Graptoloids from the Ontikan and Viruan (Ordov.) Limestones of Estonia and Sweden

By

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ABSTRACT.—The paper gives a description of graptoloids isolated from the Upper Ontikan and Viruan limestones of Estonia and Sweden. It is based mostly on the undescribed part of HOLM's collection of graptolites and on new material etched out by the present writer. The classification of the graptoloids is discussed, and the order *Graptoloidea* subdivided into four suborders: *Didymograptina* LAPWORTH, 1880, *Corynoidina* HOPKINSON *et* LAPWORTH, 1875, *Glossograptina* nov., and *Diplograptina* LAPWORTH, 1880. For the rhabdosome with stipes arranged back to back (as in biserial *Diplograptina* and *Didymograptina*) the term dipleural, and for that with stipes in contact side by side (as in *Glossograptina*) the term monopleural are introduced. Lasiograptid and gymnograptid types of thecae are distinguished and defined. It is shown that in some species of *Didymograptus* the thecae continue to grow in length at least until the rhabdosome has attained full size; hence in didymograptids the width of the rhabdosome should be used with the utmost caution as a specific character. Fragments of an isolated specimen of *Glossograptus* have made it possible for the first time to observe the actual arrangement of the thecal spines in this genus.

The genera *Pseudoclimacograptus* and *Lasiograptus* are redefined. Twenty-one different species are described (cf. Contents), of these are three not identified at the specific level, and four referred hesitatingly to already established species. Six species and one subspecies are new. *Climacograptus orthoceratophilus* BULMAN, 1932, is considered to be a junior subjective synonym of *C. distichus* (EICHWALD, 1840).

Stratigraphic classification of the Ordovician System at the series level is discussed. Attention is drawn to the confusion that has resulted from indiscriminate use of the terms Lower, Middle, and Upper Ordovician. On account of difficulties of exact intracontinental correlation even in the graptolitic sequence the use of regional names for these series in each major palaeozoogeographical province is suggested. In the classification of the Ordovician of Baltoscandia the subdivision proposed by RAYMOND (1916) is followed, the boundaries being drawn according to his suggestions. The correct terms for the series so defined are, in descending order, the Harjuan, Viruan, and Oelandian Series (KALJO, RÕÕMUSOKS, & MÄNNIL 1958). The boundary between the Harjuan and Viruan Series is defined as that separating the zones of *Dicranograptus clingani* and *Pleurograptus linearis*, and between the Viruan and Oelandian Series as that between the zones of *Didymograptus bifidus* and *D. murchisoni*. The Oelandian Series is subdivided into the Tremadocian and Ontikan Subseries.

The chrono-stratigraphic classification of the Ontikan Subseries is discussed, and a uniform terminology proposed for the Baltoscandian shelly sequence. A new term is Latorp Stage for beds previously called *Planilimbata* Limestone. The limestone formation in Scania between the Lower and Upper *Didymograptus* Shale is termed Komstad Limestone.

The correlation of the Ontikan and Viruan shelly and graptolitic sequences is treated in some detail, and that of the British-Scandinavian, Chinese (Lower Yangtze valley), and Australian-New Zealandian graptolitic sequence is briefly considered. It is suggested that the level of the boundary between the Canadian and Champlainian Series of North America lies considerably below the British-Scandinavian zone of *Didymograptus bifidus*.

Contents

Introduction

Somewhat before 1890 Gerhard Holm began to etch out graptolites from limestones, mainly Swedish and Estonian, and this work he continued with for almost 30 years, bringing together huge amounts of isolated graptolites. Only a small part of the material was, however, published (Holm 1890, 1895). Most of the illustrations for the description of the remaining material were completed, and the plates printed, but Holm never got time to write the text.

The majority of these plates were issued in BULMAN's now classic series of papers "On the graptolites prepared by Holm" which treated the main part of HOLM's collection of graptolites. However, a substantial amount of HOLM's material still remained undescribed, particularly a great part of the collections destined for a monographic treatment of Estonian graptolites. The description of this material as well as some additional remarks on species described by BULMAN form the main subject of the present paper. HOLM's material belongs to the Palaeozoological Department of the Naturhistoriska Riksmuseet, Stockholm, and the writer is very much indebted to Professor ERIK STENSIÖ for entrusting him with the task of describing it.

During recent field work and from borings new graptolite material has been gathered in limestones of southern Öland, the Siljan district, and Västergötland. These graptolites have been isolated by the present writer, and their description is included in this paper. Most of this material belongs to the Museum of the Palaeontological Institute of Uppsala University and some specimens to the Museum of the Geological Survey of Sweden. The writer offers his sincerest thanks to Prof. BIRGER BOHLIN, Uppsala, for placing the rock samples from Seby, Öland, at his disposal, and to the authorities of the Survey for permission to describe the specimens from that institution.

This paper is mainly a taxonomic study. Most of the treated material is strongly carbonized, and early developmental stages are few or poorly preserved. Serial microtome sections of the proximal end promise some information about the early astogenetic development, but it was found advisable to treat these in another connection.

The illustration of described species has offered some difficulties. The figures in HOLM's plates are drawings rather than photographs, though owing to the well-known artistic skill of G. LILJEVALL most of them are masterpieces. The results of this method of illustration are often very beautiful and very distinct in their details, but sometimes less convincing. The writer was unable to utilize the already printed edition of HOLM's plates. The plates with Estonian graptolites described here were among the first completed by HOLM, many of the figures being pencil drawings not by LILJEVALL, but by some other artist. The quality of these drawings is much inferior to the photographs retouched by LILJEVALL, and is not satisfactory. Of these specimens new photographs are given. Also the printed edition of HOLM's plates is too small for modern needs. From the satisfactory figures of HOLM's original plates new plates were assembled, and these are reproduced here as Pls. I and II. The photographs of specimens on other plates were made of dry specimens coated with ammonium chloride. They are not, or slightly, retouched. Most of the strongly carbonized, opaque specimens isolated by the present writer are mounted dry in a cell between two glass slides, being often attached to one with a touch of gum tragacanth.

In the course of completing this paper the writer has received help from many colleagues. He would wish to thank Dr. C. C. BRANSON and Dr. W. E.

HAM, Oklahoma Geological Survey, for kind help during his examination of DECKER's material of graptoloids; Professor O. M. B. BULMAN, Cambridge, for help with the terminological question concerning the use of stipe and rhabdosome; Mr. RAGNAR NILSSON, Lund, for unpublished data about the succession of graptolite faunas in the Koängen bore and for identification of graptolites from the Norra Skagen bore; Dr. A. M. OBUT, Leningrad, for a photostat of MU's paper of 1950 and for photographs of Estonian specimens identified by him as *Didymograptus bifidus*; Professor G. REGNÉLL, Lund, for the loan of TÖRNQUIST's and EKSTRÖM's types; Mr. DAVID SKEVINGTON, Cambridge, for generous information about preliminary results of the examination of new graptoloid material from the Hälludden section; Dr. ISLES STRACHAN, Birmingham, for photographs of the type specimen of *Lasiograptus retusus* and much useful information; Professor PER THORSLUND, Uppsala, for information about unpublished material from the Upper *Didymograptus* Shale of Jämtland and for many welcome suggestions; Dr. ADAM URBANEK, Warszawa, for photographs and manuscript notes on the new material of *Gymnograptus* found in Polish erratic boulders, and Professor H. B. WHITTINGTON, Harvard University, for kind help and guidance during the writer's examination of some of the Newfoundland graptolite material collected by KINDLE and WHITTINGTON. The help by the technical staff of the Palaeontological Institute, Uppsala University, is gratefully acknowledged. The revision of the English manuscript has been carried out by Prof. O. ZDANSKY, Uppsala.

The following abbreviations are used to indicate the whereabouts of particular specimens:

LM	Museum of the Palaeontological Institute, University of Lund.
RM	Palaeozoological Department, State Museum of Natural History, Stockholm (Naturhistoriska Riksmuseet).
SGU	Museum of the Geological Survey of Sweden (Sveriges Geologiska Undersökning).
UM	Museum of the Palaeontological Institute, University of Uppsala.

Remarks on Stratigraphic Terms

For some time it has been felt that most of the current terms used in the classification of the Ordovician sequence of Sweden are inappropriate and not in accordance with the modern terminology now applied in most other countries. Recent work has shown that the neglect of distinguishing between chronostratigraphical and litho-stratigraphical units in this sequence has led in certain cases to grave misconceptions. This is not the proper place for an exhaustive treatment of the terminology of the Ordovician rocks of Sweden. However, as the described graptolite material has a certain bearing on correlation and stratigraphic classification, some remarks on the terminology of the strata concerned are unavoidable. In the following only those terms of the stratigraphic units are treated which have a direct bearing on the subject of the present paper or which are necessary for the understanding of the general stratigraphic discussion herein.

SERIES.—Following the decision of Eighth International Geological Congress of 1900 (RENEVIER 1901, pp. 192–203) the term series is used here as a chronostratigraphic unit which normally (except where subsystems can be recognized) ranks next below a system.

There exists an astonishingly great number of different definitions of the terms Lower, Middle, and Upper Ordovician Series. Indeed, the confusion is so great that it is sometimes difficult to know exactly what part of the Ordovician is meant. For this reason the use of these terms ought to be discouraged until an international agreement about their definition has been attained. Owing to the present difficulties of an exact intracontinental correlation of the Ordovician rocks a classification of the Ordovician System which would be recognized and put into practical use all over the world does not yet seem to be possible. The use of separate regional names, like Canadian, Champlainian, and Cincinnatian, for units of series category within each major palaeozoogeographical province would avoid further confusion, and ought to be encouraged.

In Baltoscandia there never have existed serious divergences about the definition of the Upper Ordovician Series. The lower boundary of the series has now been closely fixed as the boundary between the zones of *Dicranograptus clingani* and *Pleurograptus linearis* (THORSLUND 1940, 1948). The correct, and only available, term for this series is Harju Series (ÖPIK MS; LUHA 1940; KALJO, RÕÕMUSOKS, & MÄNNIL 1958). The Harju Series seems to correspond fairly closely to the Cincinnatian Series of North America, but as the lower boundary of the latter series has not yet been defined in terms of the graptolite zones, its exact correlation with the European succession is not possible at present.

The position of the level of the boundary between the Lower and Middle Ordovician Series of Baltoscandia has been a matter of much discussion and divergence of opinion. In recent literature the following levels for this boundary have been proposed:

(1) The boundary between the *Didymograptus* and *Dicellograptus* Shales, i.e. that between the zones of *Didymograptus murchisoni* and *Glyptograptus teretiusculus* (JAANUSSON & STRACHAN 1954). The corresponding level in the limestone succession was thought to lie between the Aseri and Lasnamägi Stages, this level being considered as the lower boundary of the Middle Ordovician by JAANUSSON (1945, 1953, 1957a), RÕÕMUSOKS (1956), and others. From the material described in the present paper it becomes, however, evident that the correlation between the graptolitic and limestone succession was not exact in this part of the sequence. The boundary between the zones of *Didymograptus murchisoni* and *Glyptograptus teretiusculus* does not correspond to

that between the Aseri and Lasnamägi Stages, but is situated at a somewhat higher level (cf. the Chapter on correlation). This, together with other considerations, makes this level less apt as a serial boundary.

(2) STØRMER (1953) drew this boundary between the *Orthoceras* Limestone and the Upper *Didymograptus* Shale of the Norwegian sequence. He suggested that in the graptolitic succession this level is comparable to the boundary between the zones of *Didymograptus hirundo* and *D. bifidus*, i.e. to that between the Arenigian and Llanvirnian of the modern British classification. In the limestone sequence the comparable level was thought to lie between the *Vaginatum* Limestone (=Kunda Stage) and *Platyurus* Limestone (=Aseri Stage). However, the material described in the present paper shows that in the Oslo region the contact between the *Orthoceras* Limestone Group and the Upper *Didymograptus* Shale corresponds neither to a boundary between graptolite zones nor to that between the Kunda and Aseri Stages. The level comparable to the boundary between the zones of *Didymograptus hirundo* and *D. bifidus* is situated in that area within the *Orthoceras* Limestone Group (3c), but its exact position has not yet been determined (see the Chapter on correlation). It is obvious that STØRMER's suggestion cannot be followed, since it does not seem possible to identify the exact level of the change from the limestone facies to the shale facies of the Oslo area outside that region.

(3) The boundary between Arenigian and Llanvirnian of the modern British classification, or more exactly that between the zones of *Didymograptus hirundo* and *D. bifidus*. An important reason for drawing the boundary between Lower and Middle Ordovician at the level corresponding to the boundary between Arenigian and Llanvirnian has been the postulated close correspondance of this level with the boundary between the Canadian and Champlainian Series of North America (WHITTINGTON 1954; KINDLE & WHITTINGTON 1958; WHITTINGTON & BOHLIN 1958). As the ultimate aim for a chrono-stratigraphic classification is its world-wide applicability, the correspondance of the boundaries of different regional chrono-stratigraphic classifications must be taken into account as much as is possible from the available evidence. The faunistic change from the Canadian to the Champlainian Series is fairly abrupt in North America, and involves most groups of invertebrates. For this reason FLOWER (1957, 1958) has recently suggested the separation of the Canadian as a separate system or subsystem. It should, however, be explicitly stressed here that the North American and Arctic faunistic change in the boundary region between the Canadian and Champlainian Series has no contemporaneous counterpart in the richly fossiliferous Baltoscandian limestone succession, irrespective of which of the recent correlations is applied. Comparable, though perhaps not so extensive, faunal changes take place here at higher levels, viz. at the boundary between the Kunda and Aseri Stages, and between the Aseri and Lasnamägi Stages.

The correlation of the Canadian-Champlainian boundary with the British standard graptolitic succession is still an intricate problem. The two most recent attempts at correlation (KINDLE & WHITTINGTON 1958 and BULMAN 1958a) arrive in part at widely different results. According to KINDLE & WHITTINGTON (cf. also BERRY 1956) the level of this boundary corresponds to, or lies somewhat below of, the Arenigian-Llanvirnian boundary, whereas the comparison of British and Australian graptolitic succession suggested by BULMAN (cf. also HARRIS & THOMAS 1938) presumes a much lower position of the Canadian-Champlainian boundary, probably somewhere in the boundary region between the zones of *Didymograptus extensus* and *D. hirundo* of the British succession. The writer's opinion roughly agrees with that of BULMAN (cf. the Chapter on correlation). However, the correlation of the relevant portions of the North American shelly sequence with the British-Scandinavian graptolite zones is still too vague for an exact correlation of the Canadian-Champlainian boundary across the Atlantic. For this reason arguments based on comparison with the North American sequence can hardly be used at present for the definition of the Middle Ordovician in Europe. For avoiding the confusion which would result from an erroneous correlation it is preferable to admit the existence of a profound palaeozoogeographical differentiation in the early part of the Ordovician Period by using separate subdivisions of the series category.

BULMAN (1958a) has stressed the importance of the sudden appearance of the diversified diplograptid fauna as a level which has considerable correlative value, and which may be useful as the boundary between the Lower and the Middle Ordovician. This level coincides in Europe with the boundary between the Arenigian and Llanvirnian of the modern British classification, i.e. with that between the zones of *Didymograptus hirundo* and *D. bifidus*. However, the correlation of this level as drawn by BULMAN is evidently not without objections. In China and Australia the diplograptid fauna appears already in beds comparable to the upper part of the *Didymograptus hirundo* zone (MU & LEE 1958; cf. the Chapter on correlation). The boundary between the zones of *Didymograptus hirundo* and *D. bifidus* does not seem to represent a level of greater correlative value than most other boundaries between the graptolite zones of the standard British section.

(4) The concept of Middle Ordovician Series was introduced in Europe by RAYMOND (1916). He drew the lower boundary of this series between beds corresponding to, in modern terms, the Kunda and Aseri Stages of the limestone succession and the zones of *Didymograptus bifidus* and *D. murchisoni* of the graptolitic succession. By STØRMER (1953) the boundary between the Kunda and Aseri Stages was compared with the base of the Middle Ordovician, and in the modern Russian literature (SOKOLOV 1953; ALICHOVA 1953, 1957; ALICHOVA *et al.* 1958; BALASHOVA & BALASHOV 1959; and others) a closely comparable level is considered as the boundary between the Lower and Middle Ordovician. In the most recent literature about the Estonian sequence the lower boundary

of the Viru Series (Middle Ordovician) is drawn in accordance with RAYMOND's suggestion (MÄNNIL 1958). The correlation of this level with the graptolitic succession is still not quite exact, but as an approximation it may be taken as comparable to the boundary between the zones of *Didymograptus bifidus* and *D. murchisoni* (cf. the Chapter on correlation).

It is recommended here to define the base of the Middle Ordovician of Europe as the boundary between the zones *Didymograptus bifidus* and *D. murchisoni*. This level has priority, and is now more extensively used in Europe and Asia as the boundary between the Lower and Middle Ordovician than any of the other levels. The correct, and the only available, name for the Middle Ordovician so defined is Viru Series (ÖPIK MS; LUHA 1940; JAANUSSON 1945; KALJO, RÕÕMUSOKS, & MÄNNIL 1958; MÄNNIL 1958), and for the Lower Ordovician Series, i.e. for the sequence between the Viru Series and the Cambrian System, Oeland Series[1] (KALJO, RÕÕMUSOKS, & MÄNNIL 1958; MÄNNIL 1958).

In Europe the Oeland Series falls by tradition into two well-defined divisions, here considered as subseries. The lower subseries is generally termed the Tremadocian, while the correct name for the upper subseries would be Arenigian. However, the term Arenigian can only be used, when either the upper boundary of the Oeland Series coincides with the lower boundary of the Llanvirnian, or when the upper boundary of the Arenigian is drawn according to the original definition of this unit in a chrono-stratigraphical sense (HICKS 1875), i.e. between the zones of *Didymograptus bifidus* and *D. murchisoni* (cf. also ELLES 1937). In the latter sense this term was in general use until Llanvirnian (HICKS 1881) became incorporated into the British standard section chiefly under the influence of ELLES' paper of 1922. Now the definition of Arenigian cannot be changed back to its original concept without an official British authorization, since confusion might otherwise arise from the contemporaneous existence of two different definitions of this term. As long as the upper boundary of the Oeland Series is defined as above (between the zones of *D. bifidus* and *D. murchisoni*), and the upper boundary of the Arenigian is currently drawn below the zone of *Didymograptus bifidus*, it is best to use the term Ontikan (KALJO, RÕÕMUSOKS, & MÄNNIL 1958; MÄNNIL 1958) for the upper subseries of the Oelandian.

The classification of the Ordovician System at the series level used in the present paper is summarized in the Table 1.

The boundaries between series must be defined in terms of the graptolitic sequence (JAANUSSON & STRACHAN 1954), if they are to be recognized outside the area of distribution of the shelly fauna distinctive for the unit in the type area. If later investigations would prove the present correlation between graptolite zones and divisions of the shelly sequence incorrect, a corresponding

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[1] The term Öland Group has been used in about the same chrono-stratigraphical sense (but excluding the *Dictyonema* Shale) by ANGELIN (1877, pp. 23–25). His definition of this group is, however, fairly vague.

Table 1. Adopted classification of the Ordovician System.

Series	Subseries	Graptolite zones
Harjuan (Upper)		*Dicellograptus anceps* *Pleurograptus linearis*
Viruan (Middle)		*Dicranograptus clingani* *Didymograptus murchisoni*
Oelandian (Lower)	Ontikan Tremadocian	*Didymograptus bifidus* *Dictyonema* of the *flabelliforme* group

adjustment of the level of the serial boundary ought to be made in the shelly sequence.

When the above was already written the writer had the opportunity to see a recent paper by Lu (1959). The proposed chrono-stratigraphic classification of the Ordovician sequence of China completely agrees with that adopted above. The Ichang, Neichiashan, and Chientangkiang Series are, as far as the present writer understands, the exact equivalents of the Oeland, Viru, and Harju Series, respectively, as defined in this paper. Indeed, the correlation seems to be so exact that it is questionable, whether in this case two different sets of names are advisable. The names used in the present paper evidently have priority.

CHRONO-STRATIGRAPHIC UNITS OF STAGE CATEGORY.—A compilation of a chrono-stratigraphic scheme applicable to the whole Baltoscandian limestone sequence of Ontikan and Lower Viruan age presents but few difficulties. There is a fairly general agreement on both sides of the Baltic on what constitutes a stage, and with some adjustments a uniform terminology is easily found. The stages of the Lower Viruan age (cf. Table 2) have been discussed by JAANUSSON (1960), and only the Ontikan stages need be considered here.

The ultimate aim in the chrono-stratigraphic classification of the sequence in question would be the applicability of stage names common to both the shelly and the graptolitic facies. Such a classification has been aimed at by TJERNVIK (1956) for the lowermost Ontikan beds of Sweden. However, the unconditional use of terms of stage category common to both facies is possible only if the boundaries of the graptolite zones coincide with those of the units of the shelly sequence. If the boundaries do not coincide, the subdivisions defined in each facies can be roughly correlated, but a name defined in one facies would be of little practical use in the other facies. THORSLUND (1948, p. 359) suggested the improbability that the graptolite succession should coincide in detail with

Table 2. Chrono-stratigraphic classification of the Lower Viruan limestone sequence.

Series	Chrono-stratigraphic units for the Baltoscandian limestone sequence used in the present paper		Units of stage category previously used in Sweden
	Stage		
Viruan	Tallinnan	Uhakuan	*Crassicauda* Limestone
		Lasnamägian	*Schroeteri* Limestone
	Aserian		*Platyurus* Limestone

the shelly facies. The factors which control the almost world-wide distribution of the pseudo-planctonic graptoloids are in part a priori somewhat different from those which influence the local benthonic faunas. The present paper gives some indications that at least in one portion of the Baltoscandian sequence the faunal units of different facies overlap. The level of a change in the graptolite fauna (the boundary between the zones of *Didymograptus murchisoni* and *Glyptograptus teretiusculus;* cf. the Chapter on correlation) probably falls within a sequence of limestones, where in the benthonic faunas no distinct change can be observed, and the extensive faunal change at the boundary between the Aseri and Lasnamägi Stages (Jaanusson 1945; Rõõmusoks 1956) has evidently no contemporaneous counterpart in the graptolitic sequence. Likewise the faunal change at the boundary between the *Nemagraptus gracilis* and *Diplograptus multidens* zones (Nilsson 1960) is at present not recognizable in the shelly sequence of Sweden.

It seems to be premature or even impossible at present to force at the stage level the graptolitic and shelly facies into one chrono-stratigraphic scheme. This does not apply to the classification at the series level, since in case of so large chrono-stratigraphic units the correlation can be considered exact enough to be usable in the practice.

In this connection it ought to be stressed that numerous mistakes have been made, and are probably still made, by assuming that the level of boundary between a zone with a shelly fauna lacking distinctive graptoloids and an underlying or overlying graptolite zone corresponds to the upper or lower boundary, respectively, of that graptolite zone. The correlation of British standard classification of the Ordovician with the British standard graptolite zones includes several such assumptions, and the exact correlation of units like Llandeilo or Caradoc outside the occurrence of the particular shelly fauna distinctive for these units is bound to be uncertain.

TJERNVIK (1956) classified the lowermost Ontikan of Sweden into two stages, termed the Hunneberg and the Billingen Stage ("Group"). He intended that these terms should be usable for both the shelly and the graptolitic facies, and accordingly the type areas were selected among those, where both facies alternate. However, the correspondance of the boundaries of the graptolite zones with those of the trilobite zones has not yet been conclusively proven (cf. also LINDSTRÖM 1957). On the other hand, the present writer feels that there exists a need for a common name for the beds which include both stages, and which corresponds to the term *Planilimbata* Limestone as used by earlier writers in Sweden. The term Latorp Stage is proposed here for the beds between the *Ceratopyge* Limestone and the zone of *Megistaspis* (*Megistaspis*) *lata* as typified by the Latorp section, Närke, described by TJERNVIK (1956, pp. 130–133). The Hunneberg and Billingen beds, as defined below, may be considered as substages of the Latorp Stage or as stages which may be united in the Latorp Superstage. In the present paper they are provisionally treated as substages, and defined in the shelly sequence according to TJERNVIK's use of these divisions in the Latorp section.

The correlation of the Hunneberg and Billingen Substages with the Estonian sequence has been given by TJERNVIK (1956, pp. 184–185), and JAANUSSON (1957a, pp. 151–155) has discussed the correlation of the whole Ontika Subseries on both sides of the Baltic. The Mäeküla beds ($B_I\beta$) of Estonia and Ingermanland are certainly of Latorpian age[1] as are the Päite beds (ORVIKU 1958) which contain the index fossil of the zone of *Megistaspis estonica*. The "*Limbata*" and *Lepidurus* Limestones of Sweden are of Volkhovian age, and this term can in a chrono-stratigraphic sense be used to advantage also in Sweden. The *Vaginatum* Limestone of Sweden corresponds to the Kunda Stage of the Estonian-Ingrian sequence.

In the Baltoscandian limestone sequence the Latorp Stage is characterized, among others, by the locally abundant occurrence of the *planilimbata* group of *Megistaspis* (and of *Megalaspides* and *Lannacus*), the Volkhov Stage by the subgenus *Megistaspis* (*Megistaspis*), and the Kunda Stage by the subgenus *Megist-*

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[1] BALASHOVA & BALASHOV (1959) have considered the occurrence of *Asaphellus* and *Protopliomerops* as evidence of the Tremadocian age of the Mäeküla beds. But *Ptychopyge* ? *inostrancefi* LAMANSKY is certainly not an *Asaphellus*, and "*Protopliomerops*" *ingricus* (FR. SCHMIDT) belongs to the genus *Pliomeroides* HARRINGTON & LEANZA, 1957. A species of the latter genus [*P. toernquisti* (HOLM)] occurs in the zone of *Megalaspides dalecarlicus* of the Siljan district. The general fauna of the Mäeküla beds with *Megalaspides*, *Megistaspis* of the *planilimbata* group, *Paurorthis*, *Panderina*, *Porambonites*, and *Antigonambonites*, is strongly suggestive of Billingenian age, and as these beds are overlain by limestones containing the index fossil of the zone of *Megistaspis estonica*, the correlation with the zone of *Megalaspides dalecarlicus* is at present more probable than with a part of the Hunnebergian Substage.

aspis (*Megistaspidella*) which, however, makes its appearance already in the uppermost Volkhovian ($B_{II}\gamma$).

The faunal development during the Ontikan Epoch has been so similar on both sides of the Baltic that also zones and substages are mostly identical. The three divisions of the Kunda Stage distinguished by LAMANSKY (1905) are here regarded as substages, and are easily recognizable in the limestone sequence of all Baltoscandian countries. The middle of these substages ($B_{III}\beta$) has been termed by ORVIKU (1958) the Valaste Substage (= "Raniceps" Limestone of Sweden) and the upper one ($B_{III}\gamma$), the Aluoja Substage. The correlation of the latter substage with the zones of *Megistaspis* (*Megistaspidella*) *obtusicauda* and *M.* (*Megistapidella*) *gigas* of Sweden (JAANUSSON & MUTVEI 1953; JAANUSSON 1957a) has been further supported by the report of the occurrence of *M.* (*Megistaspidella*) *obtusicauda* in the lower part of the Aluoja Substage in Estonia as well as in Ingermanland (BALASHOVA & BALASHOV 1959). The identification requires, however, further confirmation. For the lower substage ($B_{III}\alpha$) no name is available. For this substage here the name Hunderum Substage is proposed. The unit is called after the village of Hunderum, northern Öland, and as the type locality is regarded the Hagudden section (cf. BOHLIN 1949) within the area of this village. The beds with *Asaphus* (*Asaphus*) *lepidurus* have been called by ORVIKU (1958) the Langevoja Substage, and this name is applied here also to the corresponding part of the Scandinavian limestone sequence. The faunal succession of the remaining part of the Volkhov Stage is still poorly described in Sweden as well as in Estonia and Ingermanland, and further studies are needed before a well-founded chrono-stratigraphic subdivision can be established.

This paper describes and discusses material from both sides of the Baltic. It is the author's hope that the uniform chrono-stratigraphic classification of the limestone sequence proposed here (cf. Table 3) contributes to the clarity and brevity of stratigraphic discussions. The new terms used may seem numerous and strange, but will supposedly once become as self-evident as the old and accustomed terms are.

LITHO-STRATIGRAPHIC UNITS.—The litho-stratigraphic classification of Lower and Middle Viruan limestones of Sweden has been treated by JAANUSSON (1960). In the Ontikan limestones the introduction of one new name for a lithologic unit is needed for the purposes of the present paper.

KOMSTAD FORMATION (new name). Limestone formation in Scania between the Lower and Upper Didymograptus Shale. Type locality is the quarry W of and close to the highway in Komstad (as to details, cf. FUNKQUIST 1919, pp. 20–21). The formation has previously been called the *Orthoceras* or Orthoceratite Limestone which, however, is the term also for the whole limestone sequence of Ontikan and Lower Viruan age of the other districts of Sweden (cf. JAANUSSON 1958, pp. 270–272). The Komstad Limestone represents a thin

Table 3. Classification of Ontikan limestone sequence.

Series	Subseries	Chrono-stratigraphic units for the Baltoscandian limestone sequence used in the present paper		Estonia and Ingermanland (Leningrad district)	Sweden	
		Stage	Substage		Units of stage category previously used in Sweden	Trilobite zones
Oelandian	Ontikan	Kundan	Aluojan	$B_{III}\gamma$	*Vaginatum* Limestone	*Megistaspis gigas* *Megistaspis obtusicauda*
			Valastean	$B_{III}\beta$ Zone of *Asaphus raniceps*		*Asaphus raniceps*
			Hunderumian	$B_{III}\alpha$ Zone of *Asaphus expansus*		*Asaphus expansus*
		Volkhovian	Langevojan	$B_{II}\gamma$ Zone of *Asaphus lepidurus*	*Lepidurus* Limestone	*Asaphus lepidurus*
				$B_{II}\beta$ Vääna Limestone $B_{II}\alpha$ Saka Limestone	"*Limbata*" Limestone	? *Megistaspis lata*
		Latorpian	Billingenian	$B_{I}\gamma$ Päite Limestone $B_{I}\beta$ Mäeküla Limestone	*Planilimbata* Limestone	*Megistaspis estonica* *Megalaspides dalecarlicus*
			Hunnebergian	Hiatus		*Megistaspis planilimbata* *Megistaspis armata*

tongue of the latter group of limestones. The main part of the formation is probably of Langevojan age, but the faunal succession is not yet studied in detail, and the exact limits of the formation in terms of chrono-stratigraphic units are therefore unknown.

GRAPTOLITE ZONES.—Many of the graptolite zones have a wide spatial distribution, and a uniform terminology for identical or closely similar assemblages is highly desirable. Through the fundamental work of LAPWORTH and subsequent British writers most of the British Ordovician standard graptolite zones are well defined and extensively used as a kind of international standard reference for the classification of the Ordovician rocks at the stage level. In the present writer's opinion the use of different names outside the British Isles for exactly the same or closely comparable zones ought to be discouraged provided that there is no serious objection against the definition of the corresponding British standard graptolite zone or that the local faunal development can be proved not to be conspicuously different from that in the type region of this zone on the British Isles.

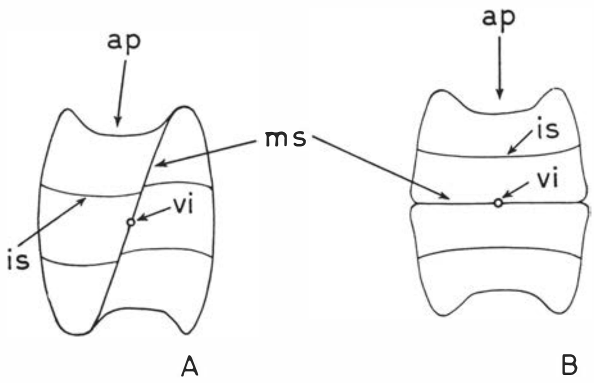
Table 4.

Terms used in the present paper	Terms used for the Scanian graptolitic sequence by EKSTRÖM (1937) and HEDE (1951)
Zone of *Nemagraptus gracilis*	Zone of *Nemagraptus gracilis*
Zone of *Glyptograptus teretiusculus*	Zone of *Climacograptus putillus* (=*C. haddingi*) Zone of *Glossograptus hincksi* or *Diplograptus (= Gymnogr.) linnarssoni*
Zone of *Didymograptus murchisoni*	Zone of *Didymograptus clavulus* Zone of *Pterograptus elegans*
Zone of *Didymograptus bifidus*	Zone of *Didymograptus bifidus*

In Scania EKSTRÖM (1937) subdivided the beds which were previously included in the zone of *Didymograptus geminus* (LINNARSSON 1879) into two separate zones, viz. the zone of *Pterograptus elegans* and the zone of *Didymograptus clavulus*. As evident from the range of species within this part of the sequence in Scania (EKSTRÖM 1937; HEDE 1951) the faunal differences between EKSTRÖM's zones are slight and concern only a few species. Both zones together are in Scania, as on British Isles, characterized by *Didymograptus murchisoni*, *D. geminus*, and their "varieties". For the sake of uniformity it seems better to include these beds also in Scania in the zone of *D. murchisoni*, and to regard EKSTRÖM's zones as subzones. This terminology is used in the present paper.

In Scania the beds between the zones of *Didymograptus murchisoni* and *Nemagraptus gracilis* have been commonly included in two separate zones. The lower zone has been called the zone of *Glossograptus hincksi* or the zone of *Diplograptus* (=*Gymnograptus*) *linnarssoni*, and the upper zone the zone of *Climacograptus putillus* or, more correctly, *C. haddingi*. Here again the faunal differences between these zones are slight, and no species is known to be restricted to the lower zone. JAANUSSON & STRACHAN (1954) included these zones as subzones in one single zone to which they applied the name, zone of *Glyptograptus teretiusculus*, of the corresponding zone of the standard British classification. This term is used in the same sense also in the present paper. *Glyptograptus teretiusculus* has a wide range, and hence is not without objections as a name for this zone, but neither is any other species of the assemblage of this zone a quite satisfactory "index fossil".

A comparison of the current terms of the Scanian graptolitic sequence with those used in the present paper is given in Table 4.



Text-fig. 1. Diagrammatic cross-sections of rhabdosomes to illustrate the difference between monopleural (A) and dipleural (B) arrangement of thecae in biserial graptoloids. *ap*, thecal aperture; *is*, interthecal septum; *ms*, median septum; *vi*, virgula.

Notes on Terminology and Morphology

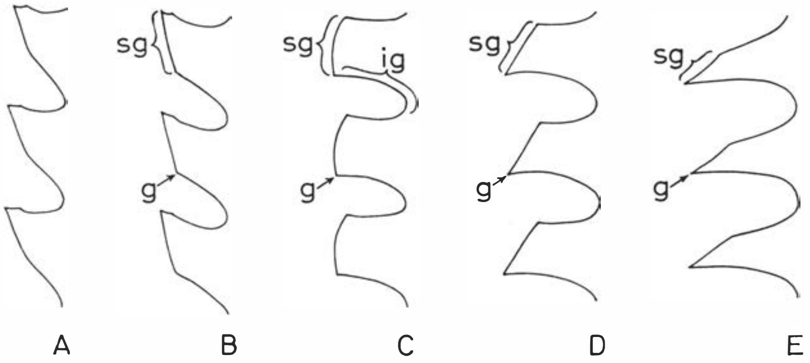
The terminology used in the present paper is that summarized by BULMAN (1955). For the sake of clarity some additions are, however, proposed. In biserial graptoloids the whole rhabdosome may be termed stipe (BULMAN 1955, p. V 7), but the same term is also occasionally applied to only one row of thecae (cf. e.g. BULMAN 1955, p. V 81). Here the term stipe is provisionally confined to only one row of thecae in biserial graptoloids, both rows together being termed rhabdosome. Such usage would best agree with the use of these terms in uniserial graptoloids.

Among biserial graptoloids two different types of arrangement of the stipes occur, viz. one in which the stipes are in contact back to back (biserial *Didymograptina* and *Diplograptina*) and the other with the stipes in contact side by side (*Glossograptidae*). The descriptions and discussions become shorter and easier, if each of these types is designated by a special term. For the type of biserial graptoloid rhabdosome, where the stipes are in contact back to back the term *dipleural*, and for the rhabdosome with side by side arrangement of thecae the term *monopleural* is here proposed (text-fig. 1). The terms refer to the fact that in the dipleural rhabdosome both lateral walls of the stipes are visible externally, but only one in the monopleural rhabdosome.

The abbreviation (*tr*). indicates the direction transverse, and (*long.*) that parallel to the axis of the stipe, respectively.

As *dicalycal theca* (from Greek: ϰαλυξ, bud) is designated the theca which gives rise to a double bud. In *Didymograptus bifidus* th 1^1 is dicalycal, in *Isograptus gibberulus* th 1^2, in *Glyptograptus dentatus* th 2^1, etc.

Within *Diplograptidae* the following types of thecae have lately been distinguished: orthograptid, glyptograptid, climacograptid, and amplexograptid (cf. BULMAN 1955, pp. V 85–V 87, diagnoses of genera). The theca of orthograptid type are similar to those of dichograptid type, being simple straight tubes as in *Orthograptus gracilis* (ROEMER). The glyptograptid type includes thecae with gently sigmoidal curvature but without well-defined geniculation, whereas



Text-fig. 2. Diagrammatic drawings of distal portions of thecae in diplograptids to illustrate the different types of thecae. A, glyptograptid type; B, unnamed type; C, climacograptid type; D, lasiograptid type; E, gymnograptid type. *g*, geniculum; *ig*, infragenicular part of the free ventral wall; *sg*, supragenicular part of the free ventral wall.

the climacograptid type of thecae have a sharply angular geniculation. The exact meaning of the amplexograptid type is not clear, the specimens illustrated by BULMAN (1938a, fig. 19 k; 1955, fig. 31:8) as *Amplexograptus* belonging in the present writer's opinion to *Pseudoclimacograptus*, while details of the shape of thecae in the type species of *Amplexograptus* are unknown.

The morphological line from the orthograptid type of thecae to thecae of climacograptid type is well documented. There exist all possible transitions between these extremes. The change of the former type towards the latter type involves increasing convexity of the free ventral wall until a distinct geniculation develops. The bend, here termed *geniculum* (cf. text-fig. 2), defines a proximal part of the free ventral wall that faces the aperture of the preceding theca continuing proximally into the interthecal septum, and a distal part between the apertural margin and the geniculum. Here the proximal part of the free ventral wall is termed *infragenicular wall*, and the distal part *supragenicular wall* (cf. text-fig. 2). In the simplest type of geniculate theca the supragenicular wall is inclined in dorsal and proximal direction (as in *Diplograptus leptotheca*, BULMAN 1946, Pl. VI, fig. 11). A satisfactory name for this type of theca is difficult to find, since the generic reference of forms which such thecae is at present uncertain. Further development involved a successively steeper position of the supragenicular wall until this portion of the free ventral wall was directed parallel to the axis of the rhabdosome as in climacograptids.

The material described in the present paper shows a continuation of the morphological line of thecae starting from the climacograptid type. A successive inclination of the supragenicular wall in distal and dorsal direction resulted in the *lasiograptid type*. It is interesting to note that some specimens of both *Pseudoclimacograptus eurystoma* n. sp. and *Lasiograptus haplus* n. sp. show a tendency towards the lasiograptid or climacograptid type of thecae, respectively. Further inclination of the supragenicular wall towards the horizontal position has lead to the *gymnograptid type*. In the latter the supragenicular wall forms in lateral view roughly a continuation of the apertural margin with only a slight change in curvature indicating the real ventral boundary of the thecal aperture. In *Gymnograptus* the proximal thecae are still of lasiograptid type, while in distal direction the supragenicular wall becomes shorter and successively more and more inclined towards the horizontal plane. In lateral view it is difficult to draw the boundary between the lateral margin of the thecal aperture and the supragenicular wall, especially in compressed specimens. An elaborated gymnograptid type of thecae is present in *Hallograptus ? hystrix*.

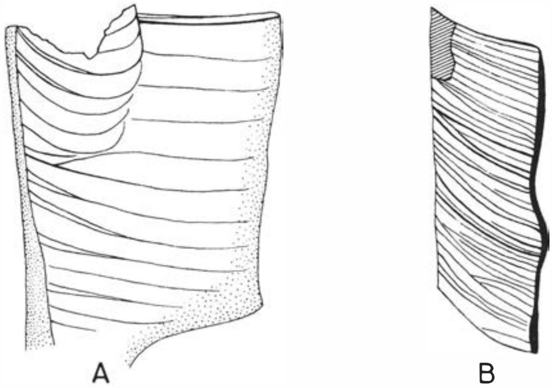
In lateral view the gymnograptid type of thecae resembles the orthograptid type, and has been referred to as such (BULMAN 1953, p. 515, 1955, p. V 87). However, the gymnograptid type evidently forms a terminal or subterminal member of a long morphological series. It is possible that a further development of the gymnograptid type of thecae may have lead to a shortening of the supragenicular wall until its disappearance, and in this case it may be difficult to distinguish the resulting shape of the thecae from a primarily orthograptid type.

The thecal spine that originates from the geniculum is termed here *genicular spine*, and the spine arising from the apertural margin the *apertural spine*.

It has generally been assumed that in biserial graptoloids without, or with incomplete, median septum the development of thecae has been alternate along the whole length of the rhabdosome or until the begin of the chitinized septum, respectively. This is undoubtedly true in many cases, and can be proved by the arrangement of the fuselli. However, the existence of several otherwise closely similar species which differ by the presence or absence of a median septum casts some doubt upon the universal validity of this assumption. Mere absence of a periderm of the median septum does not necessarily signify the absence of any partition between the stipes. The stipes may have been separated by a membrane of soft tissues without formation of a periderm. There are indications that the latter interpretation may be applicable to some forms.

Gymnograptus linnarssoni has stout rods of the median septum of the same type as in at least most species of *Pseudoclimacograptus*. But none of the examined specimens, except one, shows any trace of a periderm between the rods, and they evidently lacked this periderm. In one specimen (cf. the description of the species) the periderm is developed between two of the rods, but not between others. The available evidence suggests that in *G. linnarssoni* the stipes were separated, although no periderm of the median septum is as a rule developed (cf. also URBANEK 1959). URBANEK (1959) has proposed the term cryptoseptate for the condition of stipes that are separated, but without septal periderm.

The species of *Glyptograptus* described in the present paper seem to have some bearing on the above subject. *Glyptograptus cernuus* n. sp. has a low septal list upon the inside of the rhabdosome, but none of the examined specimens shows any periderm connecting this list with the virgula. The material is strongly carbonized, and no transparencies are available, but the succession of



Text-fig. 3. *Climacograptus kuckersianus* WIMAN. A, fuselli of a metatheca and the protheca of the succeeding theca. B, fuselli in the median septum. Both × 80.

thecae suggests two separate stipes. *Glyptograptus vikarbyensis* n. sp. also lacks a periderm of the median septum, but again the arrangement of thecae suggests cryptoseptate conditions.

The formation of the median septum is still poorly known as are details of its morphology. In *Climacograptus kuckersianus* the fuselli of the median septum are much more closely spaced than in the corresponding metathecae (text-fig. 3). This applies to all transparencies studied of this species. On account of strong carbonization the material available of other species is inconclusive in this respect.

Remarks on the Classification of Graptoloids

A classification of graptoloids at the order-group level may seem premature, since very little is known about the detailed morphology of many families. On the other hand, there exists always the need to find the current knowledge about the relationships within a large group expressed also in the taxonomic subdivision of this group. This dilemma is common to all groups of extinct invertebrates, the graptoloids forming no exception.

In the last twenty years the subdivision of *Graptoloidea* into two groups of order category *Axonolipa* and *Axonophora* (FRECH 1897) as emended by RUEDEMANN (1904) has been abandoned by most writers, although a few still continue to use it. BULMAN (1938a, p. D 26; 1955, p. V 44) stated that no hard and fast line can be drawn between these two groups, and for this reason dropped them. Most of the subsequent writers have followed BULMAN in this respect.

A new classification of the graptoloids on the order group level has recently been proposed by OBUT (1957). He subdivided the class *Graptoloidea* into the following order group taxa:

Order *Axonolipa* FRECH, 1897, emend. RUEDEMANN, 1908, 1947
    Suborder *Dichograptina* subordo nov.
    Suborder *Leptograptina* subordo nov.

Order *Axonophora* FRECH, 1897, emend. RUEDEMANN, 1908, 1947
Suborder *Diplograptina* subordo nov.
Suborder *Monograptina* subordo nov.

OBUT's suborders correspond exactly to LAPWORTH's (1880, pp. 191–192) groups *Didymograpta*, *Dicellograpta*, *Diplograpta*, and *Monograpta*, and thus LAPWORTH has to be considered as the author of these taxa[1]. However, this classification does not seem satisfactorily to express the phylogenetic and morphological relationships within the *Graptoloidea.*

BULMAN (1945, p. 23) has stressed the isolated position of the *Corynoididae* (*nom. correct.* BULMAN, 1945; *ex Corynoideae* RUEDEMANN, 1908) within the *Graptoloidea.* Primitive features in the morphology of this family have been underlined by KOZŁOWSKI (1953). As pointed out by him (p. 208) there is no serious evidence suggesting the inclusion of *Corynoididae* in a separate order equal to *Graptoloidea* and *Dendroidea* as proposed by some earlier writers. Their general features are of graptoloid character but, in the present writers opinion, the morphological discontinuity between *Corynoididae* and the other graptoloids is so sharp that the inclusion of this family in a separate suborder, *Corynoidina* (*nom. correct.* herein, *ex Corynoidea* HOPKINSON & LAPWORTH, 1875), seems to be well justified.

Dichograptids and LAPWORTH's group *Dicellograpta* are evidently closely related and derivation of the simple forms of the latter from extensiform *Didymograptus*-stock presents few difficulties (BULMAN 1955, p. V 71), although transitional types between the dichograptid sicula with a ventral virgelloid process and the dicranograptid sicula with a true virgella do not seem to be known. The known differences between *Didymograpta* and *Dicellograpta* hardly justify their separation into two different order-group taxa.

Previously diplograptids were often thought developed via proximally biserial but axonolipous dicranograptids, and the actual difficulty in drawing a hard and fast limit between *Axonolipa* and *Axonophora* evidently was the supposed absence of an important morphological and phylogenetical discontinuity between diplograptids and dicranograptids. BULMAN's detailed studies have, however, shown that the derivation of diplograptids via *Dicranograptus* is hardly tenable. The origin of diplograptids and related biserial forms is cryptogenetic, and still an unsolved problem (BULMAN 1947, p. X; 1954, p. 211; 1955, p. V 72; 1958a, p. 161; 1958b, p. 28).

BULMAN (1955, p. V 74) has given a useful survey about the probable origin of monograptids. At the present state of our knowledge the morphological similarity of diplograptids and monograptids indicates a close relationship, and their separation into different order-group taxa seems to be out of proportion.

A virgula exists also in glossograptids. The only morphologically well-known

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[1] It should also be noted that a nomenclaturally correct name for the unit called by OBUT (1957) Class *Stereostolonata* nom. nov. seems to be *Cladophora* HOPKINSON (in HOPKINSON & LAPWORTH 1875, pp. 633–634).

form of this group, *Cryptograptus* (BULMAN 1938b; 1945, pp. 29–36), shows the almost simplest possible development of proximal thecae. According to BULMAN (1938b; 1947, pp. IV–V; 1955, p. V 71) glossograptids have evolved from dichograptids quite independently from the other axonophorous forms. This would imply the formation of a virgula on at least two separate occasions during the phylogenetic development of graptoloids. BULMAN's suggestion of independent origin of glossograptids and diplograptids is based on the obvious fact that there exists no known biserial form which would bridge the *bifidus* stage of the proximal end of *Cryptograptus* and the diplograptid type of proximal development with at least four alternating thecae.

Thus glossograptids are separated from the other axonophorous forms by a considerable morphological discontinuity which is expressed not only by the widely different stage of the development of proximal thecae but also by different orientation of the stipes in the rhabdosome. Glossograptids have, in terms proposed in the present paper, a monopleural biserial rhabdosome with the rows of thecae in lateral contact, whereas in the other biserial axonophorous graptoloids the rhabdosome is dipleural with the rows of thecae arranged back to back. So even if the glossograptids be considered as being close to the ancestor of the axonophorous graptoloids, they are removed so far from the main stem of *Axonophora* that the relationship is not obvious, and at the present state of our knowledge not conclusively demonstrable. For this reason the inclusion of the glossograptids in a separate taxonomic subdivision equal to the total of other axonophorous graptoloids seems to be more in agreement with the known facts than their treatment as one of several axonophorous groups of equal rank.

A subdivision of *Graptoloidea* in four main groups seems to be the classification which is best in accordance with the present phylogenetic conceptions and known morphological facts. These groups obviously represent order group categories, and are treated here as suborders. The names for these suborders are formed in accordance with the general practice employed in the Treatise on Invertebrate Paleontology. The proposed classification is as follows:

Order *Graptoloidea* LAPWORTH, 1875
  Suborder *Didymograptina* LAPWORTH, 1880, emended
    Family *Dichograptidae* LAPWORTH, 1873
      Nemagraptidae LAPWORTH, 1873
      Dicranograptidae LAPWORTH, 1873
      Abrograptidae MU, 1958
  Suborder *Corynoidina* HOPKINSON & LAPWORTH, 1875
    Family *Corynoididae* RUEDEMANN, 1908
  Suborder *Glossograptina* nov.
    Family *Glossograptidae* LAPWORTH, 1873
  Suborder *Diplograptina* LAPWORTH, 1880, emended
    Family *Diplograptidae* LAPWORTH, 1873

Retiolitidae LAPWORTH, 1873
Dimorphograptidae ELLES & WOOD, 1908
Monograptidae LAPWORTH, 1873

The differences in the classification and nomenclature of the family group categories between the above list and the current classification (BULMAN 1955) are explained in the proper places of the following text.

The groups distinguished by LAPWORTH (1880) and OBUT (1957) may be useful at the superfamily level. This is true with regard to *Dichograptacea* and *Dicranograptacea* within the *Didymograptina*, whereas the subdivision of *Diplograptina* into *Diplograptacea* and *Monograptacea* does not seem quite as satisfactory. For the purposes of the present paper the superfamilies are not needed.

Systematic Description

Suborder *Didymograptina* LAPWORTH, 1880, emended

[*Nom. correct.* JAANUSSON, herein (*ex Didymograpta* LAPWORTH, 1880)] (=*Didymograpta* + *Dicellograpta* LAPWORTH, 1880; *Dichograptina* + *Leptograptina* OBUT, 1957).

DIAGNOSIS.—Uniserial, rarely biserial and dipleural, or quadriserial graptoloids without virgula, but with more than four thecae in full-grown rhabdosomes.

FAMILIES.—*Dichograptidae* LAPWORTH, 1873
Nemagraptidae LAPWORTH, 1873
Dicranograptidae LAPWORTH, 1873
Abrograptidae MU, 1958

It is possible that *Didymograptidae* TÖRNQUIST, 1890 (syn. *Apotograptidae* HARRIS, 1926, *Isograptidae* HARRIS, 1933, *Azygograptidae* MU, 1950, and *Sinograptidae* MU, 1957) ought to be separated from *Dichograptidae* (syn. *Phyllograptidae* LAPWORTH, 1873 and *Tetragraptidae* MU, 1950). *Nemagraptidae* LAPWORTH, 1873 (syn. *Coenograptidae* RUEDEMANN, 1904) has priority over *Leptograptidae* LAPWORTH, 1879, and as long as *Nemagraptus* and *Leptograptus* are included in one family the nomenclaturally correct name of this family is *Nemagraptidae*.

OCCURRENCE.—The suborder *Didymograptina* is exclusively Ordovician. The earliest forms have been recorded from the Upper Tremadocian strata, and the latest species have been found close to the top of the Ordovician.

Family *Dichograptidae* LAPWORTH, 1873

Genus *Didymograptus* M'COY in SEDGWICK & M'COY, 1851

Didymograptus cf. *murchisoni murchisoni* (BECK, 1839)

Pl. V, figs. 2–3.

1890 *Didymograptus* — MOBERG, p. 16.
1911 *Didymograptus geminus* (HIS.) — MOBERG, p. 85.

DESCRIPTION.—The available material consists of numerous fragments of stipes, the largest (Pl. V, fig. 2) 21 mm long and with the distal end preserved. The maximum width of the latter stipe 3.2 mm, minimum width at the proximal termination 2.7 mm; 14 thecae in 10 mm, inclined at an angle of 35–45°, overlapping $\frac{3}{4}$ to $\frac{4}{5}$ of their length.

DISCUSSION.—The above stipes belong to a species related to, or identical with, *D. murchisoni murchisoni*. The maximum width of the stipe, which would be somewhat greater if the specimen were flattened, falls outside that prevailing in *D. geminus geminus*. The considerable minimum width of the largest stipe indicates either a rhabdosome of considerable length or a very rapid increase in the width of the stipe. Even in the latter case the ordinary length of the rhabdosome would considerably exceed that of *D. geminus latus* (1.5 to 2 cm, cf. EKSTRÖM 1937). The distal part is curved slightly inwards as in *D. murchisoni murchisoni*, and not outwards as usual in *D. geminus geminus* and *D. geminus latus*. The above fragments are scarcely specifically determinable, but the observable characters seem to indicate that they may belong to *D. murchisoni*.

OCCURRENCE.—The largest fragment of the stipe is the specimen mentioned by MOBERG (1890, p. 16) as a probably specifically determinable fragment of *Didymograptus* from the lowermost beds of the grey *Centaurus* (=*Schroeteri*) limestone (=Seby or lowermost Folkeslunda Limestone). In the subsequent literature the specimen has commonly been referred to as *D. geminus*, and has formed the evidence for the previous correlation of the *Schroeteri* (*Centaurus*) limestone with the zone of *D. geminus* (MOBERG 1911; BULMAN 1936; and others). MOBERG's material has been found in a grey calcarenite E of and close to Skärlövs bridge, Hulterstad parish, Öland, and is associated with *Climacograptus distichus* (EICHW.) and a thoracic segment of an asaphid probably belonging to *Pseudoasaphus aciculatus* (ANG.). Further fragments of rhabdosomes (including fragmentary proximal ends) have been encountered in an exposure of the Seby Limestone c. 500 m E of the northernmost house of the village of Seby (cf. JAANUSSON 1960 for the associated fauna).

Didymograptus pakrianus n. sp.

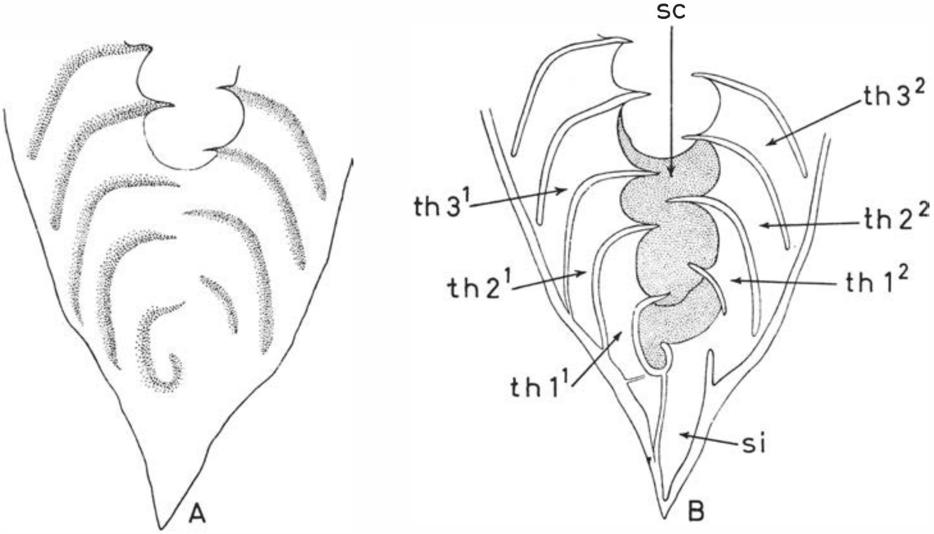
Pl. I, figs. 1–8; Pl. III, figs. 1–5; text-fig. 4.

1958 *Didymograptus bifidus* (J. HALL) — OBUT, p. 14.

HOLOTYPE.—Rhabdosome RM No. Cn 54569, figured on Pl. I, fig. 1.

TYPE STRATUM AND LOCALITY.—Estonia, Isle of Väike Pakri. Pakri calcareous sandstone, Valastean ($B_{III}\beta$) or Aluojan ($B_{III}\gamma$) Substage.

DIAGNOSIS.—A species of the pendent group of *Didymograptus* distinguished by complete lack of free ventral wall of thecae along the whole length of the stipe. Fullgrown rhabdosomes more than 6 cm long with the maximum width of the stipe about 2 mm; 15–17 thecae in 10 mm. Proximal end robust on account of secondary outgrowth of peridermal tissue between the stipes.



Text-fig. 4. *Didymograptus pakrianus* n.sp. A, diagrammatic drawing of the external side of the specimen figured in fig. B. B, diagrammatic drawing of a proximal portion of an old rhabdosome showing internal view of the reverse side (cf. Pl. I, fig. 6) to illustrate the extension of secondary cortical outgrowth (*sc*) between the stipes. *si*, sicula. Note that the interthecal septae between th 1^1 and 2^1 and between 2^1 and 3^1 extend to the dorsal wall of the rhabdosome without leaving any space for a common canal (this is not evident from the strongly retouched photograph on Pl. I, fig. 6). Ca. × 16.

DESCRIPTION.—The longest available rhabdosome (RM No. Cn. 54580) is 61 mm long, but the distal end is still incomplete. Stipes widen slowly and gradually being commonly parallel-sided or nearly so; their dorsal margin straight or with a slight inward curvature. The angle of divergence between the distal parts of the stipes varies within fairly wide limits: in many specimens they are parallel, in others continuously divergent with all intermediary stages between the extremes (cf. below). The longest available stipes have a maximum width of 2 mm. 15–17 thecae in 10 mm, somewhat more numerous in a given unit of length in the proximal and less numerous in the distal part of the stipes; inclined to the axis at an angle of 45–50°. In side view the margin of the thecal apertures is slightly concave, and extends from the base of the apertural process to that of the succeeding theca, no free ventral wall being formed. The apertural processes are disc-like, orientated perpendicular to the axis of the stipe, semicircular, 0.3–0.4 mm long, and with rounded external margin.

The proximal portion of the rhabdosome is robust in all specimens. HOLM's excellent dissections show that this is due to a secondary outgrowth of peridermal tissue which, in lateral view, covers, and completely conceals sicula and three to four proximal thecae of both stipes, uniting the proximal parts of the stipes into a stout proximal portion of the rhabdosome (Pl. I, figs. 5, 6). This evidently imparts to the rhabdosome a greater mechanical resistence in a region, where the stipes are narrowest and consequently weakest. In the specimen

No. Cn 54568 the periderm is 0.07–0.08 mm thick in the proximal part of the stipe, and 0.1 mm thick around the sicula. In small rhabdosomes, like that figured on Pl. I, fig. 4, the periderm of the roughly corresponding portion of the stipe is only 0.04–0.05 mm thick. The thickened periderm is conspicuously laminated, and obviously formed by the cortical tissue. This outgrowth beyond the thecae had taken place at, or slightly below, the level of the apertural margin of the sicula and the proximal thecae, and has proceeded in distal direction (text-fig. 4). Distally the sicula and the proximal thecae had a free outward communication through the slit between the two blades of the secondary outgrowth. This slit is open in all specimens except Nos. Cn. 54570 and 54544. In the latter most of the slit is covered by a transverse sheet of periderm leaving open only a perfectly rounded opening more or less along the axis of the sicula. The meaning of this transverse connection is not clear. There is no evidence that such transverse cover had existed also in other specimens but has subsequently been broken off.

The material shows that already at a length of the rhabdosome of 15.5 mm (Nos. Cn. 54552 and 54608) the aperture of the sicula and that of two proximal thecae (1^1 and 1^2) are concealed by the outgrowth of secondary tissue; even one of the next distal thecae is partly covered. Thus the formation of the secondary cover has begun very early in the astogeny of the species, long before each stipe contained 26–27 thecae. During subsequent astogenetic development the secondary cover expanded in distal direction, and the whole proximal part of the rhabdosome became more robust by deposition of new laminae of cortical tissue upon the external side of the rhabdosome.

The origin of the stipes is fairly symmetrical, and the development of the proximal thecae is, as far as can be made out, of *bifidus* stage.

INDIVIDUAL VARIATION.—The available material shows a fairly considerable individual variation of certain characters, such as the angle of divergence of the stipes and the width of the stipes. Stipes of most of the specimens are more or less parallel (Pl. I, fig. 3), but some diverge fairly conspicuously (Pl. I, fig. 1; Pl. III, fig. 1). Both extremes are linked by intermediary stages. All specimens possess the same construction of the proximal end, and have identical thecal characters including the lack of a free ventral wall and the shape of apertural process. The material gives the impression of belonging to one chronodeme (SYLVESTER-BRADLEY 1951) with a pronounced variability of the angle of divergence of the stipes.

The variability of the width of the stipes is apparently a function of the age of the rhabdosome. Since only two complete rhabdosomes are available (Nos. Cn. 54552 and 54608) the relative age of the rhabdosomes cannot be determined from their length. However, as the secondary cover between the proximal part of the stipes evidently expands in distal direction during the growth of the rhabdosome, the length of the proximal part, from the proximal end of the sicula to the distal margin of the secondary cover, may be taken as a measure of

Table 5. Dimensions of *Didymograptus pakrianus* n. sp. in mm.

RM Mus. Nos.	Length of the rhabdosome	No. of thecae in 10 mm.	Length of the proximal portion	Width of the stipe			Distance between the dorsal margins of stipes, 10 mm from the sicula	Remarks
				In front of the proximal portion	10 mm from sicula	Maximum		
Cn. 54552	15.5	16½–17	1.7	0.5	0.9	1.0	4.0	Pl. III, fig. 2
Cn. 54608	15.5	17½	1.1 +	0.55	1.05	1.1	4.15	Pl. I, fig. 3
Cn. 54544	18 +	17	1.9	0.65	1.0	1.1 +	6.1	Pl. III, fig. 1
Cn. 54570	13.5 +	16	1.55 +	0.65	1.05	1.05 +	5.8	Pl. I, fig. 4
Cn. 54569	14 +	16	2.25	0.85	1.2	1.25 +	6.5	Pl. I, fig. 1
Cn. 54575	25 +	16	—	0.9	—	1.9 +	—	Pl. I, fig. 8
Cn. 54581	8.3 +	—	3.0	1.0	—	1.0 +	—	Pl. III, fig. 5
Cn. 54547	47 +	15–16½	—	1.1	1.25	1.9 +	—	Pl. III, fig. 4
Cn. 54553	7 +	—	2.75	1.1	—	—	—	
Cn. 54568	14 +	16	2.75	1.1	1.35	—	—	Pl. I, fig. 6
Cn. 54578	15.5 +	16	—	1.2	1.2	1.4 +	—	
Cn. 54577	3.7 +	—	2.95	1.1	—	—	—	
Cn. 54556	12.5 +	16	2.95 +	1.25	1.3	1.3 +	5.4	Pl. III, fig. 3
Cn. 54580	61 +	15.5	—	—	—	2.0	—	

the age of the rhabdosome. A comparison of the length of the proximal part of the rhabdosome with the proximal width of the stipe (cf. Table 5) shows a close connection between these values: specimens with relatively short proximal part tend to have narrow stipes, and increase of the length of the proximal end is a rule accompanied by widening of the stipe. Thus during the astogenetic development of the rhabdosome the thecae continue to grow in length probably until an upper limit is attained that according to the longest available rhabdosome (61 mm) equals 1.5 mm in the proximal part and at least 2 mm distally. The more or less fullgrown rhabdosomes have a width of the stipes that is thrice the width of a rhabdosome of a length of 15 mm. A continued longitudinal growth of thecae has been established in the monograptid genus *Saetograptus* by URBANEK (1958, pp. 59–60). If the gradual increase in length of the thecae during the astogenetic development is a fact, the width of the stipes should be used only with the utmost hesitation, if not correlated with the length of the rhabdosome, as a diagnostic character for defining species of didymograptids. Secondary changes in the shape of the proximal part of the rhabdosome, described above, also invite to caution in interpreting small differences in the length of proximal thecae as specific characters.

From the literature one easily gets the impression that in dealing with the taxonomy of species of *Didymograptus* extreme variants within a single chronodeme are often treated as subspecies or even species. Different species are often stated to be connected by contemporaneous intermediary "transients". The term transient is then usually employed not in the sense given to this term by BATHER (1927, as a substitute for "mutation" of WAAGEN 1869), but for denoting specimens which are morphologically intermediate between contemporaneous species or varieties within the same area. It is hoped that further studies on *Didymograptus* will include exact dimensions of different numerical characters of the whole material treated, and that not only specimens considered as "typical" for one or other species-group taxon will be selected for measuring. Difficulties with flattened material are probably great, but even then exact dimensions of the examined specimens give more information than the usual data on what is considered as limits of individual variability of the taxon treated.

DISCUSSION.—The species described differs from the other known species of pendent *Didymograptus* by the lack of a free ventral wall. It resembles *D. murchisoni murchisoni* in the great length of the slowly and gradually widening stipes, the number of thecae in a given unit of length, and the general shape of the stipes. *Didymograptus bifidus*, at least the Scanian material identified as such, tends to have a relatively shorter free ventral margin of thecae than *D. murchisoni*, and is in this respect closer to *D. pakrianus*. But the rhabdosome of *D. bifidus* is generally much shorter than that of the latter species.

OCCURRENCE.—See type stratum and locality.

Didymograptus ? sp. A

Pl. I, fig. 9.

Only one specimen of this peculiar type has been found. It agrees with *D. pakrianus* in all details of the shape of the proximal region and of the characters of stipes and thecae. The proximal region is robust, 3.5 mm long, the sicula and proximal thecae being concealed by a cover of secondary outgrowth of thick, distinctly laminated periderm. 8 to 8½ thecae in 5 mm (corresponding to 16–17 thecae in 10 mm), inclined to the axis of the stipe at an angle of c. 40–45°. Proximal width of the stipes slightly more than 1 mm. No free ventral wall of the thecae, shape and direction of apertural processes as in *D. pakrianus*. The described specimen differs from the latter species only by having three stipes instead of two. The third stipe originates from one of the first-order stipes somewhere in the proximal region. Its origin cannot be traced, the proximal part being concealed by the secondary cover of thickened periderm. The whole proximal region of the specimen is somewhat flattened, and also dissections proved unsuccessful. The thecae of the third stipe are directed at an angle of c. 60° to the plane of its parent stipe. Also the sagittal planes of the main stipes are somewhat twisted in relation to each other, and to the proximal region.

The very close correspondance in all details except the number of stipes between the specimen described and *D. pakrianus* produces the impression that the former specimen is simply an abnormal rhabdosome of the latter species. However, the considerable development of the secondary peridermal cover around the proximal region proves that the rhabdosome had attained a considerable length fully comparable to that of some of the largest available specimens of *D. pakrianus*. Thus the third stipe, whether abnormal or not, had certainly not been any obstacle to a successful existence of the colony. The general appearance of the rhabdosome with the proximal part of the third stipe slightly curved relative to the plane of symmetry formed by the sagittal plane of thecae of first-order stipes very much reminds of the three-stiped *Pendeograptus fruticosus*. Whether the described specimen is a *Pendeograptus* or an abnormal *D. pakrianus* cannot be decided without examination of further material of this peculiar form.

OCCURRENCE.—As in *D. pakrianus*.

Didymograptus cf. ***artus*** ELLES et WOOD, 1901

Pl. I, figs. 10–11.

DESCRIPTION OF THE PAKRI MATERIAL.—The largest available rhabdosome (RM No. Cn. 54545) is 12.7 mm long, but the distal end is incomplete. Only one specimen (Cn. 54580), 12.5 mm long, seems to have the distal end preserved. Stipes widen fairly conspicuously from an initially 0.3–0.4 mm to a maximum of 1.0 mm. The angle of divergence of the stipes shows about the same variability as in *D. pakrianus*, most of the stipes being divergent, some parallel, and some others nearly parallel. Beyond the proximal region the dorsal margin of the stipes is straight, or shows a slight inward curvature. 8.5 to 9 thecae in 5 mm (17–18 in 10 mm), inclined to the axis at an angle of 45–55°. Overlap $\frac{1}{2}$ in the proximal part and usually $\frac{2}{3}$ in the distal part; in some specimens the overlap becomes distally still greater ($\frac{3}{4}$ to $\frac{4}{5}$). The apertural margin is slightly concave in lateral view, and extended into a flattened process which in proximal thecae follows the direction of the axis of the theca. Towards the distal end of the stipe, however, it bends successively more and more inwards, and is close to the distal end of the stipe in some specimens directed perpendicularly to the axis of the stipe. The shape of the process is identical with that of *D. pakrianus*. The proximal end of the sicula is broken off in all specimens, but the sicula was probably not much longer than 1.5 mm. Development apparently of *bifidus* stage, but details are obscure.

DISCUSSION.—The described specimens resemble *D. artus* (cf. ELLES & WOOD 1901, p. 48, Pl. IV, figs. 6a–d). The thecae are, however, slightly less closely set, and the stipes frequently divergent, not constantly parallel as in the British form. A fairly considerable variation of the angle of divergence of stipes has, however, been recorded by BULMAN (1931, p. 31) in the South American material of *D. artus*.

The present writer has considered also the possibility that the described specimens are simply young rhabdosomes of the associated species *D. pakrianus*. The smallest available complete rhabdosome of the latter is 15.5 mm long, whereas the length of the largest known specimen of *D.* cf. *artus* is 12.7 mm.

Table 6. Dimensions of *Didymograptus* cf. *artus* in mm.

RM Mus. Nos.	Length of the rhabdosome	No. of thecae in 5 mm	Length of the sicula	Width of the stipe			Distance between the dorsal margins of stipes, 10 mm from the sicula	Remarks
				Proximal	10 mm from the sicula	Maximum		
Cn. 54571	9.5 +	8½	1.1 +	0.3	—	0.8 +	—	Pl. I, fig. 11
Cn. 54558	8.3 +	8½	1.3 +	0.35	—	0.75 +	—	
Cn. 54580	12.5	8¾–9	—	—	0.9	1.0	—	
Cn. 54545	12.5 +	8½	1.3 +	0.4	0.9	1.0 +	6.1	
Cn. 54561	10 +	9–9½	1.4 +	0.4	0.9	0.9 +	5.8	
Cn. 54572	12 +	8½–9	1.4 +	0.4	0.9	0.9 +	—	Pl. I, fig. 10
Cn. 54573	12 +	8½–9	1.3 +	0.4	0.9	0.9 +	6.1	
Cn. 54576	11 +	9	—	0.4	0.9	0.9 +	3.4	

The distal end of the latter specimen is incomplete, and the real length of the rhabdosome at least slightly greater. In both specimens the diagnostic features are already fully developed, such as the lack of free ventral wall of thecae and the secondary outgrowth of periderm around the proximal region in the specimen of *D. pakrianus* in question. It appears at present unlikely that a continued growth of only at most 2.5 mm in length of rhabdosomes like those of *D.* cf. *artus* would give rise to characters distinctive for *D. pakrianus.* On the other hand, in the latter species the appearance of rhabdosomes comparable in size to those of *D.* cf. *artus* is still unknown. Among a fairly large material no rhabdosome of such small size referable to *D. pakrianus* has been found. For this reason the possibility cannot be entirely excluded that the specimens referred here to *D.* cf. *artus* and *D. pakrianus* are different growth stages of rhabdosomes belonging to one chronodeme.

OCCURRENCE.—Specimens described above as *D.* cf. *artus* have been found on the Isle of Väike Pakri, Estonia. Valastean ($B_{III}\beta$) or Aluojan ($B_{III}\gamma$) Substage of the Kunda Stage. The British form of *D. artus* is confined to the zone of *D. bifidus* (ELLES & WOOD 1913, p. 516).

Didymograptus acutus EKSTRÖM, 1937

Pl. V, fig. 1.

1937 *Didymograptus acutus* n. sp. — EKSTRÖM, p. 29, Pl. V, figs. 9–14.
1951 *Didymograptus acutus* EKSTRÖM — HEDE, p. 52.

DESCRIPTION.—The examined limestone material includes one complete rhabdosome of this species, preserved in part as external mold. Length of the rhabdosome 9.5 mm, width of the stipe 5 mm from the sicula 1.2 mm, maximum width c. 1.3 mm; 7 thecae in 5 mm, inclined to the axis of the stipe at an angle of 50–60°, overlapping by one half of their length. Proximal part of the stipes narrow, details obscure; sicula at least 1.4 mm long, proximal termination broken off. Stipes pendent, slightly divergent, maximum distance between their dorsal margins 6.3 mm.

DISCUSSION.—The specimen described agrees with the specimens of *D. acutus* from the subzone of *Pterograptus elegans* of Scania as closely as can be expected from a limestone specimen in full relief compared with flattened rhabdosomes from the shale. In flattened condition the width of the stipes would be somewhat larger and evidently closely comparable to the Scanian material.

OCCURRENCE.—HOLM has found the above specimen in Malla, Estonia, in an oolitic limestone of the Aseri Stage (C_Ia). The same slab of limestone contains a cranidium of *Estoniops panderi* (FR. SCHM.).

In Scania *D. acutus* has been found in the Fågelsång and Röstånga districts and at Nyhamnsläge (EKSTRÖM 1937). According to EKSTRÖM (1937) and HEDE (1951) the species is restricted to the zone of *Pterograptus elegans*. The present writer has found several specimens of *D. acutus* also in $4a\alpha_3$ of Røyken, Oslo district, in an exposure at Djuptrekkodden. There it is associated with *Glossograptus hincksi*, "*Amplexograptus*" n. sp., and *Janograptus laxatus*.

Didymograptus ? cf. ***dubitatus*** HARRIS et THOMAS, 1935

Pl. II, figs. 8–9.

A single small proximal part of a didymograptid species is of interest by possessing a shape of thecae which is exactly that generally portrayed as the leptograptid type (cf. e.g. BULMAN 1955, Fig. 31:1). The free ventral margin of the thecae is parallel to the dorsal margin of the stipe, and exposes a sigmoidal curvature in front and dorsally of the thecal aperture of the preceding theca. The proximal margin of the thecal aperture is flattened, and extended into a short, disc-like apertural process. The initial width of the stipe is 0.25–0.3 mm and the maximum width (at the 4th theca) 0.4 mm. There seem to be 5 proximal thecae in 5 mm. The sicula is slightly less than 1 mm long, but its proximal termination of unknown length is broken off. The specimen is strongly carbonized, and the proximal development cannot be made out. Th 1^1 originates somewhere close to the proximal end of the sicula, the crossing canal is thick and fairly broad suggesting an advanced stage of development. The dimensions and apparently also the shape of proximal thecae of the specimen agree closely with those of *Didymograptus* ? *dubitatus* HARRIS *et* THOMAS (1935) from the zone of *Didymograptus* ? *nodosus* of Victoria, Australia, but an exact comparison is not possible. The species described by BULMAN (1933, p. 350, Pl. XXXIII, figs. 6a–c) as *Didymograptus* aff. *euodus* LAPW. has a slightly smaller angle of divergence of stipes, but the numerical characters and the shape of thecae agree so closely with those of the described specimen as to suggest their being conspecific.

OCCURRENCE.—Estonia, Isle of Väike Pakri. Calcareous sandstone of Valastean or Aluojan Substage.

Didymograptus ? sp. B

Pl. II, figs. 10–11.

The available material consists of two minute proximal parts and two small fragments of distal parts of stipes (RM Nos. Cn. 54548, 54562, 54563, 54582). The stipes are narrow, horizontal, initial width 0.15–0.2 mm, maximum width (Cn. 54548) 0.6 mm. Sicula 0.8–0.9 mm long with an up to 0.6 mm long nema. 3 thecae in 3 mm, with a faint sigmoidal curvature in front of the thecal aperture of the preceding theca. Ventral margin of the aperture flattened and extended into a disc-like process with rounded peripheral margin. The specimens are all somewhat shrunk, and it is difficult to estimate the exact amount of overlap. Theca 1^1 originates close to the proximal end of the sicula, at a distance from the later equalling about $\frac{1}{4}$ of the length of the sicula. Further early development of the thecae cannot be followed. Owing to the bad state of preservation and fragmentary condition of the available specimens the species can not be defined.

OCCURRENCE.—As in the preceding species.

Didymograptus ? sp. C

Pl. II, figs. 1–3.

This form is represented in the collection by numerous distal fragments of the stipes (RM Nos. Cn. 54555, 54559, 54560, 54565). Although the species does not seem to be rare in the Pakri calcareous sandstone, there is no proximal end among the available material.

The largest fragment of the stipe is 14 mm long, but its proximal part is still comparatively broad, and the distal end not complete. The width of the stipe is 0.25 mm in the narrowest and 0.6 mm in the broadest of the available fragments; the individual fragments are almost parallel-sided indicating a very slow increase of width of the stipe and fairly considerable length of the rhabdosome. 5 thecae in 5 mm; free ventral wall of the thecae parallel to the dorsal wall of the stipes. Thecal apertures small, broad (Pl. II, fig. 3), occupying about $\frac{1}{5}$ to $\frac{1}{6}$ of the ventral margin of the stipe, with upturned margins forming a collar, which is more extended distally than proximally, around the whole aperture.

The thecal characters of this species remind of those of *Didymogr. cucullus*, but are not as highly elaborated. Until the proximal end is known the generic reference is uncertain, and the species can hardly be defined.

OCCURRENCE.—As in the preceding species.

Suborder *Glossograptina* nov.

DIAGNOSIS.—Biserial and monopleural axonophorous graptoloids. The highest known developmental stage of the proximal thecae is of *bifidus* type (th 1^1 dicalycal).

DISCUSSION.—The suborder includes only one family, *Glossograptidae* LAPWORTH, 1873 (syn. *Cryptograptidae* HADDING, 1915).

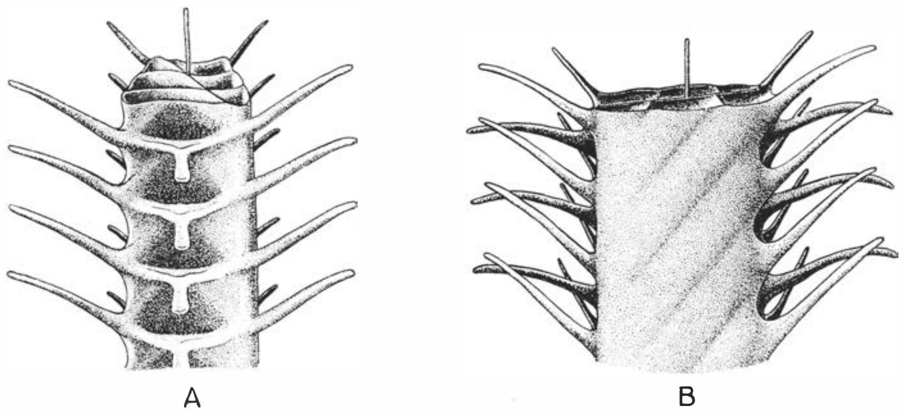
OCCURRENCE.—The earliest representatives of the suborder are known from the zone of *Phyllograptus densus* of Scania. No species seems to be known from beds higher than the zone of *Dicranograptus clingani*.

Family *Glossograptidae* LAPWORTH, 1873

Genus *Glossograptus* EMMONS, 1855

DIAGNOSIS.—A member of suborder *Glossograptina* with relatively long thecae and three apertural spines, one at the mid-line and the other at the lateral extremities of the thecal aperture.

DISCUSSION.—The interpretation of the construction of the rhabdosome in compressed specimens of *Glossograptus* has offered considerable difficulties. Different opinions about the morphology of the rhabdosome in this genus have been surveyed by HADDING (1915, pp. 305–308), BULMAN (1931, pp. 68–69), and LEMON & CRANSWICK (1956, p. 23). Prior to HADDING's paper of 1913 *Glossograptus* had been considered as a normal dipleural graptoloid, often regarded as close to, or identical with, *Diplograptus*. The distinctive features of the genus were thought to lie mainly in the presence of apertural as well as septal spines. In 1913 HADDING gave a new interpretation of the structure of the rhabdosome of *G. hincksi*, more fully treated in a subsequent paper (HADDING 1915). According to him in this genus the stipes are in contact with their lateral surfaces so that the common canal of one stipe lies beside the thecal apertures of the other stipe. The same arrangement was suggested also for *Cryptograptus* and *Nanograptus*. This arrangement of the stipes was so novel that it aroused a fairly general scepticism. BULMAN (1931) found that the material studied by him can be better interpreted in accordance with the dipleural orientation of the stipes (cf. also BULMAN 1938a). Later, specimens of *Cryptograptus* isolated and described by BULMAN (1938b; cf. also 1945) showed that HADDING's interpretation of the structure of the rhabdosome was correct for this genus. The evidence about the structure of *Glossograptus* was, however, considered as conflicting. RUEDEMANN (1949, p. 449) treated *Glossograptus* as a dipleural graptoloid, and included in the genus also the type species of *Orthograptus* and similar diplograptid species with apertural spines. A new reconstruction of *Glossograptus*, based on HADDING's interpretation of the orientation of the stipes, was given by BULMAN (1955, fig. 59:3c). Also LEMON & CRANSWICK (1956, pp. 20–24, text-fig. 6) arrived at the same result. The isolated specimen described in the



Text-fig. 5. Reconstruction of *Glossograptus hincksi* in ventral and lateral view. The shape of the cross-section of the rhabdosome is uncertain. c. × 10.

present paper fully confirms HADDING's interpretation of the arrangement of stipes in *G. hincksi*.

Still more difficult than the orientation of the stipes has been the interpretation of the position of thecal spines in *Glossograptus*. The following interpretations have been proposed: (1) Each theca has paired apertural spines and, in addition, septal spines placed at the level of every second theca (LAPWORTH 1873, p. 504; ELLES & WOOD 1908, p. 308; and others). (2) Each theca has one apertural spine, and a dorsal spine occurs at the level of every second or third theca, seldom on two successive thecae (HADDING 1913, 1915, fig. 1). (3) Each theca has one apertural spine, and a pair of lateral spines occurs at the level of every second theca (BULMAN 1931, text-fig. 35; 1938a, Fig. 38:b). (4) Each theca has one apertural spine, and a pair of long dorsal and lateral spines are developed in whorls at the level of every second, third, or fourth theca (BULMAN 1955, fig. 59:3c; LEMON & CRANSWICK 1956). None of these interpretations has proved to be quite correct.

The specimen described below shows that each distal theca has three spines of about equal length, one at the apertural margin along the ventral mid-line of the theca, and the others at the lateral extremities of the thecal aperture. The median spine is directed more or less perpendicular to the axis of the stipe and the lateral spines parallel to the axis of the theca. The difference in the direction of the spines has probably been the main cause of the conflicting interpretations about the arrangement of spines in compressed specimens.

Glossograptus hincksi (HOPKINSON, 1872)

Pl. V, figs. 8–10; text-fig. 5.

1954 *Glossograptus hincksi* (HOPKINSON) — JAANUSSON & STRACHAN, p. 686.
1955 *Glossograptus hincksi* (HOPKINSON) — BULMAN, p. V 82, fig. 59: 3a–c.

1956 *Glossograptus hincksi* (Hopkinson) — Lemon & Cranswick, pp. 20–24, Pl. I, figs. 13–14, text-figs. 5a–f, 6–7.

For further synonyms, see Lemon & Cranswick (1956, p. 20).

Description.—Only one specimen embedded in limestone, that mentioned by Jaanusson & Strachan (1954, p. 686), was available. A part of it was etched out. The specimen is somewhat compressed, strongly carbonized and cracked. Upon being isolated it fell into fragments of various size. Owing to compression it is difficult to determine the exact outline of the cross-section of the rhabdosome.

Maximum width of the lateral side 1.8 mm, but the distal end is evidently not preserved. 7 thecae in 5 mm, the two series of thecae lying side by side in two obliquely opposed rows. Thecal aperture oval to somewhat semilunar, surrounded by peridermal lists. Each thecal aperture with three spines of about equal length (1.7–1.8 mm). The median spine is flattened, with a faint longitudinal furrow along the middle of its distal side, slightly curved, and directed almost perpendicular to the axis of the rhabdosome (cf. text-fig. 5; Pl. V, fig. 10). The proximal margin of the aperture is thickened, protruding, with a low ridge formed by a peridermal list which continues on either side of the median spine almost straight into lateral apertural spines. The spine on the right side of the aperture passes across the back of the common canal of the other row of thecae (Pl. V, fig. 8), and its free part is accordingly somewhat shorter than that of the left spine. The lateral apertural spines are directed almost along the axis of the theca and at an angle of 45° relative to the median spine. Their cross-section is oval to almost rounded.

Suborder *Diplograptina* Lapworth, 1880, emended

[*Nom. correct.* Obut, 1957 (ex *Diplograpta* Lapworth, 1880)] (= *Diplograpta* + *Monograpta* Lapworth, 1880; *Diplograptina* + *Monograptina* Obut, 1957; both excluding *Glossograptus* and related genera).

Diagnosis.—Biserial and dipleural or monoserial axonophorous graptoloids.

Families.—*Diplograptidae* Lapworth, 1873
Retiolitidae Lapworth, 1873
Dimorphograptidae Elles & Wood, 1908
Monograptidae Lapworth, 1873

The studied material of *Lasiograptidae* Lapworth, 1879 (non Bulman, 1955) shows a close similarity to diplograptids in the development of proximal thecae and general morphological characteristics. For this reason the lasiograptids are regarded here as a subfamily of *Diplograptidae.*

Occurrence.—The earliest forms of this suborder appear in the upper part of the zone of *Didymograptus extensus* of Great Britain; doubtful (Harris 1935, p. 320) forms have been recorded from the Upper Castlemainian of Victoria.

Family *Diplograptidae* LAPWORTH, 1873

In this paper the following subfamilies are distinguished within this family: *Diplograptinae* LAPWORTH, 1873, *Lasiograptinae* LAPWORTH, 1879, *Petalograptinae* BULMAN, 1955, and *Peiragraptinae* nov. (characters of the type genus). The subfamily *Climacograptinae* FRECH, 1897 is included in *Diplograptinae* on account of the present difficulties to define the former taxon. *Peiragraptus* (STRACHAN 1954) is a peculiar genus with three alternating proximal thecae and a monoserial stipe. Its affinities are probably with *Diplograptidae* (STRACHAN 1954). The genus can be considered as a representative of a monotypic family or a monotypic subfamily of *Diplograptidae*. The latter course is provisionally followed here.

Subfamily *Diplograptinae* LAPWORTH, 1873

Genus *Glyptograptus* LAPWORTH, 1873

Glyptograptus cf. *teretiusculus* (HISINGER, 1840)

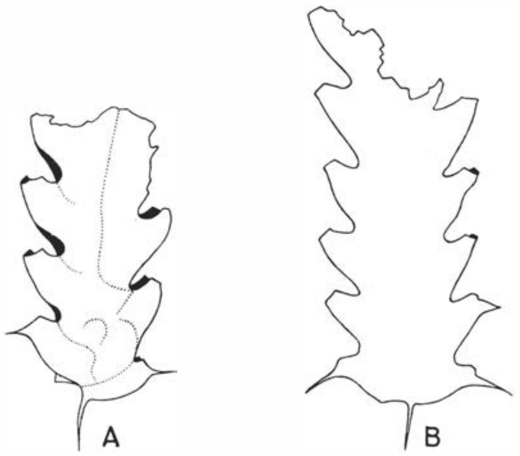
Pl. III, figs. 10–11.

MATERIAL.—Eight mostly fragmentary rhabdosomes.

DESCRIPTION.—Rhabdosome with ovoid proximal and almost circular distal cross-section. Width (*tr.*) at the level of th 2^1–2^2 1.1 mm increasing gradually to 2.2 mm; $6\frac{1}{2}$ to 7 thecae in 5 mm proximally (beginning with th 2^2 or 2^1) and $5\frac{1}{2}$ to 6 distally. Virgella slender, 0.3 mm long, th 1^1 and 1^2 with subapertural spines situated close below the apertural margin. Free ventral wall of thecae gently convex and conspicuously sigmoidal in the proximal thecae, more or less straight in distal thecae. Apertural margin with a ventrally inclined broadly concave ventral part and a dorsal part which slopes in dorsal and proximal direction; both portions of the apertural margin meet in an obtuse angle. In distal view the outline of the aperture is roughly quadrangular, and this applies also to the other species of *Glyptograptus* described in this paper. Mid-line of the lateral surface with a longitudinal furrow. Median septum complete.

DISCUSSION.—The figured specimens are evidently those referred to by BULMAN (1936, p. 87) as "a species of *Glyptograptus* practically identical with the true *teretiusculus*". It differs, however, from *G. teretiusculus* as typified by the lectotype (TULLBERG 1882, Pl. II, fig. 1) by the greater number of thecae in a given length. HADDING (1913, p. 44) distinguished three different forms of *G. teretiusculus*, but the relation of the described specimens to any of his forms is not obvious. As long as the individual variation of *G. teretiusculus* has not been closely studied, the significance of minor differences in the number of thecae and the width of the rhabdosome is not clear.

OCCURRENCE.—Öland. Folkeslunda limestone: Stora Mossen, Gärdslösa, Sjöstorp. Seby Limestone: Seby (watering hole c. 500 m E of the last house of the village).



Text-fig. 6. A, *Glyptograptus cernuus* n. sp. after the holotype (Pl. III, fig. 9); B, *G. vikarbyensis* n. sp. after the holotype (Pl. III, fig. 8). Both × 15.

Glyptograptus vikarbyensis n. sp.

Pl. III, figs. 6–8; text-fig. 6B.

1911 *Diplograptus* (*Glyptograptus*) *teretiusculus* HISINGER var. — TÖRNQUIST, pp. 423–425, Pl. 5, figs. 4–6.

HOLOTYPE.—UM No. D 761, figured on Pl. III, fig. 8.

TYPE STRATUM and LOCALITY.—Furudal Limestone. Siljan district, Vikarbyn, highest beds of the section excavated in 1947.

DIAGNOSIS.—A narrow, almost parallel-sided species of *Glyptograptus*, proximally 1.4–1.45 mm and at the level of the eighth pair of thecae 1.55 mm wide; thecae $7\frac{1}{2}$ in 5 mm proximally and 6 distally; distal portions of th 1^1 and 1^2 with only a gentle upward curvature.

DESCRIPTION.—Largest preserved fragment of rhabdosome 11 mm long. Rhabdosome with ovoid to almost tabular cross-section proximally and almost circular distally. Width (*tr.*) at the level of th 2^1–2^2 1.4 to 1.45 mm, at the level of the eighth pair of thecae 1.55 mm. Proximal thecae closely set ($7\frac{1}{2}$ in 5 mm), those of both stipes almost in juxt-apposition; 6 thecae in 5 mm distally. Virgella fairly short, th 1^1 and 1^2 with short spines which originate from the apertural margin. In the holotype also th 2^1 with a short apertural spine, not observed in other specimens. Free ventral wall of thecae with gentle sigmoidal curvature in proximal four pairs of thecae and almost straight in distal thecae. Apertural margin almost quadrangular in distal view; its ventral margin slightly convex in distal view and faintly concave in ventral view; its lateral margin comparatively short; ventral and lateral portions of proximal apertural margin meet in an obtuse angle which is well defined and somewhat extended in lateral direction. The apertural margin evidently strengthened by a peridermal list.

No trace of median septum in any specimen; also dissections and sections of specimens still in limestone did not reveal any median septum. Some specimens show a faint longitudinal furrow along the mid-line of the lateral surface. Virgula thin, free.

No early growth stages have been found. The aperture of the sicula is gently concave in lateral view. The proximal end of the rhabdosome is comparatively broad and angular, the distal portions of th 1^1 and 1^2 being almost horizontal, with only a slight upward curvature. In this respect the proximal end resembles that of *Climacograptus distichus*.

DISCUSSION.—From the associated *G. cernuus* the described species differs by much more closely set proximal thecae, the almost transverse direction of the distal portions of th 1^1 and 1^2, greater proximal width of the rhabdosome, and other characters. It is a much narrower form than *G. teretiusculus*, and differs from the latter by several distinct features.

OCCURRENCE.—Furudal Limestone. Siljan district: Vikarbyn, Fjäcka (loc. 6). It is fairly common in these beds.

Glyptograptus cernuus n. sp.

Pl. III, fig. 9; text-fig. 6A.

HOLOTYPE.—UM No. D 765, figured on Pl. III, fig. 9.

TYPE STRATUM AND LOCALITY.—Furudal Limestone. Siljan district, Fjäcka, locality No. 6.

DERIVATION OF THE NAME.—From Lat. *cernuus*, inclining, alluding to the inclined free ventral wall of thecae.

DIAGNOSIS.—A narrow species of *Glyptograptus*, width 1.2 to 1.3 mm proximally and at least 1.7 mm distally; thecae 6 in 5 mm proximally and 5½ distally; distal portions of th 1^1 and 1^2 with conspicuous upward curvature; no median septum, but a longitudinal groove on the lateral surface and a peridermal list on the corresponding level inside; aperture of sicula concave in lateral as well as ventral view, without apertural processes.

DESCRIPTION.—Rhabdosome with ovoid cross section proximally and almost circular distally. Width (*tr.*) at the level of th 2^1–2^2 1.2 to 1.3 mm, maximal width of the largest specimen (1 cm long) 1.55 mm (at the level of the twelfth pair of thecae), maximum width in the available material 1.7 mm. 6 thecae in 5 mm proximally (beginning with th 2^1 or 2^2), 5½ thecae distally. Virgella fairly short, th 1^1 and 1^2 with spines which originate close below the apertural margin. Thecae conspicuously alternating even in the proximal region, with faintly sigmoidal free ventral walls and with about the same degree of curvature in proximal as well as in distal thecae. Shape of the proximal margin of thecal aperture as in *G. vikarbyensis*.

Virgula observed only in specimens still in matrix; it is free, tiny, only about 0.07 mm thick. All specimens show a fairly distinct longitudinal furrow along the mid-line of the lateral surface beginning on reverse side between th 3^1 and

3^2. At the corresponding level inside the rhabdosome is a narrow and low peridermal list which is, however, never seen to be developed as a continuous cover up to the virgula, even in specimens still in the fine-grained limestone matrix.

No early growth stages have been found. The aperture of the sicula is strongly concave in lateral view and gently concave in ventral view. The ventral apertural region extends somewhat beyond the th 1^2. Contrary to *G. vikarbyensis* the upward curvature of th 1^1 and 1^2 is pronounced.

DISCUSSION.—*Glyptograptus cernuus* resembles *G. uplandicus* (WIMAN) which species was included in *Orthograptus* by STRACHAN (1959). However, the paired apertural processes of the sicula, invariably present in *O. uplandicus*, are missing in *G. cernuus*, the thecae are somewhat more closely placed, the rhabdosome with a considerably more rounded cross-section, and the longitudinal furrow, which indicates the cryptoseptal median septum, can be followed down to the proximal region of the rhabdosome. Also the free ventral wall of the thecae shows a more pronounced curvature in *G. cernuus* than in *O. uplandicus*. *Glyptograptus teretiusculus* is a much broader species, and differs also in several details.

OCCURRENCE.—Furudal Limestone. Siljan district: Vikarbyn (highest beds of the section excavated in 1947), Fjäcka (loc. 6). The material includes 8 fragments of rhabdosomes, most of them with proximal end preserved.

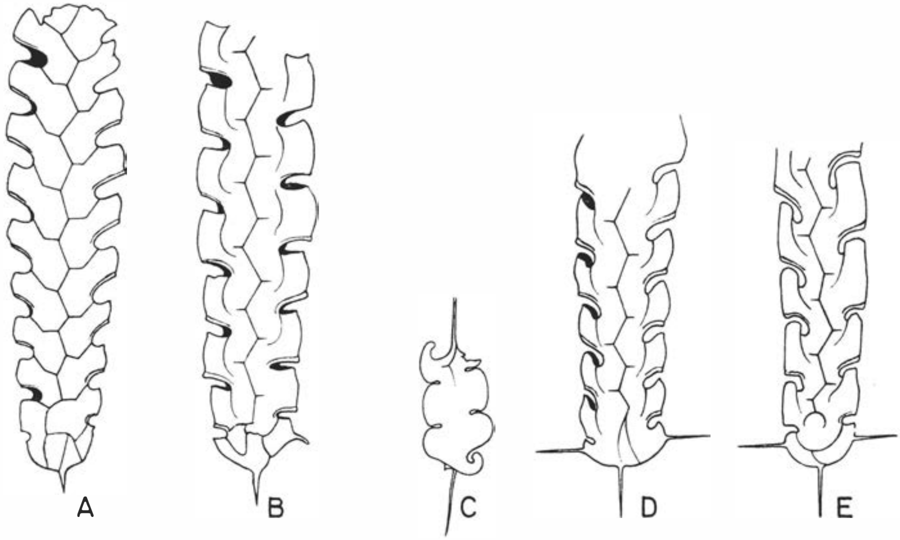
Gen. ***Pseudoclimacograptus*** PŘIBYL, 1947

TYPE SPECIES.—*Climacograptus Scharenbergi* LAPWORTH, 1876.

DIAGNOSIS.—*Diplograptidae* with distinctly convex supragenicular wall of the thecae and mostly a zig-zag median septum. Apertural excavations deep (*tr.*), of climacograptid type but mostly somewhat introtorted or introverted, or both.

SPECIES.—*Climacograptus Scharenbergi* LAPWORTH, 1876
Climacograptus riddelensis HARRIS, 1924
Climacograptus scharenbergi var. *stenostoma* BULMAN, 1947
Climacograptus scharenbergi var. *angulatus* BULMAN, 1953
Pseudoclimacograptus romanovskyi KELLER, 1956
Pseudoclimacograptus formosus MU *et* LEE, 1958
Pseudoclimacograptus sinicus MU *et* LEE, 1958
Pseudoclimacograptus romanovskyi var. *sinensis* HSÜ, 1959
Pseudoclimacograptus eurystoma n. sp.
Pseudoclimacograptus angulatus sebyensis n. subsp.
Pseudoclimacograptus luperus n. sp.

In addition also the species described by BULMAN (1936, pp. 61–63, Pl. 3, figs. 22–33) as *Amplexograptus* aff. *coelatus* LAPW. is considered here to belong to this genus. Further, the "Amplexograptid with proximal zig-zag septum"



Text-fig. 7. A, *Pseudoclimacograptus eurystoma* n.sp. (after BULMAN 1932a, Pl. 1, fig. 19); B, *P. scharenbergi* (LAPWORTH) (after BULMAN 1947, Pl. VIII, fig. 6); C, *P. luperus* n.sp. (after the holotype, cf. Pl. IV, fig. 1); D, *P. angulatus sebyensis* n. subsp. (after the holotype, cf. Pl. IV, fig. 8, reconstructed); E, *P. angulatus angulatus* (BULMAN) (after the holotype, reconstructed). All × 12.

from the Upper *Didymograptus* Shale of the Oslo area mentioned by BULMAN (1953, p. 511) seems also to be congeneric.

DISCUSSION.—When defining the genus *Pseudoclimacograptus*, PŘIBYL (1947) attached great importance to the presence of a zig-zag median septum, and included in this genus all climacograptids with this character. However, the shape of the median septum does not seem to be a sufficiently stable feature to serve as basis of the definition of a genus. The Upper *Didymograptus* Shale of the Oslo area includes a species with proximally zig-zag (to the level of the eighth pair of thecae) and distally slightly undulating median septum (mentioned by BULMAN 1953, p. 511; cf. also *Pseudoclimacograptus romanovskyi sinensis* in HSÜ 1959) and other species, such as the specimen figured by BULMAN 1953, Pl. I, fig. 9, which have a slightly undulating or straight median septum, but the thecal characters of a *Pseudoclimacograptus*. Also in some other genera, such as *Glyptograptus* and *Lasiograptus*, the earliest species have a more or less distinct zig-zag median septum, whereas in later forms the median septum becomes gradually straighter, or is quite straight. The feature which in the present writer's opinion characterizes the group of species included here in *Pseudoclimacograptus* is the distinctly convex supragenicular wall of the thecae and deep thecal excavations.

The Silurian species included by PŘIBYL (1947) in *Pseudoclimacograptus* do not seem to be closely related to the species considered here as belonging to the genus. They have a long and more or less straight supragenicular wall of the thecae, and the median septum seems to have an angular course like that figured by TÖRNQUIST (1893, Pl. I, figs. 23–27) in *Climacograptus internexus* TÖRNQ. and by BULMAN (1953, Pl. 2, fig. 13) in *C. pauperatus* BULMAN.

The genus *Pseudoclimacograptus* as emended here seems to include a well defined group of related species sufficiently distinct from other diplograptids to merit distinction of a separate genus.

The recognition of generic characters of *Pseudoclimacograptus* in flattened material is not always easy. An examination of specimens figured by EKSTRÖM (1937) as *Amplexograptus maxwelli*, and referred to by HEDE (1951) as *A.* cf. *differtus* HARRIS & THOMAS showed this species apparently to be a *Pseudoclimacograptus* close to the "amplexograptid" with proximal zig-zag median septum of the Upper *Didymograptus* Shale of the Oslo district. In the specimen figured by EKSTRÖM (1937) as Pl. VIII, fig. 2 (LO 3357t) the proximal zig-zag median septum is clearly discernible, and also characters of the thecae suggest reference to *Pseudoclimacograptus*.

OCCURRENCE.—Species of *Pseudoclimacograptus* belong to the earliest known biserial and dipleural axonophorous graptoloids appearing already in the subzone of *Glyptograptus austrodentatus* of the zone of *Didymograptus hirundo* (MU & LEE 1958). The latest known indisputable members of the genus come from the upper part of the zone of *Diplograptus multidens* (zone of *Climacogr. wilsoni* of the Scottish succession).

Pseudoclimacograptus eurystoma n. sp.

Pl. IV, fig. 10, text-fig. 7 A.

1932 *Climacograptus scharenbergi* LAPWORTH — BULMAN, pp. 6–10, Pl. I, figs. 1–22, 27–30, 34–35, text-figs. 1–3 [non Pl. I, figs. 23–26 = *Lasiograptus haplus* n.sp.; ? Pl. I, figs. 31–32].

HOLOTYPE.—Rhabdosome figured by BULMAN 1932, on Pl. 1, fig. 19.

TYPE STRATUM AND LOCALITY.—Folkeslunda Limestone. Öland, Gärdslösa.

DIAGNOSIS.—A species of *Pseudoclimacograptus* with 8 to 9 thecae in 5 mm proximally and 7 to 7½ distally; width 0.8 to 1.0 mm proximally, increasing to 1.3 to 1.55 mm at the level of sixth to ninth pair of thecae, rhabdosome thereafter parallel-sided or slightly narrowing towards the distal end; apertural excavations wide, occupying about one half of the free ventral margin of the stipe, more or less transverse; parietal lists connected with the median septum by a transverse list.

DESCRIPTION.—The species has been described and figured by BULMAN (1932) as *Climacograptus scharenbergi*, and here only some additional remarks are given. The largest available rhabdosome is 13 mm long. The width of rhabdosome varies within fairly wide limits as illustrated in Table 7. The maximum width of 1.3 to 1.55 mm is attained usually at the level of the sixth or seventh pair of thecae, but in some specimens the rhabdosome is widening up

Table 7. Dimensions of *Pseudoclimacograptus eurystoma* n. sp. in mm.

Mus. No.	Width at the level of th 2^1–2^2	Width at the level of th 6^1–6^2	Maximum width (level of maximum width given in brackets)	Height (*long.*) of the supragenicular wall of th 6^1 or 6^2	No. of thecae in 5 mm beginning with th 2^1 or 2^2
SGU 164	1.0	1.45	1.55 + (th 8^2)	0.3	8½
SGU 190	1.0	1.45	1.5 (th 7^2)	0.4	—
SGU 152	1.0	1.4	1.45 (th 7^1)	0.4	—
RM Cn 54605	0.95	1.3	1.35 (th 7^1)	0.3	9
RM Cn 54611	0.9	1.35	—	—	—
SGU 167	0.9	1.2	1.3	0.35	—
SGU 166	0.8	1.3	1.3 (th 6^1)	0.45	8
SGU 170	0.8	1.1	1.35 (th 9^2)	0.3	9

to the ninth pair; thereafter the rhabdosome is commonly parallel-sided; in some specimens a slight distal decrease of width has been observed. The thecae number 8 to 9 in 5 mm proximally (beginning with th 2^1 or 2^2) and 7 to 7½ distally. In most specimens the supragenicular wall of the thecae is distinctly convex, 0.3 to 0.45 mm high (*long.*), but in some specimens the wall of some thecae at least is almost straight and occasionally of almost a lasiograptid type, gently inclined dorsally and distally. The development of the proximal thecae will be considered in another connection.

DISCUSSION.—BULMAN (1953, p. 511) pointed out that this form from the Grey Lituitid Limestone (= Folkeslunda Limestone) differs in several characters from the Scottish and Norwegian specimens of *P. scharenbergi*. The main distinguishing character of *P. eurystoma* is the development of clathria which is quite similar to that of several lasiograptids. The parietal lists are connected with the median septum by continuous transverse lists. The other species of *Pseudoclimacograptus* have short lateral transverse lists which extend from the median septum in ventral direction, but do not reach the parietal lists, or are without lateral transverse lists. The specimens figured by KELLER (1956, Pl. III, figs. 4–6) from the Anderkenyn Formation of Kazakhstan as *Pseudoclimacograptus scharenbergi* also have complete transverse lists, but the rhabdosome is much narrower (1–1.2 mm) than in *P. eurystoma*.

OCCURRENCE.—Folkeslunda Limestone. Öland: Stora Mossen, Gärdslösa, Sjöstorp, Lerkaka, and Källa. It is fairly common in the Folkeslunda Limestone of Öland. BULMAN (1932, p. 6, Pl. I, figs. 31–32) reported this species also from the Lower *Vaginatum* Limestone of Hälludden, but all pertinent specimens are fragmentary and do not allow of a specific identification; they may belong to another species.

Pseudoclimacograptus luperus n. sp.

Pl. IV, figs. 1–4, text-fig. 7C.

HOLOTYPE.—Specimen RM No. Cn. 54587, figured on Pl. IV, fig. 1.

TYPE STRATUM AND LOCALITY.—Folkeslunda Limestone. Öland, Gärdslösa.

DERIVATION OF THE NAME.—From Greek λυπηρός, sad, alluding to the shape of thecal aperture.

DIAGNOSIS.—A species of *Pseudoclimacograptus* with about 15 thecae in 10 mm, narrow (*long.*) apertural excavations which occupy $\frac{1}{5}$ to $\frac{1}{9}$ of the ventral margin of the stipe, and Λ-shaped genicular edge of the thecae. Proximal width of the rhabdosome 0.8 to 0.85 mm, maximum width about 1.1 to 1.2 mm. Distal part of th 1^1 forms a free curved tube.

DESCRIPTION.—The available material consists of three specimens with proximal ends and two distal fragments. The largest preserved distal fragment of the rhabdosome (RM No. Cn. 54589) is only 3.5 mm long. It carries five pairs of thecae, $4\frac{1}{2}$ thecae in 3 mm, so that the thecae appear to number about 15 in 10 mm. The height (*long.*) of free ventral margin of the theca is 0.7 mm, and the height of apertural excavation 0.1–0.15 mm, so that the latter occupy about $\frac{1}{5}$ to $\frac{1}{9}$ of the ventral margin of the stipe. The thecal excavations are 0.3 to 0.35 mm wide (*tr.*) thus occupying about half the width of the rhabdosome. The supragenicular wall of thecae (Pl. IV, fig. 2) is conspicuously convex, particularly in its distal part. The shape of the thecal aperture is distinctive: the genicular margin has a broad, Λ-shaped notch (Pl. IV, fig. 3) and, on either side of it, sends out wing-like processes protruding in lateroventral and lateral direction. Apertural margin provided with a narrow and inconspicuous marginal list.

The zig-zag median septum is supported by transverse rods. It is difficult to see details of clathrial lists, but it appears as if there were no lists connecting the lateral transverse lists of the median septum with the proximal terminations of the parietal lists.

The proximal end is 0.8 to 0.85 mm wide at the level of th 2^1–2^2. The proximal development of the thecae cannot be followed. Virgella slender, 1.1 to 1.2 mm long. A distinctive feature is the shape of th 1^1: the proximal part of th 1^1 evidently descends close to the sicula, the distal part bends at the level of sicular aperture in transverse direction, and from this point onwards is free and not in contact with the succeeding theca. The free part of th 1^1 is strongly curved so that it is distally directed along the axis of the rhabdosome (Pl. IV, fig. 1); it is almost of an equal width along its whole extension, and narrower than the other proximal thecae. Apertural excavation as in other thecae, but the wing-like processes faint. This peculiar shape of th 1^1 is not an abnormal feature, since all available proximal ends are identical in this respect.

DISCUSSION.—The described species is apparently that referred to by BULMAN (1936, p. 87) as *Climacograptus* sp. It differs from other species of *Pseudo-*

climacograptus by several unique features, such as the shape of th 1^1 and of the genicular margin.

OCCURRENCE.—Folkeslunda limestone. Öland: Gärdslösa, Lerkaka.

Pseudoclimacograptus angulatus sebyensis n. subsp.

Pl. IV, figs. 5–9; text-fig. 7D.

HOLOTYPE.—Specimen UM No. Öl. 980, figured on Pl. IV, fig. 8.

TYPE STRATUM AND LOCALITY.—Grey Seby Limestone. Öland, watering hole c. 500 m E of the last house of the village of Seby (loc. 19 II).

DIAGNOSIS.—A subspecies of *P. angulatus* with 6 to 6½ thecae in 3 mm in the proximal region of the rhabdosome, and 14 to 15 thecae in 10 mm in the distal part.

DESCRIPTION.—The largest available distal fragment of rhabdosome is 6 mm long. Width of the rhabdosome at the level of th 2^1–2^2 0.95 mm, maximum width 1.3 mm. The rhabdosome is widening rapidly to the seventh or eighth pair of thecae (width at that level 1.2 mm), and is thereafter almost parallel-sided. Thecae 1^1 and 1^2 with straight subapertural spines, directed perpendicular to the axis of the rhabdosome, 0.6–0.7 mm long; sicula with a virgella of about the same length. The thecae are closely set proximally, and number there 6 to 6½ in 3 mm (beginning with th 2^1 or 2^2), their length increases rapidly in distal direction so that in distal fragments the thecae number 7 or slightly more than 7 in 5 mm. Supragenicular wall of thecae in distal parts of the rhabdosome (at a width of 1.25 to 1.3 mm) 0.6 to 0.7 mm high (*long.*), height of apertural excavations 0.1 to 0.15 mm; width (*tr.*) of apertural excavations 0.4 mm. The apertures are situated in deep, narrow, and inclined excavations occupying about two-thirds of the width of the rhabdosome and one-sixth to one-seventh of the length of its ventral margin. The supragenicular margin is conspicuously convex, and is inclined distally towards the axis of the rhabdosome. The aperture is introverted and apertural margins with well developed narrow lists. Development of interthecal septae, zig-zag median septum, and peridermal lists as in *P. angulatus angulatus*.

Owing to the shrunk and strongly carbonized condition of the early growth stages and even the siculae, little can be made out of the proximal development of thecae. The sicula is about 1.5 mm long, and the bud arises at about half the length of the sicula. The foramen for th 2^1 is situated close to the top of the descending part of th 1^2. Further development obscure, though apparently similar to that described by BULMAN (1953) in *P. angulatus angulatus*.

DISCUSSION.—The described specimens are very similar to *P. angulatus* (BULMAN 1953, pp. 511–512, Pl. I, fig. 8, text-fig. 2) from the Upper *Didymograptus* Shale of Oslo. In these beds of the Oslo district the latter form does seem not to be rare. In addition to the holotype several specimens have been examined from the collections of RM and UM. To the description given by

Bulman may be added that the thecae 1^1 and 1^2 have slender subapertural spines of about the same length as in *P. sebyensis* (text-fig. 7E). Measurements carried our by the present writer have given a somewhat greater proximal width of the rhabdosome (0.9 mm at the level of th 1^2–2^2 in the holotype) than recorded by Bulman.

Pseudoclimacograptus angulatus sebyensis differs from the nominal subspecies by much more closely set proximal thecae (6 to 6½ in 3 mm in *sebyensis*, 4½ in *angulatus*) and shorter thecae also in the distal part of the rhabdosome (14 to 15 in 10 mm in *sebyensis*, 11 to 12 in *angulatus*). In other known characters these two forms are almost identical. For this reason the described form is treated here, until contrary evidence, as a geographical subspecies of *P. angulatus*.

Occurrence.—See type stratum and locality. It is fairly common in these beds. Holm found some fragmentary specimens at Sjöstorp in the Folkeslunda Limestone.

Pseudoclimacograptus cf. ***scharenbergi*** (Lapworth, 1876)

Pl. II, figs. 4–7.

1932 *Climacograptus* sp. — Bulman, Pl. 3, fig. 34.

The available material from the Jõhvi Stage (D_I) of Estonia consists of three incomplete rhabdosomes, none of them with the proximal end preserved. Two of the largest specimens are 11 mm long. The specimen RM Cn. 54584 (Pl. II, figs. 5–7) is close to the proximal end (apparently only a few proximal thecae are missing) 0.85 mm, and at the incomplete distal end 1.2 mm wide, has 14 thecae in 10 mm, somewhat more closely set proximally than distally. The specimen figured by Bulman (1932, Pl. 3, fig. 34) has 13 thecae in 10 mm. The height (*long.*) of the supragenicular margin of the distal thecae is (Cn 54584) 0.65 mm, and that of the apertural excavation 0.2 mm; the apertural excavations occupy thus about ¼ of the ventral margin of the rhabdosome. The width (*tr.*) of the thecal excavation is distally about 0.35 mm, and the thecal excavations of both stipes thus occupy altogether somewhat more than half the width of the rhabdosome. The thecal characters, the median septum, and the arrangement of clathrial lists agree closely with those of Laggan Burn material of *P. scharenbergi* (Bulman 1947, Pl. VIII, figs. 1, 5–7). The latter material is obviously conspecific with specimens from the type stratum (Lower Hartfell shales of Scotland, probably the zone of *Climacograptus wilsoni*) of this species.

The specimens described are closely similar to *Pseudoclimacograptus scharenbergi* as typified by the Laggan Burn material, except that the rhabdosome is narrower (maximum width 1.2 mm in Estonian specimens, about 1.6 mm in specimens from Laggan Burn). The importance of this difference cannot, however, be evaluated until the proximal end of Estonian specimens has been studied, and the individual variation of the width of the rhabdosome of the Scottish material has become better known.

On comparison with the published figures of the Scottish material specimens of *Pseudoclimacograptus*, generally identified as *P. scharenbergi*, from the Upper *Didymograptus* Shale (cf. BULMAN 1953, Pl. I, figs. 1–7) and the zone of *Glyptograptus teretiusculus* of Scandinavia reveal clear and constant differences. They seem to be at least subspecifically distinct from the form of *P. scharenbergi* of the zone of *Diplograptus multidens*. The main differences are a conspicuously narrower (*long.*) apertural excavation and a broader (*long.*) apertural flange in the Scandinavian specimens in question. Differences in the development of the proximal thecae have been noted by BULMAN (1953). A separation of these forms may be of stratigraphical value.

OCCURRENCE.—The Estonian specimens have been found at Põõsaspea (Spitham) and in an exposure between Kaesal and Keila (specimen figured by BULMAN 1932, Pl. 3, fig. 34). The horizon of both localities is the upper part of the Jõhvi Stage (D_1).

Genus *Climacograptus* HALL, 1865

Climacograptus pauperatus BULMAN, 1953

Pl. III, figs. 12–14.

1953 *Climacograptus pauperatus* sp. nov. — BULMAN, pp. 512–514, Pl. I, figs. 10–12, Pl. II, figs. 13–16, text-fig. 3.

DESCRIPTION OF ISOLATED SPECIMENS FROM ÖLAND.—The largest available fragment of rhabdosome is 3 mm long. Width of the rhabdosome, at the level of th 2^1–2^2, 0.5–0.55 mm, increasing rapidly to a maximum of 0.7 mm. Height (*long.*) of free ventral wall of thecae proximally 0.6 mm, that of apertural excavation 0.15 mm; width (*tr.*) of the latter 0.15 to 0.2 mm. Apertural excavations occupy $\frac{1}{4}$ of the ventral margin of stipe and $\frac{3}{7}$ to $\frac{4}{7}$ of the width of the rhabdosome. Distally there are roughly 4 thecae in 3 mm. Free ventral wall of thecae very slightly convex, interthecal septae more or less parallel to the axis; distinct furrows clearly mark their course upon the surface. Median septum and its origin as in specimens from the Oslo district.

Several early growth stages have been found, but all are shrunk and strongly carbonized, details being obscure. Sicula slender, 1.3 to 1.4 mm long, with a virgella which is 0.5 mm long in early growth stages and somewhat longer in other specimens (0.7 mm in specimen of Pl. III, fig. 14).

The described specimens agree in all details with *C. pauperatus* from the Upper *Didymograptus* Shale of the Oslo district.

OCCURRENCE.—Upper *Didymograptus* Shale (zone of *Didymograptus murchisoni*) of the Oslo district: Rigshospitalet, Frelseres gravlund, Gamle Akers kirke. It is associated there with *Janograptus laxatus*, *Pseudoclimacograptus angulatus angulatus*, and pendent didymograptids. Grey Seby Limestone of Öland: watering hole c. 500 m E of the last house of the village of Seby.

Climacograptus kuckersianus WIMAN, 1896

Pl. IV, figs. 11–12.

1896 *Climacograptus kuckersianus* HOLM — WIMAN, pp. 275–276, Pl. IX, figs. 2–3, Pl. X, figs. 1–5.

LECTOTYPE.—Specimen UM No. E3, figured by WIMAN 1896, Pl. IX, fig. 2.

TYPE STRATUM AND LOCALITY.—Kukruse Stage (apparently the Kohtla Substage, $C_{II}\alpha$). Estonia, Kukruse.

DIAGNOSIS.—Rhabdosome narrow, parallel-sided, width 0.6 mm proximally and not exceeding 0.8 mm distally; thecae 7 in 5 mm, apertural excavations one-fifth of the ventral margin of stipe and about half the width of the rhabdosome. Median septum complete, aperture of sicula with a blunt dorsal flange; virgella prominent, usually short.

DESCRIPTION.—The species was first described by WIMAN (1896), and though he attributed the species to HOLM, he ought to be regarded as the nomenclatural author of this taxon. *Climacograptus kuckersianus* has never been properly described, and for this reason a description is given here of available material which consists of 10 fragmentary rhabdosomes isolated by HOLM and several fragmentary specimens isolated, bleached, and mounted by WIMAN. All have been collected by LINNARSSON in 1872. The specimen depicted by WIMAN (1896) as Pl. IX, fig. 3 could not be identified.

The largest available fragment is 7 mm long. Rhabdosome narrow, parallel-sided, width at the level of th 2^1–2^2 0.6 mm, maximum width 0.8 mm. The thecae number 7 in 5 mm. Height (*long.*) of the free ventral wall of thecae (at the level of maximum width) 0.6 mm, that of the apertural excavations slightly less than 0.15 mm; width (*tr.*) of the apertural excavation 0.2 mm distally, and 0.15 mm at th 2^2. These dimensions are practically constant among the examined specimens. Supragenicular wall of thecae parallel to the axis of rhabdosome, slightly concave proximally, and somewhat convex distally. Apertural excavations with a straight proximal margin, perpendicular to the axis of the rhabdosome, and a concave distal margin. The course of the interthecal septae is scarcely visible upon the surface. Median septum complete. It seems to have a faintly undulate course like that of *C. pauperatus*.

The material does not include early growth stages and as also the transparencies of proximal ends are more or less crushed, the development of the proximal thecae cannot be made out. The sicula is 1.1 mm long and 0.3 mm wide (along the dorso-ventral plane) at the aperture. Free portion of virgella usually fairly short though of varying length which does not exceed 0.8 mm. The aperture of the sicula is somewhat constricted along the lateral mid-line, and the lateral margins of the aperture conspicuously concave. Dorsally the apertural margin extends in a short and blunt flange, well visible as a short process also in dry specimens.

Discussion.—The species which bears the closest resemblance to *C. kuckersianus* is *C. brevis mutabilis* Strachan from the contemporaneous beds of the Tvären area. The latter species differs mainly by being slightly larger (proximal width 0.7 to 0.75 mm, maximum width 1 mm) and by twice as high apertural excavations (0.3 mm in distal part). Also the shape of the aperture of the sicula is different.

Occurrence.—The species has been found hitherto with certainty only in the type locality.

Climacograptus distichus (Eichwald, 1840)

Pl. V, fig. 5.

1840 *Lomatoceras distichus* m. — Eichwald, p. 101.
1860 *Diplograpsus distichus* m. — Eichwald, p. 425, Pl. XXVI, fig. 7a, b.
1932 *Climacograptus orthoceratophilus* n.sp. — Bulman, pp. 17–20, Pl. IV, figs. 1–28, Pl. V, figs. 1–6, text-figs. 9, 10.

Lectotype.—The specimen figured by Eichwald (1860), herein Pl. V, fig. 5.

Type Stratum and Locality.—Lasnamägi Stage ($C_{I}b$), Estonia, Osmussaar (Odinsholm).

Description of the Lectotype.—The specimen of *C. distichus* figured by Eichwald (1860) was borrowed by Holm from the Geological Department of the St. Petersburg University to Riksmuseet, Stockholm. It is a fragment of rhabdosome, 11 mm long, with proximal end preserved but somewhat flattened. The periderm is thick and strongly carbonized, especially around the proximal part of the rhabdosome. Virgella stout, preserved length 0.6 mm. Thecae 1^1 and 1^2 are directed almost perpendicular to the axis of the rhabdosome, and provided with a stout spine. Width of the rhabdosome at the level of the second pair of thecae 1.3 mm, maximum width 1.6 mm; the rhabdosome widens gradually in the proximal 4 to 5 mm, and is thereafter parallel-sided. 7 thecae in 5 mm with strong sigmoidal curvature; somewhat less than half the free ventral edge of the thecae slightly concave and more or less parallel to the axis of the rhabdosome. Overlap $\frac{1}{3}$ to $\frac{1}{2}$; apertural excavations 0.3–0.35 mm wide (*tr.*), surrounded by a thickened selvage. They occupy somewhat less than $\frac{1}{2}$ of the ventral edge of the stipe and $\frac{1}{5}$–$\frac{1}{6}$ of the width of the rhabdosome.

Discussion.—There is scarcely any doubt that the specimen described is conspecific with *Climacograptus orthoceratophilus* Bulman. All dimensions are identical, and the only difference noticed are the more robust proximal spines in the lectotype of *C. distichus*. Most of the proximal ends of *C. orthoceratophilus* figured by Bulman (1932) apparently belong to young rhabdosomes; the spines are slender, short, and the thecal apertures of th 1^1 and 1^2 approximately equal in size to those of succeeding thecae. With growing age the periderm of the proximal part of the rhabdosome was secondarily thickened, the spines became stout, and the apertures of thecae 1^1 and 1^2 constricted. Two such fairly old proximal ends of *C. orthoceratophilus* are figured also by Bulman (1932, Pl. 5, figs. 6, 7), and they closely resemble the lectotype of *C. distichus*. In the latter specimen the periderm around the proximal part of the rhabdosome seems to be even thicker than in the old rhabdosomes of *C. orthoceratophilus* mentioned above, and this may account for the massive appearance of its proximal spines.

To the description of *C. orthoceratophilus* by Bulman (1932) may be added that the longest now available rhabdosome (without proximal end) measures 23 mm, and the maximum width of this specimen (SGU, associated with the stipe of *Didymograptus* cf. *murchisoni murchisoni* figured as Pl. V, fig. 2) 2.1 mm.

Occurrence.—*Estonia*. Lasnamägi Stage ($C_{I}b$), probably its lower part: Osmussaar; Väike Pakri (RM No. Cn 54583, coll. Holm 1883). *Sweden*, *Öland*, Seby Limestone: exposure c. 500 m E of the last house of the village of Seby; E of and close to Skärlövs bridge, Hulterstad parish. Folkeslunda Limestone: Lerkaka, Gärdslösa, Folkeslunda. *Norway*, *Oslo district*. Upper *Didymograptus* Shale (probably the zone of *Didymograptus murchisoni*): Rognstrand (one rhabdosome, RM No. Cn. 42735, not too well preserved; associated with *Pseudoclimacograptus angulatus angulatus*).

Subfamily ***Lasiograptinae*** Lapworth, 1879

(*Nom. transl.* Jaanusson, herein, *ex Lasiograptidae* Lapworth, 1879) (= *Hallograptidae* Mu, 1950).

Diagnosis.—Members of *Diplograptidae* with lasiograptid to gymnograptid type of thecae. Clathria as a rule well developed.

Genus ***Lasiograptus*** Lapworth, 1873

(= *Thysanograptus* Elles *et* Wood, 1908, obj.)

Diagnosis—Thecae of lasiograptid type throughout the rhabdosome.

Discussion.—In the former definitions of this genus emphasis has been laid on the presence of lacinia and of genicular spines. The earliest representatives of the genus (*L. retusus* Lapw. and *L. haplus* n.sp.) lack the spines and the lacinia, but resemble otherwise closely the type species (Bulman 1947, Pl. VIII, fig. 11) in the shape of thecae. As long as the morphology of the laciniferous species of *Lasiograptus* is poorly known it is difficult to evaluate the phylogenetic importance of presence or absence of spines. For this reason in the definition of the genus emphasis is laid here on the shape of thecae.

Defined as above the genus includes the following species:

Diplograpsus Harknessi NICHOLSON, 1867
Lasiograptus costatus LAPWORTH, 1873 (type species)
Lasiograptus retusus LAPWORTH, 1880
Lasiograptus spinatus HADDING, 1913
Paraclimacograptus weberi KELLER, 1956
Lasiograptus haplus n.sp.

The known characters of *L. weberi* are so close to those of *L. harknessi* as to make these forms indistinguishable.

The thecae of *Lasiograptus hystrix* BULMAN, 1932 are of gymnograptid type throughout the rhabdosome. In lateral view compressed specimens of this species would probably closely resemble *Hallograptus*, and hence the species is here referred to as *Hallograptus* ? *hystrix*. The Bolivian species *Lasiograptus armatus* BULMAN, 1931 and *L.* ? *porrectus* BULMAN, 1931 evidently are climacograptids (s. lato). The thecae of *Lasiograptus eucharis* (J. HALL, 1860) resemble those of *Hallograptus*, and this is the case also with *Lasiograptus* ? *inexpectatus* PŘIBYL, 1949. The Victorian *Lasiograptus etheridgei* HARRIS, 1924 seems to belong to the genus *Paraglossograptus* (MU in HSÜ 1959).

OCCURRENCE.—The earliest known representative of the genus (ELLES & WOOD 1908, Pl. XXXIV, fig. 3 c) occurs in the zone of *Didymograptus murchisoni*, but the generic reference of this specimen is not quite certain. The latest known occurrence is in the zone of *Dicranograptus clingani*. Undoubted representatives of the genus have been recorded from Great Britain, Sweden, Kazakhstan, and Argentina.

Lasiograptus haplus n. sp.

Pl. V, figs. 6–7; text-fig. 8.

1932 *Climacograptus scharenbergi* LAPWORTH — BULMAN, Pl. I, figs. 23–26 (non Pl. I, figs. 1–22, 27–30, 33–35 = *Pseudoclimacograptus eurystoma* n.sp.; nec Pl. I, figs. 31–32 = *Pseudoclimacograptus* sp. indet.).

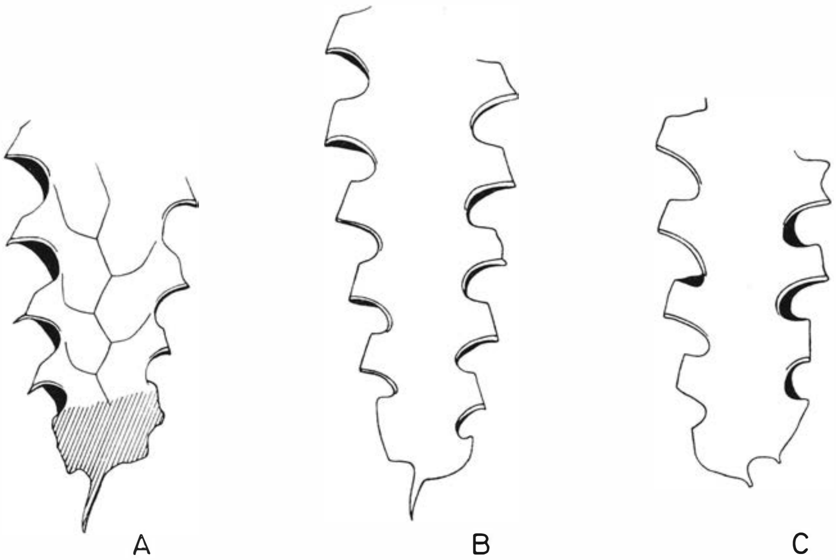
HOLOTYPE.—RM Cn. 54598, figured on Pl. V, fig. 6.

TYPE STRATUM AND LOCALITY.—Folkeslunda limestone. Öland, Gärdslösa.

DERIVATION OF THE NAME.—From Greek ἁπλοῦς, simple.

DIAGNOSIS.—A species of *Lasiograptus* without genicular spines, with 7 thecae in 5 mm proximally, and broad apertural excavations. Rhabdosome widening rapidly from 1.0–1.2 mm at the level of th 2^1–2^2 to 1.7–1.75 at the level of the fifth or sixth pair of thecae, thereafter almost parallel-sided.

DESCRIPTION.—The largest preserved rhabdosome (RM Cn. 54592) is 6 mm long, and the thecae number 7 in 5 mm (beginning with the second pair of thecae). The width of the rhabdosome varies in the available material (14 fragments of rhabdosomes, all except one with the proximal end preserved) from 1.0 to 1.2 mm, being commonly 1.1 mm; width at the level of th 4^1–4^2 1.45 to



Text-fig. 8. Three specimens of *Lasiograptus haplus* n. sp. to illustrate the variation of the thecal shape in this species. A, a specimen with strongly inclined supragenicular wall of the thecae bearing in this respect resemblance to *Gymnograptus* (after the specimen figured as fig. 7 on Pl. V). B, a specimen with a shape of the thecae usual for this species (after the holotype, cf. Pl. V, fig. 6) C, a specimen with almost vertical supragenicular wall in some thecae (after the specimen RM No. Cn. 54600). ×15.

1.55 mm, at the level of the fifth pair of thecae 1.7–1.75 mm. Thereafter it seems to be constant or only very slightly increasing. At the level of the fourth pair of thecae the width (*tr.*) of the apertural excavation is 0.35–0.4 mm, and the height (*long.*) of the latter 0.35 mm. The supragenicular margin of the thecae is generally straight and inclined distally and dorsally; apertural excavation well defined, transverse, of the general climacograptid type. In one specimen (text-fig. 8A, Pl. V, fig. 7) the distal margin of the supragenicular wall is rather poorly defined in lateral view. The latter condition recalls that of the distal thecae of *Gymnograptus*. In another specimen (RM Cn. 54600, text-fig. 8C) some proximal thecae have almost vertical supragenicular walls. None of the specimens has any apertural spines, not even in th 1^1 and 1^2. In the specimen RM Cn. 54601 the geniculum is flattened, and projects slightly in ventral direction (Pl. V, fig. 7); the outer margin of the genicular process is evenly rounded but might suggest short genicular spines in flattened specimens.

The zig-zag median septum is connected with parietal lists by a lateral transverse peridermal list, exactly as in *Pseudoclimacograptus eurystoma*.

The development of the proximal thecae will be considered in another connection.

Discussion.—The thecal characters of *L. haplus* resemble closely those of *L. harknessi* (Bulman 1947, Pl. VIII, fig. 11) save the absence of genicular spines. The described species is fairly similar to *L. retusus* LAPWORTH which also seems to be without spines. The type specimen of *L. retusus* (B.U. 1349) appears to be the only specimen that can at present be referred with certainty to this species, since the other specimens, including those figured by ELLES & WOOD (1908, Pl. XXXIV, figs. 3b, 3c), differ too much for being considered as conspecific. It is extremely difficult to compare a flattened specimen such as the lectotype of *L. retusus* with isolated material of *L. haplus*, but a conceivable difference is found in a somewhat higher number of thecae in the former species. According to kind information from Dr. I. STRACHAN the type of *L. retusus* comes from the Upper Llandeilo of LAPWORTH, i.e. from beds comparable to the zones *Nemagr. gracilis* and *Climacogr. peltifer* which are considerably above the horizon of *L. haplus*.

OCCURRENCE.—Folkeslunda Limestone. Öland: Gärdslösa and Folkeslunda.

Genus *Gymnograptus* BULMAN, 1953

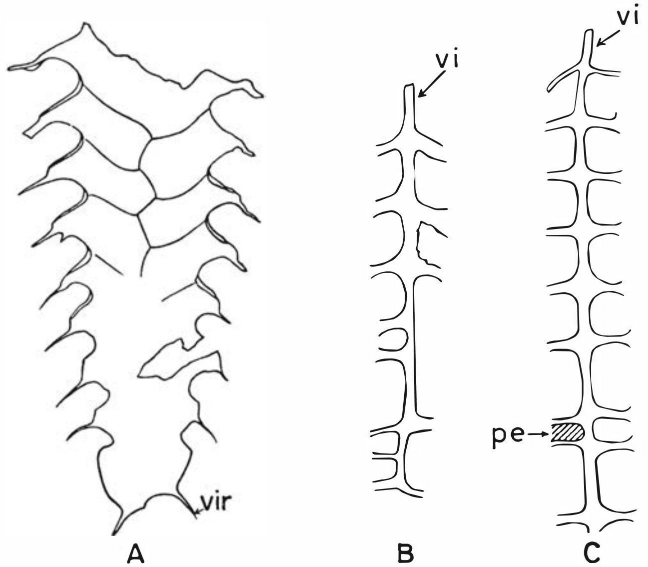
Gymnograptus linnarssoni (MOBERG, 1896)

Pl. V, fig. 4, text-fig. 9.

1879 *Diplograptus* cfr. *mucronatus* HALL — LINNARSSON, p. 243.
1880 *Gymnograptus Linnarssoni* TULLBERG MS — LAPWORTH, Tables IV and X [*Nomen nudum*].
1882 *Gymnograptus Linnarssoni* TULLBERG mscr. — TULLBERG, p. 20 [*Nomen nudum*].
1883 *Gymnograptus Linnarssoni* TULLBERG mscr. — TULLBERG, p. 243 [*Nomen nudum*].
1896 *Diplograptus Linnarssoni* n.sp. — MOBERG, p. 17 (footnote), figs. a–e.
1911 *Lasiograptus* (*Hallograptus*) *mucronatus* HALL, var. *bimucronatus* NICHOLSON — TÖRNQUIST, pp. 422–423, Pl. 5, figs. 1–3.
1913 *Diplograptus Linnarssoni* TULLB. — HADDING, pp. 48–49, Pl. III, figs. 13–14.
1927b *Diplograptus linnarssoni* TÖRNQ. — ÖPIK, p. 28.
1928 *Diplograptus linnarssoni* — ÖPIK, pp. 6–7, 35.
1947 *Lasiograptus* (*Hallograptus*) *mucronatus* var. *bimucronatus* — JAANUSSON, p. 46.
1951 *Diplograptus linnarssoni* (TULLBERG) — HEDE, p. 59, Table 4.
1953 *Gymnograptus linnarssoni* (MOBERG) — BULMAN, pp. 515–517, text-fig. 4, Pl. 2, figs. 17–22.
1954 *Gymnograptus linnarssoni* (MOBERG) — JAANUSSON & STRACHAN, p. 686, text-fig. 1.

DISCUSSION.—The specimens isolated from the Furudal Limestone of the Siljan district are strongly carbonized, fragmentary, and mostly flattened. They contribute but little to the knowledge of the species as described by BULMAN (1953) and URBANEK (1959).

Several of the specimens from the Siljan district exhibit the transverse rods that connect the virgula with the zig-zag list of the median septum on the lateral wall. These rods are similar to those described and figured by BULMAN (1932, Pl. 1, figs. 33–35) in *Pseudoclimacograptus eurystoma* n.sp. In some specimens their arrangement is somewhat irregular (cf. text-figs. 9 B–C and Pl. V, fig. 4).



Text-fig. 9. *Gymnograptus linnarssoni* (MOBERG). A, lateral view of the specimen UM No. D 383, figured by JAANUSSON & STRACHAN (1954) as text-fig. 1. × 12. *vir*, virgella. B and C, virgula (*vi*) and irregularly spaced rods of the median septum in the specimens UM D 770 (Pl. V, fig. 4) and D 771. × 15. *pe*, periderm of the median septum between two of the rods.

Usually one septal rod descends from each corner of the zig-zag line of the lateral surface. Occasionally one or several rods are lacking on one side of the virgula, or supernumerary rods are present. These irregularities do not seem to upset the regularity of the zig-zag line. A periderm between the rods has been observed only in one instance, the space between two narrow and closely spaced rods being filled by thin peridermal structure (*pe*, text-fig. 9C). In all other instances no trace of a periderm is present between the rods, not even in specimens still embedded in fine-grained matrix.

The second to fourth pairs of thecae have a well-defined, short, straight to somewhat concave supragenicular wall that is inclined dorsally and distally, and resembles that of *Lasiograptus haplus* and *L. harknessi*. Distally the wall shortens, and from the fifth pair of thecae onwards its direction almost coincides with that of the apertural margin. Farther in distal direction the supragenicular wall is reduced to a thickened base of the genicular spine. Occasionally the spines vary greatly in shape. Contrary to the specimens described by URBANEK (1959) they are often single and median, especially on proximal thecae, but also double and even triple spines occur.

OCCURRENCE.—*Sweden*. The vertical range of *G. linnarssoni* in Scania is illustrated by HEDE (1951, Table 4). It is a characteristic species of the lower half of the zone of *Glyptograptus teretiusculus*. In Scania it has hitherto been found only in the Fågelsång district. Other localities are Västergötland, Kinnekulle: Norra Skagen boring, at the level of 25.18 m (base of the Furudal Formation); Siljan district: Vikarbyn and Fjäcka (both Furudal Limestone), cf. JAANUSSON & STRACHAN (1954, p. 686); South Bothnian district: erratic boulder Erken No. 10 (Uhakuan Stage; the ostracode fauna of the boulder has been described by JAANUSSON 1957b); Gotland: Visby boring, between the levels of 227.27–229.79 m; Gotska Sandön: boring at Hamnudden at the levels of 150.05 m, 149.18 m, 149.15 m, and 149.05 m.

Estonia. Tallinn, Lasnamägi, locality close to South Lighthouse (ÖPIK 1927b, 1928). The horizon obviously represents the Uhakuan Stage. A specimen apparently belonging to this species has recently been found by Dr. R. Männil in the *Xenasaphus devexus* beds of the Lasnamägi quarry (Lasnamägi Stage).

Norway. Oslo district, Oslo, Sofies gate 1 (RM, coll. HOLM) associated with *Ogygiocaris sarsi* and *Pseudoclimacograptus scharenbergi* subsp. From the same, evidently limited locality HOLM has collected also *Pseudomegalaspis patagiata* (TÖRNQ.), *Glyptograptus teretiusculus* (HIS.), *Climacograptus haddingi* GLIMBERG, and stipes of a dicranograptid belonging probably to *Dicranograptus irregularis* HADDING. *Gymnograptus linnarssoni* is represented by numerous specimens. To judge from the characters of the rock and the appearance of the fossils, the specimens of *G. linnarssoni* described by BULMAN (1953) probably come from the same locality.

Remarks on Correlation

Some of the material described in the present paper is of importance for the correlation between the graptolitic and the shelly facies of Upper Ontikan and Lower Viruan age. The correlation of the Middle Ordovician (Viru Series) has recently been discussed by JAANUSSON & STRACHAN (1954), but new material has accumulated which has lead to some slight revision of the correlations given there.

KUNDA STAGE.—BULMAN (1936, pp. 12–15) discussed the correlation of the glauconitiferous grey *Vaginatum* Limestone of northernmost Öland with the graptolitic succession. He found that the general stratigraphic composition of the graptolite fauna, collected in these beds by HOLM, and described by HOLM (1895) and BULMAN (1932a, b, 1936), suggests comparison with the upper part of the *Didymograptus hirundo* zone of Britain. The graptoloids of this fauna are listed in Table 8. Many species are still unknown outside northernmost Öland. The remaining species are either not known in the graptolitic facies above the zone of *Didymograptus hirundo* or are long-ranging forms.

BULMAN (1950a, p. 4) suggested that "*D. cucullus* may eventually be shown to be identical with *D. climacograptoides*", and regarded also *Didymograptus obscurus* EKSTRÖM as identical with the latter species. The present writer has examined the types and additional material of these three species. In best preserved portions of the stipes the apertural excavations of *D. obscurus* are not semicircular as described by EKSTRÖM (1937, p. 30), but semiovoid, somewhat

Table 8. Graptoloids from the Hunderumian and Lower Valastean limestones of Öland.

Species of graptoloids in "the glauconitiferous grey *Vaginatum* Limestone" of northernmost Öland		Known range in the graptolitic facies	
Names used in the present paper	Names used by Bulman, 1932 a, b, and 1936	Zone of *Didymograptus hirundo*	Zone of *Didymograptus bifidus*
Didymograptus formosus Bulman	*D. formosus* Bulman	—	—
D. aff. *gracilis* Törnq.	*D. gracilis* Törnq. mut. Holm	—	—
D. cf. *minutus* Törnq.	*D. minutus* Törnq. mut. Holm	cf.	—
D. cucullus Bulman	*D. cucullus* Bulman	—	*D. obscurus* Ekstr.
Isograptus gibberulus (Nichols.)	*I. gibberulus* (Nicholson)	+	—
Holmograptus callotheca (Bulman)	*Didymograptus callotheca* Bulman	—	*H. lentus* (Törnq.)
Azygograptus aff. *suecicus* Moberg	*A. suecicus* Moberg mut.	—	—
Tetragraptus bigsbyi Hall	*T. bigsbyi* Hall	+	—
Phyllograptus angustifolius Hall	*P. angustifolius* Hall	+	+
Pseudoclimacograptus sp. A	*Amplexograptus* aff. *coelatus* Lapw.	—	—
Pseudoclimacograptus sp. B	*Climacograptus scharenbergi* Lapw.	—	—
Glyptograptus dentatus (Brongn.)	*G. dentatus* (Brongn.)	+	—
G. aff. *teretiusculus* His.	*G. dentatus-teretiusculus* transient	—	cf.

introverted, and exactly of the same shape as in *D. cucullus*. The distal margin of the aperture is produced into a short spine, and a similar spine is occasionally discernible also on the proximal margin. Owing to the flattened condition and poor state of preservation these details are, however, obscure. The dimensions agree closely with those of *D. cucullus*. The identity of *D. cucullus* and *D. obscurus* seems possible, but cannot be conclusively proved until details of the shape of the apertural margins are known in the latter species. The available material of *D. climacograptoides* is too poorly preserved to permit the observation of details of the shape of thecal aperture, and a slightly too high number of thecae in a given unit of length may indicate specific differences.

An examination of types and additional, in part pyritized, material of *Holmograptus lentus* (Törnquist) from the *bifidus* shale of the Fågelsång district, Scania, has suggested that this species is, in all probability, a senior synonym of *H. callotheca*. The thecae of the Scanian material are preserved as internal moulds (Pl. V, fig. 11), and hence a close comparison of all apertural details with those of isolated limestone specimens is not possible. However, as a whole the shape of the apertural region of *H. lentus* resembles that of *H. callotheca* as closely as can be expected from pyritized internal moulds compared with entire specimens. The dimensions of the specimen figured by Bulman (1932b) on Pl. 2, fig. 8 are closely comparable to those of the Scanian specimens, whereas the other specimens from Öland have slightly more closely set thecae (4 thecae in 3 mm against slightly less than 3½ proximal thecae in 3 mm in the Scanian material). The form described by BULMAN (1950b) as *Didymograptus callotheca* from the zone of *Phyllograptus angustifolius elongatus* of Tossåsen, Jämtland (cf. TJERNVIK 1956, pp. 168–169) differs in the present writer's opinion distinctly from *H. callotheca*. The possibility of its belonging to *H. leptograptoides* (MONSEN) does not seem to be excluded.

Recent field work on northernmost Öland has shown that there HOLM's grey glauconitiferous *Vaginatum* Limestone includes three different successive stratigraphic divisions, viz. in ascending order the Langevoja Substage (*Lepidurus* Limestone), Hunderum Substage (*Expansus* Limestone), and the lowermost part of the Valaste Substage (lowermost "*Raniceps*" Limestone). The two latter divisions are graptolitiferous. It is evident that the bulk of HOLM's material is from the Hunderumian beds, but also the Valastean beds have contributed with many specimens. New and exactly dated material, collected from these beds by Dr. H. MUTVEI *et al.*, is being studied by Mr. DAVID SKEVINGTON of the Sedgwick Museum, University of Cambridge, England. Mr. SKEVINGTON's preliminary determinations of isolated graptoloids from the Hälludden section show that *Didymograptus cucullus* and reclined tetragraptids (evidently several species) have been found there only in beds of Hunderumian age. *Holmograptus callotheca* makes its appearance in the Valastean beds. The isolated material does not include specimens of *Pseudoclimacograptus* or *Glyptograptus* aff. *teretiusculus*. Provided *H. callotheca* is identical with *H. lentus*, its occurrence in the lowermost Valastean beds may suggest that the level comparable to the boundary between the zones of *D. hirundo* and *D. bifidus* is situated somewhere at the base of, or below the Valaste Substage. However, the available material of graptoloids from northernmost Öland still does not permit an exact correlation of the limestone sequence with the graptolite zones.

The exact correlation of the beds in the boundary region between the zones of *D. hirundo* and *D. bifidus* is hampered by the circumstance that in Scandinavia nowhere the transition between these zones is developed as graptolitic shales. We do not know the details of the change in the graptolite faunas at this boundary. The assemblage of graptoloids listed by BULMAN (1950a, pp. 2–4) from the Brabant massif, and regarded by him as consistent with a reference to the top of the *D. hirundo* zone strongly suggests to the present writer the *D. bifidus* zone as developed in Scania. BULMAN's (1958a, p. 166) reference to the Lower Llanvirn of Belgium seems to indicate that he has arrived at the same conclusion. This has some bearing also on the correlation of the Lower Kundan fauna of Öland, since BULMAN's faunal lists from the Bramant massif contain several forms considered by him as identical with, or close to the species from Öland.

In all districts of Scandinavia, where the zone of *D. bifidus* is developed the shales containing the fauna of this zone are underlain by a limestone formation. In Scania the shale of the *D. bifidus* zone overlies a limestone, previously called the *Orthoceras* or Orthoceratite Limestone, and there termed the Komstad Formation. EKSTRÖM's (1937, p. 15) record of a specimen of *Megistaspis* (*Megistaspis*) (determined by him as *Megalaspis limbata*) only 9 cm below the shale with graptolites distinctive for the zone of *D. bifidus* suggests that in the middle limestone quarry of Fågelsång the *D. bifidus* zone overlies beds older than the Hunderum Substage. The subgenus *Megistaspis* (*Megistaspis*) has nowhere been found in beds higher than the Langevoja Substage. STØRMER (1953, p. 131) suggested that in the Fågelsång district of Scania a considerable hiatus must exist between the Komstad Limestone and the shales of the zone of *D. bifidus*. However, the transition between this limestone and the superimposed shale is in that district more or less gradual (cf. the description of the section in EKSTRÖM 1937, pp. 14–15), and from HEDE's (1951) description it is evident that there are no lithological indications, like a discontinuity surface or concentration of phosphorite, which would suggest a hiatus at this level.

STØRMER (1953) assumed that in the Oslo district the zone of *D. bifidus* overlies the zone of *Megistaspis* (*Megistaspidella*) *gigas*, the topmost zone of the Kunda Stage in Sweden. He also suggested that in that district the boundary between the Orthoceratite Limestone and the Upper *Didymograptus* Shale coincides roughly with the boundary between the zones of *D. hirundo* and *D. bifidus*. Since in Scania the Upper *Didymograptus* Shale overlies a limestone horizon close to the base of the Kunda Stage, beds comparable to practically the whole Kunda Stage (*Vaginatum* Limestone) were thought by STØRMER to be missing in the Scanian sections. As STØRMER's correlation is in contradiction with the data discussed above, the facts on which his correlation is based must be critically examined in some detail.

In the Oslo district STØRMER (1953) distinguished two trilobite zones between the beds with *Asaphus* (*Asaphus*) *expansus* (=Hunderum Substage) and the zone of *D. bifidus* of the Upper *Didymograptus* Shale. The lower of these zones was termed the zone of *Megalaspis grandis*, and the upper the zone of *M. gigas*. As *Megistaspis* (*Megistaspidella*) *gigas* is in Sweden confined to the topmost *Vaginatum* Limestone (zone of *M. gigas*) the Orthoceratite Limestone succession of the Oslo district was thought to include beds corresponding to the whole *Vaginatum* Limestone of Sweden. Subsequent examination of specimens determined by STØRMER as *Megalaspis gigas* ANG. (BOHLIN 1955, p. 136) showed that they belong to one or several new species not occurring in Sweden and are therefore at the time being without any bearing on the correlation. *Megalaspis grandis* (BOECK) was considered by STØRMER to be identical with *M. centaurus* sensu BOHLIN, 1949 [=*Megistaspis* (*Megistaspidella*) *obtusicauda* (BOHLIN, 1955)] distinctive in Sweden for the zone next below the zone of *Megistaspis gigas*. At that time the Swedish representatives of the subgenus *Megistaspis* (*Megistaspidella*) were poorly known, and the identifications often highly uncertain. Subsequent revision of Swedish and Norwegian species of this subgenus by BOHLIN (1955, 1960) showed *Megistaspis* (*Megistaspidella*) *grandis* to be different from anything yet recognized in Sweden, and thus also this species has no direct bearing on the correlation. In fact, there exists at present from the Oslo district no evidence that the *Orthoceratite* Limestone includes beds higher than the Valaste Substage. The Orthoceratite limestone facies ranges higher in the Oslo district than in Scania, but evidently not so high as suggested by STØRMER.

There is no evidence that in the Oslo district the boundary between the *Endoceras* Limestone and the Upper *Didymograptus* Shale should coincide with that between the zones of *D. hirundo* and *D. bifidus*. *Phyllograptus nobilis*, the index fossil of EKSTRÖM's lower subzone of the zone of *D. bifidus*, has been found in the Oslo district in several localities above the *Endoceras* Limestone (STØRMER 1953). However, in Scania this species ranges through most of the sequence of the *D. bifidus* zone (cf. EKSTRÖM 1937 and HEDE 1951), and hence its occurrence does not necessarily indicate the base of this zone. It ought to be remembered that also in Scania the correspondence of the boundary between the Upper *Didymograptus* shale and the Komstad Limestone to that between the zones of *D. hirundo* and *D. bifidus* has not yet been demonstrated (cf. below).

The perhaps clearest evidence against STØRMER's (1953) comparison of the Kunda Stage with the upper part of the zone of *D. hirundo* is the graptolite fauna of the Pakri calcareous sandstone of western Estonia described in the present paper. This sandstone is a facies of the upper part of the Kunda Stage comprising beds of Valastean ($B_{III}\beta$) and Aluojan ($B_{III}\gamma$) age (ÖPIK 1927a; ORVIKU 1958). In the material studied these divisions have not been distinguished, and further collecting is necessary for an exact stratigraphic attribution of the different species. The graptoloid fauna includes the following species:

Didymograptus pakrianus n.sp.
D. cf. *artus* ELLES *et* WOOD
D. ? sp. A
D. ? cf. *dubitatus* HARRIS *et* THOMAS
D. ? sp. B
D. ? sp. C.

This fauna does not give a definite indication as to the age of these beds in terms of the graptolite zones other than that it is certainly younger than the zone of *D. hirundo*. It is interesting to note that this fauna has no species in common with HOLM's fauna from the glauconitiferous grey *Vaginatum* Limestone, and that no biserial graptolites have been found. The fauna lacks also *Phyllograptus angustifolius* which is a common species in the Hälludden-Hagudden fauna as well as in the lowermost Valastean Voka Member ("lower oolitic limestone") of eastern Estonia. The endemic aspect is further stressed by the presence of specialized and advanced morphologic characteristics in several species.

The position of the level of the boundary between the *D. hirundo* and *D. bifidus* zones in the limestone sequence is not clear. The section in the middle limestone quarry of Fågelsång described by EKSTRÖM suggests that the shales with the fauna of the *D. bifidus* zone overlie limestones of Langevojan age, and in this case also the Hunderum Substage ought to be included in beds compared to *D. bifidus* zone. The Komstad Limestone is underlain by shales with the fauna of the zone of *D. hirundo*, and overlain by shales belonging to the *D. bifidus* zone. The level of the boundary between these zones may lie at the base or on the top of, or within this limestone. A further complication is the present insufficient knowledge of the correlation of the sequence of the Komstad Limestone with that of northern Öland and Estonia. In the present writer's opinion the main part of this formation is of Langevojan age (i.e. comparable to the zone of *Asaphus lepidurus*), but some species listed from this limestone indicate that in places the formation may include also beds comparable to the zone of *Asaphus expansus*. It is also possible that the base of the limestone is within beds contemporaneous with the "*Limbata*" limestone of other districts of Sweden. In the Oslo district the *Megalaspis* Limestone (3 cα) seems to be at least a part equivalent of the Komstad Formation. In Slemmestad the *Megalaspis* Limestone overlies shales of the zone of *Didymograptus hirundo* (SPJELDNÆS 1953). Fossils in UM collected in the lowermost part of this limestone at Slemmestad by Dr. H. MUTVEI, the present writer, and others include *Megistaspis* (*Megistaspis*) *limbata* (BOECK) s. str., *Dysplanus acutigenia* JAAN., and *Ptychopyge incipiens* BRÖGGER, and indicate Langevojan rather than "*Limbata*" age.

In the Oslo district limestones of apparently Valastean age are overlain by a thick sequence of shales with graptolites of the zone of *D. bifidus* (STØRMER 1953). This indicates that at least most of the post-Valastean sequence of the Kunda Stage falls still within the range of the zone of *D. bifidus*. The exact level of the upper boundary of the zone of *D. bifidus* within the Baltoscandian limestone sequence is not known yet, but its correlation with the boundary between the Kunda and Aseri Stages seems to be a reasonably close approximation.

The correlation of Ontikan shelly and graptolitic sequences of Baltoscandia is given in Table 9.

ASERI STAGE.—The only determinable graptoloid so far known from this stage is the specimen of *Didymograptus acutus* EKSTRÖM described in the present paper. The exact stratigraphic level of this specimen within the Aseri Stage is not known, but it probably comes from the upper part of the stage. The occurrence of this species indicates beds comparable to the zone of *Didymograptus murchisoni*.

LASNAMÄGI STAGE.—The *Schroeteri* limestone of Sweden was compared by JAANUSSON & STRACHAN (1954) to the subzone of *Glossograptus hincksi* of Scania. This correlation was based on the following evidence: (1) In the Oslo district the division 4 aα_3 contains trilobites indicative of the *Schroeteri* Limestone of Sweden together with *Glossograptus hincksi*. For this reason the Scanian zone of *G. hincksi* was compared to the division 4 aα_3 by STØRMER (1953). (2) At Andersön, Jämtland, the *Ogygiocaris* shale with the zone of *Climacograptus haddingi* (*C.* "*putillus*") at its base overlies limestone generally assumed to belong

Table 9. Correlation of the Ontikan shelly and graptolitic sequences of Baltoscandia. REMARKS. — The correlation of Latorp and lower Volkhov Stages is given after TJERNVIK (1956). The correlation of the zone of *Didymograptus balticus* with the shelly sequence is uncertain. The lower Ontikan graptolite zones need redefinition based on exact data about the range of different species.

Chrono-stratigraphic units of the shelly sequence		Trilobite zones of Sweden	Litho-stratigraphic units of the Oslo district	Graptolite zones
Stage	Substage			
Kundan	Aluojan	*Megistaspis gigas* *Megistaspis obtusicauda*	4 a α_1 Upper *Didymograptus* Shale (lower part)	*Didymograptus bifidus*
	Valastean	*Asaphus raniceps*	3 c. »*Orthoceras*» (Orthoceratite) Limestone	
	Hunderumian	*Asaphus expansus*		?
Volkhovian	Langevojan	*Asaphus lepidurus*		?
	?	?	Lower *Didymograptus* Shale	*Didymograptus hirundo*
	?	*Megistaspis lata*		
Latorpian	Billingenian	*Megistaspis estonica*		*Phyllograptus angustifolius elongatus*
		Megalaspides dalecarlicus		*Phyllograptus densus*
	Hunnebergian	*Megistaspis planilimbata*		*Didymograptus balticus* *Tetragraptus phyllograptoides*
		Megistaspis armata		?

to the *Schroeteri* Limestone. (3) The graptoloid fauna of the Folkeslunda Limestone of Öland (the Grey *Lituites* Limestone of HOLM) includes *Dicellograptus*, and suggests a comparison with the zone of *Glyptograptus teretiusculus* rather than with that of *Didymograptus murchisoni*. *Dicellograptus* is unknown in Scandinavian graptolitic facies below the former zone. (4) The find of *Glossograptus hincksi* in the lowermost *Schroeteri* mudstone of the Norra Skagen bore, Kinnekulle (JAANUSSON & STRACHAN 1954), seemed to supply additional support to the above correlation.

Earlier (MOBERG 1911, p. 85; TROEDSSON 1928, p. 179; BULMAN 1936, p. 12) the *Schroeteri* ("*Centaurus*", "*Chiron*") Limestone has generally been compared to the zone of *Didymograptus geminus* of Scania (z. of *D. murchisoni* of the present paper). This correlation was based on a find of a pendent *Didymograptus* (MOBERG 1890, p. 16), determined by MOBERG (1911, p. 85) as *D. geminus* in the beds of southern Öland now classified as the Seby Limestone (JAANUSSON 1960). Fortunately, the present writer succeeded in finding the actual specimen in the collections of the Geological Survey of Sweden. It is described in the present paper as *Didymograptus* cf. *murchisoni murchisoni* (BECK). In addition a graptoloid fauna of the Seby Limestone of another locality has been etched out by the present writer, and is described in this paper. This fauna contains the following species:

Didymograptus cf. *murchisoni murchisoni* (BECK)
Abrograptus n. sp.
Climacograptus pauperatus BULMAN
Climacograptus distichus (EICHWALD)
Pseudoclimacograptus angulatus sebyensis n. subsp.
Glyptograptus cf. *teretiusculus* (HIS.)

The affinity of this assemblage to the faunule described by BULMAN (1953) from the (zone of *D. murchisoni* of the) Upper *Didymograptus* Shale of the Oslo district is unmistakable, and it is quite clear that the Seby Limestone and older beds of Lasnamägian age must be compared to the zone of *D. murchisoni*.

Examination of the graptolite material collected in 1950 by the present writer from the division 4aα_3 of Slemmestad (Djuptrekkodden), Oslo-Asker district, has shown that in that locality *Glossograptus hincksi* occurs associated with *Didymograptus acutus* EKSTRÖM, *Janograptus laxatus* TULLB., and "*Amplexograptus*" n. sp., all these species occurring occasionally upon the same bedding plane. This association of species is indicative of the zone of *Didymograptus murchisoni*, and suggests that at least a part of the beds with *Glossograptus hincksi*, and of the division 4aα_3, must be compared to a part of the *D. murchisoni* zone and not to the *Glossogr. hincksi* zone or subzone as defined in Scania (HADDING 1913; EKSTRÖM 1937; z. of *Diplogr. linnarssoni* in HEDE 1951). No trilobites were found associated with the graptolites in the above locality. *Glossograptus hincksi* has been recorded from the zone of *D. murchisoni* also in Scania (EKSTRÖM 1937).

There is still no conclusive evidence that the beds underlying the *Ogygiocaris* Shale at Andersön, Jämtland are of Lasnamägian and not of Lower Uhakuan age.

The Folkeslunda Limestone of Öland has yielded a fairly rich fauna of graptoloids collected by HOLM, and described by BULMAN (1932a, b) and in the present paper. The fauna consists of the following species:

Dicellograptus geniculatus BULMAN
Pseudoclimacograptus eurystoma n.sp.
Pseudoclimacograptus luperus n.sp.
Climacograptus distichus (EICHWALD)
Glyptograptus cf. *teretiusculus* (HIS.)
Lasiograptus haplus n.sp.
Hallograptus ? *hystrix* (BULMAN)

This fauna has only two species in common with that of the Seby Limestone listed above, viz. *Climacograptus distichus* and *Glyptograptus* cf. *teretiusculus*. In spite of a very large number of specimens isolated by HOLM no traces of pendent didymograptids have ever been found, though they are common in exactly the same kind of rock of the Seby Limestone of southern Öland. With the exception of the two species that occur also in the Seby Limestone none of the species of the Folkeslunda Limestone have yet been found outside Öland, and hence the assemblage does not give a clear indication as to the correlation with the graptolite zones. The presence of *Dicellograptus* suggests comparison with the zone of *Glyptograptus teretiusculus* rather than with that of *Didymograptus murchisoni*, but the evidence is not conclusive, *Dicellograptus* being known in Great Britain in beds as low as the zone of *D. bifidus* (cf. ELLES & WOOD 1914).

When the above was already written the writer found in HOLM's material some fragmentary specimens of *Pseudoclimacograptus angulatus sebyensis* from the Folkeslunda Limestone of northern Öland. The specimens were found in a domiciliar cavity of *Baltoceras burchardi* and were associated with *Glyptograptus* cf. *teretiusculus*. The possibility that they are derived from beds corresponding to the zone of *Lituites lituus* is not excluded.

In Estonia Dr. RALPH MÄNNIL has found a specimen of *Gymnograptus* in the *Xenasaphus devexus* beds of the Lasnamägi Stage, and according to unpublished identification by Dr. A. M. OBUT this specimen probably belongs to *G. linnarssoni* (cf. also OBUT 1958). If the determination is correct, at least the upper part of the Lasnamägi Stage is evidently comparable to the zone of *Glyptograptus teretiusculus*.

The available evidence thus shows that the lower part of the Lasnamägi Stage is of the age of the upper part of the zone of *Didymograptus murchisoni*. The correlation with the graptolite zones of the upper part of the stage is not quite clear yet, but there are indications that it may be comparable to the lower part of the zone of *Glyptograptus teretiusculus*.

UHAKU STAGE.—The Uhakuan beds of the Siljan district have yielded the following graptoloids described in the present paper:

Gymnograptus linnarssoni (MOBERG)
Glyptograptus vikarbyensis n. sp.
Glyptograptus cernuus n. sp.

The first of these species has a wide occurrence in the Uhakuan limestones of Baltoscandia, being recorded from the Siljan district, Västergötland, the South Bothnian district, Gotland, Gotska Sandön, and Estonia. In the Fågelsång district of Scania it is confined to the lower half of the zone of *Glyptograptus teretiusculus* (cf. HEDE 1951). This suggests that at least the greatest part of the Uhaku Stage has to be compared with the zone of *Glyptograptus teretiusculus* (JAANUSSON & STRACHAN 1954). No determinable graptoloids are yet available from the uppermost part of the Uhakuan limestones.

A further Uhakuan graptoloid species is *Gymnograptus retioloides* (WIMAN). In Sweden it is encountered only in erratic boulders derived from the South Bothnian area. Only two specimen from two different boulders have hitherto been found, and only one of these boulders contained additional fossils. In the boulder Höganäs No. 10 (WIMAN 1908, Table 6) *G. retioloides* is associated with *Estoniops* n. sp. and *Christiania* cf. *holtedahli* SPJELDNÆS indicating Uhakuan age of the boulder.

In the Norra Skagen bore the basal beds of the Uhakuan Furudal Limestone contain *Dicellograptus divaricatus salopiensis* ELLES *et* WOOD associated with *Gymnograptus linnarssoni* (cf. JAANUSSON & STRACHAN 1954).

MIDDLE AND UPPER VIRUAN BEDS.—The Middle and Upper Viruan shelly sequence of Sweden is still incompletely described, and hence a chronostratigraphic classification of these beds is not attempted. The lower part of this sequence is, on account of lack of better terms, called here *Ludibundus* beds s. lato, and the upper part *Macrourus* beds s. str. The boundary between these divisions is drawn at the level of appearance of *Chasmops macrourus* ANG. and *Sampo indentata* SPJELDNÆS.

The lower boundary of the *Ludibundus* beds probably coincides with, or is close to the base of the zone of *Nemagraptus gracilis*. The graptolite fauna described by STRACHAN (1959) from boulders of *Ludibundus* Limestone of the Tvären district contains the following graptoloids:

Climacograptus bekkeri (ÖPIK)
Climacograptus brevis mutabilis STRACHAN
Orthograptus uplandicus (WIMAN)
Dicellograptus divaricatus salopiensis ELLES *et* WOOD

These species give very little evidence for correlation with the graptolitic sequence (STRACHAN 1959). Except for *D. divaricatus salopiensis* none of these forms has with certainty been found in beds of Uhakuan age. *Climacograptus bekkeri* (ÖPIK) and *C. kuckersianus* WIMAN have been described from the Kukruse Stage of Estonia.

In the Norra Skagen bore, Västergötland, *Diplograptus molestus* THORSLUND appears 5.30 m above the base of the *Ludibundus* beds, and is fairly common in the next two to three metres of the core. In Scania this species makes its entrance in the *Nemagraptus gracilis* zone (HEDE 1951), where it is common, and continues into the overlying zone. The lower five metres of the *Ludibundus* beds of the Norra Skagen bore contain no determinable graptolites.

Of great importance for correlation is the discovery by Mr. RAGNAR NILSSON, Lund, of the *Diplograptus multidens* fauna in the Koäng bore, Scania (NILSSON 1960). This fauna appears c. 20 m below the thick bentonite beds which are comparable to the thickest beds of bentonite in Västergötland, Östergötland, and some other districts of Scandinavia (NILSSON 1960). The exact level of the boundary between the zones of *Nemagraptus gracilis* and *Diplograptus multidens* within the shelly sequence cannot be determined yet, but it probably is well down within the Dalby limestone. Pending publication of the relevant data the correlation of this boundary as well as of the parts of Estonian and Norwegian sequences corresponding to the lower and middle part of the *Ludibundus* beds will not be discussed here.

SPJELDNÆS (in HAGEMANN & SPJELDNÆS 1955, pp. 46–48) suggested that in Kinnekulle the *Dicranograptus clingani* shale (incorrectly termed *Macrourus* limestone by SPJELDNÆS, op. cit., and SWEET 1958, p. 13, Table I) and the *Ludibundus* beds are separated by a hiatus which comprises equivalents to the divisions 4bβ, 4bγ, and almost the whole 4bδ of the Oslo-Asker sequence. The presence of a hiatus of the same magnitude at the same level was suggested by SWEET (1958, p. 13, Table I) also for the Siljan district, Dalarna. There certainly is a hiatus on Kinnekulle on the top (cf. THORSLUND 1948) and at the base of the *D. clingani* shale, the latter indicated by a pyritic layer at the base of the shale. But the magnitude of the latter hiatus, though not yet exactly determinable, is certainly in no way comparable to that suggested by SPJELDNÆS. In the Siljan district the sequence is undoubtedly essentially continuous from the "complex of bentonite beds" to the top of the *Macrourus* beds. Recent studies have proved that the faunal boundary between the *Ludibundus* and *Macrourus* beds lies much higher in the sequece of that district than what has generally been considered as the (lithologic) boundary between these beds. The sequence in question is much more condensed in the Siljan district than in the Oslo district and in Estonia, but without evidence of any gap in the faunal succession.

The Estonian Jõhvi Stage (D_I) has been compared to the lower part of the *Macrourus* beds of Sweden (e.g. THORSLUND 1948, p. 359; JAANUSSON & STRACHAN 1954). This comparison is roughly correct in so far as it refers to the lower part of the litho-stratigraphic unit defined as the *Macrourus* Limestone in the Siljan district. Of this litho-stratigraphic division the upper part corresponds to the Keila (D_{II}) and probably also Oandu (D_{III}) Stages, and the lower part with the *Asaphus ludibundus* fauna roughly to the Jõhvi Stage (D_I).

Table 10. Correlation of the Viruan shelly and graptolitic sequences.

Estonian sequence	Shelly sequence of Sweden		Litho-stratigraphic units of the Oslo district	Graptolite zones
$\mathrm{D_{III}}$ Oandu Stage $\mathrm{D_{II}}$ Keila Stage		*Macrourus* Limestone s. str.	4 b δ 4 b γ	*Dicranograptus clingani*
$\mathrm{D_{I}}$ Jõhvi Stage $\mathrm{C_{III}}$ Idavere Stage $\mathrm{C_{II}}$ Kukruse Stage		*Ludibundus* Limestone s. lato	4 b β 4 b α	*Diplograptus multidens*
			4 a β	*Nemagraptus gracilis*
$\mathrm{C_{I}}$ c Uhaku Stage	[S. Öland]	Furudal Limestone	4 a α_4	*Glyptograptus teretiusculus*
$\mathrm{C_{I}}$ b Lasnamägi Stage		Folkeslunda Limestone	4 a α_3	?
		Seby Limestone Skärlöv Limestone		*Didymograptus murchisoni*
$\mathrm{C_{I}}$ a Aseri Stage		Segerstad Limestone	4 a α_2	

The upper part of the Jõhvi Stage of western Estonia contains *Pseudoclimacograptus* cf. *scharenbergi*, described in the present paper, and *Amplexograptus* ? n.sp. (BULMAN 1932, Pl. 3, figs. 21–23). As *Pseudoclimacograptus* is not known with certainty from beds above the Scottish *Climacograptus wilsoni* zone, the Jõhvi Stage is evidently older than the zone of *Dicranograptus clingani*, and should be compared to the upper part of the zone of *Diplograptus multidens* (cf. also OBUT 1958). This is in accordance with the above correlation of the Jõhvi Stage with the shelly sequence of Sweden.

On Kinnekulle the *Ludibundus* Limestone is overlain by shales with *Dicranograptus clingani*, and the limestone bed above the shales contains *Tretaspis ceriodes* (ANG.) (THORSLUND 1948, pp. 343, 345) which is distinctive for the *Macrourus* beds (recorded also from the lowermost beds of the Slandrom Limestone of the Skute Nappe, Jämtland; THORSLUND 1940, p. 82).

The correlation of the Viruan shelly and graptolitic sequence of Baltoscandia is given in Table 10.

REMARKS ON THE CORRELATION BETWEEN THE BRITISH-SCANDINAVIAN AND AUSTRALASIAN GRAPTOLITIC SEQUENCES.—Recent studies, particularly those by BERRY (1956) and KINDLE & WHITTINGTON (1958), have shown an exact correlation of the British-Scandinavian and Australian graptolitic sequence to be of great importance for the correlation between the European and North American shelly facies. As certain points concerning this correlation have been touched in this paper (cf. the Chapter on stratigraphical terms), some remarks are necessary for making clear the writer's opinion.

The association of Australian and European species in the Ningkuo Shale of the Lower Yangtze valley of China is at present of particular aid in correlating a part of British-Scandinavian and Australian graptolitic sequence. The zonal subdivision of the Ningkou Shale is as follows (Hsü 1934; Mu 1957; Mu & Lee 1958):

Zone of *Amplexograptus confertus*	Subzone of *Azygograptus fasciculatus* Subzone of *Climacograptus* ? *gracillicornis* Subzone of *Didymograptus ellesae*
Zone of *Didymograptus hirundo*	Subzone of *Glyptograptus austrodentatus* Subzone of *Cardiograptus*

The correlation of the zone of *Didymograptus hirundo* and of the subzone of *D. ellesae* has recently been discussed by Mu & Lee (1958). The subzone of *Cardiograptus* was considered to be comparable to the Yapeen Stage, and the subzones of *Glyptograptus austrodentatus* and *Didymograptus ellesae* to the *G. austrodentatus* and *G. intersitus* zones, respectively, of the Victorian sequence. The correlation suggested by them of the Ningkuo Shale with the European sequence agrees with that of Hsü (1934): the *D. hirundo* zone is regarded as a counterpart of the European zone of *D. hirundo*, and the zone of *Amplexograptus confertus* compared with the zone of *Didymograptus bifidus* (cf. also Bulman 1958a, p. 167). These correlations seem to be well founded except that the comparison of the subzone of *Didymograptus ellesae* with the European sequence, based mainly on the appearance of a form identified as *Amplexograptus confertus*, cannot be considered as proved. An unconditional identification at the specific level of a biserial axonophorous graptoloid in flattened material is often uncertain provided that the species does not possess some unusual and easily recognizable characters. The faunal differences between the subzones of *Climacograptus* ? *gracillicornis* and *Azygograptus fasciculatus* (Hsü 1934) are slight, and concern only a few species. Several species are identified which in Europe are distinctive for the zone of *Didymograptus bifidus*. Perhaps the most characteristic of them is *Azygograptus fasciculatus* (type species of the genus *Nicholsonograptus* Bouček & Přibyl 1952), known from the zone of *Didymograptus bifidus* in Great Britain, Bohemia (Bouček 1932), Sweden (*Azygograptus falciformis* Ekström, considered identical with *A. fasciculatus* by Lemon & Cranswick 1956; index fossil of Ekström's upper subzone of the *D. bifidus* zone of Scania), and Peru (Lemon & Cranswick 1956). The Chinese specimens of this species differ mainly, or exclusively, by the greater length of the stipe (Lemon & Cranswick 1956). The correlation of the two upper subzones of the zone of *Amplexograptus confertus* with the Victorian succession is not quite certain, but they may be comparable to the zone of *Diplograptus* *decoratus* and "*Didymograptus*" *nodosus* (M.O.3). "*Didymograptus*" *spinosus* RUED., characteristic for these subzones of the Lower Yangtze valley, closely resembles "*D.*" *nodosus*, and *Phyllograptus nobilis* (confined to, and common in the zone M.O.3) is common in the *D. bifidus* zone of Scandinavia. A species closely similar to, or identical with *Didymograptus* ? *dubitatus* of the Victorian zone M.O.3 is described here from the upper Kundan beds which are compared with the upper part of the *D. bifidus* zone. A possibly identical species (*Didymograptus* aff. *euodus* in BULMAN 1933) is known from Peru in an assemblage which according to BULMAN (1933) is probably of early *Didymograptus murchisoni* age, but which may be of *Didymograptus bifidus* age (the specimen of *D. murchisoni geminus* figured by BULMAN 1933, Pl. 33, fig. 4 is *D. bifidus* as defined by EKSTRÖM 1937, and pendent didymograptids with climacograptoid thecae are not known with certainty above the *D. bifidus* zone). So the available evidence indicates that the Victorian zone M.O.3 ought to be compared with (a part of) the zone of *Didymograptus bifidus* rather than with the zone of *D. murchisoni* as suggested by HARRIS & THOMAS (1938). The fauna of the zone M.O.3 does not seem to include any species or genus which would indicate the *D. murchisoni* zone of Europe and South America.

The Victorian zone M.O.4 (zone of *Glyptograptus teretiusculus*) has generally been compared with the *Glyptograptus teretiusculus* zone of Great Britain. The fauna of the former zone is known mainly from two localities, Ba 67 of Victoria (HARRIS & CRAWFORD 1921; THOMAS & KEBLE 1933) and Cobb River of New Zealand (KEBLE & BENSON 1929; BENSON, KEBLE, KING & MCKEE 1936). The assemblage of this zone differs from the British-Scandinavian zone of *G. teretiusculus* by the presence of *Tetragraptus*, *Isograptus*, and *Pterograptus*, and by the absence of *Dicellograptus* and *Nemagraptus* which in Australia and New Zealand appear in the next higher beds. The latest *Isograptus* (one specimen) known from Europe comes from the zone of *Didymograptus murchisoni* of Scania (HEDE 1951, p. 52). In New South Wales one specimen of this genus has nevertheless been found associated with *Nemagraptus* and *Dicellograptus* (SHERRARD 1953, p. 80). In Scandinavia and South America (BULMAN 1931) *Pterograptus* has been found with certainty only in the zone of *Didymograptus murchisoni*, where occasionally stipes of the genus occur in great abundance. In Victoria and New Zealand the genus is confined to the zone M.O.4 (*Pterograptus incertus* HARRIS *et* THOMAS from the zone M.O.2 belongs to the genus *Pseudobryograptus;* cf. MU 1957, p. 423), whereas in China the exact stratigraphic horizon of the recorded specimens is unfortunately unknown (MU 1953). The species of *Pterograptus* of the Cobb beds of New Zealand is indistinguishable from *P. elegans* (BENSON, KEBLE, KING, & MCKEE 1936), the index fossil for the lower and main subzone of the *D. murchisoni* zone of Scandinavia (zone of *P. elegans* of EKSTRÖM 1937 and HEDE 1951). It should also be noted that flattened specimens of *Pseudoclimacograptus angulatus angulatus* from the *D. murchisoni* zone of the Oslo district resemble very much *P. riddelensis* HARRIS

Table 11.

Great Britain and Scandinavia	Lower Yangtze valley, China		Australia and New Zealand	
Zone of *Didymograptus murchisoni*	?		"Middle Ordovician"	M.O.4. Zone of *Glyptograptus teretiusculus*
Zone of *Didymograptus bifidus*	Zone of *Amplexograptus confertus*	Subzone of *Azygograptus fasciculatus* Subzone of *Climacograptus*? *gracillicornis*		M.O.3. Zone of *Diplograptus* ? *decoratus* and *Didymograptus nodosus*
?		Subzone of *Didymograptus ellesae*		M.O.2. Zone of *Glyptograptus intersitus*
Zone of *Didymograptus hirundo*	Zone of *Didymograptus hirundo*	Subzone of *Glyptograptus austrodentatus*		M.O.1. Zone of *Glyptograptus austrodentatus*
		Subzone of *Cardiograptus*	Yapeen Stage	
?	Yinchufu Shale			

(1924, Pl. VII, figs. 11–12) from the zone M.O.4 of Victoria. All this evidence and especially the distribution of *Pterograptus*, speaks in the writer's opinion for comparison of the zone M.O.4 with the zone of *Didymograptus murchisoni* and not with that of *Glyptograptus teretiusculus* as previously suggested. The species *G. teretiusculus* itself has a long range (cf. e.g. HEDE 1951).

If the above correlation is correct, the question remains: Where in the Australian-New Zealandian sequence occur beds comparable to the zone of *Glyptograptus teretiusculus* as defined in Great Britain and Scandinavia? It is difficult to give an answer, not only because the probably corresponding portion of the Australian and New Zealandian sequence is poorly known, but also because in Europe this zone lacks, with some exceptions which are often of local importance, easily identifiable distinctive fossils. The entry in force of *Dicellograptus*, *Dicranograptus*, *Nemagraptus* (a tiny form without known second-order branches), and *Gymnograptus*, and the lack of pendent *Didymograptus* and of *Tetragraptus* characterizes the zone in Scania, where its fauna and succession is better known than in Great Britain. Most of the faunal characteristics of this zone are, however, on the specific level. If the general succession of graptolite faunas is roughly the same also in Australia and New Zealand, the British-Scandinavian *Glyptograptus teretiusculus* zone is more likely comparable to some part of the sequence between the zone M.O.4 and beds with *Nemagraptus* of *gracilis* group than to the zone M.O.4.

The writer's opinion about the discussed correlation is summarized in the Table 11. Much of it still rests on feeble evidence, but there is good hope that further studies of Chinese sections may correct it, and increase the exactness.

The shales which overlie the Table Head Limestone of Newfoundland (cf. also DUNBAR 1954, pp. 255–256) were considered by KINDLE & WHITTINGTON (1958) as of Upper Yapeen age. But the species of *Cardiograptus* listed by them is *C. crawfordi* which in Victoria is indicative of the "Middle Ordovician" zones of *Glyptograptus intersitus* (M.O.2) and *Diplograptus decoratus* (M.O.3), where it is associated with, amongst others, *Isograptus forcipiformis* and *Cryptograptus schaeferi* (HARRIS 1935). The presence of *Glossograptus hincksi* and a climacograptid in the shales above the Table Head Group strongly supports the correlation with one of the above Victorian zones and (cf. Table 11) with the zone of *Didymograptus bifidus* of the British-Scandinavian succession. The Table Head Group is regarded to be of Whiterockian age (COOPER 1956), and thus the fauna of the overlying shales gives a rough idea about the age of the upper boundary of this stage in terms of graptolite zones. Whether the level of this boundary falls at the base, within, or at the top of the *Didymograptus bifidus* zone cannot be decided from available evidence[1].

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[1] The occurrence of *Didymograptus artus* ELLES *et* WOOD in the Joins Formation of Oklahoma (ULRICH 1911, p. 663; DECKER 1935, 1944), included by COOPER (1956) in the Whiterock Stage, has often been considered as an indication of the Llanvirnian age of these beds. The present writer has had the opportunity of examining all material referred by DECKER to this species. Most of the specimens identified by him as *D. artus* have decidedly too small a number of thecae in a given unit (14–16 in 10 mm; DECKER 1935, Pl. I, fig. 8, 9, 9a, 1944, fig. 27), and seem to be young rhabdosomes of the associated *D. bifidus*. Some other specimens (like that figured by

According to Kindle & Whittington (1958) the lower boundary of the Whiterock Stage roughly coincides with the boundary between the Bendigonian and Chewtonian Stages of the Victorian sequence. If this is correct, the Whiterockian corresponds to the Chewtonian, Castlemainian, Yapeen, and to at least the lowermost zone of the "Middle Ordovician" (zone of *Glyptograptus austrodentatus*, M.O.1) of Victoria, and would thus be a comprehensive unit in terms of Australian graptolite zones. The typical Yapeen fauna is not present in the Cow Head Group, or has not yet been found. Kindle & Whittington's *Isograptus caduceus* zone may correspond to both the Castlemainian and the Yapeen, for *Isograptus* is common also in the latter stage. *Pendeograptus fruticosus* extends in Scandinavia and Great Britain to the base of the *D. hirundo* zone and, if the level of its disappearance is contemporaneous in Europe and Newfoundland, the lower boundary of the Whiterock Stage may roughly correspond to the boundary between the British zones of *Didymograptus extensus* and *D. hirundo*. However, the correlation of this part of the graptolitic sequence is still very vague, and the above suggestions are scarcely more than guesses.

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Decker 1944, fig. 26) are too poorly preserved to allow of any specific identification. Only the specimen figured by Decker (1944) as fig. 28 has 10 thecae in 5 mm, and resembles *D. artus*, but its specific reference is uncertain. Thus until further notice this species ought to be excluded from stratigraphic discussions of the North American sequence. The presence of *Didymograptus bifidus* in these beds does not necessarily indicate beds corresponding to the zone of *D. bifidus* of Northern Europe. This species probably occurs in North America at a lower level than in Northern Europe (Monsen 1937; Bulman 1958a).

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Explanation of the Plates

Plate I

All figured specimens have been collected and isolated by GERHARD HOLM from the Pakri Calcareous Sandstone of the Island of Väike Pakri (Swedish: Lilla Rågö), Estonia. Valastean ($B_{III}\beta$) or Aluojan ($B_{III}\gamma$) Substage, or both. Photographs by G. HOLM, retouching by G. LILJEVALL.

Didymograptus pakrianus n. sp.

1. Rhabdosome with a fairly wide angle of divergence of stipes. Holotype. RM No. Cn. 54569. ×5.
2. Old rhabdosome with almost parallel stipes. Original specimen not found. ×2.5.
3. Young rhabdosome with parallel stipes. RM No. Cn. 54608. ×2.5.
4. Young rhabdosome with diverging stipes. RM No. Cn. 54570. ×2.5.
5. Internal view of reverse side of a proximal portion of an old rhabdosome showing the extension of secondary periderm between the stipes. See also text-fig. 4. RM No. Cn. 54567. ×11.
6. Internal view of obverse side of an old rhabdosome. RM No. Cn. 54568. ×11.
7. A part of a stipe. Note the complete lack of free ventral margin of thecae. Specimen not identified. ×5.5.
8. A part of a stipe of a comparatively old rhabdosome. RM No. Cn. 54575. ×2.5.

Didymograptus ? sp. A

9. Proximal part of a three-stiped rhabdosome. RM No. Cn. 54557. ×7.

Didymograptus cf. *artus* ELLES *et* WOOD

10. A rhabdosome with slightly diverging stipes. RM No. Cn. 54572. ×5.
11. A rhabdosome with parallel stipes. RM No. Cn. 54571. ×2.5.

Plate II

All specimens have been isolated by G. HOLM. Those figured as figs. 1–3 and 8–11 have been collected by G. HOLM from the Pakri Calcareous Sandstone of the Island of Väike Pakri, Estonia. Valastean ($B_{III}\beta$) or Aluojan ($B_{III}\gamma$) Substage, or both. Photographs by G. HOLM, retouching by G. LILJEVALL.

Didymograptus ? sp. C

1. Lateral view of a fragment of a stipe. RM No. Cn. 54609. ×14.
2. Ibid. RM No. Cn. 54565. ×12.
3. Ventral view of a fragment of a stipe. The margin of the collar around the thecal apertures is thin and not strengthened by a periapertural list as it may seem from the strongly retouched photograph. RM No. Cn. 54559. ×14.

Pseudoclimacograptus cf. *scharenbergi* (LAPWORTH)

The figured specimens have been collected by FR. SCHMIDT from Põõsaspea (Spitham), Estonia. Jõhvi Stage (D_I).

4. Fragment of rhabdosome in ventral view. The specimen could not be found. ×7.

5–7. Fragment of rhabdosome in three different views. RM No. Cn. 54584. ×8.

Didymograptus ? cf. *dubitatus* Harris *et* Thomas

8–9. Proximal part of a rhabdosome in obverse and reverse views. RM No. Cn. 54564. × 8.

Didymograptus ? sp. C

10, 11. Two small proximal portions of rhabdosomes. The state of preservation of the specimens is much worse than apparent from the strongly retouched photographs. RM Nos. Cn. 54562 and 54563. × 14.

Plate III

The specimens figured as figs. 1–5 and 10–11 have been isolated by G. Holm and those as figs. 6–9 and 12–14 by V. Jaanusson. Photographs by N. Hjorth.

Didymograptus pakrianus n. sp.

The specimens have been collected by G. Holm from the Pakri Calcareous Sandstone of the Island of Väike Pakri, Estonia. Valastean ($B_{III}\beta$) or Aluojan ($B_{III}\gamma$) Substage, or both.

1. A young rhabdosome with diverging stipes. RM No. Cn. 54544. × 4.
2. A young rhabdosome with almost parallel stipes. RM No. Cn. 54552. × 4.
3. An old rhabdosome with robust proximal end. RM No. Cn. 54556. × 4.
4. Proximal portion and a stipe of an old rhabdosome. RM No. Cn 54547. × 2.
5. Proximal portion of an old rhabdosome. RM No. Cn. 54581. × 4.

Glyptograptus vikarbyensis n. sp.

The figured specimens are from the Furudal Limestone of the Siljan district; fig. 6 from Fjäcka, locality No. 6 and figs. 7 and 8 from the top of the sequence excavated at Vikarbyn by V. Jaanusson and H. Mutvei in 1947.

6. Proximal part of a rhabdosome. The first theca on the right side is th 2^1. UM No. D 762. × 10.

7, 8. Proximal parts of rhabdosomes. UM Nos. D 763 and D 761 (fig. 8, holotype; cf. also text-fig. 6 B). × 10.

Glyptograptus cernuus n. sp.

9. Holotype. Proximal part of a rhabdosome (cf. also text-fig. 6 A). Furudal Limestone, Fjäcka, locality No. 6, Siljan district. Coll. V. Jaanusson 1948. UM No. D 765. × 10.

Glyptograptus cf. *teretiusculus* (Hisinger)

10. Öland, Stora Mossen, Folkeslunda Limestone. SGU. × 8.
11. Proximal portion of a rhabdosome.
    Öland, Gärdslösa, Folkeslunda Limestone. RM No. Cn. 54591. × 8.

Climacograptus pauperatus Bulman

The figured specimens are from the grey Seby Limestone of a watering hole ca. 500 m E of the last house of the village of Seby, Öland.

12. Proximal portion of a rhabdosome; virgella broken off. UM No. Öl. 984. × 20.
13. Fragment of a rhabdosome in ventral view. UM No. Öl. 985. × 20.
14. Proximal portion of a rhabdosome. UM No. Öl. 983. × 20.

Plate IV

The specimens figured as figs. 1–4 and 10–12 have been isolated by G. Holm and those as figs. 5–9 by V. Jaanusson. Photographs by N. Hjorth.

Pseudoclimacograptus luperus n. sp.

The specimens have been collected by G. Holm from the Folkeslunda Limestone of Öland.

1. Holotype. Proximal portion of a rhabdosome (cf. also text-fig. 7C). Gärdslösa. RM No. Cn. 54587. × 15.

2–4. Fragment of a rhabdosome in two different views. Lerkaka. RM No. Cn. 54588. Figs. 2 and 4, × 15; fig. 3, × 30.

Pseudoclimacograptus angulatus sebyensis n. subsp.

Grey Seby Limestone. Öland, watering hole c. 500 m E of the last house of the village of Seby.

5. Fragment of a rhabdosome. UM No. Öl. 975. × 15.
6. A curved fragment of a rhabdosome. The shape of the apertural excavation of the second theca to the right shows the curvature to have developed during the growth of the rhabdosome. UM No. Öl. 978. × 15.
7. Proximal portion of a rhabdosome. The subapertural spine of th 1^1 is broken off. UM No. Öl. 981. × 15.
8. Holotype. The subapertural spines of th 1^1 and 1^2 are broken off. UM No. Öl. 980. × 15.
9. A fragment of a rhabdosome in ventral view. UM No. Öl. 977. × 15.

Pseudoclimacograptus eurystoma n. sp.

10. Öland, Gärdslösa, coll. G. Holm 1894. SGU No. 152. × 10.

Climacograptus kuckersianus Wiman

The specimens have been collected by G. Linnarsson from Kukruse, Estonia. Kukruse Stage, probably its lower substage ($C_{II}\alpha$).

11–12. RM Nos. Cn. 54606 and Cn. 54607. × 15.

Plate V

Photographs by N. Hjorth, figs. 1, 2, 5, and 11 slightly retouched by E. Ståhl.

Didymograptus acutus Ekström

1. Complete rhabdosome. Estonia, Malla, Aseri Stage (C_Ia). Coll. G. Holm 1883. RM No. Cn. 54604. × 5.

Didymograptus cf. *murchisoni murchisoni* (Beck)

2. Distal fragment of a stipe. Öland, E of and close to the Skärlöv bridge. Probably grey Seby Limestone. Coll. J. C. Moberg. SGU. × 3.
3. Distal end of a stipe. Öland, watering hole c. 500 m E of the last house of the village of Seby. Grey Seby Limestone. Isolated by V. Jaanusson 1958. UM No. Öl. 971. × 5.

Gymnograptus linnarssoni (Moberg)

4. Virgula and irregularly spaced septal rods. Siljan district, Fjäcka, locality No. 6. Furudal Limestone. Collected by Jaanusson, Martna, and Neuhaus 1945, isolated by Jaanusson 1957. See also text-fig. 9B. UM Nr. D 770. × 15.

Climacograptus distichus (Eichwald)

5. Lectotype. Figured by Eichwald (1860), Pl. XXVI, figs. 7a, b. Estonia, Osmussaar (Odinsholm); Lasnamägi Stage. Geological Department of the Leningrad State University, coll. E.I. Eichwald. × 6.

Lasiograptus haplus n. sp.

The specimens have been collected and isolated by G. HOLM from the Folkeslunda Limestone of Öland.

6. Holotype. Gärdslösa. RM No. Cn. 54598. × 15. See also text-fig. 8B.
7. Folkeslunda. RM No. Cn. 54601. × 15. See also text-fig. 8A.

Glossograptus hincksi (HOPKINSON)

The specimen has been isolated by V. JAANUSSON from the "*Schroeteri*" Limestone of Norra Skagen bore (at the level of 28.47 m), Västergötland. SGU.

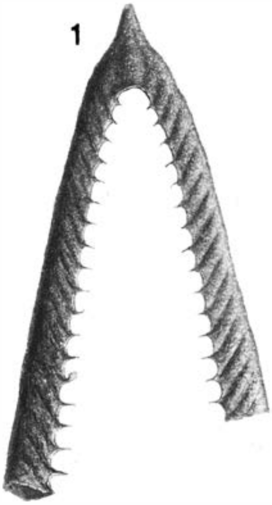
8. A fragment with a row of thecae in ventral view and the dorsal termination of the other row of thecae to the right. The latter appears to be too wide on the photograph on account of the somewhat collapsed lateral wall of that row of thecae. The median apertural spines are directed perpendicular to the plane of the photograph, and their distal ends only are visible. × 15.

9–10. A fragment of the apertural portion of one theca in two different views. Distal parts of the lateral apertural spines broken off. × 15.

Holmograptus lentus (TÖRNQUIST)

11. Specimen figured by EKSTRÖM 1937, Pl. II, fig. 7. Scania, Fågelsång, locality E 21a. Zone of *Didymograptus bifidus*. LO 3260 t. × 10.

1



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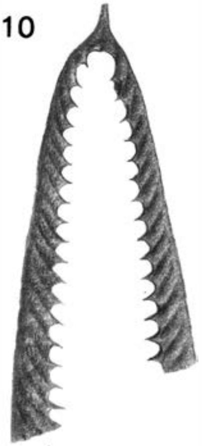

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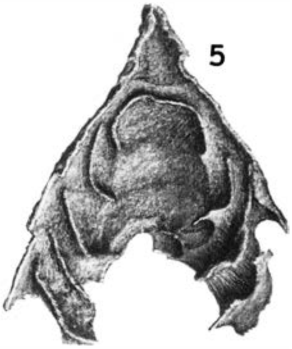

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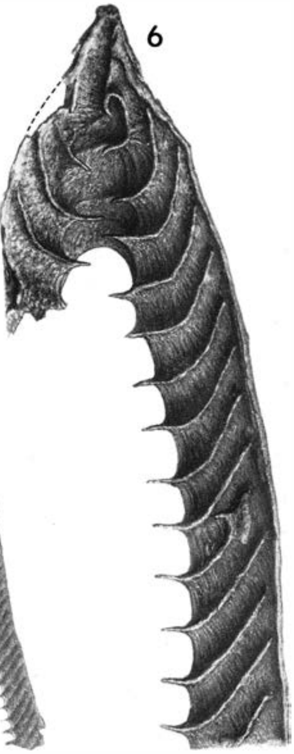

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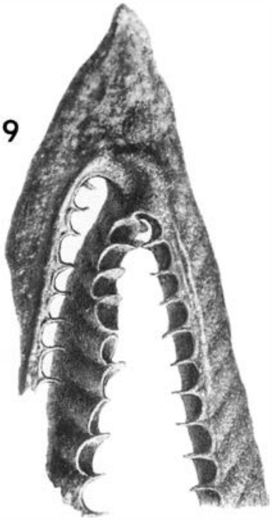

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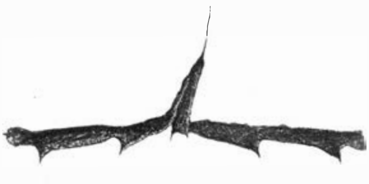
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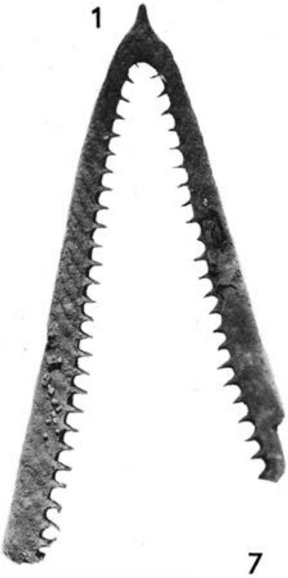

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Plate IV


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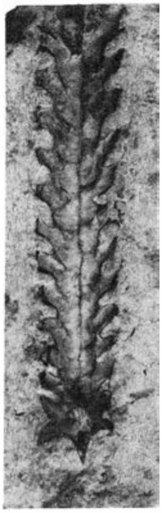

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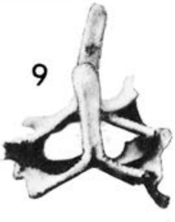

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