

Kinnegraptus, a new Graptolite Genus from the Lower *Didymograptus* Shale of Västergötland, Central Sweden

By

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ABSTRACT.—A new genus of dichograptid graptolites with two species, *Kinnegraptus kinnkullensis* n.gen. and n.sp. and *K. multiramosus* n.gen. and n.sp., is described, both species being based upon specimens isolated from the Lower Ordovician Lower *Didymograptus* Shale of Västergötland.

Introduction

The method of isolating graptolites from the matrix by means of acid is used mostly in the case of calcareous rocks. However, the greatest part of the graptolite bearing sequence is developed as shales and mudstones. In these rocks the graptolites are in most cases strongly compressed, displaying a high degree of carbonization, and having in consequence a fairly fragile periderm.

In Västergötland the Lower *Didymograptus* Shale is mostly developed as a grey to greenish grey clayey mudstone. According to HOLM (1901, p. 39), the percentage of CaCO_3 varies between 1.3 and 1.6 %. In some beds the graptolites are fairly abundant. Previous descriptions of graptolites from this part of the sequence are based on specimens exposed upon the surface of the rock slabs. As the periderm of the graptolite is usually very well preserved the present writer decided to make an attempt at etching out specimens from the rock.

Graptoliferous slabs of shale were treated with 35 % hydrofluoric acid. After 3–4 days the matrix was as a rule dissolved, the residue containing graptolites with mostly well preserved peridermal structures. Large rhabdosomes and fragments of stipes were picked out from the residue with a hairbrush. Since siculae, small rhabdosomes, and fragments were fairly sturdy, they could be separated from the residue by filtering through a net of fine mesh. After this procedure the net was inverted into a watchglass with water, when the specimens dropped into the water, and could be carefully examined. Slender stipes were so flexible that they could be bent almost 180° without breaking.

The graptolites thus obtained show different conditions of preservation. A few specimens filled with pyrite are in full relief. Most specimens are more or

less flattened, with a well preserved periderm. This is the case in siculae and young rhabdosomes, where the periderm is sometimes transparent without bleaching. To make a closer examination of the peridermal structures possible the specimens have been bleached in nitric acid and potassium chlorate. The time required was up to six days, and some specimens did not bleach at all. Contrary to specimens in full relief isolated from limestone the specimens from the shale are not damaged by such prolonged treatment. After bleaching the specimens are preserved in glycerine.

The text-figures have been drawn from photographic prints magnified twice in the positive process. All figured specimens belong to the Museum of the Palaeontological Institute, Uppsala University (abbreviated UM).

The first dissolved graptoliferous slabs were collected in 1910 by Dr. E. WIRÉN. Unfortunately no exact information of the locality was available, the slabs being only labelled "Kinnekulle" or "Hällekis". In the summer of 1960 the present writer collected boulders of graptoliferous shale in the large quarry at Hällekis. The boulders came from a digging for the foundation of an engineering work in the quarry. The sequence at this locality, described by TJERNVIK (1956, pp. 141-143), is not exposed at present. Fortunately a core drilled in 1941 by the Geological Survey of Sweden at Norra Skagen, situated 2.5 km SE of Hällekis, was available at the Institute. The species isolated from the boulders were found also in the core, and thus their stratigraphic horizon could be determined.

As demonstrated below the use of etching methods in this part of the sequence will give more detailed information about the morphology and the range of the early graptoloids than can be obtained from flattened specimens examined on the surface of rock slabs.

The hitherto dissolved fairly small quantity of mudstone has yielded isolated specimens of *Didymograptus*, *Holmograptus*, *Tetragraptus*, *Phyllograptus*, *Azygograptus*, and *Janograptus*. The examination of these genera has begun, and the results will be published later. In this paper two species of *Kinnegraptus* n.gen. will be treated.

With some success the above-described etching methods have been used also with Swedish graptoliferous clayey rocks of Upper Ordovician and Lower Silurian ages, and the new observations on the material thus obtained will be presented in forthcoming papers.

ACKNOWLEDGEMENTS.—The writer offers his sincerest thanks to Professor PER THORSLUND, Uppsala, for encouragement and helpful advice. For valuable advice and constructive criticism the present writer is indebted to Dr. VALDAR JAANUSSON, Uppsala. The help by the technical staff of the Palaeontological Institute, Uppsala University, is gratefully acknowledged.

Family *Dichograptidae* LAPWORTH, 1893Genus *Kinnegraptus* n.gen.

TYPE SPECIES.—*Kinnegraptus kinnekullensis* n.sp.

DERIVATION OF THE NAME.—The genus is named after Mt. Kinnekulle on the slope of which the type locality is situated.

DIAGNOSIS.—A genus with two or more stipes, declined or horizontal, which are narrow and thread-like. Thecae long, slender, with an almost indiscernible overlap. Sicula and thecae with long apertural processes. The relation in length between prosicula and metasicula varies from 1:1 to 7:1.

DISCUSSION.—The most important feature of the genus *Kinnegraptus* is the long slender thecae, each provided with a conspicuous apertural process. In diplograptids and monograptids the shape of the thecae is very often used as a generic character. In these two groups the development of the thecal types is fairly well known, permitting a classification at the generic level based on the shape of the thecae. In the dichograptids the thecae are mostly of a simple type, and hence the shape of the thecae has but limited taxonomic value. Recently, however, thecal characters have been used for the definition of genera (KOZŁOWSKI, 1954; MU, 1957). In the species included here in *Kinnegraptus* the shape of the thecae and the development of the apertural process differ greatly from that of other dichograptids with similar shape of the rhabdosome and are considered characters well justifying the establishment of a new genus.

In *Kinnegraptus* the sicular and thecal processes are longer than in any other dichograptids. The process has probably supported soft tissue increasing the size of the apertural region. Such a large apertural region may have been necessary on account of the very small diameter of the theca itself in relation to the length of the theca. An analogous development of the aperture can be observed in some phyllograptids and isograptids, where the thecae are provided with processes. In these two groups the thecae are very closely situated, and the competition for food may have necessitated the development of a large apertural region.

The morphological similarities between the processes of the thecae and of the sicula are striking, and suggest homologous development.

In previous descriptions of graptoloids the relation in length between prosicula and metasicula has never been reported to exceed 1:1. In *K. multiramosus* this ratio amounts to 7:1 and in *K. kinnekullensis* it varies between 1.4:1 and 1:1. It is, however, difficult to evaluate the phylogenetic significance of a prosicula longer than the metasicula, as only a few species of dichograptids are known in detail.

Although the external features of *Kinnegraptus* are fairly easily interpreted, some morphological details visible in bleached specimens complicate the interpretation of phylogeny and the classification. In *K. multiramosus* the development

of the proximal end is of the isograptid type, and in *K. kinnekullensis*, appearing later in the sequence, the development can be defined as belonging to the *bifidus* stage. Parallel with the advanced isograptid type of development in *K. multiramosus*, th 1¹ shows a primitive mode of budding, viz. from the prosicula, whereas in *K. kinnekullensis* th 1¹ originates from the metasicula. Without better knowledge of the morphological details of early graptoloids it is difficult to explain these seemingly contradictory evolutionary trends.

OCURRENCE.—The earliest representative of the genus *Kinnegraptus* is *K. multiramosus* which hitherto has been found only in the Norra Skagen core, between the levels of 62.81 and 62.86 m. Specimens of *K. kinnekullensis* have been etched from boulders collected in the quarry at Hällekis and from the core at 61.10–61.16 m. The occurrences are probably in the zone of *Phyllograptus densus* and *P. angustifolius elongatus*.

Kinnegraptus kinnekullensis n.sp.

Pl. I, figs. 1–6, text-figs. 1–4.

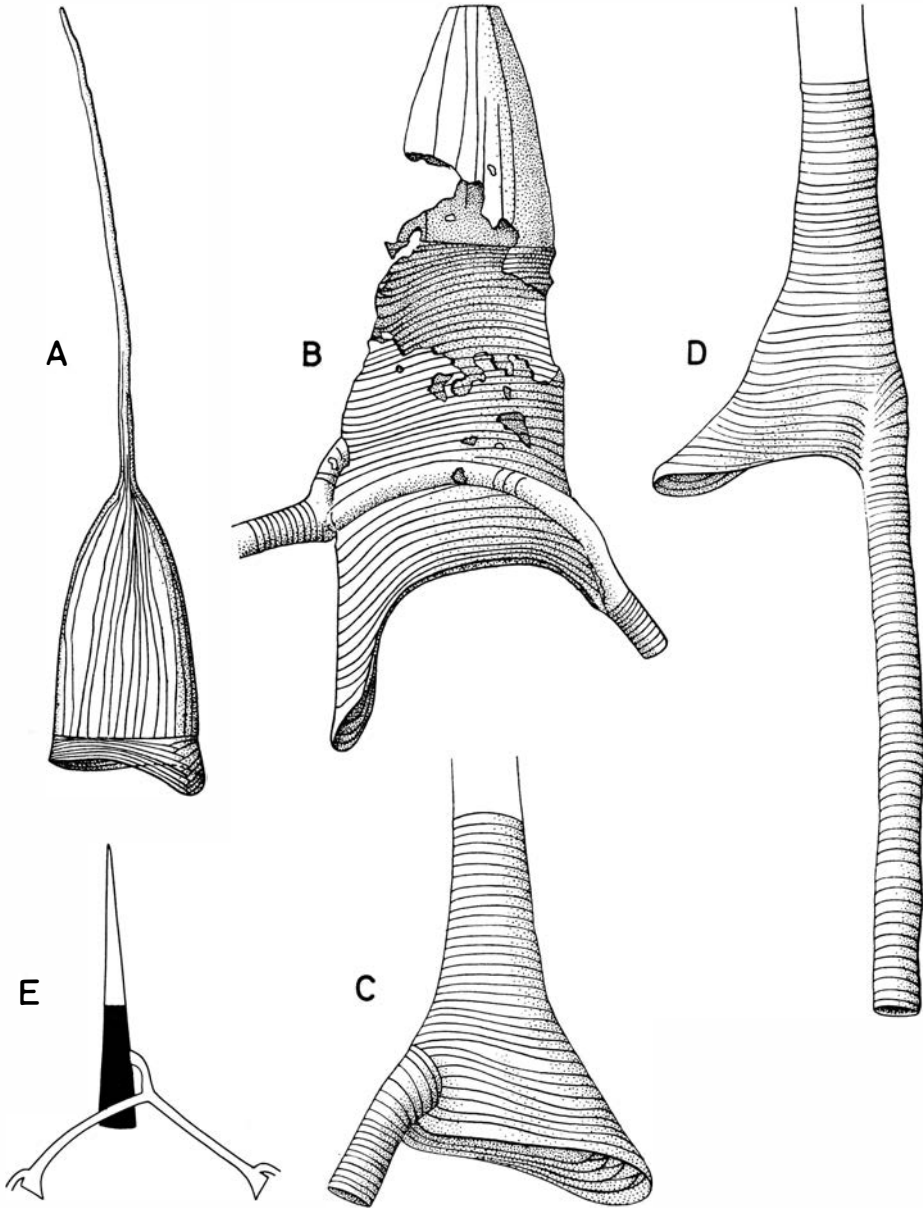
HOLOTYPE.—UM No. Vg 719, figured in text-fig. 2A.

DIAGNOSIS.—A species of *Kinnegraptus* with a long spoon-shaped apertural process in thecae as well as in sicula. Rhabdosome composed of two declined stipes. Length of the nema five times the length of the sicula. Relation in length between the prosicula and the metasicula from 1.4:1 to 1:1. Length of the thecae up to 1.6 mm. Apertural processes of the thecae directed perpendicular to the axis of the stipe. Crossing canal either on the reverse or on the obverse side. Proximal development of the *bifidus* stage. Th 1¹ buds from the metasicula.

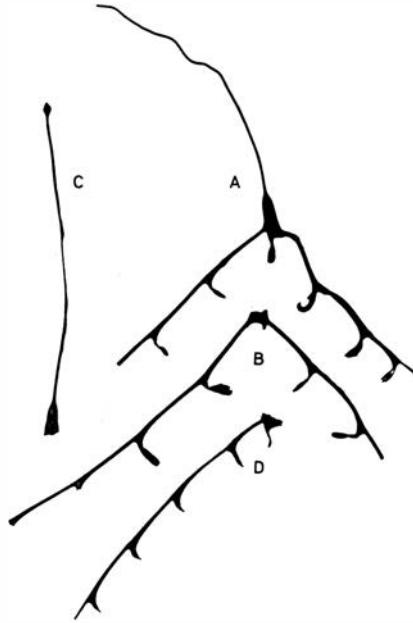
DESCRIPTION.—The available material consists of three almost complete rhabdosomes, fragments of stipes, and siculae of different stages of growth.

Angle of divergence between the proximal parts of the stipes 90° to 130°. Length of the sicula 0.85–0.95 mm, apertural width 0.30 mm. The prosicula, obtained isolated (Pl. I, fig. 1) and also discernible in transparent siculae, is 0.50 mm long, and in young specimens provided with eight longitudinal rods of fibres. In well preserved specimens a spiral thread can be discerned in the wall. The apex of the prosicula merges into the nema, and some rods of the prosicula can be followed for a short distance into the base of the nema. The available material suggests the nema to be a hollow tube; the wall of the nema is thin and transparent, and in the described young specimens somewhat wrinkled. Proximal width of the nema 0.06 mm, distal width slightly less. In one specimen (UM Vg No. 718) the nema is preserved in full length, 5 mm, and terminates distally in a claviform vesicle (text-fig. 2C). Width of the vesicle 0.20 mm.

The metasicula is sharply set off from the prosicula by the apertural ring of the latter and by the following fuselli. The formation of the apertural process can be discerned already in the proximal part of the metasicula. The fuselli, meeting in zigzag sutures on the ventral and the dorsal side, form a conspicuous



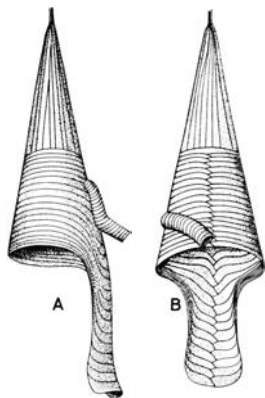
Text-fig. 1. *Kinnegraptus kinnekullensis* n.sp. *A*, early growth stage of the sicula. UM No. Vg 728. *B*, obverse view of sicula with proximal parts of th 1^1 and 1^2 . UM No. Vg 722. *C*, early growth stage of theca with the proximal part of the next theca. UM No. Vg 720. *D*, later growth stage. UM No. Vg 729. *E*, thecal diagram illustrating the mode of development of the proximal end. *A-D*, $\times 100$.



Text-fig. 2. *Kinnegraptus kinnekullensis* n.sp. *A*, holotype. Obverse view of an almost complete specimen. UM No. Vg 719. *B*, reverse view of a specimen with the sicula and the apertural process of the sicula broken off. UM No. Vg 718. *C*, proximal parts of the specimen, figured as *B* with sicula and nema terminating into a vesicle. *D*, obverse view of the apertural part of the sicula with one stipe. UM Vg 723. *A-D*, $\times 13$.

projection on the ventral side of the sicula (text-fig. 1*A*). The length of the projection increases during the ontogeny, the maximum being 0.5 mm (text-fig. 2*A*). The fuselli of the most distal part of the process seem to merge in dorsal direction into the lateral border of the process.

The first theca, th 1¹, originates on the ventral side of the metasacula 0.16 mm below the aperture of the prosacula. Proximally th 1¹ grows downwards along the sicula for 0.15 mm, and is then directed outwards forming an angle of 45° with the axis of the sicula. Width of the proximal part of the thecae 0.08 mm. Th 1² issues from th 1¹, where the latter curves outwards. Th 1² forms a gentle curve on the reverse or on the obverse side of the sicula (text-fig. 1*B*), and leaves the sicula on the dorsal side immediately above the sicular aperture. The following thecae, th 2¹ and 2², originate from th 1¹ and 1², respectively. The overlap is very small, reaching $\frac{1}{5}$ – $\frac{1}{7}$ of the length. The length of the thecae of the same stipe varies between 0.90 mm and 1.6 mm (text-fig. 2*D*). In the available material there is no obvious relation between the length of the thecae and their position in the stipe. On account of the variation in length of the thecae no exact figure can be given for the number of thecae in 10 mm length of stipe. The initial width of the thecae is maintained up to the level 0.3–0.4 mm below the aperture. Then follows a gentle increase in width (text-fig. 1*C*, *D*).



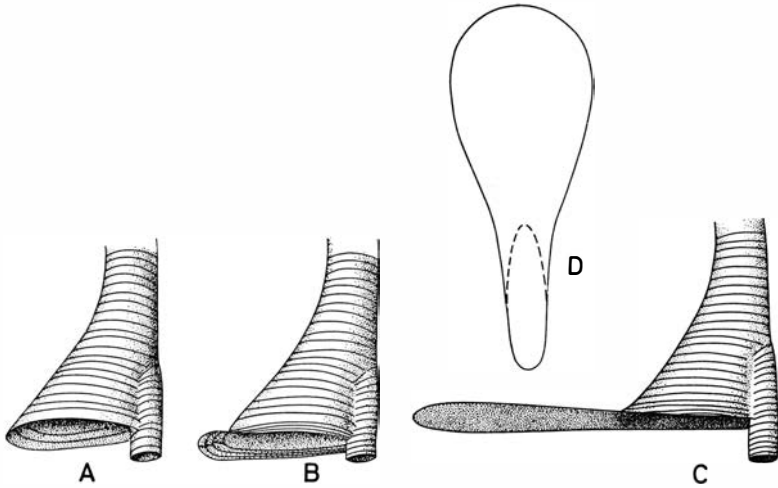
Text-fig. 3. Reconstruction of a sicula of *Kinnegraptus kinnekullensis* n.sp. with th 1^1 and 2^1 and the crossing canal on the obverse side. *A*, reverse view of sicula with proximal part of th 1^1 . *B*, dorsal view of sicula with proximal part of th 2^1 . *A* and *B*, approx. $\times 30$.

The width of the aperture of the theca prior to the formation of the process is 0.3 mm.

The length of the process reaches 0.6 mm, its proximal width being 0.1 mm. Distally the width increases to 0.4 mm, and the distal margin is broadly rounded (text-fig. 4*D*) giving the process a spoon-shaped appearance. The broad fuselli forming the process can be traced back into the lateral wall of the aperture, where they are fairly narrow. At the transition from the lateral wall of the thecae to the process the direction of the surface of the fuselli changes from longitudinal to transverse. The growth of the process is reconstructed schematically in text-fig. 4*A–C*.

DISCUSSION.—The general shape of the rhabdosome of *K. kinnekullensis* is that of *Didymograptus*, but several of the morphological details described above are unknown in that genus.

The prosicula is provided with a nema of considerable length, and in this species almost certainly developed as a hollow tube. In earlier descriptions of graptoloids of this stage (see KOZŁOWSKI, 1948, p. 66; 1954) the length of the nema has been reported as moderate. In *K. kinnekullensis* the prosicula was very likely fixed by the nema in this early stage of growth. KRAFT (1926, p. 224) suggested a planktonic mode of life of the prosicula in *Orthograptus gracilis* ROEMER, where according to him the nema has very small dimensions. In old rhabdosomes of *K. kinnekullensis* the wall of the nema is thicker and almost opaque in spite of bleaching treatment. It is probable that there is a secondary thickening, giving rise to the concentric structure observed in thin sections (URBANEK, 1958, p. 15, fig. 3). In one specimen the nema terminates in a vesicle, and this formation supports the interpretation of the nema as a hollow tube filled with soft tissue, as it is difficult to explain the growth of a vesicle with only external tissue. The interpretation of the vesicle is difficult. Perhaps it



Text-fig. 4. Reconstruction of the growth of the apertural process of a theca of *Kinnegraptus kinnekullensis* n.sp. *A*, early stage before the formation of the process. *B*, theca with the proximal part of the process. *C*, later stage showing the extent of the full-grown process. In the lateral wall of the aperture the fuselli are narrow, their ventral continuations into the process increase considerably in width. *D*, outline of the aperture with the process. *A-D*, approx. $\times 60$.

was connected with the fixation of the rhabdosome, but as the shape of the vesicle is not suitable for this purpose, the external tissue probably also contributed to the fixation.

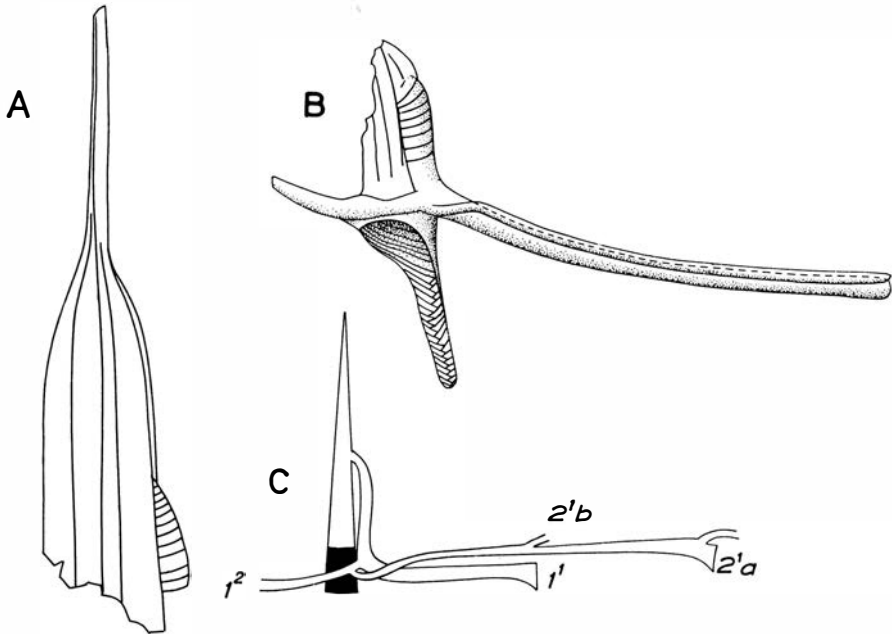
In *K. kinnekullensis* at least four of the eight longitudinal rods of the prosicula continue to varying height in the periderm of the nema. During the ontogeny there is an increase of the number of the rods as can be seen in text-fig. 1*A* compared with Pl. I, fig. 1. All the secondarily developed rods are fused with each other or with the primary rods, and do not end free as described in *Orthograptus* by KRAFT (*op. cit.*).

The proximal part of the metasicula does not deviate from the normal growth observed in graptolites. When full-grown, the length of the sicula is comparatively small, and the length ratio of prosicula and metasicula varies between 1.4:1 and 1:1.

As in nearly all didymograptids no true virgella is present. The initial part of the apertural process is developed in the same way as that giving rise to a true virgella in diplograptids. The growth of the process takes place simultaneously with the growth of the first thecae (Pl. I, fig. 4, text-fig. 2*D*).

The apertural processes of the thecae are as conspicuous as the apertural process of the sicula. The relation between the length of the apertural process and the proximal width of the thecae probably exceeds anything previously described.

With regard to the development of the proximal end the mode of growth of the crossing canal is peculiar. As in *K. multiramosus* the position of the cross-



Text-fig. 5. *Kinnegraptus multiramosus* n.sp. A, reverse view of a broken prosicula with the proximal part of th 1^1 . UM No. Vg 740. $\times 100$. B, reverse view of the apertural part of a sicula with th 1^1 , 1^2 , and $2^1 a$. The specimen is somewhat twisted. UM No. Vg 746. $\times 60$. C, thecal diagram illustrating the mode of development of the proximal end.

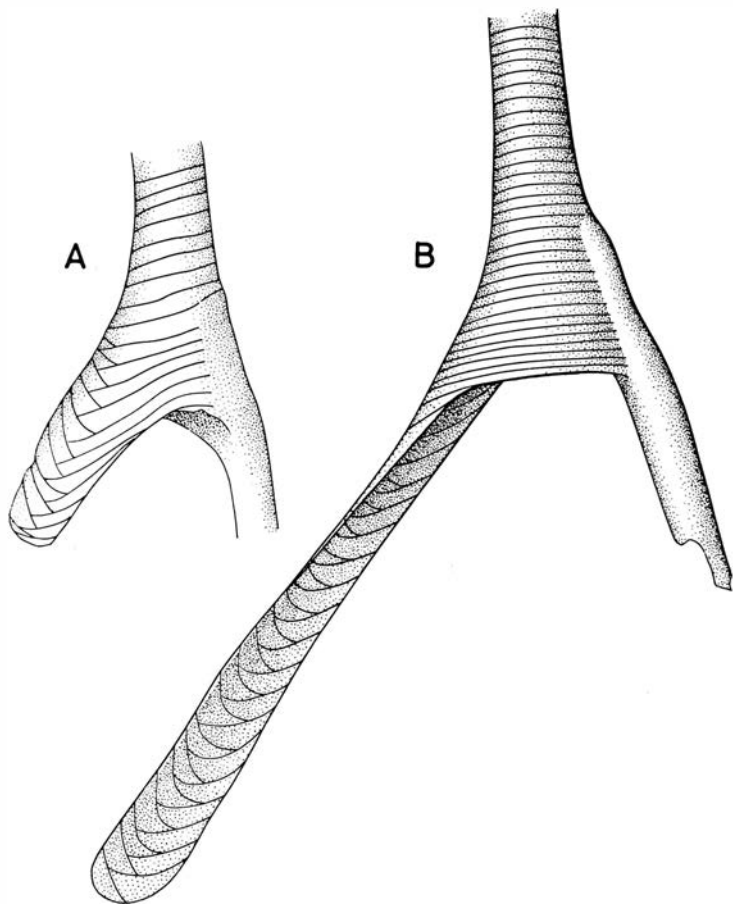
ing canal varies, the latter being situated either on the reverse or on the obverse side of the sicula. In all graptoloids previously described the crossing canal is situated on the reverse side. Deviations from a normal growth of the proximal end has so far been reported for *Didymograptus* sp. (? *Didym. formosus* BULMAN) (WIMAN, 1895, Pl. 9, fig. 6; BULMAN 1935, p. 25, text-fig. 6; cf. KOZŁOWSKI, 1948, p. 56) in which th 1^1 issues from the dorsal side of the sicula. In dendroids a similar variation in the position of the crossing canal has been observed (BULMAN, 1932, p. 5).

Kinnegraptus multiramosus n.sp.

Pl. I, figs. 7-10, text-figs. 5-7

HOLOTYPE.—UM No. Vg 742, figured on Pl. I, fig. 9.

DIAGNOSIS.—A species of *Kinnegraptus* provided with at least three stipes. Proximal parts of the stipes horizontal. Apertural processes of the thecae form an angle of 45° with the axis of the stipe. The length of th 2^1 is 5 mm, the other thecae reach half of this length. Development of the proximal end of isograptid type, with the crossing canal either on the reverse or on the obverse side of the sicula. Th 1^1 issues from the prosicula. The length of the prosicula is up to seven times the length of the metasicula.

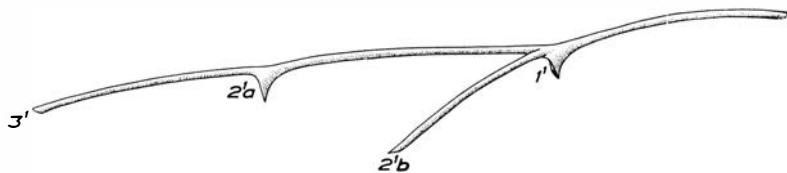


Text-fig. 6. *Kinnegraptus multiramosus* n.sp. Lateral view of thecae of different stages of growth. *A*, early stage, with the proximal part of the process. UM No. Vg 744. *B*, theca with apertural process of maximum length. UM No. Vg 743. *A* and *B*, $\times 100$.

DESCRIPTION.—The available material consists of one specimen provided with th 1^1 , 2^1a , the proximal parts of th 1^2 , 3^1 , and 2^1b , of siculae with proximal parts of the first three thecae, and of fragments of stipes.

The prosicula is available in one broken specimen and in two complete siculae. Apex slightly pointed (Pl. I, fig. 7; text-fig. 5 *A*), length of the prosicula 0.60–0.70 mm and width of the aperture 0.09–0.12 mm. The wall of the prosicula is provided with eight longitudinal rods, and some of them continue into the base of the nema. In the available material the number of rods is constant during the ontogeny. No complete nema has been observed; in one specimen the nema is 0.15 mm long, but the distal part is missing. To judge from the examined specimens the nema is developed as a hollow tube.

The metasicula is 0.09–0.13 mm long, and the apertural width amounts to 0.20 mm. The dorsal and the ventral zigzag sutures of the fuselli are fairly



Text-fig. 7. *Kinnegraptus multiramosus* n.sp. Lateral view of a fragment of a stipe. The apertural processes of th 1¹ and 2¹a are missing. UM No. Vg 745. × 15.

well visible. The aperture of the sicula is ventrally provided with a linguiform process up to 0.40 mm in length. The width of the process decreases somewhat in distal direction.

Th 1¹ originates on the ventral side of the prosicula, 0.25 mm above its aperture. The theca grows down along the sicula to a level somewhat below the boundary between the prosicula and the metasicula, and then grows outwards perpendicular to the sicula. Th 1² buds from th 1¹ somewhat above the bend of the latter. Th 1² buds either on the reverse or on the obverse side of th 1¹. Th 1² grows obliquely across the sicula, and leaves the sicula dorsally immediately above the aperture. Th 2¹a is derived from the proximal part of th 1², grows across th 1¹, and continues along the dorsal wall of th 1¹ (text-fig. 5B). The proximal width of th 1¹ is 0.05 mm, the corresponding width of th 2¹a is about half as large.

Th 2¹a gives rise to th 2¹b, forming the third stipe, and th 3¹. Th 2¹b buds from th 2¹a at the level of the aperture of th 1¹ (text-fig. 7). After the budding of this theca, th 2¹a continues to grow about 0.20 mm before developing the bud of th 3¹ and forming the aperture.

In the examined material th 1² is broken proximally in all specimens, and nothing can be stated about its distal part. Th 2¹a is 5.0 mm long, the other thecae measure 2.5 to 2.6 mm.

The proximal width of the thecae is maintained to a level 0.2 mm below the aperture, where a gentle widening begins. The width of the aperture is 0.2 mm. Beyond the aperture the free ventral wall continues into a 0.6 mm long process. This includes an angle of 45° with the direction of the theca (text-fig. 6). The width of the process is somewhat smaller distally than proximally. The most proximal fuselli of the process continue into the lateral walls of the aperture of the theca, whereas distally the fuselli have no connection with the latter.

DISCUSSION.—Compared with *K. kinnekullensis*, *K. multiramosus* displays some important differences. In *K. multiramosus* th 1¹ buds from the prosicula. This mode of budding occurs in most dendroids (BULMAN, 1955, p. 29) and in several dichograptids. As these two groups are considered primitive, this mode of budding may also represent a primitive feature.

The above species of *Kinnegraptus* have each a distinctive shape and an arrangement of the fuselli of the apertural process, and thus these characters

seem to be of diagnostic value at the specific level. In *K. multiramosus* the resemblance between the process of the sicula and that of the theca is as conspicuous as in *K. kinnekullensis*. The number of stipes cannot be determined from the material at hand. In the available fragments of branched stipes, thecae of the same type as th 2¹a gives rise to the thecae corresponding to th 2¹b and th 3¹, and no other type of branching has so far been found.

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Explanation of Plate I

Unless otherwise stated the specimens are photographed in glycerine. All specimens isolated by the author. Photographs by Mr. N. HJORTH. All figures are unretouched.

Kinnegraptus kinnekullensis n.sp.

Unless otherwise stated the specimens are collected by the author in 1960.

1. Proscicula. Boulder, Hällekis. UM No. Vg 727. × 100.
2. Proscicula with early growth stage of metasicula. "Hällekis." Collected by E. WIRÉN in 1910. UM No. Vg 728. × 80.
3. Reverse view of sicula with proximal parts of th 1¹ and 1². Boulder, Hällekis. UM No. Vg 721. × 40.
4. Obverse view of a fairly early growth stage of a rhabdosome. Sicula and distal part of th 1² broken. "Hällekis." Collected by E. WIRÉN in 1910. UM No. Vg 724. × 60.
5. Early growth stage of the apertural part of a theca. "Hällekis." Collected by E. WIRÉN in 1910. UM No. Vg 720. × 100.
6. Proximal part of a rhabdosome, with the crossing canal on the reverse side. The specimen is mounted dry and not bleached. Norra Skagen boring, 61.10 m. UM No. Vg 739. × 27.

Kinnegraptus multiramosus n.sp.

7. Reverse view of a broken proscicula with the proximal part of th 1¹. Norra Skagen boring, 62.79 m. UM No. Vg 740. × 100.
8. Reverse view of a broken sicula with proximal parts of th 1¹, 1², and 2¹. Crossing canal on the reverse side. Norra Skagen boring, 62.16 m. UM No. Vg 741. × 65.
9. Holotype. Reverse view of a sicula, with the proximal part of the proscicula bent to the obverse side. All thecae are broken off. Norra Skagen boring, 62.16 m. UM No. Vg 742. × 65.
10. Lateral view of a theca with a fully developed apertural process and the proximal part of the next theca. Norra Skagen boring, 62.16 m. UM No. Vg 743. × 90.

