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TUBOID GRAPTOLITES FROM ERRATIC BOULDERS OF POLAND

Abstract. — Cyclograptidae (= Idiotubidae) are described from the Ordovician to Silurian erratic boulders of Poland. Some problems involved in tuboid taxonomy and colony organization are considered. One new genus (*Kozlowskitubus* gen.n.) and three new species (*Epigraptus eisenacki* sp.n., *E. kozlowskii* sp.n., *Dendrotubus bulmani* sp.n.) are erected. Names *Idiotubus* Kozłowski, 1949, and Idiotubidae Kozłowski, 1949, were recognized for junior synonyms of *Epigraptus* Eisenack, 1941, and Cyclograptidae Bulman, 1938, respectively.

INTRODUCTION

The Tuboidea make a rather poorly known order of benthic graptolites. They have so far been recorded in the lowermost Ordovician (Tremadocian) to Upper Silurian (Ludlovian) of Europe and North America. Many points in tuboid paleobiology are still far from clear. This is the case with astogeny and colony organization of most tuboid genera as well as with phylogenetic relationships both within the order and to the other benthic graptolites. Bulman (1970) assigned 12 genera to the Tuboidea but unrecognized tuboids may also be expected to be among the taxa attributed traditionally to the Dendroidea. In fact, poorly preserved tuboid rhabdosomes are hardly distinguishable from dendroid colonies (Bulman 1970).

Outline morphology of the Tuboidea was established by Kozłowski (1949) after the specimens extracted from the Tremadocian chalcedonites from Wysoczki, Holy Cross Mts. Later on, the tuboid paleobiology was considerably enlightened by Kozłowski (1963), Skevington (1963), Bulman and Rickards (1966), and Urbanek (1973).

The occurrence of tuboids in erratic boulders of Poland was noticed first by Kozłowski (1953) who reported subsequently (Kozłowski 1963, 1970) the following tuboid genera from the erratics: *Idiotubus* Kozłowski,

drotubus Kozłowski, *Discograptus* Wiman, and *Reticulograptus* Wiman. The Tuboidea from the Baltic area were also studied by Eisenack (1941, 1968, 1974, 1976).

The present paper is meant to investigate the tuboid graptolites from the Ordovician to Silurian erratic boulders of Poland. The investigated material is housed at the Museum of the Earth of the Polish Academy of Sciences at Warsaw (abbreviated as MZ).

Acknowledgements. — I am greatly indebted to Professor Adam Urbanek for discussion, helpful remarks, estimating the age of the boulder MZ/47 as well as for the reading the typescript. My thanks are also due to Dr Jerzy Macewicz for scanning electron micrographs.

MATERIAL AND METHODS

The investigated material consists of specimens extracted with the use of 10—15% acetic or hydrochloric acid from calcareous erratics found in the Pleistocene glacial deposits of Poland. The erratic boulders are briefly described below.

Boulder No. MZ/18, Orzechowo, Słupsk province. Limestone similar to the Baltic Limestone (Ostseekalk). It yielded: Foraminifera: *Blastammina* sp.; Melanoscleritoidea: *Melanocyathus dentatus* Eis. among others; Chitinozoa: *Cyatochitina campanulaeformis* Eis., *Conochitina* sp., and *Lagenochitina* sp.; Polychaeta: *Polychaetaspis* sp., *Pteropelta* sp., and *Mochtyella* sp.; Hydroida: *Rhabdohydra tridens* Kozł.; Problematica: *Parachitina curvata* Eis. and *Cylindrotheca* sp.; Graptolithina: *Kozlowskitubus erraticus* (Kozł.), *Mastigograptus* sp., and *Dendrograptus* sp. The occurrence of *Parachitina curvata* and *Rhabdohydra tridens* indicates the Ordovician age of the boulder, as *P. curvata* ranges in Estonia from the Johvi (D_1) to Rakvere (E) stages (Eisenack 1968b), that is since the Early Caradocian to Late Caradocian (Early Ashgilian).

Boulder No. MZ/24, Orzechowo, Słupsk province. Limestone similar to the Baltic Limestone. It yielded: Melanoscleritoidea: *Melanorhachis brachycladus* Eis., and ?*Melanorhachis* sp.; Chitinozoa *Conochitina minnesotensis* (Stauff.) and *Lagenochitina* sp.; Hydroida: *Desmohydra flexuosa* Kozł.; Polychaeta: *Mochtyella fragilis* Szan., *Atraktoprion* sp., *Polychaetaspis* sp., and *Lunoprionella* aff. *asymmetrica* Eis.; Graptolithina: *Discograptus schmidti* Wiman. The occurrence of *D. schmidti* indicates the Late Ordovician age of the boulder (cf. Urbanek and Towe 1974: 2).

Boulder No. MZ/38, Poddębie, Słupsk province. Light-gray coarse-grained limestone. It yielded: Chitinozoa: *Ancyrochitina primitiva* Eis.; Melanoscleritoidea: *Melanorhachis brachycladus* Eis. among others; Po-

lychaeta: *Mochtyella* ex gr. *trapezoidea* Kielan-Jaw., *Vistulella* sp., *Xanioprion* sp., *Tetraprion* sp., *Lunoprionella* sp., *Polychaetaspis* sp., and *Symmetroprion* sp.; Problematica: *Cylindrotheca profunda* Eis. and *Chitinodendron bacciferum* Eis., Graptolithina: *Epigraptus kozlowskii* sp.n. The occurence of *Ancyrochitina primitiva* and *Mochtyella* ex gr. *trapezoidea* indicates the Silurian age of the boulder, as *A. primitiva* has so far been recorded in the Lower Llandovery to Lower Ludlovian (Laufeld 1974).

Boulder No. MZ/47, Orzechowo, Słupsk province. Dark-gray medium-grained limestone. It yielded: Chitinozoa: *Ancyrochitina* sp.; Polychaeta: *Mochtyella angelini* Mierz., *Mochtyella* sp., *Paulinites* sp., and ?*Polychaetaspis* sp.; fragments of eurypterid cuticle Graptolithina: *Epigraptus kozlowskii* sp.n., *Dendrotubus wimani* Kozł., *Kozlowskitubus erraticus* (Kozł.), *Bulmanicrusta* cf. *latialata* Kozł., and Neocucullograptinae. The occurrence of Neocucullograptinae indicates the Late Ludlovian age of the boulder (cf. Urbanek 1970).

Boulder No. MZ/70, Orzechowo, Słupsk province. Limestone similar to the Baltic Limestone. It yielded: Algae: *Tasmanites* sp.; foraminifers; Chitinozoa: *Cyathochitina campanulaeformis* Eis. and *Conochitina* sp.; Polychaeta: *Mochtyella cristata* Kielan-Jaw., *Ramphoprion elongatus* Kielan-Jaw., *Pistoprion* sp., and *Polychaetaspis* sp.; Problematica: *Parachitina curvata* Eis. and *Cylindrotheca* sp.; Graptolithina: *Epigraptus eisenacki* sp.n., *Bulmanicrusta* sp., and ?*Climacograptus* sp. The occurrence of *P. curvata* and *M. cristata* indicates the Ordovician age of the boulder (see also remarks on the boulder No. MZ/18).

Boulder No. MZ/88, Poddębie, Słupsk province. Limestone similar to the Baltic Limestone. It yielded: Polychaeta: *Mochtyella cristata* Kielan-Jaw. and ?*Tetraprion* sp.; Graptolithina: *Epigraptus* ex gr. *bilinguis* Kozł., *Epigraptus* sp., A ?*Stolonodendrum* sp., and Crustoidea. The occurrence of *M. cristata* indicates the Ordovician age of the boulder (cf. Kielan-Jaworowska 1966).

Boulder No. MZ/124, Poddębie, Słupsk province. Light-gray crystalline limestone. It yielded: Polychaeta: *Vistulella kozlowskii* Kielan-Jaw., *Mochtyella* ex. gr. *trapezoidea* Kielan-Jaw. and *Polychaetaspis* sp.; tabulates; Graptolithina: *Dendrotubus bulmani* sp.n. and gen. et sp. indet. 1. The occurrence of *M.* ex gr. *trapezoidea* may indicate the Silurian age of the boulder.

Boulder No. MZ/148, Poddębie, Słupsk province. This boulder of Ludlovian age was described in details by Mierzejewski (1977). It yielded: Graptolithina: gen. et sp. indet. 2.

Boulder No. MZ/151, Warsaw. Dark-gray coarse-grained limestone. It yielded: Hydroida: *Rhabdohydra tridens* Kozł.; Graptolithina: *Kozlowskitubus erraticus* (Kozł.). The occurrence of *R. tridens* indicates the Ordovician age of the boulder.

REMARKS ON COLONY ORGANIZATION IN CYCLOGRAPTIDAE

The colony organization in Tuboidea was studied first by Kozłowski (1949). It was subsequently considered by Bulman (1955, 1970) and Urbanek (1971, 1973). Kozłowski (1949) found a considerable variability in colony organization in Cyclograptidae (= Idiotubidae) as expressed in the pattern of autothecae distribution. He claimed that the genera *Epigraptus* Eisenack (= *Idiotubus* Kozłowski), *Dendrotubus* Kozłowski, and *Discograptus* Wiman represent successive levels of colony organization. *Epigraptus* was regarded as displaying the least organized colonies with the autothecae irregularly distributed at the thecorhizal surface. In *Dendrotubus*, the autothecae were claimed to be clustered into irregular thecal groups. *Discograptus* was recognized for the highest level of colony organization among the cyclograptids, as its regular thecal groups are orderly distributed at the thecorhizal surface. As demonstrated by new findings of cyclograptids, the above-summarized concepts on the successive levels of cyclograptid colony organization are to be revised.

When claiming the disorderly nature of *Epigraptus* colonies, Kozlowski (1949) inferred from but small fragments of the rhabdosomes; the largest illustrated specimen (Kozłowski 1949: pl. 13: 1) comprised only five autothecae. Owing to the newly found fairly large fragments of *Epigraptus* colonies, I was able to recognized the actual morphology of the colonies as being quite different from that supposed by Kozłowski (1949). The largest investigated specimen attributed to *Epigraptus* ex gr. *bilinguis* parallel rows at its surface. The same pattern of autothecae distribution is parallel rows at its suface. The same pattern of autothecae distribution is also shown by two smaller-sized specimens of *Epigraptus* sp. which are not described in the present paper. Only the autothecae are regularly distributed in a colony, whereas the bithecae appear randomly. With this pattern of *Epigraptus* colonies taken into account, one may also discern autothecal rows in the specimen of Kozłowski (1949). Undoubtedly then, *Epigraptus* cannot be regarded as a primitive form with irregular rhabdosome shape. It is noteworthy that the regular distribution of its autothecae resembles closely the pattern of the colonies of Crustoidea and some Camaroidea.

It is rather difficult to compare the colony organization levels shown by *Epigraptus* and *Dendrotubus*, as one can hardly say anything on spatial distribution of the thecal groups in the later genus. In some cases, those groups appear to display the autothecae in rows, resembling the colony morphology of *Epigraptus*. This resemblance is still increased by single autothecae which sometimes continue the row of autothecae of a thecal group outside the group itself. This may reflect close phylogenetic relationships between the genera *Epigraptus* and *Dendrotubus*. The shapes of the whole rhabdosomes remain in both genera unknown.

The highest cyclograptid organization level was certainly achieved by the colonies of *Discograptus* displaying a rim composed of five autothecae encircling the sicula at the center of the discoidal rhabdosome. In turn, the rim is surrounded by concentric rims composed of thecal groups increasing successively in complexity (Bulman and Rickards 1966). Urbanek (1971, 1973) explained this high level of colony organization by reference to a morphophysiologic "complexity gradient" and pointed to a close analogy with the colonies of Plumulariidae (Hydroida) investigated by Schenk (1965). In fact, with the concentric structure of *Discograptus* rhabdosome taken for granted (Bulman and Rickards 1966), a radial spread of morphogenetic factor from the dominant center, namely the sicula, is to be expected. This would resemble the spread of morphogenetic factor in plumulariid colonies where the center consists in the primary monopodium and the morphogenetic factor spreads radially along the stolons (Schenk 1965). However, the analysis of the early astogeny in *Discograptus* (see below) indicates the spiral structure of the rhabdosomes, thus confirming the supposition of Bulman (1970). Hence, the morphogenetic factor must have spread along a spiral rather than radially. The spiral growth of *Discograptus* colonies allows to claim their close analogy to the colony organization in Monograptina. The rhabdosomes of "*Monograptus*" *limatulus* Törnquist and various Dimorphograptinae show rapid changes in morphology in the course of astogeny. Urbanek (1960, 1973) considers such changes as responses to a decrease in morphogenetic-factor concentration below a certain level. I believe that this hypothesis appears also relevant to the mechanisms responsible for colony organization in *Discograptus*.

When considering cyclograptid colony organization, the high variability in autothecal apertural apparatus is also to be taken into account. In general a variability in graptoloid apertural apparatus is among the manifestations of morphophysiologic gradient (see detailed discussions by Urbanek 1960, 1963, 1966, 1973). There are some distinct varieties among the apertural apparatuses of *Epigraptus kozlowskii* sp.n. A considerable variability is also shown by the apertural apparatuses of *E. eisenacki* sp.n., *Dendrotubus wimani* Kozł., and *D. bulmani* sp.n. The preservation state of the investigated specimens of the above-mentioned species makes impossible any study of the variable apertural processes versus the autothecal succession. Hence, the influence of morphogenetic gradient cannot be considered either. Nevertheless, the problem can be tentatively solved by analysing the variability in apertural processes in *Discograptus schmidti* (see below). In the latter species, there is no relationship between the apertural apparatus type and the position of autotheca within a colony. This indicates that the shape of the distal part of autothecae was beyond morphogenetic control in *Discograptus*. One may claim that this was also the case with *Epigraptus* and *Dendrotubus* colonies.

DESCRIPTIONS

Class **Graptolithina** Bronn, 1846

Order **Tuboidea** Kozłowski, 1938

Family **Cyclograptidae** Bulman, 1938

Synonym: Idiotubidae Kozłowski, 1949.

Diagnosis. — See Bulman (1970: V47).

Remarks. — Bulman (1950: 567) believed that the familial names Cyclograptidae Bulman and Idiotubidae Kozłowski had been erected "for virtually the same assemblage of genera", however, he could not establish which name possessed the priority. Therefore, he proposed to retain the name Idiotubidae in use. This decision is invalid under the rules of ICZN, as the priority of the name Cyclograptidae is obvious. Actually, it had been erected and published (Bulman 1938) eleven years before the name Idiotubidae was (Kozłowski 1949).

I feel that the family Cyclograptidae as it is now conceived (see Bulman 1970) is not a natural taxon. One can doubt whether all the cyclograptids did formed discoidal colonies. There are stoloniferous forms in the family as well as those with stolons lacking partly or totally. The cyclograptid siculae display a bilateral symmetry or a radial one of indetermined rank; they may or may not have an apertural apparatus. Nevertheless, I believe that a revision of the family Cyclograptidae would be precarious for the moment. In fact, most genera are known exclusively after isolated thecal groups or singular autothecae of unknown position within the colonies.

Stratigraphic and geographic range. — Lower Ordovician to Upper Silurian; Europe, North America.

Genus *Dendrotubus* Kozłowski, 1949

Type species: Dendrotubus wimani Kozłowski, 1949.

Diagnosis. — See Kozłowski (1949: 153).

Remarks. — The shape of the whole rhabdosome is unknown. Specimens of this genus are usually preserved in the form of thecal groups at a fragment of the thecorhiza. The specimens described so far may indicate that the colonies resembled *Epigraptus* colonies in shape.

Species assigned: Dendrotubus wimani Kozłowski, 1949 and *D. bulmani* sp.n.

Dendrotubus erraticus Kozłowski, 1963, is now attributed to the genus *Kozlowskitubus* gen.n.

Occurrence. — Ordovician to Silurian; Poland.

Dendrotubus wimani Kozłowski
(pl. 25: 2)

1949. *Dendrotubus wimani* Kozłowski: 154, figs 43—44; pl. 15: 3—8; pl. 16: 1—9, pl. 17: 5—11.

Material. — Fragment (MZ VIII 0/47 p/1) of an autothecal group from the Ludlovian erratic boulder No. MZ/47.

Description. — The group consists of seven autothecae lacking their proximal portions and showing a distinct gradation in height. The apertural apparatus is

poorly developed. The specimen is consistent with the description given by Kozłowski (1949: 154).

Remarks. — *D. wimani* was insofar known only from the Tremadocian (Kozłowski 1949). The present finding shows that the species ranges up to the Ludlovian.

Occurrence. — Poland: Tremadocian (Wysoczki), Ludlovian (erratic boulders).

Dendrotubus bulmani sp.n.
(fig. 1)

Type specimen: Thecal group (MZ VIII 0/124 p/1) shown in fig. 1.

Type horizon and locality: Erratic boulder No. MZ/124 of the ?Silurian age, Poddębie, Słupsk province.

Derivation of the name: In honour of O.M.B. Bulman, an eminent British graptologist.

Diagnosis. — Both appertural processes are well-developed, tongue-shaped; ventral processus equals or considerably exceeds in size the dorsal one.

Material. — Besides of two illustrated specimens (fig. 1), there are also two thecal groups consisting each of four autothecae with thecorhiza fragments, and some other autothecal antd thecorhizal fragments (MZ VIII 0/124 p/1—4).

Description. — The type specimen is a group of four inclined autothecae variable in height settled at a thecorhiza fragment comprising also some bithecae. The authothecal apertural processes are tongue-shaped, variable in length but always well-developed. In the type specimen, the ventral processes are much longer than the dorsal ones. Length of the erect portions of autothecae is 1435—2300 μm; diameter of autothecae is 150—190 μm; length of ventral and dorsal processes is 230—420 μm and 95—150 μm, respectively; diameter of bithecal apertures approximates 150 μm.

There is a variability in height and diameter of the autothecae and in length of the apertural processes. Within a single autothecal group, the ventral processus may equal or much exceed in size the dorsal one (fig. 1*b*).

Remarks. — The type material of *D. bulmani* sp.n. derived from a single incomplete colony split down during the laboratory treatment. *D. bulmani* sp.n. differs from *D. wimani* in its much stronger developed autothecal apertural apparatus; a dorsal processus does always occur although it is often much shorter than the ventral one.

Occurrence. — Poland: ?Silurian (erratic boulders).

Dendrotubus sp.
(fig. 2)

Material. — A single fragment (MZ VIII 0/47 p/2).

Description. — This is a rhabdosome fragment composed of six autothecae settled at a thecorhiza. All the autothecae are in a single row. Four autothecae are clustered into a thecal group, the others are isolated. There is no apertural apparatus in the autothecae.

Remarks. — The specimen displays the features of both *Epigraptus* and *Dendrotubus*. In fact, there are both isloated autotheca and a thecal group, and the autothecae form a regular row.

Occurrence. — Ludlovian erratic boulder No. MZ/47, Orzechowo, Słupsk province.

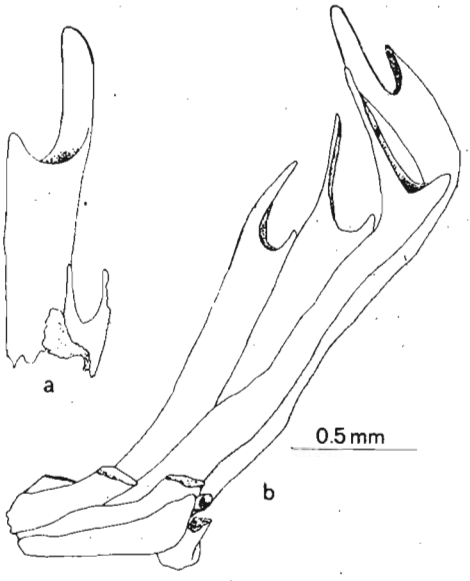

Fig. 1. *Dendrotubus bulmani* sp.n., Silurian?, erratic boulder No. MZ/124, Poddębie: *a* fragment of a thecal group (specimen No. MZ VIII 0/124p/ /1); *b* type specimen, thecal group with fragment of thecorhiza (specimen No. MZ VIII 0/124p/2).

Genus *Discograptus* Wiman, 1902

Type species: Discograptus schmidti Wiman, 1902.

Diagnosis. — See Bulman and Rickards (1966: 66).

Remarks. — This is monotypic genus. The date of its introduction is commonly

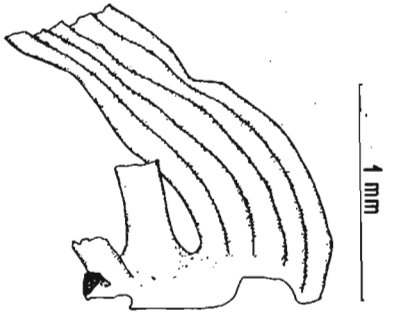

Fig. 2. *Dendrotubus* sp., Upper Ludlovian, erratic boulder No. MZ/47, Orzechowo. Fragment of colony with partially preserved two isolated autothecae and a thecal group (specimen No. MZ VIII 0/47p/2).

cited as 1901; however, the paper by Wiman appeared actually in 1902 eventhough it made part of a 1901 volume.

Discograptus schmidti Wiman, 1902
(pl. 25: 3; fig. 3)

1895. *Dictyonema peltatum* Wiman: pl. 12: 1—2, pl. 14: 23—29.
1898. No III; Wiman: 358, pl. 13: 1—11.
1902. *Discograptus schmidti* Wiman; Wiman: 191, pl. 8: 1—18.
1966. *Discograptus schmidti* Wiman; Bulman and Rickards: 66, figs 44—46.
1970. *Discograptus* sp.; Kozłowski: 400, fig. 4.

Material. — Several fragments of discs and stipes (MZ VIII 0/24 p/5—7).

Description — Morphology of the species was described in details by Bulman and Rickards (1966). Therefore, I present here only the early astogeny of the colony and the structure and variability of the apertural processes, which points were neglected by those authors.

The specimen illustrated in pl. 25: 3 represents the central part of a colony in attachment-side view. It consists of a sicula, four bithecae, and three autothecae. Originally, it comparised five autothecae, that is the entire internal rim of the colony, but it has disintegrated in the course of its preparation for SEM-investigation. The sicula is cylindrical in shape and resembles the autothecae of the internal rim but it lacks an encrusting portion typical of the autothecae and its erect portion is a little lower. The apertural processes are identical; they widen distally without showing any tendency to bifurcate. The sicula diameter approximates 86 μm. I was unable to observe the boundary between the prosicula and metasicula. The bitheca b_1 arises at the sicula and makes a wide around its base; however, its connection with the sicula cannot be seen. At the prolongation of the arc made by the bitheca b_1, there are the encrusting portions of the autothecae and bithecae showing a distinctly spiral nature of the colony growth. The encrusting portions of the autothecae are 400—490 μm long and 120—150 μm wide. The encrusting portions of the bithecae b_2, b_3, b_4 are 375—440 μm long and 75—100 μm wide. They are attached to the encrusting portions of the autothecae a_2, a_3, and a_4, respectively, and their apertures are at the base of the autothecal erect portions. Any stolons have not been found in the investigated specimen studied in details under both light and scanning electron microscope, which agrees with the observations by Bulman and Rickards (1966). This makes difficult any more precise analysis of the astrogeny and formation of the successive elements of the rhabdosome.

The autothecal apertural processes are highly variable. Most commonly, the ventral processus is bifurcate and longer than the tongue-shaped dorsal one (fig. 3*a*, *d*). Sometimes, both the processes are tongue-shaped (fig. 3*d*) or widened distally

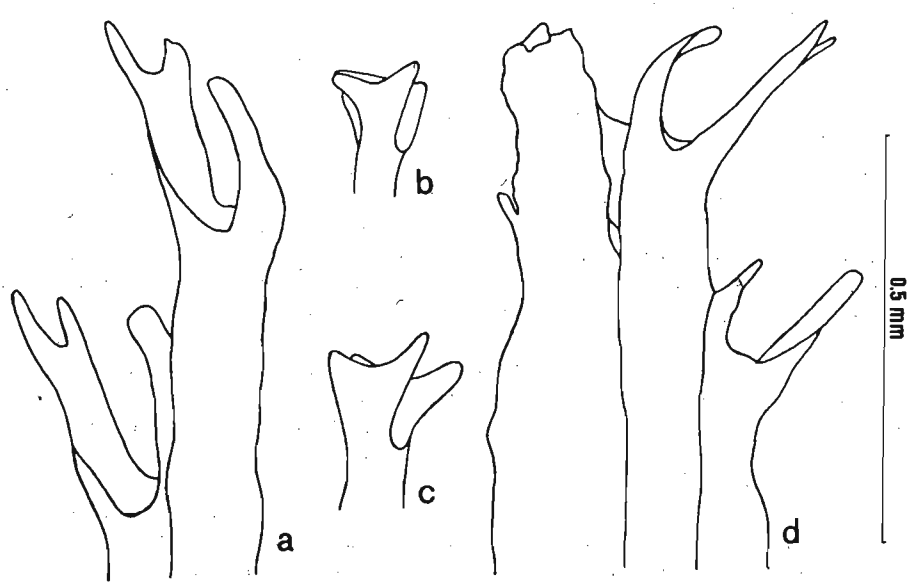

Fig. 3. *Discograptus schmidti* Wiman, 1902, Upper Ordovician, erratic boulder No. MZ/24, Orzechowo. Distal parts of autothecae (MZ VIII 0/24p/5).

with a tendency to bifurcate (fig. 3*b*, *c*). There is no relationship between the apertural apparatus type and the position of autotheca within a colony.

Remarks. — The structure of the above described central part of *D. schmidti* rhabdosome is consistent with the spiral nature of colony growth in this species as claimed by Bulman (1970). The same nature of colony growth at the early astogenetic stages is also typical of *Kozlowskitubus erraticus* (Kozł.). The arc-like shape of the first bitheca of *D. schmidti* and the way of budding its from the sicula resemble closely the specimen assigned by Kozłowski (1970) to *Idiotubus* sp., Specimen C. One may claim that the latter specimen may actually represent an initial growth stage of *D. schmidti*.

The sicula of *D. schmidti* shows some features typical of both the tuboid and dendroid sicules. Its base part is cylindrical in shape, as it is in the Dendroida; whereas it is transformed into a bubble-like swelling in the Tuboidea. However, the apertural apparatus of the sicula is distinctly tuboid in structure.

Occurrence. — Gotland: Upper Ordovician; Poland: Upper Ordovician (erratic boulders).

Genus *Epigraptus* Eisenack, 1941, emend.

Synonym: *Idiotubus* Kozłowski, 1949

Type species: Epigraptus bidens Eisenack, 1941.

Emended diagnosis: The erect portions of autothecae are arranged in rows and arise directly from the surface of thecorhiza. The autothecal apertural apparatuses are in the form of a single or two lamelliform or bifurcate processes. The bithecae are restricted to the thecorhiza.

Remarks. — The genera *Epigraptus* Eisenack, 1941, and *Idiotubus* Kozłowski, 1949, were so far regarded as distinct taxa within the family Cyclograptidae (Bulman 1955, 1970). Eisenack (1974) noticed that the only difference is in the structure of their apertural apparatuses; in *Epigraptus*, a single or both apertural processes are bifurcate, while there is no bifuraction in *Idiotubus*. I found a considerable intraspecific variability in morphology of the apertural apparatus and hence, one can no more regard this feature as *differentia generica*. The more as both *Epigraptus*-type and *Idiotubus*-type processes occur in a single fragment of the rhabdosome of *Epigraptus eisenacki* sp.n. Actually the variability in shape of the apertural processes appears much lower than the intraspecific variability in structure of the apertural apparatus observed in *Epigraptus kozlowski* sp.n.

Therefore, I consider the generic name *Idiotubus* Kozłowski, 1949, as a junior synonym of the name *Epigraptus* Eisenack, 1941. By a chance, the type specimens of the type species of both the genera resemble closely each other (they consist each in a single autotheca with a thecorhiza fragment and bithecae).

I ascribe the following species to the genus *Epigraptus* Eisenack, 1941, emend.: *Epigraptus bidens* Eisenack, 1941, *E. bilinguis* (Kozłowski, 1949), *E. crassus* (Kozłowski, 1949), *E. eisenacki* sp.n.; *E. hyperlinguatus* (Kozłowski, 1949); *E. kozlowskii* sp.n.; *E. linguatus* (Kozłowski, 1949); *E. rectus* (Kozłowski, 1949); *E. tetradens* Eisenack, 1974; *E. tubilinguis* (Kozłowski, 1949); *E. typicalis* (Kozłowski, 1949).

The high variability in the apertural apparatuses of *Epigraptus eisenacki* sp.n. and *E. kozlowskii* sp.n. indicates that their congeners described after but a few distal portions of the autothecae are to be revised. One may expect that the seven nominal species reported by Kozłowski (1949) from the Tremadocian of Poland shall be reduced to a single or two true species.

Occurrence. — Europe: Lower Ordovician to Upper Silurian.

Epigraptus eisenacki sp.n.
(fig. 4)

Type specimen: Specimen (MZ 0.VIII/70p/1) illustrated in fig. 4.

Type horizon and locality: Ordovician erratic boulder No. MZ/70, Orzechowo, Słupsk province.

Derivation of the name: In honour of Professor Alfred Eisenack, an eminent German paleontologist.

Diagnosis. — Both the autothecal apertural processes are well-developed. The ventral processus is longer; it ends usually with two short spines or sometimes it is tongue-shaped. The dorsal processus is shorter, tongue-shaped, without any spines.

Material. — Aside of the type specimen, there are also five isolated autothecae (MZ VII 0/70p/2).

Description. — The type specimen is a rhabdosome fragment comprising two autothecae settled at a piece of the thecorhiza. The autothecae arise 835 μm (a_1) and 815 μm (a_2) above the surface of the thecorhiza. They are ovate in cross section and expand gradually distalwards. Their diameters are 125 μm (a_1) and 110 μm (a_2) at the base and 180 μm and 200 μm, respectively, at the distal ending. The dorsal apertural processus is tongue-shaped; the ventral one is longer, tongue-shaped (a_2) or ended with two short spines (a_1). A tubotheca of some 50 μm in diameter runs between the autothecae. All the other specimens comprise only distal parts of autothecae. Their ventral apertural processes are always ended with two spines (fig. 4).

The intraspecific variability consists in the presence or absence of spines at the ventral apertural processus, and in the size relationship between the processes

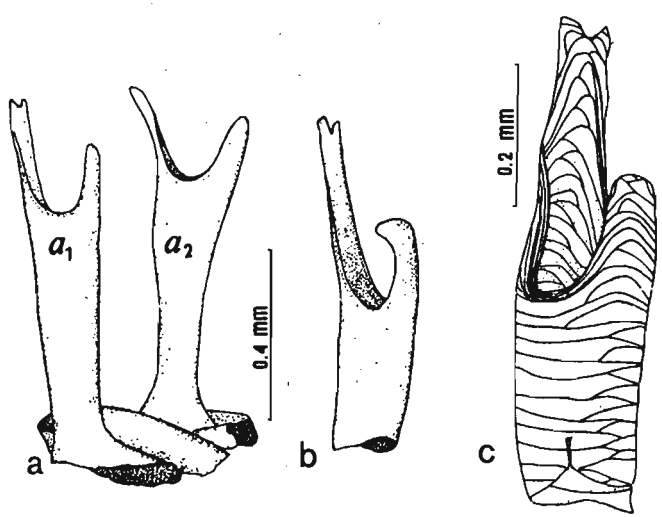

Fig. 4. *Epigraptus eisenacki* sp.n., Ordovician, erratic boulder No. MZ/70, Orzechowo: *a* type specimen, two autothecae with fragment of thecorhiza (specimen No. MZ VIII 0/70p/1); *b* distal part of autotheca (specimen No. MZ VIII 0/70p/2); *c* arrangement of fuselli in distal part of autotheca (specimen No. MZ VIII.0/70p/3).

(the ventral processus may be but slightly or much larger than the dorsal one).

Remarks. — *E. eisenacki* sp.n. resembles in the structure of the apertural apparatus both *E. bilinguis* (Kozł.) and *E. bidens* Eis.; in fact, it appears intermediate between the two species. From the former species, it differs in that it usually although

not always) displays small spines at the ventral processus. From *E. bidens*, it differs in its much smaller spines at the ventral apertural processes. Possibly, the morphocline *E. bilinguis* — *E. eisenaki* — *E. bidens* is also a phyletic lineage. This is, indeed, suggested by the stratigraphic data, as *E. bilinguis* occurs in the Lower Ordovician (Kozłowski 1949, Eisenack 1976), *E. bidens* in the Middle Caradocian (Eisenack 1974), and *E. eisenacki* derived from an erratic boulder assigned to the Lower Caradocian to Upper Caradocian/Lower Ashgilian.

The investigated specimens of *E. eisenacki* sp.n. are associated with some thecorhizal fragments with partly preserved autothecae. The autothecae lack, however, their apertural processes and therefore, they cannot be proved to be conspecific with the specimens described above.

Occurrence. — Poland: Ordovician erratic boulders.

Epigraptus kozlowskii sp.n.
(pl. 26: 1; figs 5—6)

?1971. *Idiotubus* sp.; Kozłowski: 316, fig. 2.
?1974. ?*Epigraptus* sp.; Eisenack: 672, fig. 18.
?1977. *Idiotubus*; Andres: 76, figs 27—28.

Type specimen: Colony fragment (MZ VIII.0/38p/1) composed of a single autotheca and a single bitheca.

Type horizon and locality: Silurian erratic boulder No. MZ/38, Poddębie, Słupsk province.

Derivation of the name: In honour of Professor Roman Kozłowski (1889—1977), an eminent Polish paleontologist.

Diagnosis. — The autothecal apertural apparatus is well-developed, complex, and highly variable. The ventral and dorsal apertural processes either differ in shape, dimensions, or size relations, or are identical to each other. A single or both

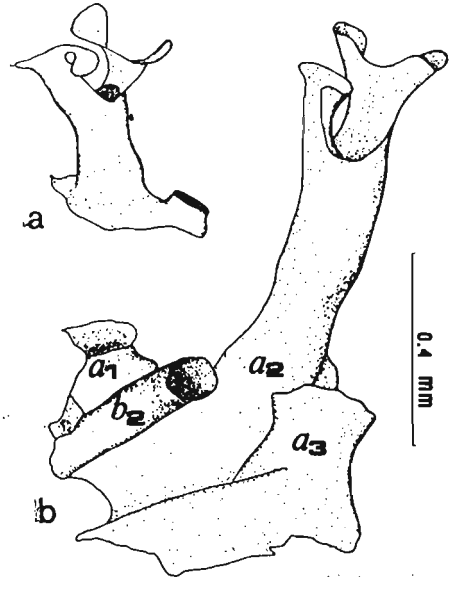

Fig. 5. *Epigraptus kozlowskii* sp.n., Silurian, erratic boulder No. MZ/38, Poddębie: *a* type specimen — autohteca with bitheca (specimen No. MZ VIII 0/38p/1); *b* fragment of colony composed of three fragmentary autohteca, two bithecae, now partially damaged specimen No. MZ VIII 0/38p/2).

processes display their lateral margins turned outwards and expanding distally, often with characteristic lateral lobes.

Material. — In addition to the type specimen, the type material includes also one colony fragment composed of three autothecae and two bithecae (MZ VIII.0/38p/2) and 90 isolated autothecae or autothecal apertural apparatuses (MZ VIII.0/38p/3—4) from the Silurian boulder No. MZ/38, and 20 isolated autothecae (one preserved along with a thecorhiza fragment) or autothecal apertural apparatuses (MZ VIII.0/47p/5—6) from the Silurian boulder No. MZ/47.

Description. — The type specimen (fig. 5*a*) is a thecorhizal fragment with a single autotheca and a single bitheca preserved. The autotheca is circular in cross section. It attains ca 100 μm in diameter and 285 μm in height (185 μm excluding the apertural processes). The lateral margins of the apertural processes are turned outwards. Both the apertural processes expand considerably in their distal parts and form characteristic lateral lobes (one lobe of the ventral processus fell away during the bleaching). The bitheca occurs at the base of the autotheca; its aperture approximates 80 μm in diameter.

The largest specimen (fig. 5*b*) has become considerably damaged during the bleaching. Originally, it consisted of a thecorhizal fragment with three autothecae and two bithecae preserved. The best preserved autotheca (a_2) attained 660 μm in heigt (500 μm excluding the apertural processes) and ca 130 μm in diameter (it was subovate in cross section). The autothecae a_1 and a_3 were but fragmentarily preserved; they attained 130—135 μm in diameter. The bitheca b_1 is only partly preserved. The bitheca b_2 approximates 35 μm in aperture diameter.

The autothecae are highly variable in morphology of their apertural apparatus, their height, and the cross section. There are the following varieties of the apertural apparatus:

Type A (fig. 6*a*). The shorter processus is tongue-shaped, with its lateral margins turned distinctly outwards; it is inclined over the aperture. The longer processus is but slightly larger; its lateral margins are turned outwards and the upper margin is distinctly notched. The processus expands distally and declines somewhat off the aperture.

Type B (fig. 6*b*). The shorter processus is wide, with its lateral margins turned outwards and the upper margin distinctly notched. The longer processus is but slightly larger; it resembles the shorter one in shape but it is less wide and slightly declined off the aperture.

Type C (figs 5*b*, 6*c*, *i*, *j*). Both the processes are almost identical. They expand distally and considerably turned outwards lateral margins; their upper margins are notched to a variable degree.

Type D (fig. 6*e*, *f*). The shorter processus is slightly inclined over the aperture. It expands considerably distalwards and displays distinct lateral lobes; the lateral margins are turned outwards and the upper margin is notched. The longer processus is declined off the aperture. It expands distally and shows distinct lateral lobes; its lateral margins are turned outwards.

Type E (fig. 6*h*, pl. 26: 1). The shorter processus is very small, tongue-shaped, straight, and flat or with but slightly turned outwards lateral margins. The longer processus is very large and trapezoidal in shape; its lateral margins are turned outwards and the upper margin is notched.

Type F (fig. 6*g*). The shorter processus is tongue-shaped, with the lateral margins turned slightly outwards. The longer processus is only a little larger; it expands distally and shows rudimentary lateral lobes but it is less wide than the shorter processus.

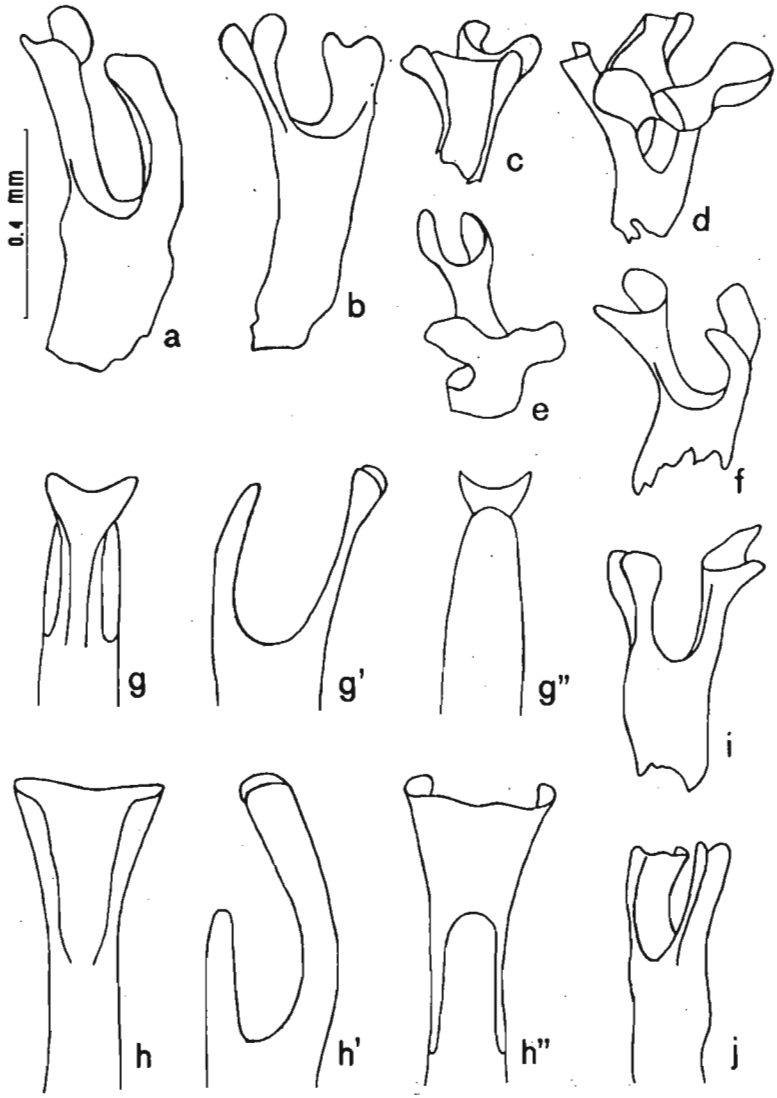

Fig. 6. *Epigraptus kozlowskii* sp.n., Silurian erratic boulders Nos MZ/38, Poddębie, and MZ/47, Orzechowo. Variability of apertural apparatus.

Type G (figs 5*a*, 6*d*). Both the processes are almost identical, with large lateral lobes. They are inclined over the aperture and sporadically fused at their upper margins.

The autothecae range from 280 μm to 850 μm in height. They are circular, subovate, or ovate in cross section.

Remarks. — The apertural apparatus of *E. kozlowskii* sp.n. is markedly different from those of the insofar known tuboid species. In turn, it resembles a little the apertural apparatuses of some Crustoidea (*Bulmanicrusta latialata latialata* Kozł.) or Dendroidea (*Dendrograptus cofeatus* Kozł.).

The apertural processus recorded by Eisenack (1974) in the Silurian of Gotland and assigned to *?Epigratus* sp. does probably also belong to *E. kozlowskii* sp.n. One

may also suppose that the tuboids reported by Kozłowski (1970: fig. 2) and Andres (1977) from the Ordovician erratic boulders are conspecific with the investigated specimens.

Occurrence. — Poland: Ludlovian erratic boulders.

Epigraptus ex gr. *bilinguis* (Kozłowski, 1949)
(pl. 25: 1)

Material. — A single specimen (MZ VIII 0/88p/1) of 2×1 mm in size, extracted from the Ordovician erratic boulder No. MZ/88.

Description. — This specimen is a thecorhizal fragment with thirteen autothecae and several bithecae preserved. The autothecae are arranged into three distinct rows, whereas the bithecae are irregularly distributed at the thecorhizal surface. Only a single autotheca shows a partially preserved apertural apparatus resembling closely *E. bilinguis* (Kozł), or *E. eisenacki* sp.n.

Remarks. — This is the largest fragment of *Epigraptus* colony described so far.

Epigraptus sp. A
(pl. 26: 2)

Material. — A single rhabdosome fragment (MZ VIII 0/88p/2) from the boulder No. MZ/88.

Description. — This specimen aproximates 1.5×0.5 mm in size. It consists of a piece of thecorhiza, three autothecae, and a fragment of tubotheca. The latter fragment attains 1500 μm in length and 200 μm in diameter. It is covered entirely with a cortical tissue passing continuously into the cortex the thecorhiza and autothecae. Any data on the structure of the tubotheca wall do not come from the SEM-investigation.

Remarks. — Kozłowski (1970) described four occurrences of tubotheca in the Tuboidea and discussed in details this mysterious structural element. I believe that the use of TEM methods to the study of tuboid tubotheca ultrastructure may provide significant informations not only on the nature of tubotheca itself but also on the cortex secretion by the graptolites.

Genus *Kozlowskitubus* gen.n.

Type species: *Dendrotubus erraticus* Kozłowski, 1963.

Derivation of the name: In honour of Professor Roman Kozłowski (1889—1977), an eminent Polish paleontologist; Lat. *tubus* — tube.

Diagnosis. — The encrusiting-dendroid colonies are attached to the substrate with a discoidal thecorhiza comprising a bottleshaped sicula at the center. The system of stolons makes a spiral within the thecorhiza, prolonged into the branches. The irregular branches comprise both the thecal bunches arising from thecorhiza and thecae formed at the branches themselves. The autothecae lack any apertural apparatus.

Remarks. — The genus is monotypical. It differs from *Dendrotubus* Kozłowski in the occurrence of branches comprising a stolon system, the absence of apertural apparatus, and the general colony form. Eventhough any whole colony of the

genus *Dendrotubus* has not so far been described, the rhabdosome fragments are markedly different from the rhabdosomes of *Kozlowskitubus* gen.n.

Kozłowski (1963) assigned the considered species to the genus *Dendrotubus* but doubtfully. Bulman (1970), too, regarded such an assignment as tentative.

Kozlowskitubus erraticus (Kozłowski, 1963)
(pl. 26: 3)

1963. *Dendrotubus erraticus* Kozłowski: 104, figs 1—15.

Material. — Two rhabdosomes (MZ VIII. 0/18p/1—2) from the Ordovician erratic boulder No. MZ/18 and two others (MZ VIII 0/47p/3—4) from the Ludlovian erratic boulder No. MZ/47.

Description. — The investigated specimens are entirely consistent with the description given by Kozłowski (1963). No difference was found between the Ordovician and Silurian forms. Any new data on the species do not follow the SEM-investigation.

Occurrence. — Poland: Middle Ordovician to Upper Silurian erratic boulders.

Gen. et sp. indet. 1
(fig. 7)

Material. — Distal part of a single autotheca (MZ VIII. 0/124p/5) from the ?Silurian erratic boulder No. MZ/124.

Description. — This is a part of the distal portion of an autotheca; it attains 1450 μm in length and 210 μm in diameter. The apertural processes are thick, une-

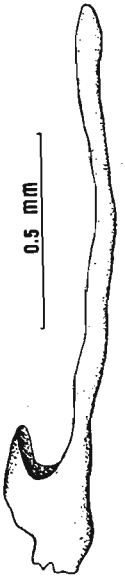

Fig. 7. Gen. et sp. indet. 1, Silurian?, erratic boulder No. MZ/124, Poddębie. Distal part of an autotheca (MZ VIII 0/124p/5).

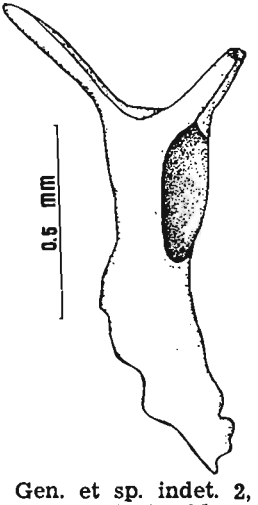

Fig. 8. Gen. et sp. indet. 2, Middle Ludlovian, erratic boulder No. MZ/148, Poddębie. Distal part of an autotheca (MZ VIII/148p/6).

qual in length, tapering distally. The ventral processus is 1185 μm long, the dorsal one is only 135 μm long.

Remarks. — The investigated specimen resembles strikingly the Tremadocian tuboids (autothecae fragments) forming the type material of *Idiotubus hyperlinguatus* Kozł. I do not attribute it to the latter species because of the following reasons: 1. *I. hyperlinguatus* Kozł. (that is *Epigraptus hyperlinguatus* (Kozł.) according to the above-discussed synonymization) was erected after merely two fragments of distal portions of autothecae and two isolated apertural processes. With the intraspecific variability in tuboid apertural apparatus and the number of nominal species recorded by Kozłowski (1949) in the Tremadocian taken into account, one may suppose that the type material of *E. hyperlinguatus* represents actually autothecal fragments of another Tremadocian species, displaying extremely well-developed apertural processes; 2. Gen. et sp. indet. 1 may also make an extreme variety of the apertural apparatus of *Dendrotubus bulmani* sp.n. (in fact, both the forms derived from the same erratic boulder).

It is noteworthy that the investigated specimen shows the largest apertural processus relative to the aperture diameter among the so far described Tuboidea.

Gen. et sp. indet. 2
(fig. 8)

Material. — Distal part a single autotheca (MZ VIII. 0/148p/8) form the Middle Ludlovian erratic boulder No. MZ/148.

Description. — This is a distal portion of an autotheca; it attains 1222 μm in length and 250 μm in diameter. Both the apertural processes are identical to each other. They are well-developed, with two long spines in their upper portions. The spines are declined outwards; they fuse with their counterparts of the other processus thus, closing the aperture.

Remarks. — The investigated autotheca is markedly different in its apertural apparatus from any Tuboidea so far known. It represents probably an unknown cyclograptid species.

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EXPLANATIONS OF PLATES 25 and 26

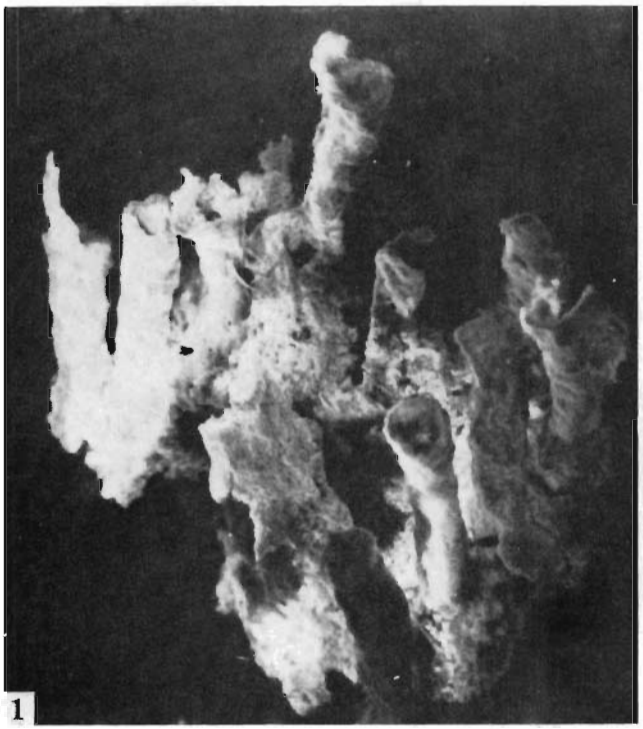
All the figures are SEM micrographs.
Abbreviations used: *a* autotheca, *b* bitheca, *s* sicula, *t* tubotheca.

Plate 25

1. *Epigraptus* ex gr. *bilinguis* (Kozłowski, 1949). Colony fragment, ×40, Ordovician, erratic boulder No. MZ/88, Poddębie.
2. *Dendrotubus wimani* Kozłowski, 1949, MZ VIII.0/47p/1. Fragment of a thecal group, ×45, Ludlovian, erratic boulder No. MZ/47, Orzechowo.
3. *Discograptus schmidti* Wiman, 1902, MZ VIII.0/245p/5. Central part of a colony in attachement-side view, ×140, Upper Ordovician, erratic boulder No. MZ/24, Orzechowo.

Plate 26

1. *Epigraptus kozlowskii* sp.n., MZ VIII.0/38p/1. Erect part of an autotheca, ×140, Silurian, erratic boulder No. MZ/38, Poddębie.
2. *Epigraptus* sp. A, MZ VIII.0/88p/2. Colony fragment with tubotheca, ×150, Ordovician, erratic boulder No. MZ/88, Poddębie.
3. *Kozlowskitubus erraticus* (Kozłowski, 1963), MZ VIII.0/47p/4. Juvenile colony, ×150, Ludlovian, erratic boulder No. MZ/47, Orzechowo.



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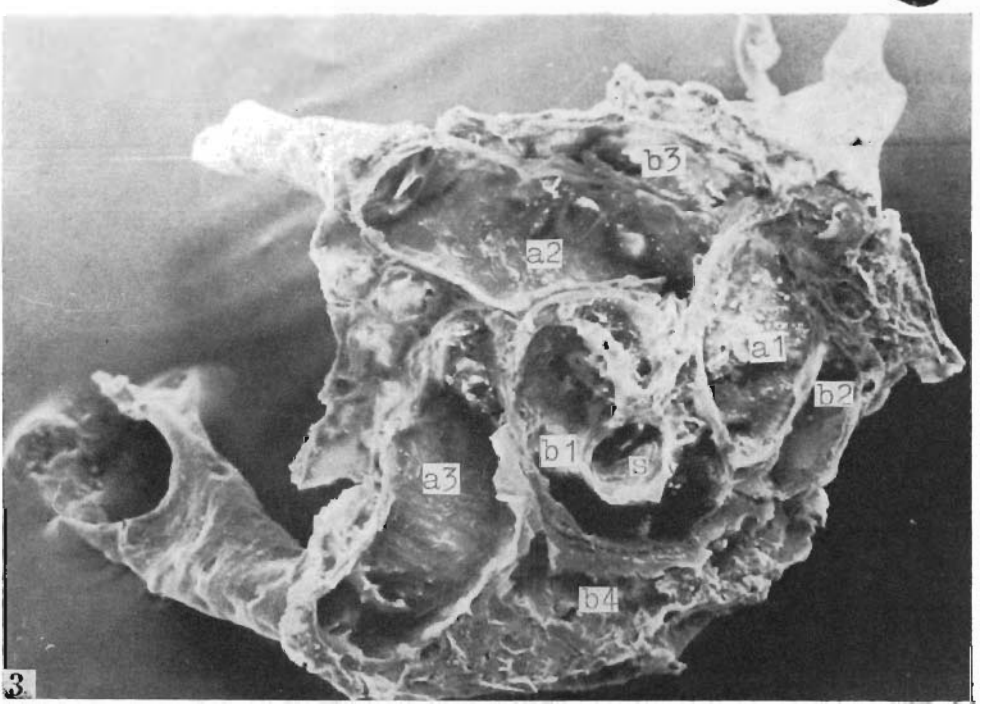

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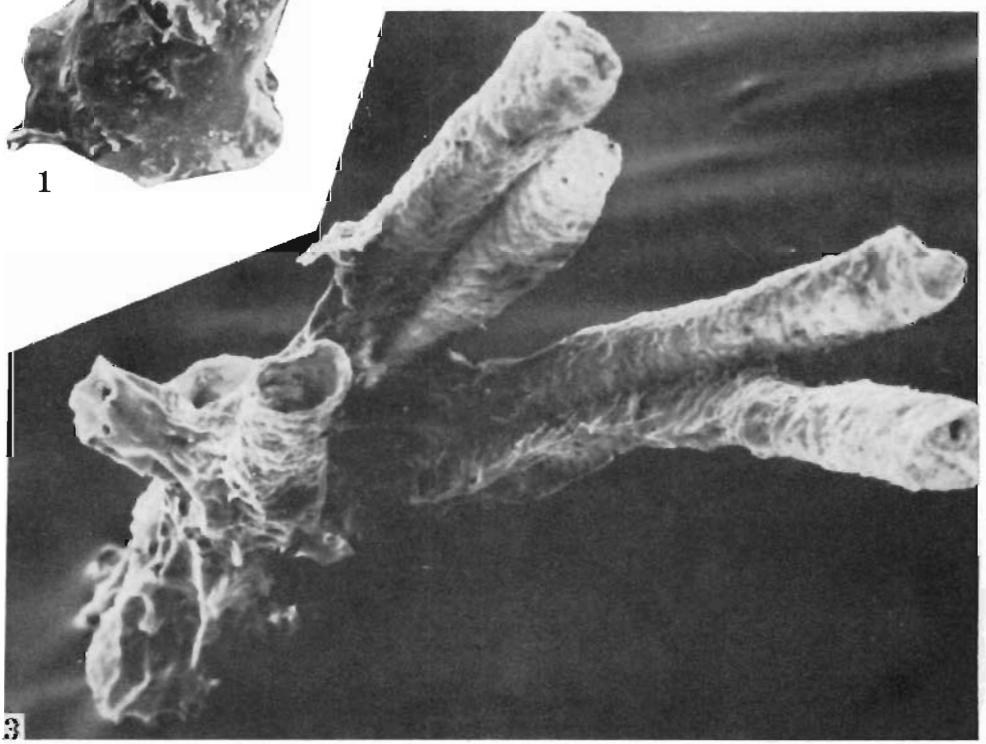

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