecal apertures are even to very slightly everted, the lip is slightly thickened, and the excavations are typically climacograptid with an infragenicular wall inclined at a high angle to the axis of the rhabdosome. The geniculum on all the thecae examined is sharp and possesses a distinct flange which projects ventrally for 0.10 mm at the most (Fig. 22). The flange is not as pronounced as the genicular hoods seen in some pseudoclimacograptids (BULMAN & RICKARDS, 1968).

The reverse view of the specimen illustrated in Fig. 22 shows the early growth of the first three thecae, in which the growth lines are clearly visible. Th1¹ has a slightly everted aperture built up of almost complete growth rings; the apertural lip is thickened. The overhanging geniculum is sharp and possesses a rudimentary flange. Although the proximal end of the sicula and th1¹ is broken, eight growth bands of th1¹ are seen before the interthecal septum (and consequent unconformity with the succeeding theca) is reached. The metathecal part of th1¹ consists of nine growth bands; the most distal is involved in the thickened lip.

The theca succeeding th1¹ at the unconformity has, at first, closely spaced growth lines which, subsequently, become the same distance apart as in the later part of th1¹. About 0.25 mm of this second theca, involving seventeen growth bands, is developed up to the level of the aperture of th1¹, where a second unconformity is seen in the growth line pattern. However, the theca succeeding th1¹ does not continue to develop and forms no apertural or even metathecal portion. The development of th2¹ follows the second unconformity and later gives rise to th2².

Remarks. The incomplete tube between th1¹ and th2¹ could be interpreted as a reduced and immature th1², and taken to illustrate the “reduction and loss of th1²” mechanism which, according to BULMAN (1955, and earlier), is one possible way of deriving an uniserial (monograptid) from a biserial (diplograptid) graptolite. However, the possibility also exists that the features observed in the original of Fig. 22 have resulted from the regeneration of a damaged rhabdosome, a phenomenon not uncommon in the Graptolithina (see BULMAN, 1955, p. V53, fig. 35).

Suborder *Monograptina* LAPWORTH, 1880
 Family *Monograptidae* LAPWORTH, 1873
 Genus *Monograptus* GEINITZ, 1852

Monograptus halli (BARRANDE, 1850)

Pl. 2, Figs. 23–25

- 1850 *Graptolithus Halli* n.sp. – BARRANDE, p. 48, pl. 2, figs. 12–13.
 ? 1852 *Monograpsus Halli* (BARRANDE) – GEINITZ, p. 41, pl. 3, figs. 5–8.
 1876 *Monograptus Halli* (BARRANDE) – LAPWORTH, pp. 354, pl. 13, figs. 1 a–d.
 1880 *Monograptus crassus* n.sp. – LAPWORTH, p. 155, pl. 4, fig. 8 b.
 1897 *Monograptus Halli* (BARRANDE) – PERNER, p. 13, pl. 13, fig. 20.
 1912 *Monograptus Halli* (BARRANDE) – ELLES & WOOD, pp. 443–5, text-figs. 305 a–e; pl. 44, figs. 8 a–f.
 1919 *Monograptus Halli* (BARRANDE) – KIRSTE, p. 164, pl. 2, fig. 32.
 1929 *Monograptus Halli* (BARRANDE) – GLÉMAREC, pp. 101–103, pl. 1, figs. 7 a–c.
 1931 *Monograptus Halli* (BARRANDE) – AIGNER, figs. 14 a–b, 15.
 1931 *Monograptus Halli* (BARRANDE) – HABERFELNER, pl. 1, figs. 22 a–b.
 1945 *Monograptus Halli* (BARRANDE) – WATERLOT, pl. 37, figs. 378.
 1952 *Monograptus halli* PERNER – MÜNCH, p. 105, pl. 30, figs. 3 a–b.
 1957 *Monograptus halli* (BARRANDE) – ROMARIZ, pl. 4, fig. 2.
 1962 *Monograptus halli* (BARRANDE) – ROMARIZ, p. 249, pl. 1, fig. 4; ? pl. 2, fig. 5.
 ? 1963 *Monograptus halli* (BARRANDE) – WILLEFERT, pp. 38–9, pl. 1, fig. 6; text-fig. 59.

Material. About twenty fragmentary proximal and distal specimens, in full relief, and mostly carbonized.

Horizon. *turriculatus* Zone; nodule no. 1, Osmundsberg.

Description. The sicula has a length of 1.10–1.20 mm and the apex reaches to the top of th1. Only the apex of the prosicula is clearly seen, but the whole appears to be approximately 0.25 mm in length (Fig. 23). Longitudinal lines of thickening are present. At the stage when the first few growth bands of th2 have been deposited a virgella 0.30 mm in length is developed. The sicula aperture is 0.20 mm in diameter.

Details of the origin of th1 cannot be ascertained but it is at least clear that the initial bud is extremely low down on the sicula. Indeed, the lowest part of the initial bud may reach slightly lower than the general level of the sicula aperture. Fairly thick deposits of cortical tissue have been observed at the base of the virgella and these may have the effect of somewhat extending the sicula.

The prothecal length of th1 is 0.90 mm and it widens gradually from an initial dorso-ventral width of 0.05 mm to a width of 0.30 mm immediately before the metatheca. The sicula decreases in diameter almost in proportion to the manner in which th1 increases; the former is thus relatively inconspicuous. The free ventral wall of th1 is inclined at a low angle to the axis of the rhabdosome. The metatheca is involved in a pronounced hook in which the dorsal thecal margin is sufficiently retroverted to ensure that the aperture faces proximally. The ventral thecal wall is also slightly retroverted (Fig. 23). A pair of slender apertural spines is developed; these spines are directed latero-ventrally and in profile view they may not be clearly visible. The spines have

their bases towards the ventral apertural margin, but not on it; they have a length of 0.10–0.30 mm, and give a total lateral width to the rhabdosome of at least 0.50 mm.

The whole of th1 is completed when only a few growth-bands have been developed around the foramen of th2. This foramen is at the distal extremity of th1 (Fig. 23), so that there is no thecal overlap. The dorso-ventral diameter of the foramen of th2 is about 0.30 mm; subsequently, the prothecal tube narrows somewhat (Fig. 24). The dorso-ventral width at the level of the aperture of th2 is 0.70 mm, whilst the spacing of the first few thecae is of the order of 10 in 10 mm.

Considerable, though gradual, changes take place as the distal part of the rhabdosome is approached. The dorso-ventral width reaches 1.70–1.90 mm in the material to hand, whilst the thecal spacing falls to 7 in 10 mm. Actual changes in thecal shape are considerable. The dorsal margin of the thecal tube gradually retreats so that the thecal aperture faces ventrally (Figs. 25 a, b), the spines become shorter in proportion to the metathecal height and may be little more than blunt processes in some specimens, and the angle of inclination of the free ventral wall increases from almost zero to 35°.

The distal thecae are triangular in appearance with ventrally-facing apertures. Thecal overlap is not easily determined but appears to be quite small. Distinct ridges roughly marking the base of each protheca are often visible (Fig. 24). As in the proximal thecae, the initial part of the protheca is of slightly greater diameter than the portion immediately following. The thecal foramen is large.

Remarks. Thecal overlap may well be greater on more distally derived fragments than those available. Apart from thecal overlap, the Swedish specimens closely resemble previously-described material. In flattened or otherwise poorly preserved specimens thecal overlap is not easy to see and may be considerably over-estimated: in silhouette profile view the thecae appear to have a much greater overlap than is in fact the case.

M. halli is clearly so close to the earlier *M. sedgwicki* (PORTLOCK) that it is inconceivable they are unrelated. Although the latter has not been studied from isolated material, the thecal hooks and spines are fundamentally the same as in the proximal thecae of *M. halli*, with a pronouncedly retroverted dorsal margin to the hook and a pair of latero-ventrally directed spines. In *M. sedgwicki* the spines are longer throughout, whilst the thecae throughout the rhabdosome appear to be more or less uniform. It would seem that *M. halli* has evolved from *M. sedgwicki* by reduction in spinosity and retreat of the dorsal thecal margin; such an interpretation involves the distal introduction of the new character. If this interpretation is correct, and it would be unreasonable to suggest that the two lacked close affinity, it renders unlikely the possibility of the *sedgwicki* line giving rise to *priodon*-like monograptids. There is, in fact, no general similarity between the distal thecae of *priodon* types and those of *M. halli*. The distal thecae of the latter have a distinctly triangular appearance.

Monograptus marri PERNER, 1897

Pl. 2, Figs. 26–29

- 1897 *Monograptus Marri* n.sp. – PERNER, p. 21, pl. 2, figs. 5, 6, 10, 11; text-figs. 23–25.
 1912 *Monograptus Marri* PERNER – ELLES & WOOD, pp. 422–3, text-figs. 284 a–b; pl. 42, figs. 4 a–d.
 ? 1933 *Monograptus Marri* PERNER – SUN, p. 38, pl. 6, fig. 4.

- 1945 *Monograptus Marri* PERNER – WATERLOT, p. 78, pl. 33, fig. 336.
 ? 1949 *Monograptus (Pomatograptus) marri* PERNER – OBUT, p. 23, pl. 4, figs. 5 a, b.
 1952 *Monograptus (Monograptus) priodon marri* PERNER – MÜNCH, p. 100, pl. 26, figs. 2 a–b.
 1958 *Monograptus marri* PERNER – OBUT, pp. 61–62, pl. 4, figs. 7–11; text-figs. 10 a–b.
 1962 *Monograptus marri* PERNER – ROMARIZ, p. 252, pl. 16, fig. 8.

Material. Numerous specimens in full relief, including early growth stages and long proximal and distal fragments. Some specimens are transparent.

Horizon. *turriculatus* Zone; nodules nos: 2 and 3, Osmondsberg.

Description. The slender sicula is conspicuous, attaining a length of 1.60 mm; its apex is always above the level of th1, and in some specimens it is nearer the hook of th2. The prosicula is large, up to 0.50 mm long, and it makes up the bulk of the sicula above th1. Several longitudinal thickening threads are visible. The metasacula has an apertural diameter of rather less than 0.20 mm and a slender virgella not exceeding 0.40 mm in the available material. A characteristic feature of the specimens is the ventral curvature of the late metasacular dorsal wall (Fig. 26), which culminates in a pronounced dorsal process.

The primary notch of th1 occurs as much as 0.30 mm above the sicula aperture. Th1 has a total length of 1.00–1.20 mm of which approximately 0.20 mm consists of the metathecal hook. At the proximal end, the thecal hook occupies about half the total dorso-ventral width of the rhabdosome. At the level of th1, the dorso-ventral width is usually 0.40 mm and occasionally as much as 0.50 mm. The proximal thecal spacing is 10–12 in 10 mm falling to 10 in 10 mm distally. The distal fragments available have a dorso-ventral width of 0.90 mm. The proximal end shows a gentle dorsal flexure affecting from one to seven thecae.

The proximal thecal hooks are of simple type with a pronouncedly retroverted dorsal margin and a somewhat thickened ventral lip which turns over but slightly. Each dorso-lateral margin of the thecal aperture ends in a blunt, almost plate-like, process in which only a little transverse expansion can be seen (Figs. 26, 27). In ventral view the dorsal apertural lip is seen to vary from horizontal to distally-arched along the line of the zig-zag suture (Figs. 26, 27).

The distal thecae show some changes from the proximal thecae, and such differences as exist are achieved gradually. The blunt ventral processes mentioned above show considerably more transverse expansion in the distal thecae so that they are clearly visible in dorsal view (Figs. 28 b, c); in addition they are enrolled, thereby producing what is in effect a laterally-directed open tube (Fig. 28 a). In ventral view, the actual dorsal lip varies from horizontal to gently arched distally (as in the proximal thecae), although there is also a slight tendency to enrolling even in the mesial parts of the lip. The free ventral wall in the distal thecae is inclined at a slightly higher angle to the axis than in the proximal thecae (10° +, compared with 5° +).

Remarks. The Swedish specimens resemble previously described material in most respects: in size and position of sicula, in thecal spacing, and in the proportions of the thecal hooks. The slight dorsal curvature of the proximal end is not typical of *crispus* and *griestoniensis* Zone specimens from the north of England, which tend to be almost straight, but it is present in the specimens figured by ELLES & WOOD (1913). It is doubtful if the apertural process described above would

be visible in flattened material. A few *turriculatus* Zone specimens from the Cross Fell area (northern England) have been examined in which the processes are just visible (Fig. 29), but this material is in very low relief.

The present material would seem to be allied to the *priodon* group of monograptids, and it contrasts strongly with the *sedgwicki-halli* types. It would seem that in *M. halli* the thecal hooks and processes are in a degenerative phase, rather than that they are developing along lines which could produce *priodon*-like monograptids. On the other hand, to produce *priodon* types from *marri* would require only slight modification of the apertural processes, and small changes in thecal proportions.

It is equally difficult to envisage common roots for the *sedgwicki* and *marri* lines of evolution. Ignoring thecal processes and sicular differences (which are considerable), the prothecal form is strongly suggestive of a different origin. The *priodon* types could have their origins in an early monoclimalid such as *M. crenularis*. This latter species already shows considerable apertural eversion (as in later monoclimalids) and could develop hooks via the intermediate "lappet" stage typified by *M. galaensis*. No change of prothecal structure is involved and it would be necessary only to lose the genicular hood present in *M. crenularis*; with the development of a true hook, a hood would presumably be superfluous. The present *marri* material does nothing to lessen the above argument, and supports it to some degree by the nature and proportions of the proximal end, and by the manner in which the dorsal lip in *M. marri* can be arched distally along the line of the zig-zag septum.

A subsequent stage to the production of hooks in this manner would be the development of spines from the short open tube typical of *marri*. The production of hooks and spines from lappets is exhibited by *Cyrtograptus rigidus* n. subsp. A, THORSTEINSSON (1955), the new features probably being proximally introduced characters.

Monograptus* cf. *M. barrandei

sensu ELLES & WOOD, 1913

Pl. 2, Figs. 30–32

cf. 1913 *Monograptus Barrandei* (SUSS) – ELLES & WOOD, p. 462, pl. 46, figs. 6 a, b; text-fig. 320.

M a t e r i a l. Several hundred proximal fragments in full relief and all more or less transparent.

H o r i z o n. *turriculatus* Zone; nodule no. 2, Osmundsberg.

D e s c r i p t i o n. The sicula has a total length of 0.60–0.70 mm, of which 0.40–0.50 mm consists of the metasicula. The prosicula is, therefore, relatively conspicuous; longitudinal lines of thickening are visible. A small virgella is present, and there is a rather diminutive dorsal process on the sicula aperture. The sicula aperture has a diameter of 0.10 mm.

Th1 originates rather less than 0.10 mm above the sicula aperture and reaches a total length (including the "lobe") of 0.80–0.90 mm. The dorso-ventral width at the level of th1 is 0.20 mm. More distally derived fragments have a dorso-ventral width of 0.30 mm. Thecal spacing is of the order of 13–14 in 10 mm, and there is no thecal overlap. The prothecal ventral wall is inclined to the axis at a very low angle.

Both dorsal and ventral walls of the thecal hook are so strongly retroverted that much of the aperture faces almost dorsally. Occasionally a small "pore" is seen separating the late metathecal parts from the late prothecal parts (Figs. 31, 32). More commonly, however, the metatheca is so tightly enrolled that it impinges directly upon the late prothecal

portion which, in either case, may be faintly depressed opposite the thecal aperture. Access to the exterior must have been quite difficult for the zooid, and in most cases would have been restricted to the small, mesial upturned lip on the dorsal margin of the aperture (Figs. 30 a, c, 31). Each thecal hook seems to be more or less complete by the time the succeeding theca begins to grow.

The early prothecal stage is preceded by the growth of a slim, but rigid, nema. In a dorso-ventral sense the earliest part of the protheca is wider than the subsequent mesial portion; however, the morphology is complicated by a structure which is homologous to the prothecal folds in some Ordovician graptolites. Since the protheca is preceded by the growth of a nema, actual dorsal folding of the growing tube is impossible and the result is a pronounced dorso-lateral expansion on both obverse and reverse walls (Figs. 30–32). There seems to be no serious constriction of the protheca, merely a rapid expansion following an initially very narrow foramen. At the distal extremity of the prothecal fold, the dark pigmented area (Figs. 30 b, 32) represents a very slight infolding producing a ring-like, but not strongly pronounced, internal flange. The protheca assumes a more "normal" shape after less than 0.10 mm. These prothecal folds are particularly conspicuous in dorsal and ventral views of the rhabdosome (Figs. 30 b, c, d, 32), but they can often be seen in lateral view where they temporarily obscure the nema (Figs. 30 a, 31).

R e m a r k s. These specimens closely resemble the *barrandei* distal fragments described and figured by ELLES & WOOD (1913), and probably represent the proximal end of the species. The Swedish specimens are slightly narrower and have more closely spaced thecae, as might be expected in the proximal region.

The occurrence of prothecal fold structures has not previously been recorded in monograptids, but is described herein in two different groups (see above p. 3 and below pp. 11, 12).

The thecal structure of *Monograptus* cf. *M. barrandei* is simpler, though closely akin to that in *M. nodifer* s.s. (Dr. Bertil WAERN has well-preserved specimens of the latter). These two, together with an undescribed species (*M. sartorius* sensu WILSON, 1954: see above), are referable to *Streptograptus* YIN. Little can be done with the numerous other species previously included in YIN's genus except to leave them in the genus *Monograptus* s.l. It seems preferable to leave all these monograptids in *Monograptus* s.l. until more is known of their thecal morphology and evolution.

***Monograptus* sp. 1**

Pl. 2, Figs. 33–42

M a t e r i a l. Numerous flattened and fragmentary specimens, at least partially transparent.

H o r i z o n. *gregarius* Zone, Silvberg.

D e s c r i p t i o n. This species is somewhat unusual in that about half of the short sicula consists of the prosicula (Figs. 33, 34). The prosicula reaches a length of 0.30–0.40 mm, and, as a rule, has four or five longitudinal lines of thickening, whilst the metasicula is rarely longer than 0.30–0.40 mm. A slender virgella is commonly present and the sicula aperture is slightly undulating and has a short dorsal process.

Th1 originates fairly low on the sicula, and reaches a total length of 1.00–1.10 mm. The dorso-ventral width at the level of th1 is 0.15 mm (flattened) including the thecal "hook" (see below). Distally, this value increases to 0.40 mm, whilst the thecal length may be as much as 1.70 mm. Proximally there is little thecal overlap, but distal thecae may overlap

for up to 0.30 mm, which is about one-fifth of the total thecal length. The ventral thecal wall is inclined to the axis at approximately 5° in the proximal thecae, and up to almost 10° in the distal thecae. In each theca, the prothecal portion is initially slender and widens quite gradually to the meta-thecal part.

The thecae are uniform with extremely elongate, triangular prothecal parts, and short metathecal parts terminating in beaklike "hooks". The ventral and lateral metathecal walls end in a slightly thickened thecal lip, whilst the dorsal thecal wall is strongly retroverted and slightly expanded transversely (Fig. 38) to produce a cap-like "hook" to the theca. This "cap" has slightly thickened rims (Figs. 35, 36, 39, 40) and is composed of attenuated periderm which is quite transparent and commonly missing altogether. The "cap" almost closes the thecal aperture, although this may be to some extent a preservational feature.

R e m a r k s. It has not been possible to identify this species, though there is some resemblance to MÜNCH's (1938) *Pomatograptus* sp. . From this species, however, the present material differs in having a much larger dorsal "cap" which envelopes the thecal aperture to a greater extent. In flattened, and particularly in carbonized, material details of the above structures would be unrecognizable. Figs. 37, 41 and 42 illustrate the form such specimens would have. It is obvious that relationships between species cannot be worked out from such material: the specimens described above, for example, bear a superficial resemblance to the profile appearance of the proximal thecae of *M. revolutus* s.l. and yet they have a fundamentally different apertural apparatus.

Monograptus exiguus (NICHOLSON, 1868)

Pl. 2, Figs. 43–46

- 1868 *Graptolites lobiferus* var. *exiguus* var. nov. – NICHOLSON, p. 533, pl. 19, figs. 27, 28.
 1871 *Graptolithus plumosus* sp. nov. – BAILY, p. 23, figs. 1 a–c.
 1876 *Monograptus exiguus* (NICHOLSON) – LAPWORTH, p. 503, pl. 20, fig. 6.
 1892 *Monograptus exiguus* (NICHOLSON) – TÖRNQUIST, p. 25, pl. 2, fig. 22.
 1899 *Monograptus exiguus* (NICHOLSON) – TÖRNQUIST, p. 24 to 25, pl. 4, figs. 26–28.
 1912 *Monograptus exiguus* (NICHOLSON) – ELLES & WOOD, pp. 453–4, text-figs. 312 a–c; pl. 46, figs. 1 a–d.
 1919 *Monograptus exiguus* (NICHOLSON) – KIRSTE, p. 169, pl. 2, figs. 40 a–b.
 1923 *Monograptus exiguus* (NICHOLSON) – GORTANI, pp. 13–14, pl. 1, figs. 23–27.
 ? 1931 *Monograptus exiguus* (NICHOLSON) – HABERFELNER, p. 135, pl. 2, figs. 5 a–c.
 1932 *Monograptus exiguus* (NICHOLSON) – GLÉMAREC, pp. 108 to 110, pl. 2, figs. 4 a–d.
 1939 *Monograptus exiguus* (NICHOLSON) – MÜNCH, p. 20, figs. 27 a–d.
 1942 *Monograptus (Streptograptus) exiguus* (NICHOLSON) – BOUČEK & PŘIBYL, p. 5–6, pl. 1, figs. 1–3; text-figs. 3 a–d.
 1949 *Monograptus (Streptograptus) exiguus* (NICHOLSON) – OBUT, pp. 23–24, pl. 4, fig. 7 a.
 1958 *Streptograptus exiguus* (NICHOLSON) – OBUT, p. 63, pl. 5, figs. 3–4, text-fig. 13.
 1962 *Streptograptus exiguus exiguus* (NICHOLSON) – ROMARIZ, pp. 263–4, pl. 22, figs. 13, 11; ? fig. 7.

M a t e r i a l. Twelve partially transparent specimens in full relief.

H o r i z o n. *turriculatus* Zone; nodule no. 1, Osmundsberg.
D e s c r i p t i o n. The sicula has a total length of 0.80–0.90 mm of which 0.20–0.30 mm consists of the prosicula. Its apex reaches approximately midway between the thecal hooks of th1 and th2. The sicula aperture possesses a slender virgella and a pronounced dorsal process and has a diameter of 0.10 mm.

Th1 originates 0.10 mm above the sicula aperture, and reaches a total length (including the hook) of 0.70–0.80 mm. That part of the proximal end involving th1–th3 is almost straight but a strong ventral curvature develops thereafter, resulting in a rhabdosome of very characteristic shape. The thecal spacing is 18–20 in 10 mm proximally, and 13 in 10 mm distally. At the level of th1 the dorso-ventral width is 0.40–0.50 mm (including the hook). The distal width barely reaches 0.60 mm. There is no thecal overlap.

The ventral prothecal walls are more or less parallel to the axis of the rhabdosome, whilst less than one-third of the theca is involved in the actual metathecal hook (Figs. 43, 45). The protheca begins, as in *Monograptus* cf. *M. barrandei* (described above), with structures homologous to the prothecal folds of some Ordovician graptolites. A slender nema slightly precedes the development of fusellar tissue, and the prothecal folding is reflected in pronounced dorso-lateral expansions (Figs. 43, 46 a, b, c). In dorsal view, two tumid areas, 0.15 mm in diameter, can be seen at the proximal extremity of the protheca. In either lateral view a single inflated area is seen obscuring part of the nema and dorsal margin. The development of the prothecal folds is best considered by examination of Figs. 46 a, b, c. A normal unconformity of fusellar layers is seen at the thecal foramen. The foramen is transversely expanded and occupies at least the full lateral width of the rhabdosome (0.30 mm); it is an extremely narrow (0.05 mm) slit, dorsally positioned against the nema. The proportion of dorso-ventral width to lateral width of the slit is, therefore, 1 : 6.

On leaving the preceding theca, the zooid deposited tissue to form a tube which expands both laterally and dorsally, except for the median dorsal area occupied by the already-formed nema. At this stage, the protheca is wholly open ventrally. Subsequently, this dorso-laterally expanding tube turns inwards (Fig. 43) before straightening to form the later part of the protheca, which is of "normal" proportions. When the early growth rings of the "normal" part are being deposited, the ventrally open part of the protheca is closed. The junction of the inflated portions of the protheca with the "normal" part is marked by slight thickening, though there is no real constriction of the protheca other than that provided by the change in the angle of deposition. In growth stages developed a little beyond the prothecal folds it is possible to look down the protheca and see the slight thickening, the inflated parts, the nema, and the narrow foramen. Most of the "base" of the protheca is occupied by the dorsal wall of the preceding theca. The final part of the protheca is more or less parallel sided and uncomplicated.

The whole of the metatheca is involved in a complex thecal hook which includes retroversion of both ventral and dorsal walls. Most of the complex apertural apparatus is constructed from the dorsal wall, but the ventral wall is distinctly retroverted and has an undulating lip whose lateral margins are more retroverted than the mesial part.

The dorsal wall of the theca is retroverted to such an extent that the main part of thecal aperture faces dorsally. As the apertural lip is approached the dorsal wall is involved in considerable transverse expansion and the fusellae enroll to form long, laterally directed spines (Figs. 43, 44, 46 a, b, c). The dorsal lip, excluding the portion involved in the lateral

spines, is as a whole slightly enrolled (Fig. 43), but mesially there is an upturned lip (Figs. 43, 46 a, b, c). On the late free ventral wall, facing the aperture of the same theca, there is a flattened area which presumably gave the zooid slightly better access to the exterior.

R e m a r k s. The prothecal folding in *M. exiguus* is of the type seen in *Monograptus* cf. *M. barrandei* (described above), although in this latter species it is less clearly seen. It seems possible that the folding represents an attempt by a rapidly maturing zooid to deposit a tube of reasonable proportions, given the two initial restrictions placed upon its development: an existing nemal rod and a very narrow foramen. In Ordovician graptolites with prothecal folds one of these restrictions (the nema) does not operate, but the thecal foramen appears to be quite small in some at least (SKEVINGTON, 1965).

The nature of the thecal hook described above has been quite unsuspected and *M. exiguus* has usually been placed in the genus *Streptograptus* YIN, or has been considered to have tightly enrolled thecal "lobes". It is understandable that the thecal spines, directed laterally, would be undetectable in most, if not all, material that was not chemically isolated from the matrix. It is unlikely, for example, that *M. exiguus* could be preserved in dorsal or ventral view as is, on occasion, *M. discus*.

As has been pointed out above, there are few species that can be included in *Streptograptus* YIN, and *M. exiguus* must certainly be removed from that genus, even though it resembles *Monograptus* cf. *M. barrandei* in having a small, mesial upturned lip and a flattened area on the prothecal wall opposite the thecal aperture. The thecal hook of *M. exiguus* is, in fact, much closer to that of *M. spiralis* (GEINITZ) than to that of the streptograptids. *M. spiralis* lacks the mesial upturned lip, whilst the spines are rather open tubes (BULMAN, 1932; SUDBURY, 1958).

The general rhabdosomal features and proportions of the Swedish material closely resemble previously described specimens of *M. exiguus*. *M. exiguus* would seem to resemble *M. nodifer* only in exhibiting prothecal folding.

Monograptus* aff. *M. spiralis

(GEINITZ, 1842)

Pl. 3, Figs. 47–50

aff. 1842 *Graptolithus spiralis* n.sp. – GEINITZ, p. 700, pl. 10, figs. 26, 27.

aff. 1958 *Monograptus spiralis* (GEINITZ) – SUDBURY, pp. 513–4, pl. 21, figs. 79–82.

M a t e r i a l. Numerous specimens in full relief.

H o r i z o n. *turriculatus* Zone; nodules nos. 1 and 2, Osmondsberg.

D e s c r i p t i o n. The sicula has a total length of 1.10–1.20 mm and its apex reaches to about the level of the metatheca of th1 (Fig. 47). The prosicula is approximately 0.40 mm in length. A slender virgella is present, usually directed at a high angle ventrally, as opposed to proximally. The sicula aperture is concave with a prominent, rounded dorsal process.

Th1 originates 0.25–0.30 mm above the sicula aperture. The prothecal portion is elongate triangular and 0.80–1.00 mm long. The metatheca of th1 is inclined at a high angle to the axis (60°) and contrasts with the long, low, triangular protheca. In subsequent thecae, the metatheca remains fundamentally the same and is inclined at a high angle, but the protheca becomes shorter in proportion to the thecal height

and the ventral prothecal wall is inclined at a higher angle (up to 40°). There is no thecal overlap. Thecal spacing varies from 10–12 in 10 mm proximally to 12–13 in 10 mm distally. The distal dorso-ventral width (= thecal height) reaches 1.50 mm in the available material.

The rhabdosome shows quite tight dorsal curvature and there is a strong suggestion of spiral coiling.

The thecae are uniform and have a characteristic apertural apparatus. The ventral apertural lip is relatively simple and slightly concave (Figs. 48 a, 50), but the dorsal wall folds over strongly to form a flap over the aperture (Figs. 49, 50). The lateral margins of the dorsal lip are transversely expanded and enrolled to form a pair of horn-like open tubes or processes (Figs. 48 b, 49).

R e m a r k s. This material is basically similar to that described by previous workers (BULMAN, 1932; SUDBURY, 1958), but differs in having a sicula which reaches only to the level of th1 (contrast SUDBURY 1958, pl. 21, figs. 79, 80), a rather more complex apertural apparatus, and a rhabdosomal form which is probably less regularly, and more tightly, coiled. A number of subspecies of *M. spiralis* have been described but because of their generally poor preservation it is not easy to compare them with the present Swedish material.

The curvature of the rhabdosome resembles that of *M. turriculatus* (BARRANDE), but the proximal thecae in *M. aff. M. spiralis* are quite different and none of the thecae has spines.

***Monograptus proteus* (BARRANDE, 1850)**

Pl. 3, Figs. 51–55

1850 *Graptolithus proteus* n.sp. – BARRANDE, p. 58, pl. iv, figs. 12–14.

1851 *Graptolithus proteus* BARRANDE – SUESS, p. 39, pl. 9, figs. 3 a–d.

1851 *Graptolithus armatus* n.sp. – SUESS, pl. 9, fig. 2.

1852 *Monograptus proteus* (BARRANDE) – GEINITZ, pp. 44–45, pl. 4, figs. 13, 14 a–b; ? fig. 29 (n o n figs. 4, 6–12, 15–18, 20, 23, 25).

1876 *Monograptus convolutus* var. *proteus* (BARRANDE) – LAPWORTH, p. 23, pl. 13, fig. 4 e.

1877 *Monograptus proteus* (BARRANDE) – LAPWORTH, p. 128, pl. 5, fig. 18.

1890 *Monograptus proteus* (BARRANDE) – GEINITZ, p. 21, pl. A, fig. 28.

1892 *Monograptus proteus* (BARRANDE) – TÖRNQUIST, p. 40, pl. 3, figs. 29, 30.

1897 *Monograptus proteus* (BARRANDE) – PERNER, p. 14, pl. 12, figs. 21–23; text-fig. 13.

1897 *Monograptus proteus* (BARRANDE) – FRECH, p. 648.

1899 *Monograptus proteus* (BARRANDE) – TÖRNQUIST, p. 23, pl. 4, figs. 23–24.

1912 *Monograptus proteus* (BARRANDE) – ELLES & WOOD, p. 447, pl. 48, figs. 8 a–c; text-figs. 332 a–c.

1919 *Monograptus proteus* (BARRANDE) – KIRSTE, pp. 177–188, ? pl. 111, figs. 10–11.

1919 *Monograptus armatus* (SUESS) – KIRSTE, p. 178, pl. 3, fig. 12.

1920 *Monograptus proteus* (BARRANDE) – GORTANI, p. 48, pl. 3, fig. 37.

1923 *Monograptus proteus* (BARRANDE) – GORTANI, p. 17, pl. 1, figs. 37–40.

1931 *Monograptus proteus* (BARRANDE) – HABERFELNER, p. 143, pl. 3, figs. 1 a–b.

1939 *Monograptus proteus* (BARRANDE) – HUNDT, pp. 32, 154, 166, 184, 314, 334.

- 1944 *Monograptus proteus* (BARRANDE) – PŘIBYL, pp. 11–14, figs. 11 a–f; pl. 3, figs. 4–8; pl. 5, fig. 7; pl. 9, figs. 1–3.
 ? 1945 *Monograptus proteus* (BARRANDE) – WATERLOT, pl. 41, fig. 411.
 ? 1962 *Spirograptus proteus* (BARRANDE) – ROMARIZ, p. 268.

Material. Several hundred fragmentary specimens preserved in relief and all more or less transparent.

Horizon. *turriculatus* Zone; nodules nos: 1–3, Osmundsberg.

Description. The whole proximal end, including the sicula, is extremely slender. The sicula has a length of 0.90 to 1.00 mm and an apertural diameter of 0.10 mm. Two specimens show that the prosicula is 0.30–0.40 mm in length and that the apex reaches about halfway along th1. Th1 originates 0.35 mm above the sicula aperture on the one specimen where this can be ascertained (Fig. 52) and has a total length of 1.50 mm. At the level of the hook of th1 the overall dorso-ventral width is 0.15–0.20 mm; the late prothecal part of th1 has a width of 0.10 mm, and the initial prothecal tube of th2 a width of 0.03 mm and, at this level, therefore, the thecal hook occupies less than half the width of the rhabdosome in profile view (Fig. 52).

The rhabdosome is dorsally curved and rapidly increases in dorso-ventral width to a distal maximum of 1.60 mm. The angle of the ventral prothecal wall to the axis of the rhabdosome increases from about 3° in the proximal thecae to 35° in the distal thecae. There is no thecal overlap. Distally, the thecal hook is rather more prominent and occupies a greater proportion of the dorso-ventral width (Fig. 51) but is otherwise of the same type as the proximal hooks.

The thecal hooks are unusual, if not unique, in having the thecal axis strongly twisted so that the aperture faces the reverse side of the rhabdosome. No specimens have been seen which face the obverse side. The position of the zig-zag suture (Figs. 51, 53) confirms that the whole thecal axis is twisted, and that the asymmetry is not a result of differential development of the lateral thecal walls (as in some Ludlovian monograptids). The aperture is on the whole relatively simple; the ventral margin is even and the dorsal margin forms a flap growing towards it (Figs. 52–54). A slight transverse expansion takes place towards the aperture and incorporates the apertural region.

Remarks. There are no authenticated instances of thecal torsion in Silurian graptolites, and few records of asymmetrical development of the apertural apparatus. If the thecal torsion of *M. proteus* is ignored the thecae bear some resemblance to those of *M. planus* (BARRANDE) and others (see SUDBURY, 1958). Specimens of *M. proteus* from Britain and Scandinavia preserved in moderate to full relief sometimes show the thecal torsion (Fig. 55). However, in the absence of growth lines, details of the torsion and the thecal apertures cannot be deduced in such material.

***Monograptus* sp. 2**
 Pl. 3, figs. 56–62

Material. Numerous specimens of proximal and distal fragments, though no specimen shows the actual transition from proximal to distal. Some specimens are more or less transparent.

Horizon. *gregarius* Zone, Silvberg.

Description. The reasons for considering the proximal ends as conspecific with the distal fragments are discussed below. No siculae have been obtained but the proximal fragments must be extremely close to th1. The minimum dorso-

ventral width, at apertural level, is 0.13 mm, and a prothecal width of about half this obtains on the same part of the rhabdosome. The thecae are spaced at 8–10 in 10 mm and thecal overlap is small (Fig. 56). The ventral prothecal wall is inclined to the axis of the rhabdosome at a very low angle. The thecal apertures are introverted (Fig. 56) and the apertural lips are undulating with a median ventral saddle (Figs. 56, 57). The lateral margins of the apertural rim turn strongly inwards, whilst the free ventral wall shows distinct incurving as the aperture is approached. A sharp geniculum overhangs the apertural region (Figs. 56, 57).

The distal fragments described here are rather numerous and a little better preserved. Fragments are dorsally curved, have a maximum dorso-ventral width (flattened) of 0.55 mm, and a thecal spacing of 8–10 in 10 mm. The free ventral wall is inclined at up to 8°–10° to the axis of the rhabdosome.

The thecal aperture is strongly introverted and the ventral lip is undulating with a pronounced median ventral saddle (Figs. 58, 59). The lateral margins of the apertural lip are the most strongly inturned. A sharp geniculum is present, overhanging the aperture, and from this depends a genicular hood. The latter tends to overhang the median ventral saddle of the apertural lip. In three dimensions the tube would presumably have an undulating, slit-like aperture. In a number of specimens the hood is flattened in such a way as to obscure, or almost obscure, the aperture (Figs. 60–62). Such material would appear in the rock as a *revolutus*-like species, and structural detail would probably be obscured.

Remarks. The proximal and distal thecae described above resemble each other in general proportions, in being introverted, and in the presence of a median ventral saddle and sharp geniculum; they differ only in that a genicular hood has not been seen on the proximal thecae. This could be a matter of preservation since delicate genicular hoods are rarely preserved in Lower Silurian graptolites.

Great care must be taken when commenting upon flattened “hooked” graptolites of the *revolutus* type, or other slender forms. It seems certain that the structures described above in *Monograptus* sp. 2 (and in *Monograptus* sp. 1) would seldom be detected in flattened material retained in the matrix. Yet the structures revealed indicate a completely different relationship for these forms.

Introversion of the thecal aperture in Lower Silurian graptolites has only recently been established with certainty (RICKARDS & RUSHTON, 1968). The present material, whilst sharing introversion, general rhabdosomal form, and the presence of a genicular hood, with the *incommodus* group of monograptids (RICKARDS & RUSHTON, op. cit.), seems to bear an even closer and more remarkable affinity with the distal thecae of *Dicellograptus geniculatus* described by BULMAN (1932) from the Holm Collection. Both species exhibit introverted apertures, a median ventral saddle, a sharp geniculum, and similar proportions. There are, however, many problems in proposing an actual relationship between the two, and at the present *Monograptus* sp. 2 is regarded as an unique Lower Silurian graptolite.

***Monograptus gregarius* LAPWORTH, 1876**
 Pl. 3, Figs. 63–68

- 1851 *Graptolites Nilssoni* BARRANDE – HARKNESS, p. 61, pl. 1, figs. 7 a–d.
 1868 *Graptolites Nilssoni* BARRANDE – NICHOLSON, p. 537, pl. 20, fig. 19.
 1876a *Monograptus gregarius*, n.sp. – LAPWORTH, p. 317, pl. 10, figs. 12 a–c.

- 1876b *Monograptus gregarius* LAPWORTH – LAPWORTH, pl. 1, fig. 7.
- 1877 *Monograptus gregarius* LAPWORTH – LAPWORTH, p. 131, pl. 5, fig. 4.
- 1892 *Monograptus gregarius* LAPWORTH – TÖRNQUIST, p. 8.
- 1897 *Pristiograptus gregarius* LAPWORTH – FRECH, p. 660, fig. 215; pl. 1, figs. 3–5.
- 1899 *Monograptus gregarius* LAPWORTH – TÖRNQUIST, p. 4–5, pl. 1, figs. 1–6.
- 1910 *Monograptus gregarius* LAPWORTH – ELLES & WOOD, pp. 365–6, pl. 36, figs. 3 a–d; text-figs. 238 a–b.
- ? 1924 *Monograptus gregarius* LAPWORTH – HUNDT, pl. 5, fig. 4.
- ? 1931 *Monograptus gregarius* LAPWORTH – HABERFELNER, pl. 1, fig. 1.
- 1940 *Monograptus gregarius* LAPWORTH – DESIO, p. 31, pl. 2, figs. 16, 17.
- ? 1945 *Monograptus gregarius* LAPWORTH – WATERLOT, pl. 23, fig. 260.
- 1947 *Monograptus* cf. *gregarius* LAPWORTH – RUEDEMANN, p. 481, pl. 84, fig. 1.
- ? 1962 *Pristiograptus gregarius* (LAPWORTH) – ROMARIZ, p. 262.
- 1963 *Monograptus gregarius* LAPWORTH – WILLEFERT, p. 30, pl. 1, figs. 9, 14, 17, 18; text-figs. 44 a, b.

Material. Numerous flattened specimens, all more or less transparent.

Horizon. *gregarius* Zone, Silvberg.

Description. The prosicula is rather less than 0.50 mm in length and less than 0.10 mm in diameter, and has at least six longitudinal thickening threads which coalesce distally to form the base of the nema (Fig. 66). The prosicula aperture has a slightly thickened rim and the succeeding early part of the metatheca is commonly narrower than the prosicula. By contrast, the metascula is very long, reaching over 5.00 mm, and has an apertural diameter (flattened) of 0.20 mm. The sicula aperture is even except ventrally, where a broad base to the virgella is provided (Figs. 65, 67). The apex of the sicula reaches to about the level of th5.

Th1 originates through a notch at a variable distance (0.70 to 1.10 mm) from the sicula aperture (this measurement has been taken only from those specimens having a sicula aperture with a slightly thickened rim). Thecal overlap is not easily determined but may be as much as one-half, even near to the proximal end. Th1 has a length of up to 1.80 mm and the proximal thecal spacing is 10 in 10 mm. The distal thecae are similarly spaced, with an overlap of about one-half, whilst the dorso-ventral width achieved is of the order of 0.70 mm.

The thecal apertures are clearly seen in this material. The aperture as a whole tends to be slightly everted, with the free ventral wall itself turned considerably outwards, indicating general thecal expansion (Figs. 63, 64). The apertural lip may be thickened in mature specimens (Fig. 64). A prominent, though well-rounded, geniculum is visible in many specimens (Fig. 63) and it would seem that the apertural region grows distally to such a degree as to obscure the geniculum (Figs. 64, 68). This fact, coupled with the general eversion and expansion of the aperture, may be the cause of the apparent tendency towards isolation seen in some pyritized specimens. There is no doubt that the later part of the metatheca is turning outwards, although in the present material it does not actually become isolate at any point.

Remarks. It is of interest that the prosicula should be so short in a species possessing such a long sicula (some British specimens may have a sicula as long as 7.00 mm [Fig. 68]). If a prolonged larval stage is indicated then presumably most

of the time was occupied with the development of the metascula.

The thecae described above suggest that *M. gregarius* should not be included in the genus *Pristiograptus*. For the present it seems more reasonable to retain it, together with other monograptids of like form (*M. cyphus*, *M. acinaces*), in the genus *Monograptus*.

Genus *Rastrites* BARRANDE, 1850

***Rastrites linnaei* BARRANDE, 1850**

Pl. 3, Figs. 69–72

- 1850 *Rastrites Linnaei* n.sp. – BARRANDE, p. 65, pl. 4, figs. 2, 4.
- 1897 *Rastrites Linnaei* BARRANDE – PERNER, pp. 7–8, figs. 4, 5; pl. 13, figs. 29–31 (n o n figs. 27–28).
- 1907 *Rastrites Linnaei* BARRANDE – TÖRNQUIST, p. 14, pl. 2, figs. 21–26.
- 1913 *Monograptus (Rastrites) Linnaei* (BARRANDE) – ELLES & WOOD, pp. 493–4, text-figs. 349 a–b; pl. 51, figs. 1 a–c.
- 1923 *Monograptus (Rastrites) Linnaei* (BARRANDE) – GORTANI, p. 20, pl. 1, figs. 43–45.
- ? 1924 *Rastrites Linnaei* BARRANDE – HUNDT, pl. 11, figs. 9–14.
- 1931 *Rastrites Linnaei* BARRANDE – HABERFELNER, p. 160–1, pl. 3, fig. 12.
- 1939 *Rastrites Linnaei* BARRANDE – HUNDT, p. 268, fig. 1 (on p. 224).
- 1941 *Rastrites linnaei* BARRANDE – PŘIBYL, pp. 10–11, pl. 2, figs. 1–2; pl. 3, figs. 1–8; text-fig. 1, figs. 1–3.
- 1945 *Monograptus (Rastrites) Linnaei* (BARRANDE) – WATERLOT, pl. 44, fig. 438.
- ? 1957 *Rastrites linnaei* BARRANDE – COMA, p. 72, fig. 22.
- 1963 *Rastrites linnaei* BARRANDE – WILLEFERT, pp. 50–57, pl. 2, figs. 9–10; text-fig. 85.
- 1967 *Rastrites linnaei* BARRANDE – SCHAUER, pp. 180–182, pl. 5, figs. 1–8.

Material. Numerous fragments of rhabdosome; some in relief and transparent, others complete and preserved in the matrix.

Horizon. *turriculatus* Zone; nodules nos: 1–3, Osmundsberg.

Description. The sicula varies from 1.70–1.90 mm in length, of which 0.30–0.40 mm may consist of the prosicula although the latter has not been measured with certainty. The apex of the sicula reaches to the level of the early prothecal part of th3. Th1 originates 0.10–0.25 mm above the sicula aperture; it expands rapidly, forming a distinct bulge, and then grows distally, closely adpressed to the sicula, for a distance of up to 0.20 mm (Figs. 72 a, b). This part of the protheca of th1 is circular in cross section and has a diameter of perhaps 0.05 mm. Following this, the protheca shows rapid expansion and growth is in a ventral and proximal direction. After the deposition of a few growth bands in this manner the protheca becomes the metatheca, the base of which measures 0.30–0.40 mm parallel to the axis; the metathecal base is, therefore, extremely broad (Figs. 71, 72 a, b). The metatheca is completely isolated and is directed ventrally and proximally (that is, backwards). Th1 has a metathecal length of more than 1.00 mm.

Subsequent thecae show a rapid increase in the lengths of the prothecal and metathecal parts, in the length of the thecal “base”, and in thecal height, whilst the thecal spacing is reduced from 6–10 in 10 mm proximally to about 5 in 10 mm distally.

The isolated specimens do not show the full lengths of the metathecae, as these are invariably broken; those still in the matrix, however, show that the species has all the proportions ascribed to it by previous workers.

Since the prothecae are so slender, it has been difficult to examine their origins from the preceding thecae. A few specimens, however, show this feature fairly clearly (Fig. 70) and it can be seen that the thecal foramen is rather long. The protheca is extremely slender when compared with the adjacent metathecal base.

The thecal apertures are clearly seen on numerous fragmentary thecae. There is some variation from a relatively simple type of aperture (Fig. 69), in which the dorsal thecal

wall is not strongly retroverted, to the more usual type (Fig. 70), in which the dorsal wall is hooked right over towards the ventral wall leaving only a slender opening in the mesial part and a pair of incipient horns at the lateral margins. Considerable transverse expansion of the theca takes place as the apertural region is approached.

Remarks. The details of the thecal apertures, the early development, and the metatheca/protheca junction, are features seen for the first time. The thecal apertures are simpler than deduced by SUDBURY (1958) for some of the early rastritids, but the same fundamental characters can be recognised.

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Plate 1

Figs. 1–4: *Pseudoclimacograptus* (*Metaclimacograptus*) *hughesi* (NICHOLSON, 1869). Silvberg; *M. gregarius* Zone.

1. Immature sicula. $\times 45$. Cn 54892.
2. Sicula and $th1^1$; obverse view. $\times 45$. Cn 54893.
3. Proximal end, showing faint traces of genicular hoods; obverse view $\times 15$. Cn 54912.
4. Distal fragment. $\times 15$. Cn 54911.

Figs. 5, 6: *Orthograptus* sp. Osmundsberg; *M. turriculatus* Zone.

- 5 a, b. Cn 54920. 5 a: Proximal end, showing everted apertures; reverse view. $\times 15$. 5 b: Growing end of same, showing formation of interthecal septum. $\times 30$.
6. Proximal end, showing strongly everted apertures ($th1^1$ almost hooked); reverse view. $\times 15$. Cn 54921.

Fig. 7: *Orthograptus* sp. Balbriggan, Co. Dublin, Eire; upper part of *M. turriculatus* Zone. $\times 7.5$. TCD 8272 A, B.

Figs. 8–10: *Orthograptus* ? sp. Silvberg; *M. gregarius* Zone. Three early growth stages showing the development of the complex virgella.

8. $\times 45$. Cn 54897.
9. $\times 40$. Cn 54914.
10. $\times 50$. Cn 54913.

Figs. 11–13: *Glyptograptus tamariscus tamariscus* (NICHOLSON, 1868). Silvberg; *M. gregarius* Zone.

11. Proximal end; sub-apertural view of the first thecal series. $\times 15$. Cn 54907.
12. Sub-ventral view of a distal fragment, which, if carbonised and flattened, would give an orthograptid profile. $\times 15$. Cn 54908.
13. Proximal end growth stage; sub-apertural view of the first thecal series. $\times 15$. Cn 54909.

Fig. 14: *Glyptograptus* aff. *G. tamariscus fastigans* HABERFELNER, 1931. Osmundsberg; *M. turriculatus* Zone.

Proximal end; obverse view. $\times 15$. Cn 54922. (cross-hatching denotes badly-preserved area).

Figs. 15–18: *Petalograptus* sp. Osmundsberg; *M. turriculatus* Zone.

15. Proximal end growth stage, with $th1^1$ and early part of $th1^2$. $\times 45$. Cn 54916.
16. Same, but with the sicula somewhat better preserved. $\times 40$. Cn 54917.
17. Same, showing the formation of the interthecal septum. $\times 15$. Cn 54918.
18. Sicula and origin of $th1^1$. $\times 15$. Cn 54948.

Figs. 19–20: *Retiolites* s.l. sp. Osmundsberg; *M. turriculatus* Zone.

19. Proximal end, incompletely preserved. $\times 15$. Cn 54919.
20. Reconstruction of thecae beyond the first. (a = apertural list; d = dorsal list; op = obverse parietal list; rp = reverse parietal list; v = ventral list; s = sub-apertural ventral spine).

Figs. 21, 22: *Rhaphidograptus toernquisti* (ELLES & WOOD, 1906). Silvberg; *M. gregarius* Zone.

21. Proximal end; obverse view. $\times 15$. Cn 54910.
22. Near-proximal fragment, flattened and semi-transparent; reverse view. $\times 25$. Cn 54915.

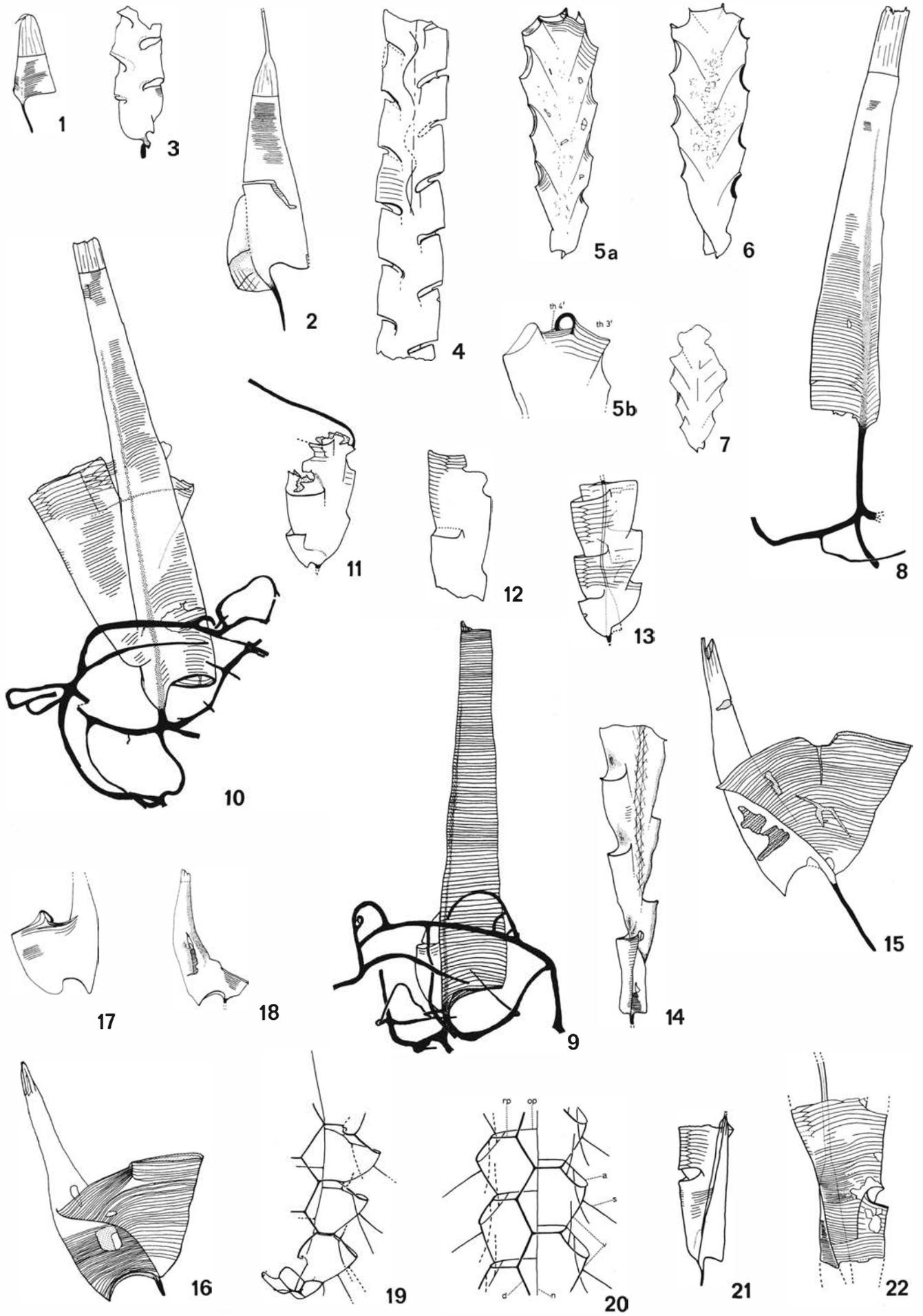


Plate 2

Figs. 23–25: *Monograptus halli* (BARRANDE, 1850). Osmundsberg; *M. turriculatus* Zone.

23. Proximal end growth stage; with sicula and th1¹. × 25. Cn 54940.
24. Proximal thecae, in profile and ventral views. × 25. Cn 54941.
- 25 a, b. Cn 54942. 25 a: Mesial to distal thecae in profile view, showing ventrally-facing apertures. × 15. 25 b: Same in ventral view. × 15 (aperture indicated by oblique shading).

Figs. 26–28: *Monograptus marri* PERNER, 1897. Osmundsberg; *M. turriculatus* Zone.

26. Early growth stage, showing mesial retreat of the dorsal thecal lip. × 35. Cn 54937.
27. Apertural view of a proximal theca. × 25. Cn 54938.
- 28 a, b, c. Cn 54939. 28 a: Mesial thecae in profile view. × 7,5. 28 b: Same in dorsal view. × 7,5. 28 c: Same in dorso-lateral view. × 7,5.

Fig. 29: *Monograptus marri* PERNER, 1897. Cross Fell, northern England; *M. turriculatus* Zone. Note blunt apertural processes on the more distal thecae. × 4. PJ 9870.

Figs. 30–32: *Monograptus* cf. *M. barrandei* sensu ELLES & WOOD, 1913. Osmundsberg, *M. turriculatus* Zone.

- 30 a, b, c, d. Cn 54923. 30 a: Fragment of stipe in profile. × 35. 30 b: Same in dorsal view. × 35. 30 c: Same in ventral view. × 35. 30 d: Same as 30 a. × 35.
31. Early growth stage. × 35. Cn 54924.
32. Fragment of stipe in dorso-lateral view. × 35. Cn 54925.

Figs. 33–42: *Monograptus* sp. 1 Silsberg; *M. gregarius* Zone.

33. Sicula and th1 (complete). × 50. Cn 54889.
34. Sicula and th1 (incomplete). × 50. Cn 54890.
35. Prosicula and th1, showing the “cap” on the thecal aperture. × 50. Cn 54891.
36. Thecal aperture, with a thickened rim to the semi-transparent “cap”. × 50. Cn 54894.
37. Distal theca; flat, carbonised and with a *revolutus*-like appearance. × 50. Cn 54895.
38. Thecal aperture in dorsal view, showing the lateral extension of the “cap”. × 50. Cn 54896.
39. Mesial thecae. × 50. Cn 54898.
40. Thecal aperture, showing the transparent “cap” formed from the dorsal thecal wall. × 50. Cn 54901.
41. Distal theca; flat, carbonised and with the “cap” broken off to reveal the apertural region. × 50. Cn 54902.
42. Distal theca; flat, carbonised and with a *revolutus*-like “hook”. × 50. Cn 54903.

Figs. 43–46: *Monograptus exiguus* (NICHOLSON, 1868), Osmundsberg; *M. turriculatus* Zone.

43. Proximal end. × 30. Cn 54929.
44. Dorsal wall of thecal aperture. × 35. Cn 54943.
45. Distal theca in profile view; somewhat abnormally “open”. × 50. Cn 54944.
- 46 a, b, c. Cn 54945. 46 a: Thecal aperture in distal view. × 50. 46 b: Ventral view. × 50. 46 c: Thecal aperture in dorsal view. × 50.

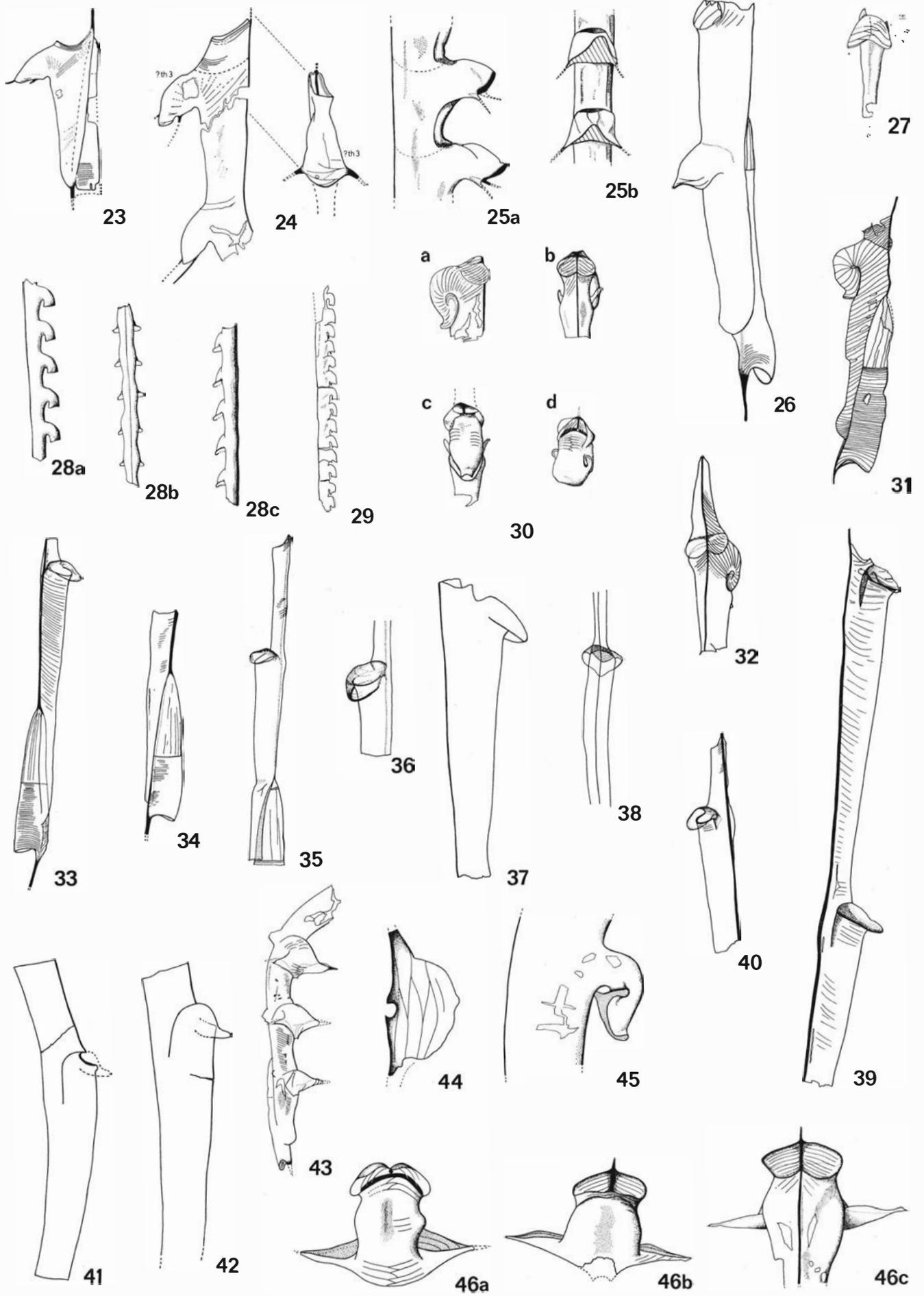


Plate 3

Figs. 47–49: *Monograptus* aff. *M. spiralis* (GEINITZ, 1842). Osmundsberg; *M. turriculatus* Zone.

- 47. Proximal end. $\times 30$. Cn 54926.
- 48 a, b. Cn 54927. 48 a: Thecal aperture in ventral view. $\times 30$.
- 48 b: Same in profile view. $\times 30$.
- 49. Thecal aperture in profile view. $\times 30$. Cn 54928.

Figs. 50–54: *Monograptus proteus* (BARRANDE, 1850). Osmundsberg; *M. turriculatus* Zone.

- 50. Distal theca. $\times 15$. Cn 54946.
- 51. Mesial theca in profile view. $\times 35$. Cn 54933.
- 52. Early growth stage. $\times 40$. Cn 54934.
- 53. Same as 52. $\times 40$. Cn 54935.
- 54. Thecal aperture in sub-profile view. $\times 40$. Cn 54936.

Fig. 55: *Monograptus proteus* (BARRANDE, 1850). Balbriggan, Co. Dublin, Ire. $\times 20$. TCD 8271 A, B.

Figs. 56–62: *Monograptus* sp. 2. Silvberg; *M. gregarius* Zone.

- 56. Thecal aperture in ventral view, showing introversion and median ventral saddle. $\times 45$. Cn 54882.
- 57. Semi-transparent specimen showing geniculum and median ventral saddle on apertural margin. $\times 45$. Cn 54883.
- 58. Distal theca showing genicular hood, introversion of aperture, and median ventral saddle on apertural margin. $\times 45$. Cn 54884.
- 59. Growing end. $\times 30$. Cn 54885.
- 60–62. Flattened, carbonised specimens, to illustrate the varying appearance of the aperture. All $\times 15$.
- 60: Cn 54886. 61: Cn 54887. 62: 54888.

Figs. 63–67: *Monograptus gregarius* LAPWORTH, 1876. Silvberg; *M. gregarius* Zone.

- 63. Distal fragment. $\times 50$. Cn 54899 (stippled area indicates bad preservation).
- 64. Detail of thecal aperture. $\times 50$. Cn 54900.
- 65. Proximal end. $\times 50$. Cn 54904.
- 66. Proscicula and initial portion of metasicula. $\times 40$. Cn 54905.
- 67. Proximal end, with the primary notch faintly indicated. $\times 50$. Cn 54906.

Fig. 68: *Monograptus gregarius* LAPWORTH, 1876. Rheidol Gorge, Wales; *M. turriculatus* Zone. $\times 15$. SM A60408 (specimen preserved in pyrite).

Figs. 69–72: *Rastrites linnaei* BARRANDE, 1850. Osmundsberg; *M. turriculatus* Zone.

- 69. Thecal aperture. $\times 25$. Cn 54930.
- 70. Same. $\times 25$. Cn 54931.
- 71. Thecal origin. $\times 25$. Cn 54932.
- 72 a, b. Cn 54947. 72 a: Origin of th1. $\times 25$. 72 b: Same enlarged. $\times 50$.

