Some data on *Milaculum* Müller, 1973

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An investigation of some faunas rich in *Milaculum* Müller, 1973 lead to the conclusion that the *Milaculum* animal was – at least partly – covered by plates of different morphology. Several specimens of *Milaculum* were encountered with adhering smaller platelets showing that the epidermal tissue of this animal consisted of a mosaic of larger and smaller plates. The characteristics of the material encountered are suggestive of an agnathan affinity of *Milaculum*.
Two new species are described, *Milaculum balticum* from the Upper Ordovician of Estonia and *M. longmyndium* from the Lower Silurian of the Welsh Borderland.

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Introduction

Small phosphatic plates of the genus *Milaculum* Müller, 1973 have probably often been encountered by students of Late Cambrian and Ordovician conodont faunas. However, they are seldom reported in the literature. Up to now I know of only six papers providing a picture of one or more specimens of this genus (Ethington & Clark, 1965, 1981; Müller, 1973; Nitecki et al., 1975; Dzik, 1986; Hinz, 1987). The scarcity of information on this problematic genus is probably due to the fact that often only small numbers of specimens are encountered. Most *Milaculum* plates occur in the finer than 100 μm sieve fraction, a fraction perhaps often not investigated.

Discovery of some rich *Milaculum* faunas in samples of Late Ordovician and Early Silurian age, faunas which moreover contained a small number of plates with adhering smaller platelets, instigated the present study.

Many of the limestone samples used for this study were taken from collections of the Rijksmuseum van Geologie en Mineralogie at Leiden. However, many of these samples were collected decades ago, and locality data do not meet modern requirements. But because of the rich faunas encountered in them I did not want to discard them. To facilitate recovery of the original sample localities I listed in an appendix all information available to me.

The *Milaculum* material and the other microfaunal elements are stored in the Rijksmuseum van Geologie en Mineralogie at Leiden with RGM numbers 339 791 - 339 797, 383 197 - 383 202, 383 221 - 383 445.

Acknowledgements

I wish to express my gratitude to Dr C.F. Winkler Prins for identifying some of the phosphatic brachiopods and for reading this paper critically. Thanks are due to Drs P.J. Chimonides and P.D. Taylor of the British Museum of Natural History for their confirmation of my identification of phosphatic rests from the Kukruse faunas as *Hemiphragma*-like bryozoans. They also gave valuable information on literature on the subject. I am indebted to Mr J. Timmers for combining the SEM micrographs into nice looking plates.

Genus *Milaculum* Müller, 1973

Type species — *Milaculum ruttneri* Müller, 1973.

Discussion — Müller attached the generic name *Milaculum* to tiny nodose phosphatic plates of unknown affinity derived from Upper Cambrian and Ordovician limestones. He encountered various forms which he assigned to four species. Müller recognized that more than one type of plate could pertain to one species. He, for instance, assigned three types of plates to *Milaculum scandicum*.

Investigation of a formic acid insoluble residue of a limestone sample from Kukruse (Estonia) provided me with a great number of *Milaculum* specimens which roughly could be sorted into five types. Subsequent investigation of other samples from Estonia, Öland, the Welsh Borderland, and southern Ontario showed that the *Milaculum* faunas from those samples also could be split into several types, types comparable to those of my first sample. This could lead to but one conclusion, that is that the *Milaculum*-bearing animal had a scleritome composed of different types of sclerites. (The term scleritome was introduced by Bengtson, 1985 for the total set of sclerites present in an organism.)

Müller encountered in his samples only isolated plates. The apparently better preserved material from Kukruse contained several plates with adhering smaller platelets (see Figs. 1A,C,D; 2; 3; 4A,B,D; 8B). Subsequently also some specimens with adhering

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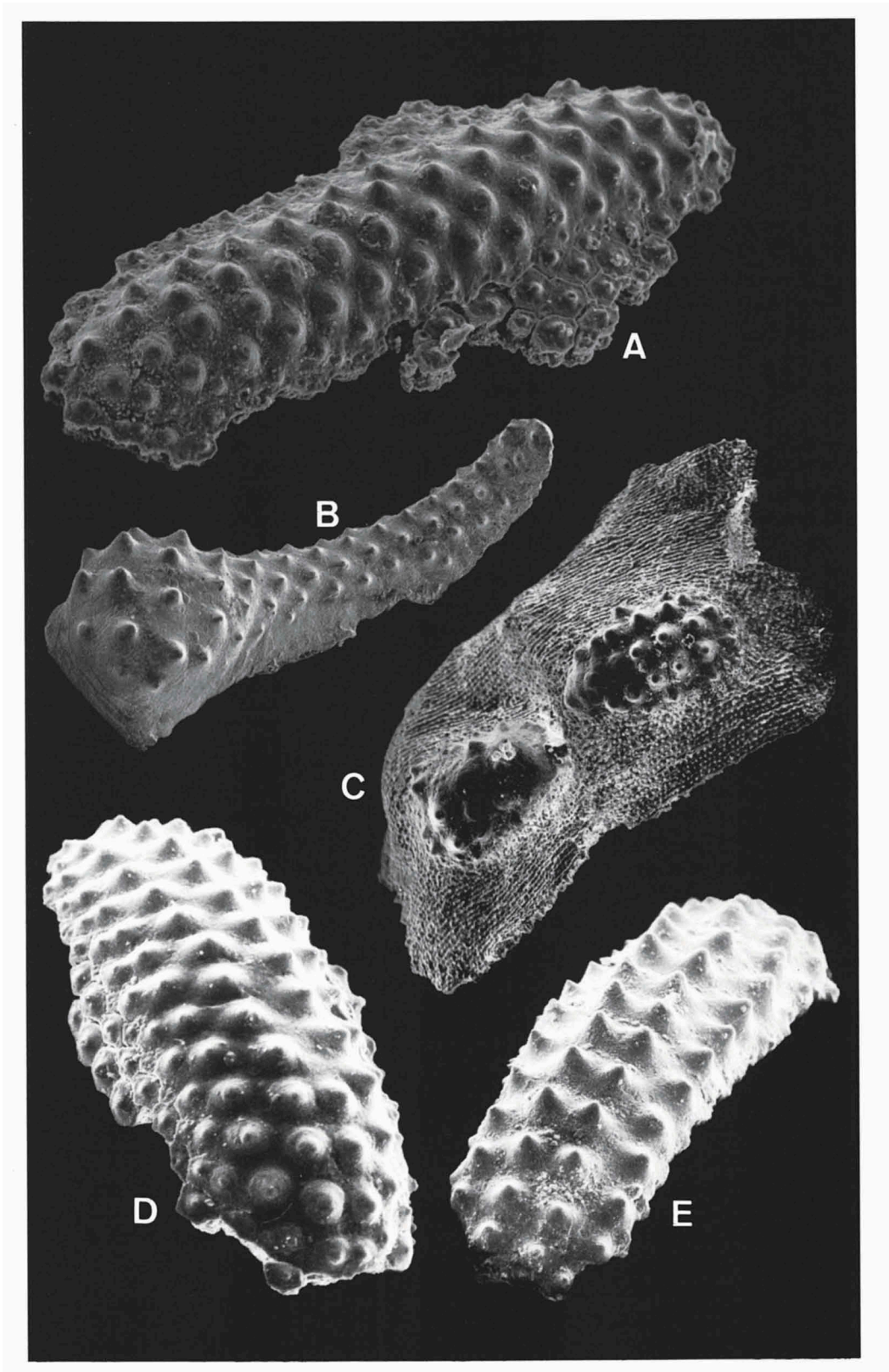
Fig. 1. *Milaculum balticum* sp. nov. from Kukruse (Estonia).
A. Holotype, Cm type of plate from sample 173 755, × 330, RGM 383 378.
B. Paratype, Cr type of plate from sample 173 757, × 280, RGM 383 380.
C. Paratype, scleritome fragment with two plates from sample 173 757, × 220, RGM 383 380.
D. Paratype, Cm type of plate from sample 173 756, × 320, RGM 383 382.
E. Cm type of plate from sample 173 756, × 380, RGM 383 382.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platelets were encountered in most of the other samples investigated (see Figs. 4C; 5A,B,E; 6A,B,D; 7C; 8C; 10B). Thus we may assume that the isolated plates of *Milaculum* were part of a complex of plates and platelets covering an as yet unknown group of animals.

Two types of platelets do occur, five- to eight-sided ones with or without a central node and narrow elongate platelets. The five- to eight-sided platelets occur adhering to the Cm (common: ovoid to elongate ovoid) type of plate and the Co (cone) type of plate. The elongate platelets are found around the Cr type of plate (plate relatively wide and strongly convex at one end, narrow and slightly convex at the other end). Elongate platelets are also found around small, rather flat, round to ovoid plates. Maximum measured length of the plates is c. 0.5 mm. The five- to eight-sided platelets have a diameter of c. 10 μm; the elongate platelets have a width varying from 3 to 12 μm and a length of up to more than 100 μm.

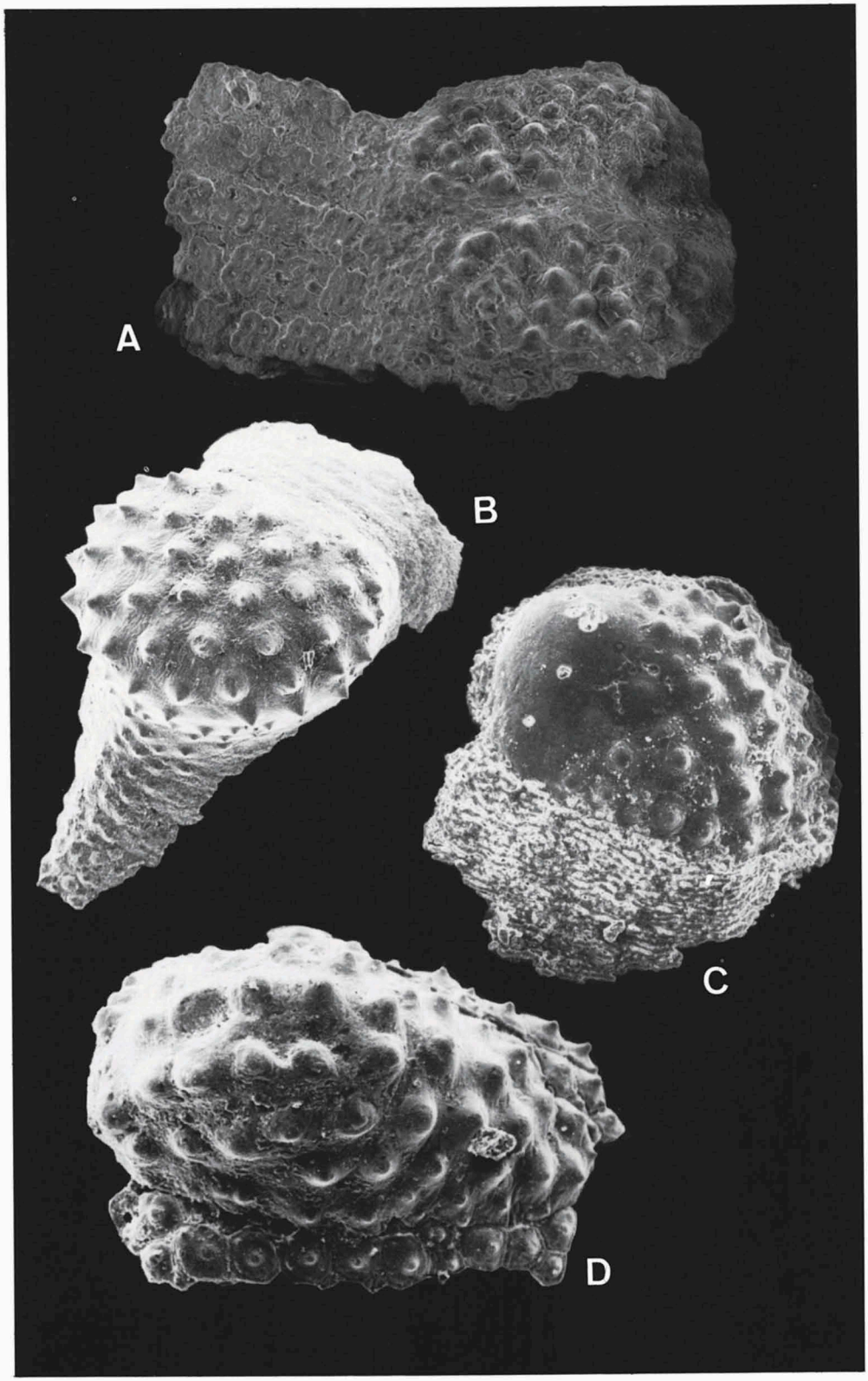
Plates and platelets are not fused to each other but rather loosely connected. The slightest touch of the picking brush will often cause some platelets to become disconnected. This explains why they are seldom found together. This is especially true for the five- to eight-sided platelets, the elongate platelets are more coherent and consequently more often found connected.

Most types of plates of the *Milaculum* species described in this paper are covered with nodes. Only one plate type of *M. ethinclarki* Müller, 1973 is different in having a part provided with holes instead of nodes and one plate type of *M. balticum* sp. nov. and one of *M. ethinclarki* are partly bald.

In sample 13/4/75 from Healy Falls (Ontario) and sample 36 477 from Port Kunda (Estonia), plates of the Cm type of respectively *M. ethinclarki* and *M.* sp. a were encountered which also were partly without nodes. There, however, this was due to breaking off of the upper layer of the plate, leaving a semi-smooth surface, which viewed in the SEM showed a spongy structure (Fig. 9B). This rather easily breaking off of the nodose upper layer suggests that the *Milaculum* plate is built of more than one layer. It must be remarked that this way of breaking only has been observed in the two samples mentioned above. In both samples the *Milaculum* plates are opaque white. This in contrast to the plates in the other samples which always are more or less transparent with colours varying per sample from very light brown to darker brown or even almost black. The opaque white condition may be the result of weathering or recrystallization. Whatever may be the case, it was some process which apparently diminished the coherence between the layers of the *Milaculum* plate.

In the other samples breakage is across the plates. Viewed with the SEM one can observe a thin dense upper layer irregularly passing into a thicker cavernous layer (Fig. 9C,D). The basal part of this layer is more dense, though perforated by pores aligned in lines causing a net-like pattern (Fig. 9C). That the upper layer is only thin could also be observed in an occasional specimen of which one node was broken off (Fig.9A). Beneath the thin upper layer one observes an irregular spongy structure. This hole caused by breaking off of a node is different from the holes in the Cr type of plate of *M. ethinclarki* (Fig. 6C) which are not the result of breakage.

Fig. 2. *Milaculum balticum* sp. nov. from Kukruse (Estonia).
A. Scleritome fragment with two ovoid plates (right) and rows of semi-quadrangles (left). For detail of left part see Fig. 4A. Sample 173 755, × 500, RGM 383 378.
B. Paratype, Cr type of plate from sample 173 755, × 210, RGM 383 378.
C. Bald type of plate from sample 173 756, × 300, RGM 383 382.
D. Paratype, oblique cone type from sample 173 755, × 350, RGM 383 378.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Some features suggest that the plates of *Milaculum* may have arisen from coalescence of smaller platelets. In Fig. 4D one observes traces of sutures penetrating the plate, and in Fig. 10B one sees polygonal platelets at one side merged with the plate. Occasionally a Cm type of plate was encountered showing some traces of sutures of polygonal platelets. The Cr type of plate seems to have arisen from coalescence of elongate platelets (Fig. 04B).

Considering the scleritome fragment of *Milaculum* in Fig. 3A,B the question arises whether the elongate platelets are indeed separate platelets or components of larger plates which in this fragment are oriented with the composing elongate elements in one plate more or less perpendicular to those of the neighbouring plate.

In a tangential section of the upper layer of a plate of the heterostracan *Eriptychius orvigi* Denison, 1967 (Denison, 1967, fig. 11D) one observes a structure which resembles that presented by the elongate platelets of *Milaculum* (see Fig. 4B), be it that there is a difference in magnitude. The structure in *Eriptychius* is c. 50 times that of *Milaculum*.

Dzik (1986) presents a photograph of a specimen of *Milaculum scandicum* of which the basal side is very well preserved (Dzik, 1986, fig. 7D). It shows a tissue penetrated by horizontal parallel canals and in each subsequent layer, the canals are oriented perpendicular to those of the underlying layer. This pattern is thought to represent the distribution of collagen cords. This basal part was according to Dzik incorporated into the skin, showing that the sclerites were dermal. In the *Milaculum* lineage the boundary disappeared between the ectodermal and mesodermal tissue (Dzik, 1986, p. 252), and Dzik continues 'The Agnatha thus developed body armor composed of phosphatic sclerites'.

Alexander (1975) reports that the scale of one of the Crossopterygii – which seems to be remarkably like the specimens from Heterostraci – consists of four layers which are (starting at the outer surface) enameloid substance, dentine, spongy layer of woven-fibred bone and surface bone. Surface bone (Alexander, 1975, p.75) consists of a series of lamellae. Within each lamella, fibres tend to run parallel. Typically the fibres in successive lamellae run at right angles to each other.

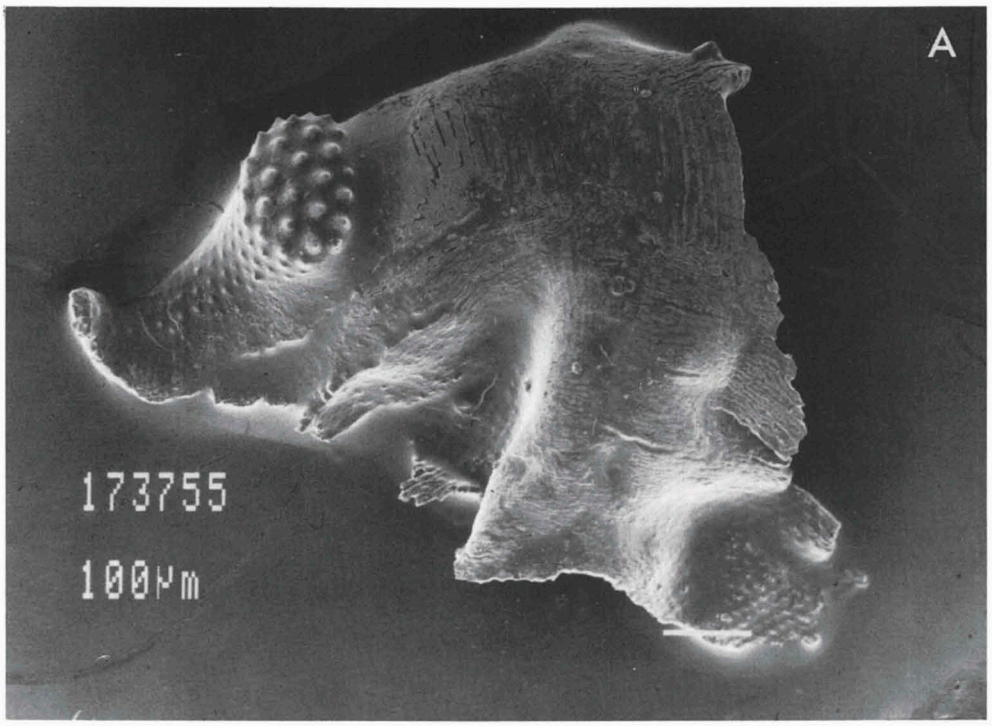
The structure of this surface bone thus seems to resemble the structure of the basal layer of *Milaculum* as shown by Dzik (1986, fig. 7D). The spongy layer of woven-fibred bone may resemble the spongy middle layer of *Milaculum*.

According to Alexander (1975, p. 80) some species of Ordovician Heterostraci have the whole head covered by a mosaic of small plates, many others have only large plates and some a combination of the two. The trunks are covered by overlapping scales.

Considering that (1) the *Milaculum* animal was covered (partly or completely ?) by a mosaic of smaller and larger plates; and that (2) the *Milaculum* plates are built of layers which seem to resemble those of Heterostraci; that (3) the structure of the platelets surrounding the Cr type of plate of *Milaculum* resembles that of *Eriptychius* (Heterostraci) be it at different orders of magnitude I am inclined to think that *Milaculum* also belongs to the Class Agnatha and may be related to the Heterostraci.

No *Milaculum* plates have been encountered which could be interpreted as overlapping scales like those of the Heterostraci. The scleritome fragment in Fig. 1C though does show some tendency to imbrication.

Fig. 3. *Milaculum balticum* sp. nov. from Kukruse (Estonia).
A. Scleritome fragment consisting of areas of elongate platelets and (upper left) a Cr type of plate from sample 173 755, × 120, RGM 383 377.
B. Detail of Fig. A, × 240.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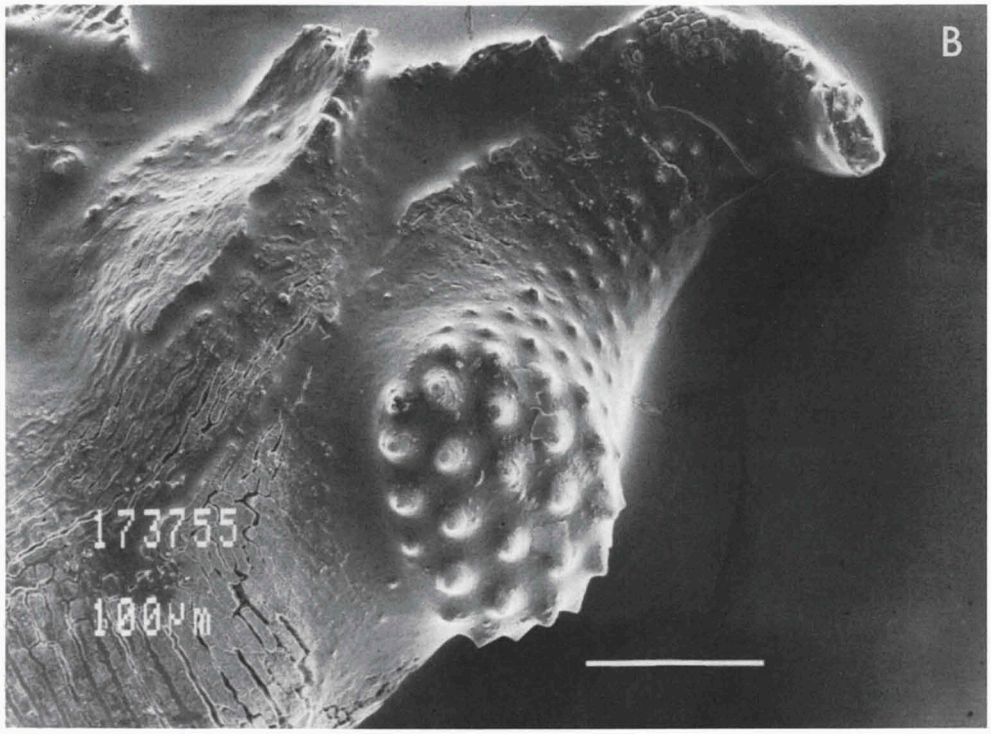
100µm


B
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If *Milaculum* really belongs to the Agnatha and if the specimen of *Milaculum* sp. from the Lower Cambrian Comley Limestone (Hinz, 1987, pl. 2, fig. 9) really is a *Milaculum* than the Agnatha already were in existence in the Lower Cambrian.

From the above it appears that still a lot of research has to be done before we really know the real *Milaculum* animal. One of the places to search for it may be the vicinity of Kukruse in Estonia, where the sediments of the Kuckers Formation yielded the best-preserved scleritome fragments.

Remarks on species and specimens of Milaculum published after Müller (1973) — Ethington and Clark (1981) described four new species of *Milaculum* from the Lower Ordovician and lower Middle Ordovician of the North American Midcontinent Province. Most likely these four species are separate species and not different types of plates of the same species as they generally do not co-occur and do have different stratigraphic ranges. However, because Ethington and Clark had only limited numbers of specimens at their disposal the possibility that some of their species are conspecific cannot be excluded.

Some of these American species probably were contemporaneous with *M. scandicum* and *M.* sp. a of Europe. The types of plates described by Ethington and Clark differ from the plate types of *M. scandicum* and *M.* sp. a and therefore I consider them as not conspecific with the European forms. Apparently the differing environments of the Midcontinent Province and the North Atlantic Province which i.a. had such an influence on the distribution of the conodonts also affected the distribution of species of *Milaculum*.

Nitecki et al. (1975, fig. 5) published a picture of a specimen of a *Milaculum* sp. from the lower Middle Ordovician of Oklahoma. This specimen is as yet not assignable to any of the known species.

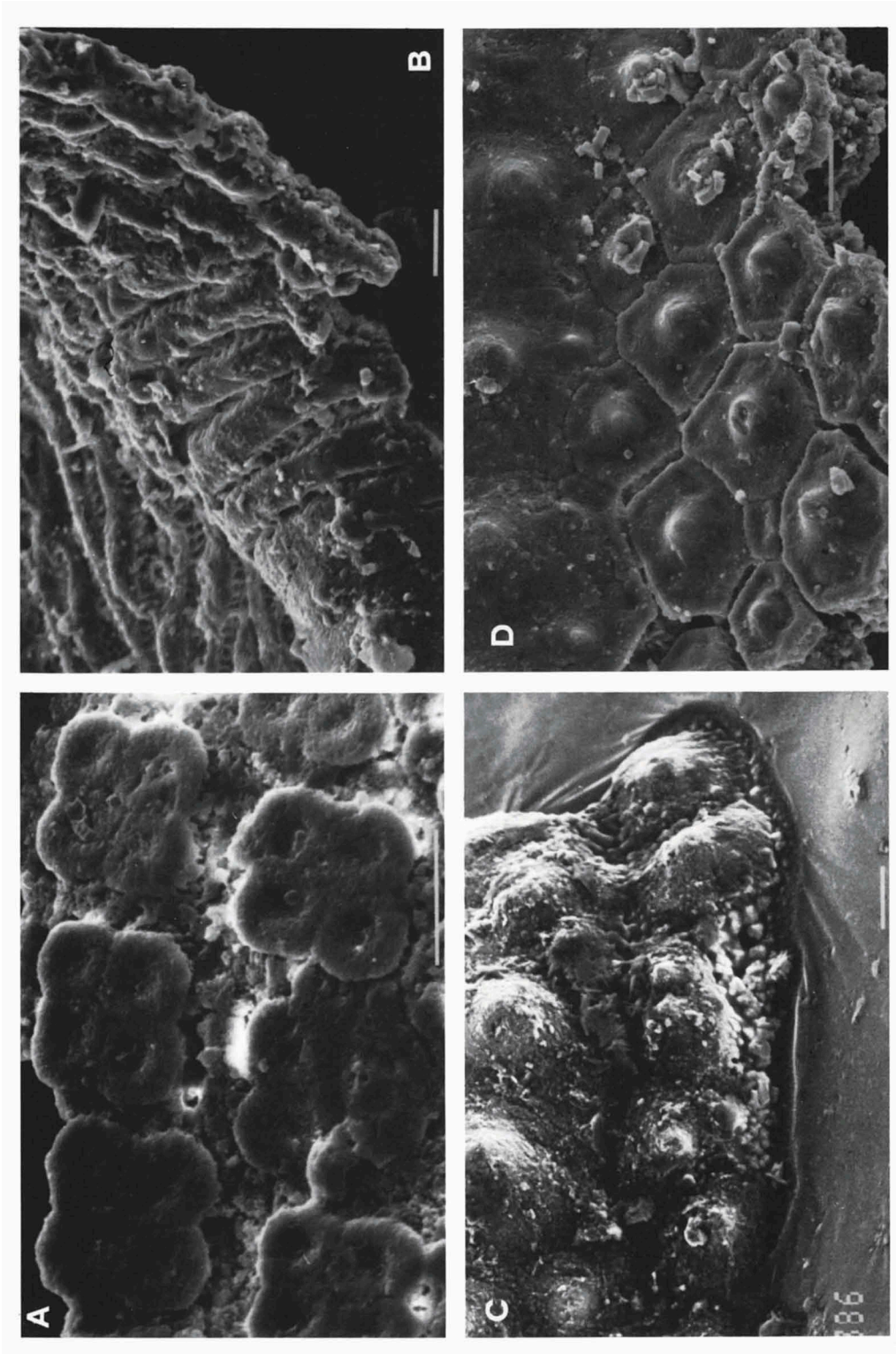
Orchard (in: Bergström & Orchard, 1985, pl. 2.4, fig. 14) gives a picture of a *Milaculum* sp. A from the Ashgillian of South Wales. This specimen shows some resemblance to the Cm type of plate of *M. longmyndium* sp. nov. and may belong to a species ancestral to that Lower Silurian species.

Hinz (1987, pl. 2, fig. 9) found a specimen in the Lower Cambrian Lower Comley limestone which she considered to be a plate of a *Milaculum* sp. and she may be correct in that assignment.

Milaculum balticum sp. nov.
Figs. 1A-E; 2A-D; 3A,B; 4A,B,D; 8B; 9C,D; 10A.

Holotype — Specimen of a Cm-type plate figured by Figs. 1A and 4D, registration number RGM 383 378.

Fig. 4. (scale bar is 10 μm).
Milaculum balticum sp. nov. from Kukruse (Estonia).
A. Detail of Fig. 2A showing rows of semi-quadrangles.
B. Elongate platelets surrounding the tip (lower left) of a Cr type of plate, sample 173 757, RGM 383 381.
D. Detail of holotype, Fig. 1A, showing some platelets adhering to the plate.
Milaculum scandicum Müller, 1973 from Öland (Sweden).
C. Detail of Fig. 7C showing some platelets adhering to the plate.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Paratypes — Cm type: Fig. 1D (RGM 383 382); Cr type: Fig. 1B (RGM 383 380); Cr type: Fig. 2B (RGM 383 378); Cr type: Fig. 3A,B (RGM 383 377); Co type: Fig. 2D (RGM 383 378); other type: Fig. 1C (RGM 383 380).
Derivatio nominis — After the Baltic States, where the type locality is situated.
Type locality — Drainage canal in the vicinity of Kukruse (Estonia). Pale brown limestone interbedded in the Kuckers Shale, Zone C 2, lower Caradocian (see Appendix).

Diagnosis — Several types of plates, the most common one (Cm type) being an elongated plate, generally 2.5 times as long as wide, with rounded ends and covered with low nodes arranged in parallel rows.

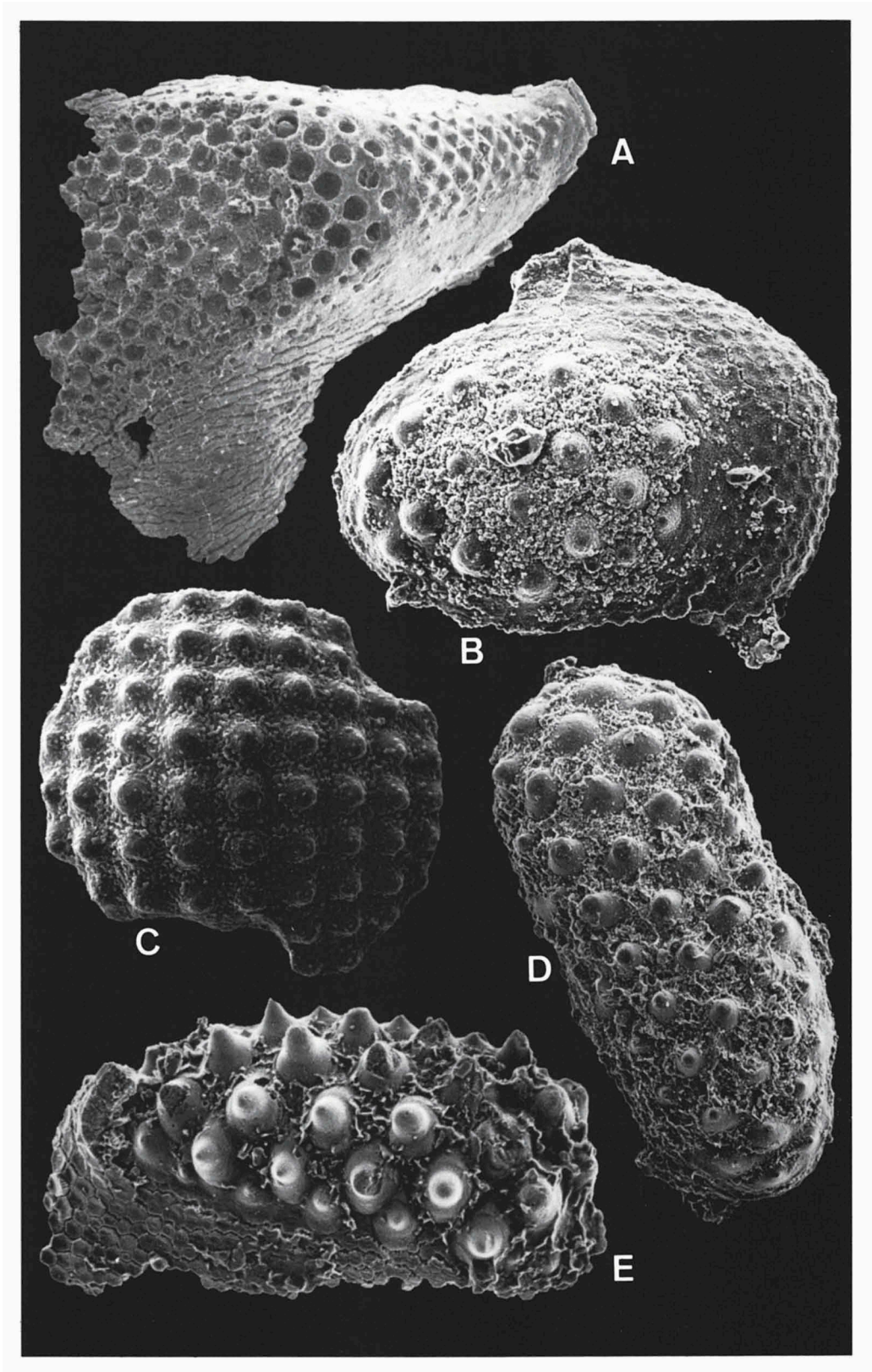
Description — Plates of the Cm (common) type (Fig. 1A,D,E) are slightly convex in lateral view as well as in cross section. The mean length/width ratio is about 2.6. They are maximally about four times as long as wide, the maximum length measured being 0.452 mm. They are covered with nodes arranged in lines which generally parallel the long sides of the plates but sometimes are at a small angle with those sides. The nodes in one line often alternate with those in the neighbouring lines. The nodes are pointed but in most specimens they are rather flat-topped, possibly due to wear at one time or another. The nodes of a plate may be almost equal or they may decrease in size toward the sides and to one or both ends.

Some well-preserved specimens of the Cm type are surrounded by small five- to eight-sided platelets which have a slightly raised rim and a central node (Figs. 1A,D; 4D).

The plates of the Cr type (baptized crocodile head during picking) consist of a nodose, rather convex ovoid part, the long axis of which is at right angles to the axis of the unit (Figs. 1B; 2B; 3A,B). From one side of this convex part a tongue extends, up to twice the length of the convex part, covered with smaller nodes, convex in cross section and more or less concave in lateral view. Some well-preserved specimens of the Cr-type plates are surrounded by small, narrow platelets which are often more than ten times as long as wide (see Figs. 3A,B; 4B; 10A). One Cr-type specimen (Fig. 3A,B) was found as part of a relatively large, vaulted scleritome fragment, which shows to be built up of several areas of parallel narrow platelets. As can be seen from Figs. 3B and 4B, the alignment of the platelets in one area is at almost right angles to the alignment in the neighbouring areas. Fig. 4B shows part of a scleritome fragment consisting of elongate platelets adhering to the tip of a Cr-type plate (lower left corner). The sides of the platelets are not smooth but seem to consist of a downward directed row of pillars.

The Co (cone) type of plate is rare. The typical Co type is an almost round unit, generally higher than wide, covered with nodes and hollow inside. The Co type of *M. balticum* is almost similar to the Co type of *M.* sp. a (Fig. 8C). Besides this typical cone occur oblique cones (Fig. 2D) which seem to represent transitional forms between the Cm type and the typical Co type. The Co type is surrounded by similar platelets as the Cm type (see Fig. 2D).

Fig. 5.
Milaculum ethinclarki Müller, 1973 from southern Ontario.
A. Cr type of plate from sample 72 015, × 270, RGM 383 389.
Milaculum longmyndium sp. nov. from the Welsh Borderland.
B. Paratype, Cm type of plate from sample 85/8, × 500, RGM 383 385.
C. Paratype, flat, semi-round plate from sample 85/8, × 380, RGM 383 383.
D. Paratype, Cm type of plate from sample 85/8, × 370, RGM 383 385.
E. Holotype, Cm type of plate from sample 85/8, × 400, RGM 383 384.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Other types of plates are the bald plates and the flat plates. The bald type of plate (Fig. 2C) is a convex ovoid plate, only partly covered with nodes and surrounded by elongate platelets. Fig. 1C is of a scleritome fragment showing elongate platelets, adorned with very small nodes, surrounding two ovoid convex plates one of which (the left one) seems to be transitional to the bald type.

The flat plates are small, round to ovoid, and covered with irregularly placed nodes. Fig. 2A shows a scleritome fragment of which the right half shows two adjoining flat plates. The left half, the top layer of which seems to be worn of, shows rows of semi-quadrangles. Each semi-quadrangle consists of four six-sided elements which all have a depression in the centre (see Fig. 4A). The quadrangles do not touch each other but are separated by fine material. These features resemble those observed at the lower side of *M. ethinclarki* by Müller (1973, pl. 34, fig. 8a,b). A scleritome fragment consisting of four small, ovoid, flat plates is shown by Fig. 8B. This fragment also has some adhering tissue consisting of semi-quadrangles.

Remarks — *M. balticum* differs from *M. ethinclarki* Müller, 1973 in the outline of the Cm element which in the latter species shows a tendency to have an hour-glass outline, and in the form of the Cr-type plate. The Cr-type plate of *M. ethinclarki* is shorter and has a perforated part. *M. balticum* differs from *M. longmyndium* sp. nov. in the length/width ratio of the Cm-type plates and in having different types of platelets adhering to the Cm-type plates. Those of *M. longmyndium* do not have a central node. The Cr-type plate of this latter species is much shorter. *M. ruttneri* Müller, 1973 and *M. perforatum* Müller, 1973 are very different in shape and ornamentation. For differences with *M. scandicum* Müller, 1973 see description of that species. *M. balticum* differs from *M.* sp. a in that that species has a different length/width ratio of the Cm type of plate and a much shorter Cr type of plate.

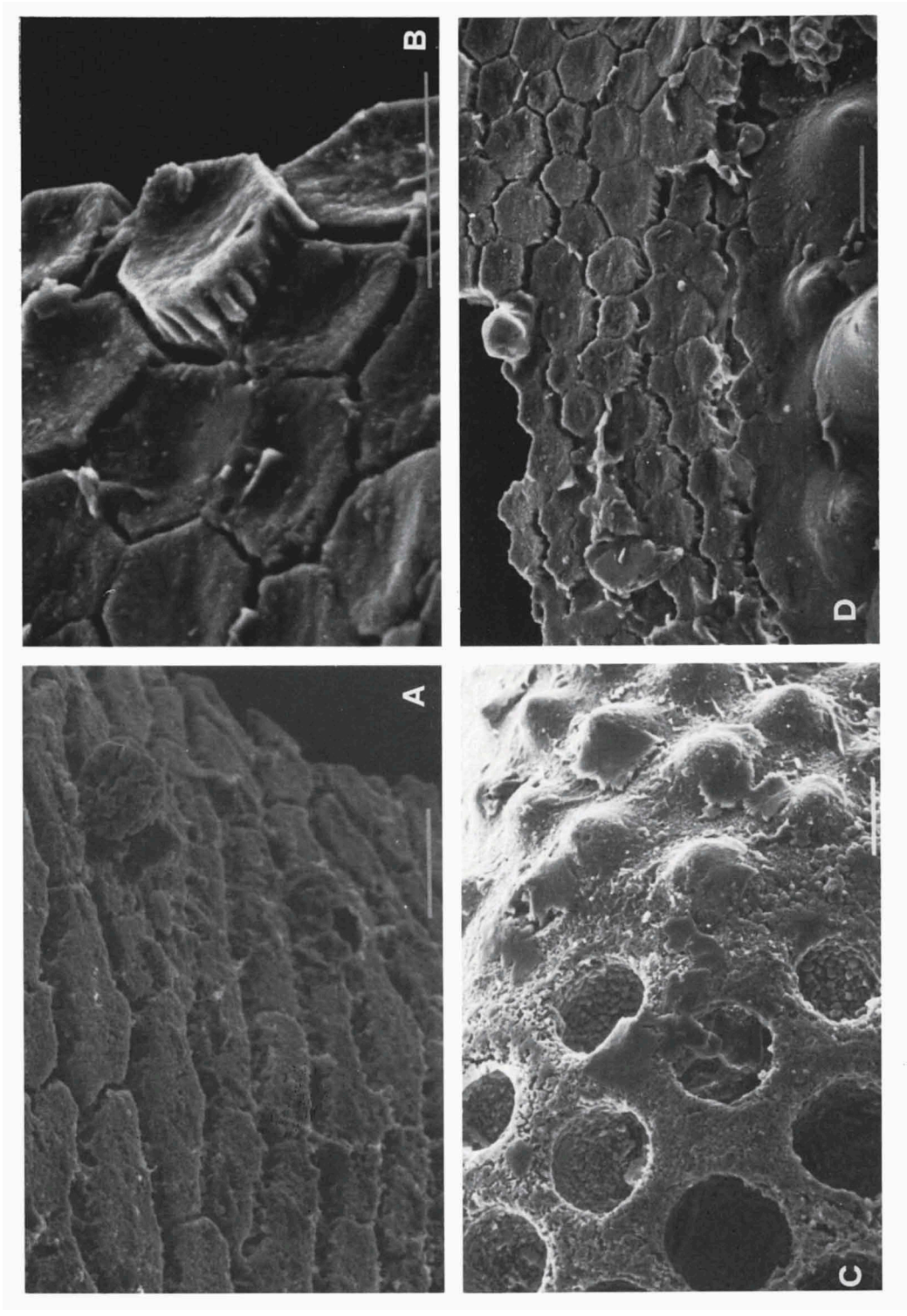
Occurrence — Samples 173 755 - 173 758 and 173 764 from lower Caradocian strata near Kukruse (Estonia) (see Appendix).

Number of specimens — Sample 173 755/1 – 302 (213 Cm, 54 Cr, 3 Co, 32 others); sample 173 755/3 – 526 (372 Cm, 90 Cr, 2 Co, 62 others); sample 173 756 – 377 (264 Cm, 9 Cr, 4 Co, 100 others); sample 173 757 – 17 (6 Cm, 4 Cr, 7 others); sample 173 758 – 34 (23 Cm, 1 Cr, 1 Co, 9 others); sample 173 764 – 3 Cm.

Milaculum ethinclarki Müller, 1973
Figs. 5A; 6A,C; 8A; 9A; 10C,D.

1973 *Milaculum ethinclarki* n. sp. – Müller, pp. 223-224, pl. 34, figs. 5, 6, 8.

Fig. 6. (scale bar is 10 μm).
Milaculum ethinclarki Müller, 1973
A. Detail of Fig. 5A, showing elongate platelets.
C. Detail of Fig. 5A, showing part of the perforated surface.
Milaculum longmyndium sp. nov.
B. Detail of holotype (Fig. 5E) with a raised six-sided platelet bounded by a row of pillars.
D. Detail of holotype (Fig. 5E) showing part of the plate and the adhering platelets.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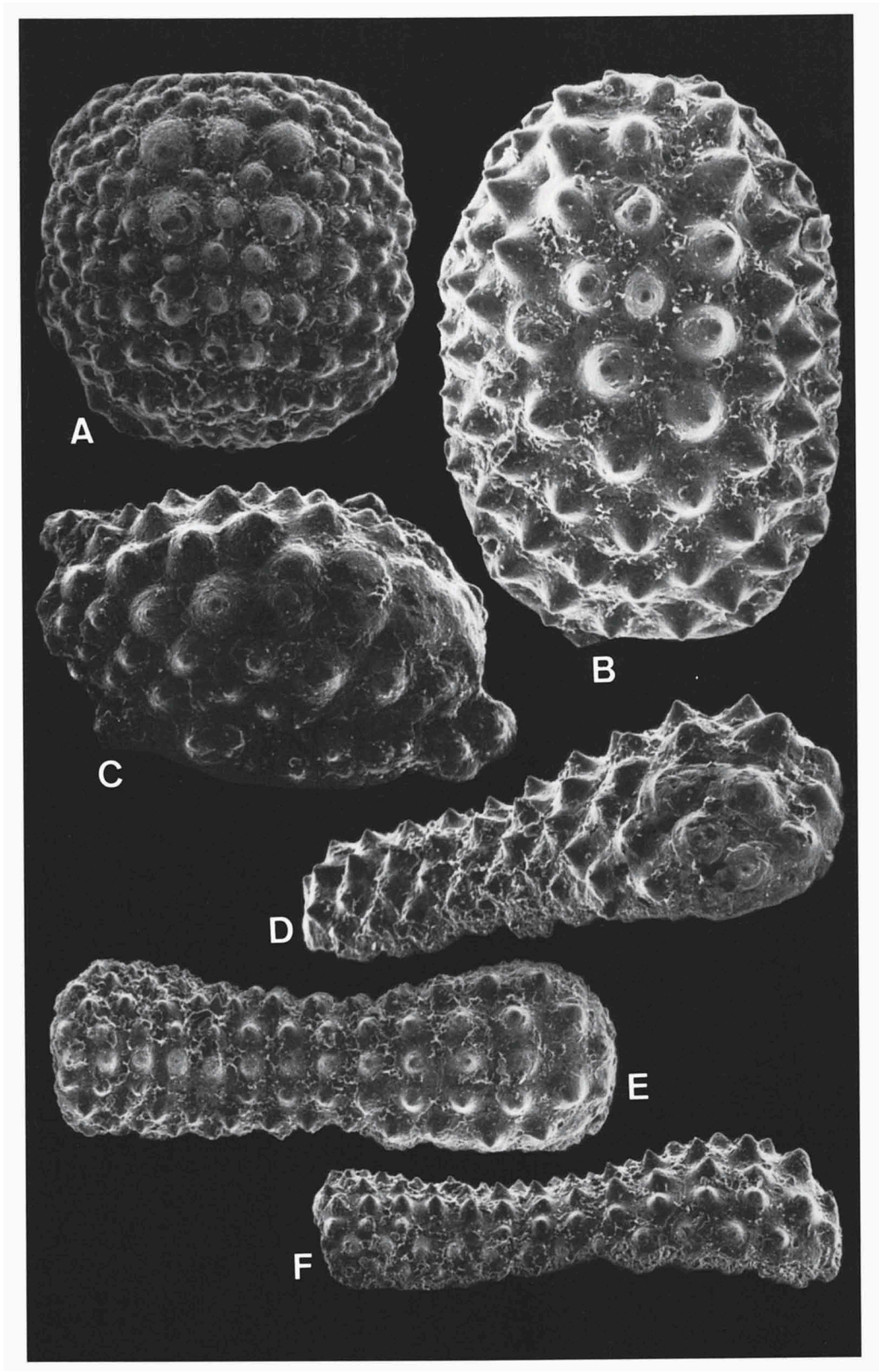
Remarks — The Cm type of plate is not ovoid as in *M. balticum, M. longmyndium, M. scandicum,* and *M.* sp. a but more or less a rectangle with convex short sides. The long sides of large specimens are not straight but concave (see Fig. 8A). In lateral view the plate is only slightly convex. It is somewhat more convex in cross section. The nodes are lined up in irregular rows which cross the length axis of the plate at an angle of c. 45°. The largest specimen has a length of 0.51 mm. Nothing is known about the adhering platelets as none of the Cm type of plates had any preserved.

Up to about half of the Cr type of plate is occupied by a more or less triangular perforated part which slopes to the end of the plate (Fig. 5A). The other half consists of a nodose tongue which narrows and slopes down in the other direction. In lateral view the tongue is slightly concave. The nodes are arranged in lines which cross the long axis of the plate at an angle of c. 45°. The boundary between both parts of the plate is abrupt, not evenly bent. This type of plate is surrounded by elongated platelets similar to those of the Cr type of *M. balticum* (Fig. 6A). The holes of the perforated part of the Cr-type plate do always occur in the same part of all of my (more than 400) specimens and therefore are considered not to result from post-mortem dissolution. They are round and deep but do not penetrate to the other side of the plate (Fig. 6C). They look very much like the perforations of the Upper Cambrian *Milaculum perforatum* Müller, 1973, but in that species the perforations reach the other side of the plate (Müller, 1973, pp. 221-222). In *M. perforatum* small sharp nodes do occur between the holes whereas in *M. ethinclarki* the surface between the holes is without nodes, almost smooth.

No Co type of plates has been encountered. Several small plates do occur which are evenly curved at one end and less convex and less wide at the other end (Fig. 10C). They are short, the length being less than twice the width. The main part of these specimens – from the crest to the narrow end – is covered with nodes arranged in lines that cross the long axis of the plate at an angle of c. 45°. The strongly curved wide end of the plate is smooth (Figs. 10C,D). At first glance it looks as if this is the result of wear, and that may partly be the case. However, at closer inspection one observes, at the transition from the bald to the nodose part, nodes one side of which is a continuation of the bald surface. These nodes do not stand perpendicular to the plate surface as generally the nodes of all types of plates do. This indicates, in my opinion, that this bald part is original, not just the result of wear. None of the specimens of this type had any adhering platelets so I do not know whether this type is comparable to the bald plate of *M. balticum*.

In two of my samples (72 014 and 72 015) the Cr type of plates is strongly dominant. This is in contrast to the other samples (72 008, 72 010 - 72 012 and 13/4/75) and also in contrast to the other species described in this paper where always the Cm type of plate is dominant, generally 60 to 70 % of the total of plates. However, in samples 72 014 and 72 015 most Cm-type plates are heavily damaged, so – may be – conditions during sedimentation are to blame for this different ratio of plate types.

Fig. 7. *Milaculum scandicum* Müller, 1973 from Öland (Sweden)
A. Semi-round plate from sample 193 86, × 560, RGM 383 391.
B. Cm type of plate from sample 193 86, × 470, RGM 383 391.
C. Co type of plate from sample 193 86, × 430, RGM 383 391.
D. Cr type of plate from sample 193 86, × 350, RGM 383 391.
E,F. Cr type of plate from sample 193 86, RGM 383 391; E: seen from above, × 280; F: lateral view, × 250.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Occurrence — Samples 72 008, 72 010 - 72 012, 72 014, 72 015 and 13/4/75 from upper Blackriverian to middle Trentonian strata in southern Ontario (see Appendix); see also Müller (1973, pp. 223, 224) for some other occurrences.

Number of specimens — Sample 72 008 – 13 (10 Cm, 3 Cr); sample 72 010 – 8 (5 Cm, 3 Cr); sample 72 011 – 774 (475 Cm, 173 Cr, 126 others); sample 72 012 – 251 (171 Cm, 64 Cr, 16 others); Sample 72 014 – 88 (35 Cm, 53 Cr); sample 72 015 – 147 (45 Cm, 102 Cr); sample 13/4/75 – 53 (44 Cm, 9 Cr).

Milaculum longmyndium sp. nov.
Figs. 5B-E; 6B,D.

Holotype — Specimen of a Cm type of plate figured by Figs. 5E and 6B,D, registration number RGM 383 384.
Paratypes — Cm type: Fig. 5B (RGM 383 385); Cm type: Fig. 5D (RGM 383 385); other type: Fig. 5C (RGM 383 383).
Derivatio nominis — The type locality is at the south end of the Long Mynd.
Type locality — Small old quarry at the Hillend Farm (Plowden locality of Aldridge, 1972), south end of the Long Mynd, Welsh Borderland (U.K.). Aeronian (mid-Llandovery) limestone (see Appendix).

Diagnosis — Several types of plates, the most common one (Cm type) being an ovoid plate, generally somewhat less than twice as long as wide, with low nodes arranged in parallel rows.

Description — The Cm-type plates (Fig. 5B,D,E) are slightly convex in lateral view. The mean length/width ratio is c. 1.95. They are maximally about three times as long as wide. The maximum length measured is 0.31 mm. They are covered with nodes arranged in lines which generally parallel the long sides of the plates but sometimes are at a small angle with those sides. The nodes in one line often alternate with those in the neighbouring lines and thus also stand in lines which cross the long axis at an angle of c. 45°. The nodes are pointed but in most specimens they are rather flat-topped, possibly due to wear. The nodes of a plate may be almost equal or they may decrease in size toward the sides. Some well-preserved specimens of the Cm type are surrounded by small five- to eight-sided platelets which have a concave upper side and lateral sides which look as rows of pillars (Figs. 5B,E; 6B,D). These platelets differ from those of *M. balticum* and *M. scandicum* in not having a central node.

Only a few Cr-type plates have been encountered. They are relatively short, slope down and narrow towards one end. They are quite similar to, be it shorter than, the

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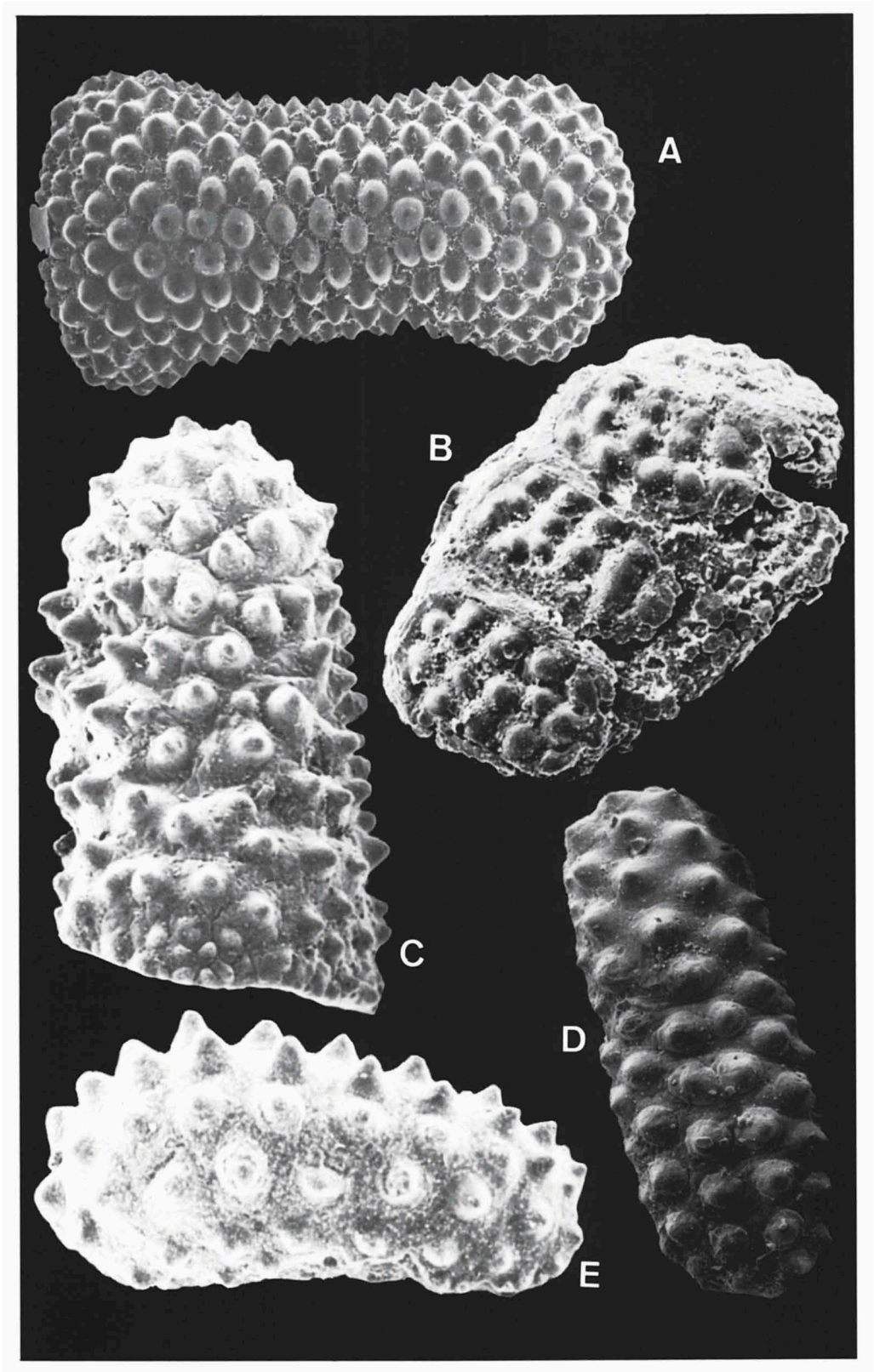
Fig. 8.
Milaculum ethinclarki Müller, 1973 from southern Ontario.
A. Cm type of plate from sample 72 015, × 190, RGM 383 389.
Milaculum balticum sp. nov. from Kukruse (Estonia).
B. Scleritome fragment comprising four ovoid plates and some semi-quadrangles from sample 173 755, × 550, RGM 383 378.
Milaculum sp. a from Port Kunda (Estonia).
C. Co (cone) type from sample 36 477, × 270, RGM 383 387.
D. Cm type of plate from sample 36 477, × 280, RGM 383 387.
E. Cr type of plate from sample 36 477, × 400, RGM 383 387.


A
B
C
D
E

Cr-type plate of *M. scandicum* shown by Fig. 7D. One rather convex plate, though still twice as long as high, may represent a Co-type plate.

More common are flat, often almost round, plates (Fig. 5C) covered with subequal nodes aligned in two perpendicular directions.

Remarks — This species differs from *M. balticum* and *M. scandicum* in the length/width ratio of the Cm-type plate and in the form of the platelets adhering to the Cm-type plate. It differs from *M.* sp. a in having a somewhat flatter Cm-type plate. Moreover *M.* sp. a seems to lack the flat round plates as described above for *M. longmyndium*.

Occurrence — Sample 85/8 from mid-Llandoverian strata near Hillend Farm, Welsh Borderland (see Appendix).

Number of specimens — Sample 85/8 – 219 (155 Cm, 10 Cr, 1 Co, 53 others).

Milaculum scandicum Müller, 1973
Figs. 4C; 7A-F.

1973 *Milaculum scandicum* n. sp. – Müller, pp. 222-223, pl. 34, fig. 1-4, 7.

Remarks — Müller comprised three types of plates in the species *M. scandicum*: a somewhat triangular type comparable to the Cr type of *M. balticum* (Müller, 1973, pl. 34, figs. 1, 3); the conical form comparable to the Co type of *M. balticum* (ibidem, pl. 34, fig. 2a,b); and a somewhat constricted elongate plate (ibidem, pl. 34, fig. 4) which also may be of the Cr type.

The Cm-type plate of *M. scandicum* differs from that of *M. balticum* in that the nodes are not placed in straight lines paralleling the sides, but are aligned in two perpendicular directions crossing the length axis of the plate at an angle of c. 45°. The mean length/width ratio also differs, being only c. 1.5 for *M. scandicum*. As a maximum 1.8 was found. The maximum length measured is c. 0.23 mm.

The Cr type of plate (Fig. 7D,E,F) is less convex at the broad end, and the tongue-like extension is relatively shorter and wider – in large specimens (Fig. 7E,F) almost as wide as the convex part – than in the Cr type of *M. balticum*. In lateral view the upper side is a straight or only slightly concave slope. The Cr type of plate generally is adorned with five rows of nodes. The large specimens (Fig. 7E,F) show some resemblance to the specimen of *M. ruttneri* figured by pl. 33, fig. 1a of Müller (1973), from the Upper Cambrian of Iran.

The Co type of plates (see pl. 34, fig. 2a,b of Müller, 1973) is rare as is the case with the other species of *Milaculum*. One specimen was found – transitional between a Cm type and an oblique cone – possessing some adhering platelets (Fig. 4C; 7C). Due to the

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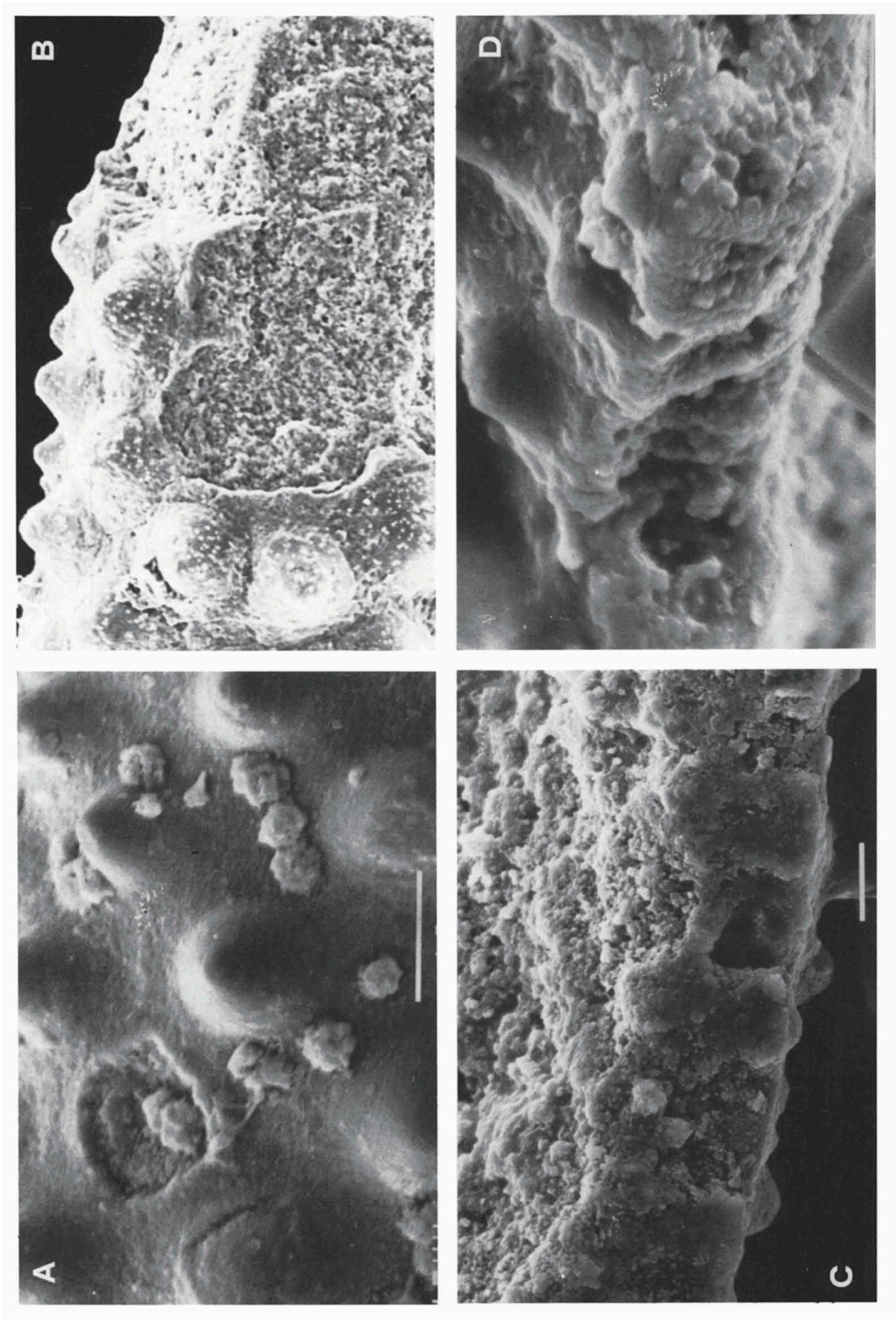
Fig. 9. (scale bar is 10 μm).
A. *Milaculum ethinclarki* Müller, 1973. Detail of Cm type of plate showing the thin upper layer at the place where one node is broken off. Sample 72 011, RGM 383 407.
B. *Milaculum* sp. a. Part of upper layer broken off. Sample 36 477, × 680, RGM 383 387.
C. *Milaculum balticum* sp. nov. showing cavernous middle layer and lower side. Sample 173 756, RGM 383 408.
D. *Milaculum balticum* sp. nov. showing cavernous middle layer and upper side. Sample 173 756, RGM 383 408, × 2250.


B
D
A
C

state of preservation it could not be ascertained whether these platelets are round or eight-sided. They possess a central node which seems to be stouter than the central node of the platelets of the Cm-type plate of *M. balticum*.

A fourth type of plates of *M. scandicum* – semi-round plates with unequal nodes (Fig. 7A) – may be comparable to the round flat plates of *M. balticum*, though it does differ because of the size variation of the nodes.

Occurrence — Samples 19 385 and 19 386 from middle Arenigian strata of Öland (Sweden) (see Appendix); see also Müller (1973, p. 223).

Number of specimens — Sample 19 385 – 112 (70 Cm, 19 Cr, 23 others); sample 19 386 – 359 (212 Cm, 64 Cr, 2 Co, 81 others).

Milaculum sp. a
Fig. 8C,D,E; 10B.

Description — The Cm-type plates (Fig. 8D) are elongate with round short sides. They are convex in lateral view and in cross section. The mean length/width ratio is c. 2.1. The maximum ratio encountered is 2.8. The maximum length measured is 0.362 mm. The plates are covered with subequal, pointed, nodes arranged in lines which generally parallel the long sides of the plates. Occasionally one can observe that a line of nodes halfway the plate splits into two lines of nodes (Fig. 8D).

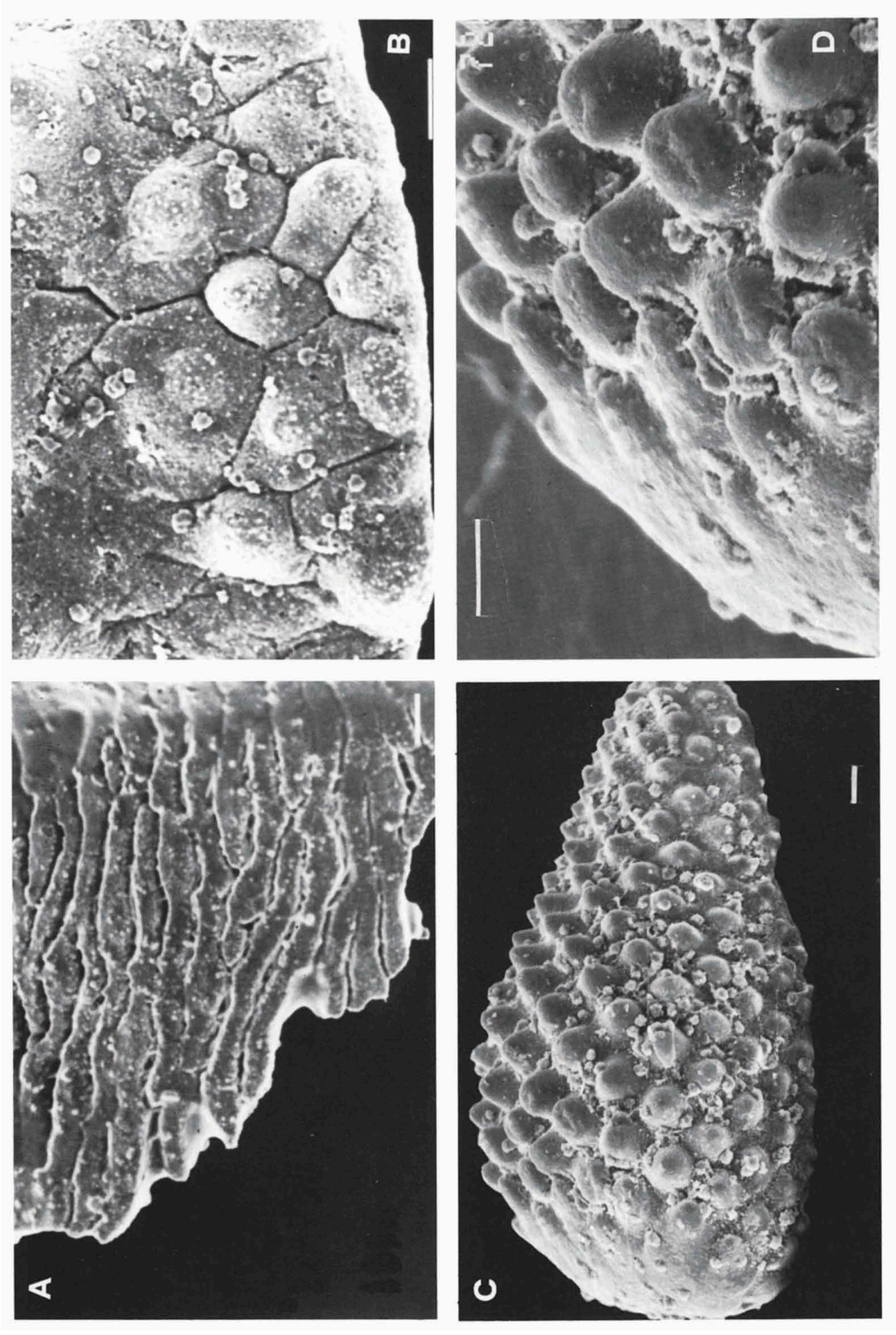
The Cr type of plate (Fig. 8E) is rather convex at one side and gently slopes down to the other end. However, all my specimens seem to lack the, generally more delicate, end of the plate. Only one broken specimen was found showing that the end of the slope is slightly concave in lateral view. This type of plate narrows towards the lower end. The nodes are aligned in parallel rows. Especially those in the outer rows decrease in size towards the narrow end of the plate.

The Co type of plates have various forms, low cones, oblique cones and high cones (Fig. 8C). The latter are almost twice as high as wide. The nodes are subequal and seem to be aligned in rows which obliquely cross the long axis of the cone. Near the base of the cone occurs an area consisting of small platelets which are not fused to each other. Each platelet bears one node (Fig. 10B).

Remarks — The Cm type as well as the Cr type of plates of this species show a resemblance to those of *M. longmyndium*. Also the length/width ratios of the Cm-type plates do not differ much. However, the cone-type plate has some platelets with a central node. *M. longmyndium* has platelets without a node around the Cm-type plate. Keeping in mind that in *M. balticum* Co type and Cm type of plates are surrounded by the same type of platelets, I do think that *M.* sp. a is not conspecific with *M. longmyndium*.

Because the number of specimens is not great (only 62) and because they are not so well preserved – the Cm-as well as the Cr-type plates do not have any adhering platelet –

Fig. 10. (scale bar is 10 μm).
A. *Milaculum balticum* sp. nov., detail of Fig. 3A, showing elongate platelets.
B. *Milaculum* sp. a, detail of Fig. 8C, basal part of cone.
C. *Milaculum ethinclarki* Müller, 1973. Partly bald type of plate, sample 72 011, RGM 383 407.
D. Detail of C.


B
D
A
C

I have to few data to know whether this late Arenigian-early Llanvirnian species really differs from the middle Arenigian *M. scandicum* and therefore I prefer to describe it here as *M.* sp. a.

Occurrence — Samples 36 467 and 36 477 from upper Arenigian to lower Llanvirnian strata near Port Kunda (Estonia) (see Appendix).

Number of specimens — Sample 36 467 – 9 (7 Cm, 2 Cr); sample 36 477 – 53 (36 Cm, 10 Cr, 6 Co, 1 other).

Appendix: Data on the samples and sample localities

Canada, southern Ontario

Sample 13/4/75 was taken by the present author from the Kirkfield Formation at Healey Falls during the field trip no 4 (Stop A 3) of the Waterloo (May 1975) meeting. The sample contains many conodonts, i.a. *Belodina compressa* (Branson & Mehl, 1933), *Phragmodus undatus* Branson & Mehl, 1933 and *Polyplacognathus ramosus* Stauffer, 1935.

Samples 72 008, 72 010 - 72 012, 72 014 and 72 015 were collected by Professor A. Brouwer during field excursion A 45 of the 24th International Geological Congress, Montreal 1972. Due to the rather abrupt closure of the Geological Institute of Leiden University and the following disorderly removal of collections and furniture Brouwer's notes concerning the samples got mislaid and are not yet recovered. Certain is, however, that the samples used for this study were taken between stop 5 and stop 13 of the excursion and that most of them originate from beds of the Kirkfield and Verulam formations because of the occurrence of *Plectodina tenuis* (Branson & Mehl, 1933), which according to Winder et al. (1975) and Sweet (1981) appears in Late Kirkfield and ranges through the Verulam and younger formations into Late Richmondian.

The formic-acid insoluble residue of sample 72 008 contains conodonts, i.a. *Plectodina aculeata* (Stauffer, 1930), many chitinozoans and many remains of bryozoans. This sample may have been derived from the Coboconk or the Kirkfield Formation. It yielded two specimens of *Milaculum* per 100 g of limestone.

Sample 72 010 contained a few conodonts, i.a. *Plectodina tenuis*, and also only two specimens of *Milaculum* per 100 g of limestone.

Sample 72 011 is rich in conodonts, i.a. many *Bryantodina abrupta* (Branson & Mehl, 1933), many *Plectodina tenuis* and a few *Phragmodus undatus*. This sample furthermore contains abundant scolecodonts, chitinozoans and 82 specimens of *Milaculum* per 100 g of limestone.

Sample 72 012 is rich in conodonts, i.a. many *Panderodus gracilis* (Branson & Mehl, 1933), many *Plectodina tenuis* and a few *Phragmodus undatus*. Furthermore it contains many scolecodonts, abundant remains of phosphatic brachiopods and 57 specimens of *Milaculum* per 100 g of limestone.

Sample 72 014 contains many specimens of *Phragmodus undatus*, very few *Plectodina* sp., abundant remains of phosphatic brachiopods and 16 specimens of *Milaculum* per 100 g.

Sample 72 015 contains many conodonts, i.a. abundant *Phragmodus undatus*, a few *Plectodina tenuis*, abundant remains of phosphatic brachiopods, and 22 specimens of *Milaculum* per 100 g of limestone.

Estonia

The samples RGM 173 755 - 173 758 and 173 764 derive from the vicinity of Kukruse (Estonia). They were some 80 years ago collected by Baron von Toll – landlord of the country-seat Kuckers and Oheim – at the request of J.H. Bonnema for ostracode research (Bonnema, 1909). According to Bonnema (1909, p. 5) the sampling locality is without doubt the drainage canal described by Schmidt (1881, pp. 28,29) 'In Estland ist die am besten ausgebeutete Stelle der grosse Entwässerungsgraben bei Kuckers, der über eine halbe Werst lang und 10 F. tief ist: zahlreiche dünne blättrige Schichten von Brandschiefer wechseln hier mit mergeligen oder festern meist etwas bituminösen Kalkschichten ab.' The stratigraphic zone is according to Schmidt (1881) Schicht C2, Kuckerssche Schicht or Brandschiefer; or (Schmidt, 1882) Stage C 2, Kuckers Shale. This zone C 2 is according to Viira (1974, p. 6) lower Caradoc.

The samples are of a pale brown to light brown limestone with moderate brown spots or irregular streaks. They are rich in macrofossils (brachiopods, bryozoans, trilobites) and microfossils. Besides a considerable number of *Milaculum balticum* n.sp. they yielded abundant: conodonts, i.a. many elements of *Baltoniodus variabilis* (Bergström, 1962) and few elements of *Amorphognathus tvaerensis* Bergström, 1962; acritarchs; chitinozoans; foraminifera, i.a. *Ordovicina oligostoma* Eisenack, 1937 and *O. pachytheca* (Eisenack, 1954); small phosphatic brachiopods, *Paterula* sp. and *Torynelasma minus rossicum* Gorjansky, 1969; and phosphatic linings of trepostome bryozoans, mainly of *Hemiphragma* sp. – forms like those described as *Labyrinthotuba kozlowskii* by Gorka, 1969; see also Dzik, 1981. (This Kukruse locality is the type locality of several of Bassler's (1911) bryozoan species).

Somewhat less abundant occur scolecodonts i.a. *Mochtyella cristata* Kielan-Jaworowska, 1961 and *Ramphoprion urbaneki* Kielan-Jaworowska, 1966. Relatively scarce occur specimens of *Graptoblastus* and *Graptoblastoides*.

The formic-acid insoluble residues of the five samples differ in dolomite and clay content and are therefore assumed to have been taken from different beds.

The trench at the estate of Baron von Toll was still in existence in 1914 when visited by Raymond and referred to as the famous principal locality of the Kuckers Formation (Raymond, 1916, p.183).

The samples 36 467 and 36 477 have been collected in 1912 by A.W. Nieuwenhuis in respectively the Arro quarry and the Mollo quarry near Port Kunda in Estonia. Sample 36 467 is of a greenish grey limestone rich in small brown lentils and sample 36 477 is of a light brown limestone which besides abundant conodonts also contains large quantities of small gastropods and echinoderm remains. Nieuwenhuis did not mention from which formation the samples derive, but judging from Raymond's (1916) publication they must have been taken from the Vaginatenkalk (of Schmidt, 1897) named Kunda Formation (B_3) by Raymond (1916, p. 192-195). Sample 36 467 must derive from the so called Lower Linsenschicht (Raymond, 1916, p. 193) which forms the base of the Kunda Formation. Sample 36 477 will be from a level higher in the Kunda Formation, a formation which according to Raymond has a fauna dominated by cephalopods and gastropods. The conodonts, i.a. *Amorphognathus variabilis*, are those of the Kundan (B III) beds and the occurrence in sample 36 477 of the form *Ambalodus pseudoplanus*

Viira, 1974 indicates that the sample is from the upper part of that series (Viira, 1974, table 2). The *Amorphognathus variabilis* conodont zone is top Arenigian base Llanvirnian (Lindström, 1977; Higgins & Austin, 1985).

Sweden

The samples RGM 19 385 and 19 386 were collected in 1957 by B. Boelens at the Island of Öland in a quarry of the Öland Bruks A.B. near Persnäs. The rock is the so-called Orthoceratite limestone, a dark red limestone abounding in conodonts – i.a. *Baltoniodus navis* (Lindström, 1955) and *Paroistodus parallelus* (Pander, 1856) – and small phosphatic brachiopods. The *Milaculum* content of both samples was 15 and 44 per 100 g of limestone, respectively.

A third sample of Orthoceratite limestone from the same quarry, though equally rich in conodonts and phosphatic brachiopods, did not yield any *Milaculum*.

The age of the limestone is approximately middle Arenigian.

United Kingdom

Sample 85/8 was taken in 1985 in the Welsh Borderland – during Field excursion B of ECOS IV – from the *Pentamerus* beds in the small old quarry at the Hillend Farm, Plowden locality of Aldridge (1972; see also Aldridge & Smith, 1985, p. 14). Besides specimens of *Milaculum* the 2600 g of limestone processed, yielded more than 300 conodont elements, i.a. elements of the species *Pterospatodus? tenuis* Aldridge, 1972, *Kockelella? abrupta* Aldridge, 1972 and *Ozarkodina hassi* Pollock, Rexroad & Nicoll, 1970. The microfauna furthermore contained circa 200 scolecodonts and about the same amount of chitinozoans which latter all occurred in the heavy fraction due to being filled with either pyrite or phosphate. The age of this limestone is Aeronian (mid-Llandovery).

References

Aldridge, R.J., 1972. Llandovery conodonts from the Welsh Borderland. — Bull. Br. Mus.(Nat. Hist.), 22, 2: 125-231.

Aldridge, R.J. & M.P. Smith, 1985. Fourth European Conodont Symposium (ECOS IV), Fieldexcursion B, Lower Palaeozoic succession of the Welsh Borderland. — Univ. Nottingham: 1-39.

Alexander, R.McN., 1975. The Chordates. — Cambridge Univ. Press, London: 1-480.

Bassler, R.S., 1911. The early Paleozoic Bryozoa of the Baltic Provinces. — U.S. Natl. Mus. Bull., 77: 1-382.

Bengtson, S., 1985. Taxonomy of disarticulated fossils. — Jour. Pal., 59, 6: 1350-1358.

Bergström, S.M. & M.J. Orchard, 1985. Conodonts of the Cambrian and Ordovician Systems from the British Isles. In: A.C. Higgins & R.L. Austin (Eds), A Stratigraphical Index of Conodonts. — Br. Micropal. Soc., Ellis Horwood, Chichester: 32-67.

Bonnema, J.H., 1909. Beitrag zur Kenntnis der Ostrakoden der Kuckersschen Schicht (C2). — Thesis Univ. Groningen: 1-84.

Denison, R.H., 1967. Ordovician vertebrates from western United States. — Fieldiana, Geol., 16, 6: 131-192.

Dzik, J., 1981 Evolutionary relationships of the Early Palaeozoic 'Cyclostomatous' Bryozoa. — Palaeontology, 24, 4: 827-861.

Dzik, J., 1986. Chordate affinities of the conodonts. In: A. Hoffman & M.H. Nitecki (Eds), Problematic Fossil Taxa. — Oxford Monogr. Geol. Geophys., 5: 240–254.

Ethington, R.L. & D.L. Clark, 1965. Lower Ordovician Conodonts and other microfossils from the Columbia Ice Fields section, Alberta, Canada. — Brigham Young Univ. Geol. Stud., 12: 185-205.

Ethington, R.L. & D.L. Clark, 1981. Lower and Middle Ordovician Conodonts from the Ibex Area, Western Millard County, Utah. — Brigham Young Univ. Geol. Stud., 28, 2: 1-160.

Gorjansky, V.Yu., 1969. Bezzamkovye brakhiopody kembrijskikh i ordovikskikh otlozhenij severo-zapada Russkoj platformy. — Mat. Geol. Pol. Iskop. Sev.-Zap. RSFSR, Sev.-Zap. Ter. Geol. Uprav. Min. Geol. RSFSR, 6: 1-173.

Górka, H., 1969. Microorganismes de l'Ordovicien de Pologne. — Palaeontol. Polonica, 22: 1-102, 31 pls.

Higgins, A.C. & R.L. Austin, 1985. A Stratigraphical Index of Conodonts. — British Micropal. Soc., Ellis Horwood, Chichester: 1-263.

Hinz, I., 1987. The Lower Cambrian microfauna of Comley and Rushton, Shropshire/England. — Palaeontographica, A, 198, 1-3: 41-100.

Lindström, M., 1977. In: W. Ziegler (Ed.) Catalogue of Conodonts, Vol. III. — Schweizerbart, Stuttgart: 51-52.

Müller, K.J., 1973. *Milaculum* n.g., ein phosphatisches Mikrofossil aus dem Altpaläozoikum. — Paläont. Z., 47: 217-228.

Nitecki, M.H., R.C. Gutschick & J.E. Repetski, 1975. Phosphatic microfossils from the Ordovician of the United States. — Fieldiana, Geol., 35, 1: 1-9.

Raymond, P.E., 1916. Expedition to the Baltic Provinces of Russia and Scandinavia. Part 1. The correlation of the Ordovician strata of the Baltic Basin with those of eastern North America. — Bull. Mus. Comp. Zool. Harvard, 56, 3: 179-286.

Schmidt, F., 1881. Revision der ostbaltischen Silurischen Trilobiten nebst geognostischer Übersicht des ostbaltischen Silurgebiets. — Mem. Acad. Imp. Sci. St.-Pétersbourg, VII, 30, 1: 1-230.

Schmidt, F., 1882. On the Silurian (and Cambrian) Strata of the Baltic Provinces of Russia, as compared with those of Scandinavia and the British Isles. — Q. J. Geol. Soc. London, 38: 514-536.

Schmidt, F., 1897. Excursion durch Estland. — Guide Excurs. VII Congr. Géol. Int., St.-Pétersbourg, 1897, 12: 1-21.

Sweet, W.C., 1981. In: W. Ziegler (Ed.), Catalogue of Conodonts, Vol. IV. — Schweizerbart, Stuttgart.

Viira, V., 1974. Ordovician conodonts of the East Baltic. — Eesti NSV Tead. Akad. Geol. Inst. Valgus, Tallinn: 1-142 (in Russian).

Winder, C.G. & B.V. Sanford, 1972. Stratigraphy and paleontology of the Paleozoic rocks of southern Ontario. In: D.J. Glass (Ed.), Guidebook Field Excursion A45-C45. — 24th Int. Geol. Congr., Montreal, 1972: 1-74.

Winder, C.G., C.R. Barnes, & T.T. Uyeno, 1975. Ordovician to Devonian stratigraphy and conodont biostratigraphy of Southern Ontario. P.G. Telford (Ed.), Field excursions guidebook, part B: Phanerozoic geology, Field trip nos. 4 and 5. — Dep. Earth Sci. Univ. Waterloo, Ont.: 119-160.

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