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EARLIEST REPRESENTATIVES OF THE GENUS *CORDYLODUS* (CONODONTA) FROM CAMBRO—ORDOVICIAN BOUNDARY BEDS OF NORTH ESTONIA AND LENINGRAD REGION

The Obolus Sandstone of the Kallavere Formation from North Estonia and sandstone of the Lomashka and Tosna Formations from the Leningrad Region have yielded abundant conodonts, among which specimens of *Cordylodus* are dominating. The purpose of this paper is to describe some of these cordylodids. The composition and biostratigraphic distribution of conodonts are given in the paper of D. Kaljo et al. (1986).

The described material is housed at the Institute of Geology, Tallinn, under the catalogue numbers Cn1078—Cn1125.

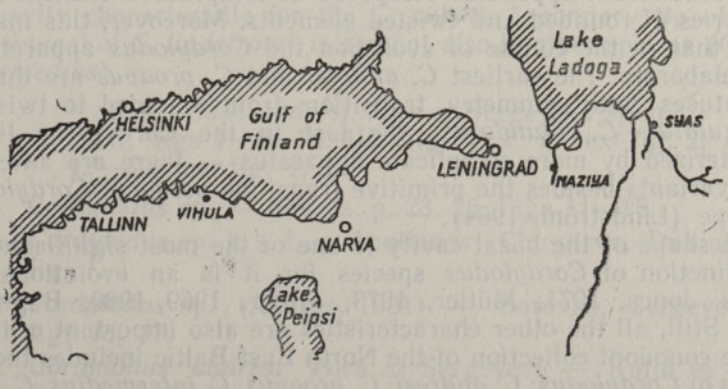
Deep gratitude is expressed to Drs N. Borovko, K. Mens and H. Heinsalu, who have provided the authors with most of the conodont collections described herein, and with the lithological columns. The authors are grateful to E. Klimov who took SEM photographs and to K. Ronk who re-drafted all the figures.

The conodont fauna from the Tosna and Ladoga Formations was discussed in the papers of N. Borovko and S. Sergeyeva (Боровко и др., 1980, 1984, 1985; Боровко, Сергеева, 1981, 1985). Systematic collection of conodonts from the Kallavere Formation was undertaken in 1983, following the recovery of a primitive cordylodid from the Vihula section by K. Khazanovich. By now conodonts have been obtained from several sections of North Estonia and the Leningrad Region. The earliest cordylodids of three sections have been illustrated by samples (text-figs 2—4). Location of the outcrops is given in text-fig. 1. Conodonts show a CAI of 1 or slightly higher. The specimens are well preserved, although many of them have broken cusps and denticles.

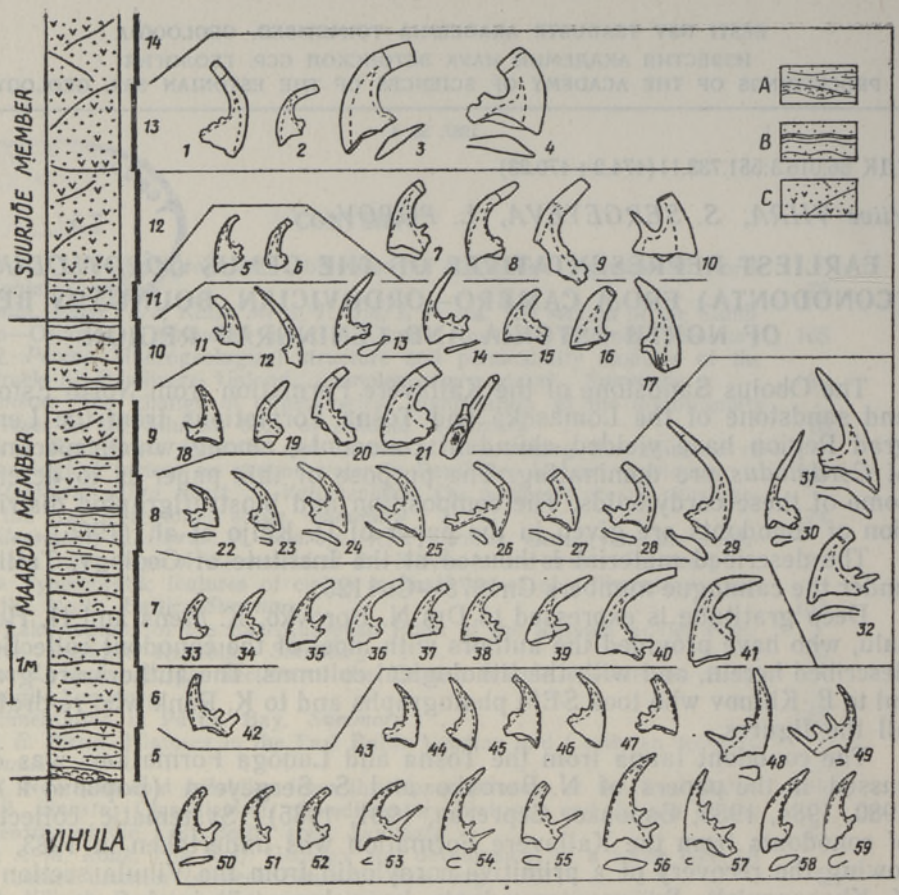
Genus *Cordylodus* Pander, 1856

Type species: *Cordylodus angulatus* Pander, 1856.

Remarks. *Cordylodus* is interpreted mostly as a two-element apparatus (Miller, 1980; Landing et al., 1980; Treatise..., 1981). G. Bagnoli et al. (1987) regard the apparatus *Cordylodus* to be more complex. This is



Text-fig. 1. Sketch map showing location of conodont localities.

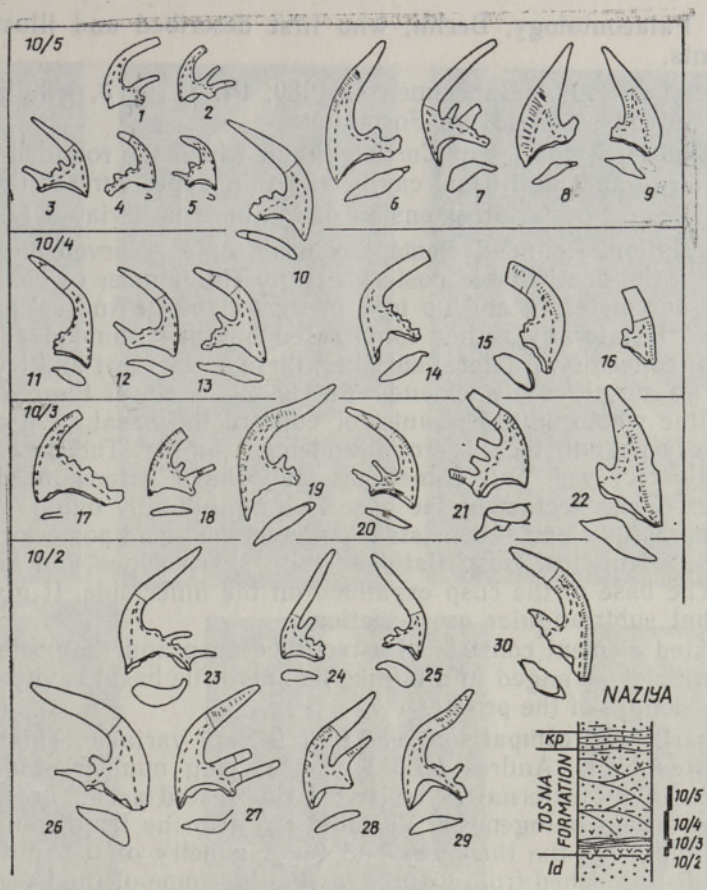


Text-fig. 2. Specimens of *Cordylodus* from the Kallavere Formation in Vihula section. Lithological column is given after H. Heinsalu. *1—3, 6—9, 11—15, 19—21, 28—29 C. proavus* Müller. *18, 33—36, 42—59 C. andresi* sp. n. *5, 22, 38, 39* transition *C. andresi — C. proavus. 30 C.* sp. *31, 32 ?C. caboti* Bagnoli, Stevens et Barnes. *A* — sandstone with complete brachiopod valves, *B* — sandstone with argillite interbeds, *C* — cross-bedded sandstone with brachiopod fragments.

expressed by the fact that the *p* elements (=rounded) include a symmetry transition series from laterally compressed symmetrical forms to markedly asymmetrical forms with low carina on the inner lateral face. The *q* elements (=compressed) have a minor variation. The northern East Baltic material, on which the present paper is based, confirms that *Cordylodus* is a multielement apparatus composed of compressed element and transition series of rounded and twisted elements. Moreover, this material also shows that in the course of evolution the *Cordylodus* apparatus became more elaborate. The earliest *C. andresi* and *C. proavus* are three-element apparatuses with symmetry transition from rounded to twisted forms. *C. angulatus—C. rotundatus*, the last in the Cordylodus lineage are characterized by more complicate apparatus — there are anterior-aboral angle variants besides the primitive transition series of *Cordylodus-Roundya* type (Lindström, 1964).

The shape of the basal cavity is one of the most significant character in distinction of *Cordylodus* species for it is an evolutionary feature (Druce, Jones, 1971; Müller, 1973; Miller, 1969, 1980; Bagnoli et al., 1987). Still, all the other characteristics are also important criteria.

The conodont collection of the North East Baltic includes the following species of *Cordylodus*: *C. andresi*, *C. proavus*, *C. intermedius*, *C. lindstromi*, *C. rotundatus*, *C. angulatus*. These species show the evolutionary develop-



Text-fig. 3. Specimens of *Cordylodus* from the Tosna Formation in Naziya section. *1, 2, 4, 5, 18* transition *C. proavus—C. lindstromi. 3, 6, 7, 10, 11, 16, 17, 22 C. proavus* Müller. *8, 9* ?*C. lindstromi* Druce et Jones. *12—15, 19—21, 27—30 C. lindstromi* Druce et Jones. ?*23, 26 C. intermedius* Furnish. *24,* ?*25 C. sp.*

ment of the present genus. G. Bagnoli et al. (1986) consider *C. primitivus* the oldest species but *C. andresi* is evidently an earlier representative, as the basal cavity is of a more primitive shape. Simple specimens with a single small denticles occurring in the East Baltic material, are placed within the variation of *C. andresi. C. caboti* lies between *C. proavus* and *C. intermedius* in the evolutionary line of G. Bagnoli et al. (1987). In the East Baltic collections some specimens have a straight anterior edge of the basal cavity characteristic for the *C. caboti.* Secondary tip of the basal cavity, typical of *C. lindstromi*, is present also in other species (*C. proavus, C. intermedius*).

Cordylodus andresi Viira et Sergeyeva sp. n.
Pl. I, figs *1—8*, Pl. III, figs *1, 2, 4,* text-fig. 2, *18, 33—36, 42—59*, text-fig. 4, *28.*

1981. *Cordylodus* sp. — Andres, p. 23, 25, Figs 11—18.

? 1984. *Cordylodus* sp. 1, s. f. — Apollonov, Chugaeva, Dubinina, Pl. 30, fig. *1.*

1985. *Cordylodus* sp. (Andres, 1981) — Borovko, Sergeyeva, Plate, figs *16, 17.*

1986. *Cordylodus andresi* Viira et Sergeyeva — Kaljo et al., Pl. II, figs *1—6, 9, 10.*

Derivation of the name. Named in honor of Dr. Dietmar Andres, Insti-

tute of Palaeontology, Berlin, who first described and illustrated these conodonts.

Holotype. Rounded specimen Cn1080, Pl. I, fig. *3*, Vihula, sample 5, Maardu Member, Kallavere Formation.

Diagnosis. A species of *Cordylodus* in which the rounded element has a very large and high basal cavity and thin upper surface layer. Number of denticles on posterior extension of the base is variable (*1—9*).

Description. Rounded element consists of a recurved cusp and large base with the denticulated posterior edge. The number of denticles varies, 1—4 in our material, and up to 9 in Fig. 11 of D. Andres' paper (1981). The unit is laterally rather compressed but has rounded edges. Due to different convexity of lateral surfaces, there occur right and left specimens. The large basal cavity extends nearly to the tip of the cusp occupying almost the whole unit. The anterior edge of the basal cavity curves convexly very near to the edge of the element proper. The posterior egde is smoothly recurved and sometimes may have extensions beneath the denticles. Cross-section of the base is longitudinally oval.

Compressed element consists of an erect cusp and posteriorly elongated base with denticles. Cusp flattened with sharp edges and bending sideward. The base of the cusp expanded on the inner side. It gives the base somewhat subtriangular cross-section.

Twisted element consists of a recurved cusp and the posterior process with denticles arranged in a fanlike manner. The basal cavity is large and runs the length of the process.

Remarks and comparison. The unit is very variable. This has already been noted by D. Andres (1981). The varying number of denticles and thickness of the external layer have been treated as features undergoing changes during ontogenesis. Variable are also the length and the curvature of the cusp, the thickness and the symmetry of the unit. *C. andresi* can be distinguished from *C. proavus* by the shape of the basal cavity.

Occurrence. Outcrops in North Estonia (Turjekelder, Muuksi, Vihula, Toolse) and in the Leningrad Region (Lomashka). Pakerort Stage, Kallavere Formation, lower part of the Maardu Member and Lomashka Member, *C. andresi* Zone. In Sweden on Öland Island, Upper Cambrian, Acerocare Zone, Westergaardia Subzone.

Material. Several hundred specimens.

Cordylodus intermedius Furnish, 1938
Pl. III, figs. *9, 10, 13*, text-fig. 3, *?23, 26*.

Diagnosis. (After W. M. Furnish, 1938). Prominent cusp and short

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PLATE I

Figs *1—8*. *Cordylodus andresi sp. n.* All specimens from the Vihula section, sample 5. *1—4* rounded element, specimens Cn1078—Cn1081 (3 holotype Cn1080), *5—7* compressed element, specimens Cn1082—Cn1084, *8* twisted specimen Cn1085.
Figs *9—11*. *Eoconodontus notchpeakensis* (Miller). Asymmetrical compressed element. *9* specimen Cn1086 from Vihula, sample 5, *10, 11* specimens Cn1087, Cn1088 from Vihula, sample 11.
Magnification: *9, 10, 11* — ×55, all others ×175.

PLATE II

Figs *1—6*. *Cordylodus proavus* Müller, rounded element. All specimens Cn1089—Cn1094 from Vihula section: *1, 2* — sample 8, *3* — sample 9, *4* — sample 10, *5* — sample 11, *6* — sample 12.
Fig. *7*. *C. lindstromi* Druce et Jones. Specimen Cn1095 from Vihula, sample 13.
Figs *8, 9*. ?*C. proavus* Müller. Specimens Cn1096, Cn1097 from Toolse section, sample 10. *8* — asymmetrical rounded element with twisted cusp and secondary tips of the basal cavity. *9* — nearly symmetrical element with straight anterior margin of the basal cavity (*C. caboti*?).
Magnification: ×175.

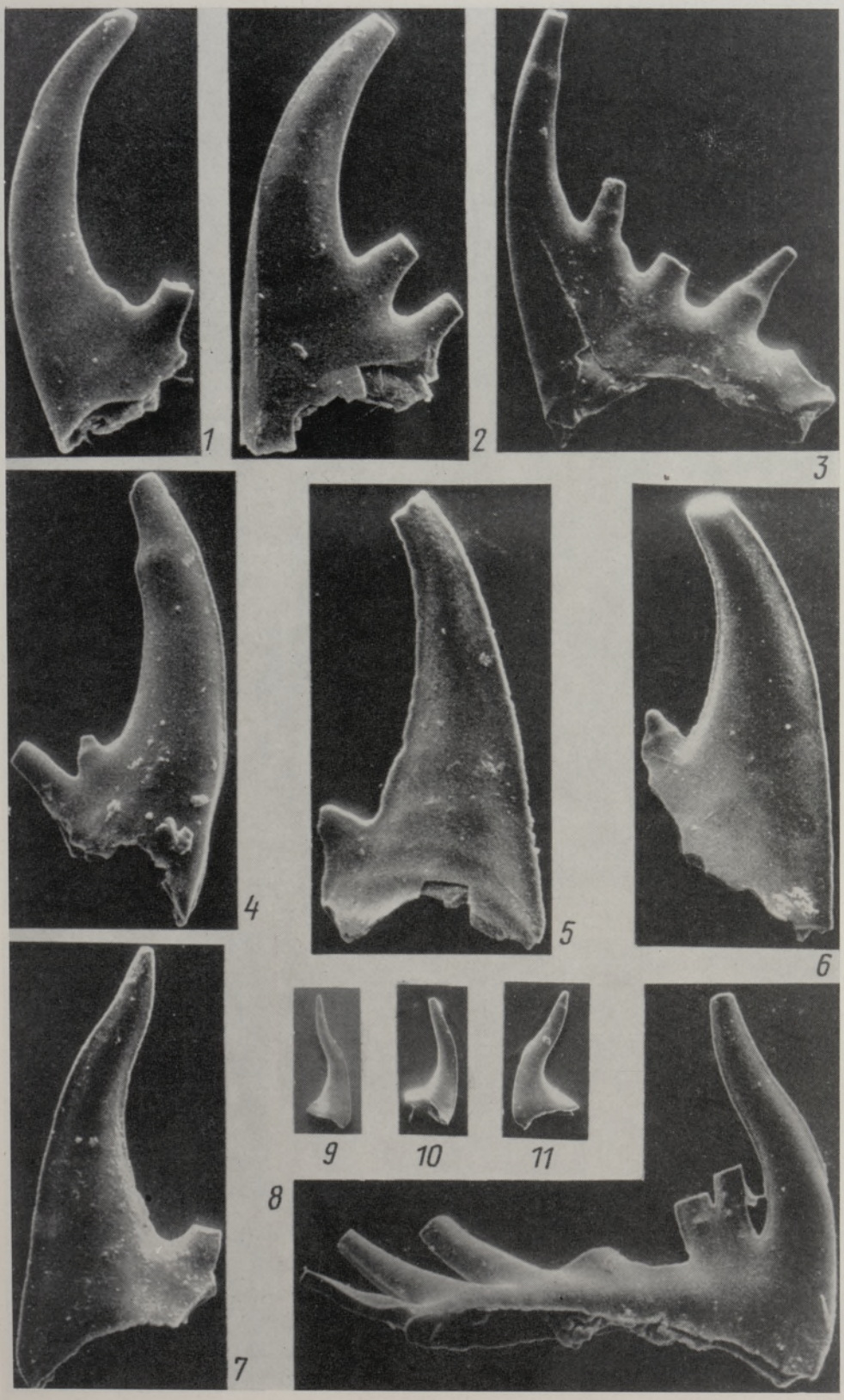
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PLATE II

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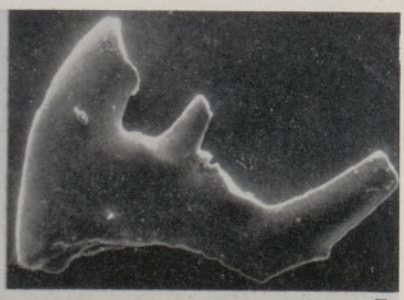
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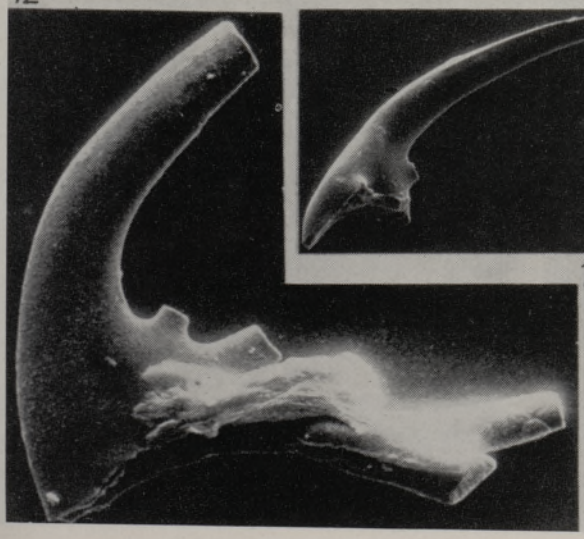

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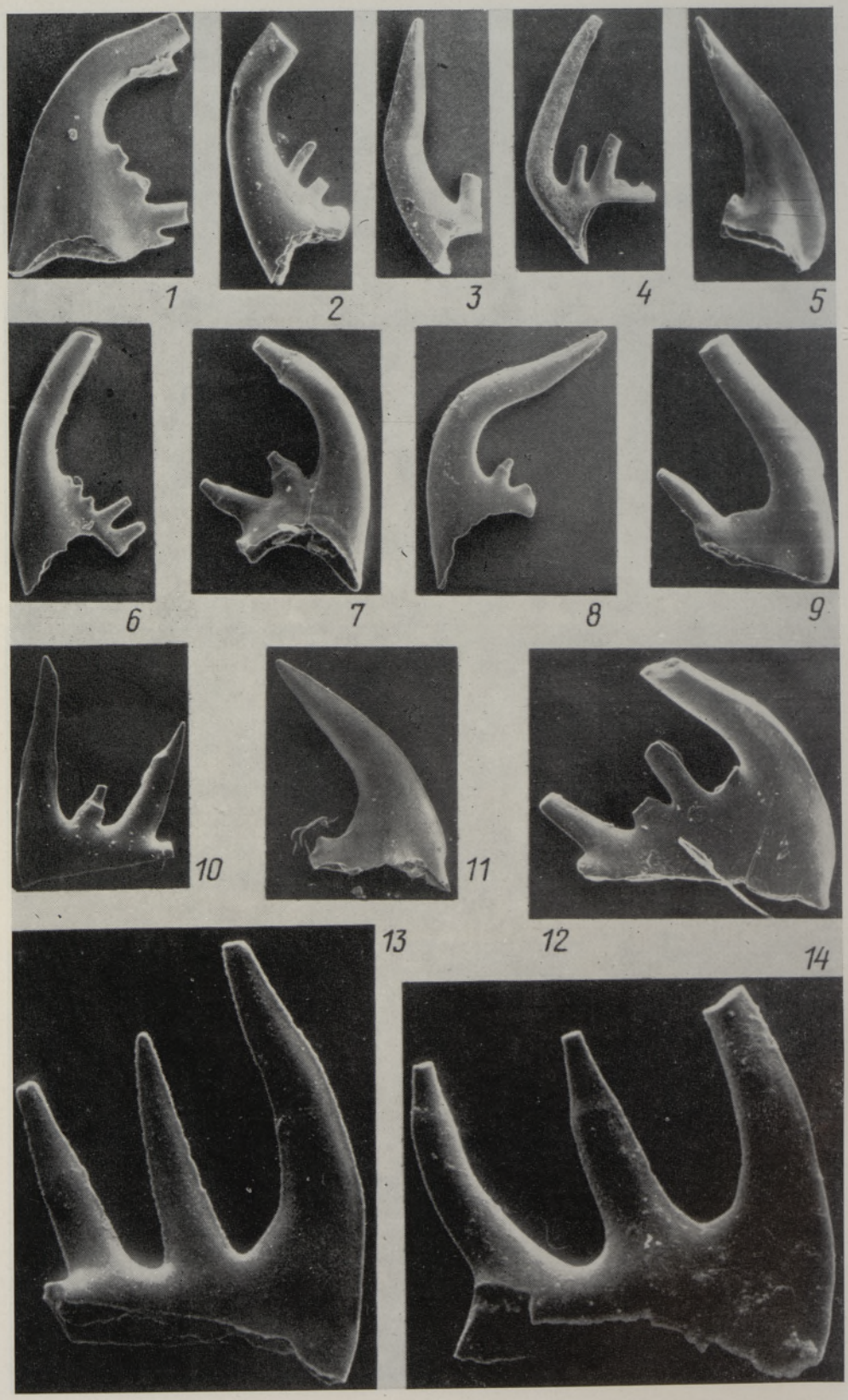
PLATE IV



arched denticulated process. Denticles relatively large, discrete, inclined and slightly flattened laterally. Axis of cusp normal to process, edged anteriorly and posteriorly, slightly twisted, with broad and flat sides. Large basal cavity attenuate and recurved anteriorly to bring the apex near the anterior margin.

Remarks. In the North East Baltic collections two morphologically different rounded elements are observed. One exists in specimens, the outer shape of which is similar to *C. proavus* and basal cavity has a concave anterior egde with the tip directed towards the cusp. The other type is in the outer shape similar to *C. angulatus* and basal cavity recurved anteriorly to bring the tip near the anterior margin. The specimens illustrated in this paper represent the rounded element of the first morphological type. It is not clear which specimens of compressed element belong to *C. intermedius* in Baltic collections. Such may be specimens with twisted cusp as illustrated on Pl. IV, fig. *11*.

Occurrence. Outcrops in North East Baltic (Suhkrumägi, Turjekelder, Tõnismägi, Ülgase, Muuksi, Toolse, Saka, Naziya, Syas), Pakerort Stage, Kallavere and Tosna Formations, *C. intermedius*, *C. lindstromi* and *C. angulatus—C. rotundatus* Zones.

Material. About a hundred specimens.

Cordylodus proavus Müller, 1959

Pl. II, figs. *1—6*, Pl. III, figs. *3*, *8*, *12*, Pl. IV, figs. *1—3*, *9*, *12*, text-fig. 2, *1—3*, *6—9*, *11—15*, *19—21*, *23—29*, text-fig. 3, *3*, *6*, *7*, *10*, *11*, *16*, *17*, *22*, text-fig. 4, *6—27*.

Diagnosis. A species of *Cordylodus* in which the rounded element has a big and stout reclined cusp. Posterior process with 1—6 discrete high denticles. The basal cavity large and conical, anterior edge convexly parallel to the anterior edge of the base. The cusp is filled with white matter above the basal cavity. Basal outline is oval.

Description. Rounded element composed of a distinct cusp and a large

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PLATE III

Figs *1*, *2*. *Cordylodus andresi* sp. n. Uncoated specimens Cn1098, Cn1099 from Vihula, sample 6.

Figs *3*, *8*, *12*. *C. proavus* Müller. *3*, *8* — rounded specimens Cn1100 from Vihula, sample 7 and Cn1105 from Toolse, sample 16. *12* — twisted spceimen Cn1109 from Toolse, sample 13.

Fig. *4*. ?*C. andresi* sp. n. Specimen Cn1101 with expanded base from Toolse, sample 5.

Figs *5*, *6*. ?*C. proavus* Müller. Specimens Cn1102, Cn 1103 with secondary tips of the basal cavity from Toolse, samples 12 and 13.

Fig. *7*. *C. lindstromi* Druce et Jones. Specimen Cn1104 from Toolse 13.

Figs *9*, *10*, *13*. *C. intermedius* Furnish. Specimens Cn1106, Cn1107 and Cn1110 from Toolse, samples 15, 17 and 13. *10* — specimen with straight margin of the basal cavity (*C. caboti*?).

Fig. *11*. *C.* sp. Specimen Cn1108 with rounded anterior edge of the base, from Naziya, sample 2.

Fig. *14*. *C.* sp. Specimen Cn1111 with triangular base from Vihula, sample 11.

Magnification: 12, 13 — ×175, all others ×90.

PLATE IV

Figs *1—3*, *9*, *12*. *Cordylodus proavus* Müller. All specimens from Syas, sample 33. *1* — alfa morph, specimen Cn1112, *2* — beta morph, specimen Cn1113, *3* — gamma morph, specimen Cn1114, *9*, *12* — twisted specimens Cn1120 and Cn1122.

Figs *4*, *7*, *8*. *C. lindstromi* Druce et Jones. Specimens Cn1115, Cn1118 and Cn1119 from Naziya, sample 5 and 3 (the last one).

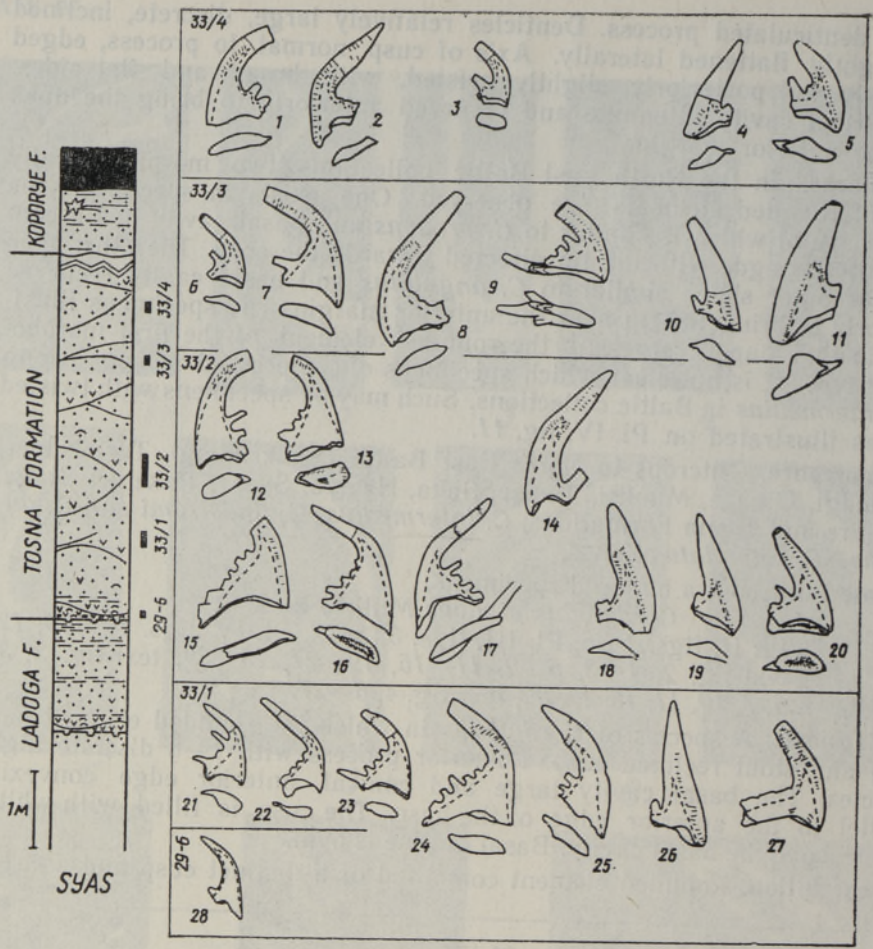
Fig. *5*. ?*C. lindstromi* Druce et Jones. Compressed specimen Cn1116 from Naziya, sample 5.

Fig. *6*. ?*C. proavus* Müller. Specimen Cn1117 with secondary tips of the basal cavity.

Figs *10*, *13*, *14*. *C. viruanus* sp. n. *10* — specimen Cn1123 from Vihula, sample 5, *13* — specimen Cn1124 from Toolse, sample 5, *14* — holotype Cn1125 from Vihula, sample 5.

Fig. *11*. ?*C. intermedius* Furnish. Compressed specimen Cn1121 with twisted cusp from Toolse, sample 12.

Magnification: *13*, *14* — ×175, all others ×90.



Text-fig. 4. *1, 2, 4, 5 C. lindstromi* Druce et Jones. *3 C.* sp. *6—27 C. proavus* Müller: *12, 13,* ?*27* — alfa morph. *15, 16, 21—24* — beta morph, *14* — gamma morph, *28 C. andresi* sp. n.

base with denticles on the posterior edge. Cusp reclined or erect, denticles discrete and parallel to the cusp. Denticles and tip of the cusp often broken. Cross-section of the cusp and denticles usually oval, but may be rounded or sharp-edged. The unit has a large conical basal cavity with the anterior edge convexly parallel to the anterior edge of the base. Tip of the basal cavity higher than the base of the denticles. Some specimens may have small secondary tip(s) under the denticle(s) on the posterior edge of the basal cavity. Cusp is filled with white matter, whereas the denticles have it only when they are much higher than the tip of the basal cavity. The unit has convex sides, usually one side being more convex than other one. The symmetrical specimens are rare. Asymmetrical specimens are dominating which is clearly seen by the basal outline of specimens given in figs *2—4*. The asymmetry is due to unequal convexity of lateral surfaces and twisting of the posterior process. Compressed element is asymmetrical. The big erect cusp is twisted sidewards. Posterior process with fused and sharp-edged denticles, often broken. Base with remarkable flaring on one side. Basal cavity rather high, conical in the cusp and extending into the posterior process. Cusp and anterior edge of the unit filled with white matter. Twisted element has the sideward deflexed process.

C. proavus is a highly variable species. The rounded element varies greatly not only in time but also within definite fauna. It concerns such features as the height and curvature of the cusp and basal cavity, the convexity of lateral surfaces and deflexity of the processes, number of denticles and others. We have treated the individual variants of the rounded element as morphotypes.

***C. proavus* alfa morph** (Pl. IV, fig. *1*, text-fig. 4, *15*, *16*). Cusp reclined, base large and wide. Small discrete denticles parallel to the cusp. Basal cavity ends near the bend of the cusp.

***C. proavus* beta morph** (Pl. IV, fig. *2*, text-fig. 4, *12*, *13*). Cusp and base weakly differentiated. Basal cavity high, extends to the cusp above the bend. Basal cavity very close to the outer surface near the base of the anterior edge.

***C. proavus* gamma morph** (Pl. IV, fig. *3*, text-fig. 4, *14*). Cusp erect, prominent. On the posterior edge one rather big denticle. Basal cavity high.

Remarks and comparison. Multielement species *C. proavus* is interpreted as a two-element apparatus (Miller, 1980; Landing et al., 1980; An, 1982; Bagnoli et al., 1986). However, the East Baltic material allows to suggest that this apparatus may include one more element. Because of its specific morphologic character it may represent a twisted element. Fanlike arrangement of denticles as a specific feature of some specimens was already noticed in the description by J. Miller (1969, Pl. 65, fig. *40*). The specimens with a twisted posterior process relative to the cusp, and forms with denticles directed laterally, have been mentioned by G. Nowlan (1985, fig. 5. 17). The twisted element may be considered as a marginal asymmetrical member of the symmetry transition series.

As noted by earlier investigations, *C. proavus* can be distinguished from other species by the shape of the basal cavity. Comparison with *C. andresi* is given in the description of the latter. *C. proavus* is similar to *C. intermedius*, but the latter has a concave anterior edge of the basal cavity.

C. proavus was first described from Oklahoma, USA by K. J. Müller (1959). By now it has world-wide distribution, occurring in the United States (Miller, 1969, 1980; Taylor, Landing, 1982; Landing, 1983), Canada (Fahraeus, Nowlan, 1978; Landing et al., 1980; Fortey et al., 1982; Nowlan, 1985; Bagnoli et al., 1986), Australia (Druce, Jones, 1971), Iran (Müller, 1973), Greenland (Stouge et al., 1985), China (An, 1982; An et al., 1983, 1985; Wang, 1985; Chen et al., 1985; Chen, Gong, 1986). In the Soviet Union *C. proavus* is found in Siberia (Абаимова, 1972, 1975; Абаимова, Марков, 1977), the Urals (Наседкина, 1975), Kazakhstan (Дубинина, 1982; Apollonov et al., 1984) and from the northern East Baltic (Боровко и др., 1984; Боровко, Сергеева, 1985; Kaljo et al., 1986). Due to its wide distribution, *C. proavus* comprises various morphological forms, possibly constituting a complex of different geographical taxons (subspecies?), as well as stratigraphical morphotypes.

Occurrence. Outcrops in North Estonia (Suhkrumägi, Tõnismägi, Ülgase, Turjekelder, Vihula, Toolse, Saka) and in the Leningrad Region (Ishora, Naziya, Syas and others). Pakerort Stage, Kallavere and Tosna Formations, from *C. proavus* up to *C. angulatus* Zones.

Material. Hundreds of specimens.

Cordylodus viruanus Viira et Sergeyeva sp. n.
Pl. IV, figs. *10*, *13*, *14*.

1986. Cordylodus sp. — Kaljo et al., Pl. III, fig. *17*.

Derivation of name. After the ancient name of North Estonia Viru.

Holotype. Rounded element Cn1125, Pl. IV, fig. *14*, Vihula section, sample 5, Maardu Member, Kallavere Formation.

Diagnosis. The unit with the cusp and denticles of almost the same height. Denticles are widely spaced. Basal cavity extends into the cusp.

Description. Rounded element with a stout erect cusp and broadly situated denticles. The cusp and denticles of almost the same height. The number of denticles 1—2 with broken processes. The base of the unit is low, the basal line is straight. Basal cavity extends conically rather high into the cusp and lowers smoothly to the end of the process. The cross-section of the cusp is rounded with sharp edges.

Remarks and comparison. The described specimens represent the rounded element. The other elements are not known. *C. viruanus* can be easily distinguished from the other species by widely spaced denticles and cusp of almost the same height.

Occurrence. Outcrops in North Estonia (Turjekelder, Vihula, Toolse). Pakerort Stage, Kallavere Formation, Maardu Member.

Material. 15 specimens.

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PEREKOND *CORDYLODUS*'E (CONODONTA) KÕIGE VARASEMAD ESINDAJAD PÕHJA-EESTIS JA LENINGRADI OBLASTIS

Põhja-Eestis ja Leningradi oblastis paljanduvas Kallavere, Lomaška ja Tosna kihistute oobolusliivakivis esinevad konodondid kuuluvad valdavalt perekond *Cordylodus*'e liikidesse. Kirjeldatud kahest uuest liigist — *C. andresi* ja *C. viruanus* — esimene on vanim selle perekonna esindaja. Joonistel 2, 3, ja 4 on kujutatud kolme läbilõike konodondid proovide kaupa.

Вийве ВИЙРА, С. СЕРГЕЕВА, Л. ПОПОВ

САМЫЕ РАННИЕ ПРЕДСТАВИТЕЛИ РОДА *CORDYLODUS* (CONODONTA) ИЗ СЕВЕРНОЙ ЭСТОНИИ И ЛЕНИНГРАДСКОЙ ОБЛАСТИ

Описаны два новых вида конодонтов рода *Cordylodus* — *C. andresi* и *C. viruanus*, содержащихся в оболовых песчаниках каллавереской, ломашкинской и тосненской свит. Первый из них является самым ранним представителем этого рода. На рис. 2—4 изображены послойно конодонты трех разрезов, иллюстрирующие ранний этап этого рода.