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CAMBRIAN-ORDOVICIAN BOUNDARY BEDS AT MÄEKALDA, TALLINN, NORTH ESTONIA

The Mäekalda section, named by the street in the eastern margin of the Kadriorg Park, Tallinn, is exposed in a fresh roadcut for the construction of a new motorway since 1986. The section of Lower Palaeozoic rocks, from the siltstones of the Lower Cambrian Tiskre Formation to the Middle Ordovician Lasnamägi Stage was introduced to the majority of the Ordovician researchers of Baltoscandia during the WOGOGOB field excursion on July 14, 1988. The authors of the present paper introduce the results of the mineralogical and palaeontological (conodont, acritarch and brachiopod) studies of the Cambrian-Ordovician boundary beds represented by the Ülgase and Kallavere Formations (Fig. 1).

The Ülgase Formation

The Upper Cambrian Ülgase Formation (thickness 3.20 m) covers the underlying greenish grey argillaceous siltstones of the Lower Cambrian Tiskre Formation (Table 1) containing the lenses of light grey coarse-grained siltstones.

The lower boundary of the Ülgase Formation is sharp, marked by the colour change and the appearance of the phosphatic pebbles and debris of inarticulate brachiopods. The upper surface of the Tiskre Formation is dissected by up to 20 cm deep pockets and up to 5 mm wide vertical burrows, filled with sandy material containing debris of inarticulate brachiopods and small flat phosphatized pebbles. The base of the Ülgase Formation contains in some places lenses of conglomerates up to 2 m in diameter with the thickness reaching 10 cm, mostly depending on the pebble size. The conglomerates contain more than 50 per cent of pebbles of various size, cemented with clay-silty matrix. The source rocks of the pebbles have been of sedimentary origin, most frequently coarse-grained siltstones and fine-grained sandstones, some of them yielding valves of inarticulates.

Except the lenses of conglomerates at the base, the rocks of the Ülgase Formation lack gravel material, consisting mainly of sandy siltstones with minor amounts of clay particles. The pelitic fraction exceeds 5 per cent only in the intercalations of argillaceous rocks and near the boundaries of the formation. By the rock types and structures, the section of the Ülgase Formation can be divided into four beds, starting from below.

Bed 1. Light-grey coarse-grained siltstones, intercalated by grey clays or argillaceous siltstones. The coarse-grained siltstones prevail, forming up to 30 cm thick layers which cover 70 per cent of the interval. The structure of this interval is generally horizontally-bedded, in places lenticular. The bedding plains of siltstones are surfaced with submillimeter clay rinds and contain brachiopod valves in higher concentrations. The uppermost 10 cm of this interval is represented by the thickest and most resistant layer of clay in this section. Thickness 1.20 m.

Bed 2 is lithologically similar to Bed 1, differing from the latter in irregular stratifications of mosaic bedding of sand- and claystones: the mixed rock-types are not formed. Thickness 0.40 m.

Bed 3. Cross-bedded, coarse-grained and sandy siltstones. The bedding planes marked by clayey films and phosphatic brachiopod fragments. Thickness 1.00 m.

Bed 4. Fine-grained sandstones and coarse-grained siltstones containing sparse pelitic material and thin clayey films on bedding planes, where the best preserved valves of phosphatic inarticulate brachiopods *Ungula inornata* and *Oepikites* sp., and the fragments of the problematic *Torellella* sp. occur. Thickness 0.60 m.

The Kallavere Formation

The overlying Kallavere Formation is divided into the Maardu (lower) and Suurjõgi (upper) Members, based on the lithological features, such as grain size, structure, distribution and roundness of brachiopod fragments (Хейнсалу, 1987).

The Maardu Member

The Maardu Member has a lower boundary, distinctly marked by various petrological characteristics. Most frequently, the base of the Maardu Member begins with up to 0.20 m thick brachiopod coquina (the so-called Obolus conglomerate), containing densely packed valves of *Ungula ingrica*. In some places the lower boundary is marked by a thin layer of kerogenous argillite, or lenses of unsorted sandstone, containing phosphatic valves and debris of inarticulate brachiopods.

Table 1

Content of debris and grain size of terrigenous clastic material

Sample	Formation	Content of debris, %	Grain size, %				Total, % >0.05 mm
			>1 mm	1.0—0.1 mm	0.1—0.01 mm	<0.01 mm	
Mä-86-20	Kallavere	28.7	0.4	95.3	1.9	2.4	96.8
Mä-86-19	Kallavere	34.7	0.3	96.3	1.2	2.2	97.5
Mä-86-18	Kallavere	9.9	—	89.6	9.0	1.4	94.6
Mä-86-17	Kallavere	10.1	—	83.0	17.0	—	99.2
Mä-86-16	Kallavere	6.0	—	43.0	50.2	6.8	91.5
Mä-86-15	Kallavere	16.6	—	54.5	43.6	1.9	98.0
Mä-86-14	Kallavere	12.1	—	—	83.2	16.8	79.0
Mä-86-13	Kallavere	32.5	34.5*	16.7	37.7	11.1	85.7
Mä-86-12	Ülgase	8.1	—	37.9	27.5	34.6	64.4
Mä-86-11	Ülgase	9.4	—	50.9	42.0	7.1	88.6
Mä-86-10	Ülgase	16.9	—	28.9	65.1	6.0	93.2
Mä-86-9	Ülgase	6.3	—	28.7	67.2	4.1	94.8
Mä-86-8	Ülgase	9.3	—	37.0	60.0	30.0	95.8
Mä-86-7	Ülgase	1.5	—	0.6	21.8	77.6	0.6
Mä-86-6	Ülgase	9.5	—	16.5	83.4	0.1	96.5
Mä-86-5	Ülgase	3.3	—	14.1	43.0	42.9	53.5
Mä-86-4	Ülgase	5.7	—	12.9	82.8	4.3	94.5
Mä-86-3	Ülgase	1.1	—	21.9	74.1	4.0	95.2
Mä-86-2**	Ülgase	0.7	—	13.4	60.0	26.6	68.2
Mä-86-2A**	Ülgase	n.d.	58.0*	6.4	24.0	11.6	81.4
Mä-86-1	Tiskre	—	—	5.7	58.3	36.0	28.8

* Including 28.7 and 52 per cent coarse clasts Mä-86-13 and Mä-86-2A, respectively.
** Sample Mä-86-2 is taken from the base of the Ülgase Formation without coarse clasts and Mä-86-2A from the lense of conglomerate.

The light-yellow quartzose sandstones and siltstones of the Maardu Member contain numerous thin intercalations or films of dark-brown kerogenous argillites (the so-called Dictyonema shales). The thickness of these intercalations varies from some millimetres to 10 cm and they form less than 10 per cent of total thickness of the Maardu Member.

The grain size of the sandstones and siltstones of the Maardu Member increases upwards: in the lower part, silt particles prevail or occur in the equal concentrations with sand grains which explicitly prevail in the upper part of the member (Table 1). The content of the pelitic particles, represented mostly by the fraction 0.01—0.02 mm is minute, except some argillaceous intercalations with higher pelite content.

Macrofossils are represented by a phosphatic inarticulate brachiopod *Ungula ingrica* and a graptolite *Rhabdinopora* ex. gr. *flabelliformis*, found in an argillite interbed, 30 cm below the upper boundary of the Maardu Member. The total thickness of the Maardu Member is 1.5 m.

The Suurjõgi Member

Because of the stairlike roadcut, the upper part of the Kallavere Formation — the Suurjõgi Member is only partly exposed at Mäekalda. Therefore, apart from the description of this section, the Suurjõgi Member was sampled and studied in the Hundikuristik section 1 km northwards.

The lower boundary of the Suurjõgi Member is distinct: light grey fine-grained horizontally-bedded sandstones of the Maardu Member are covered by brownish-grey cross-bedded fine- to medium-grained sandstones, containing rounded brachiopod debris in remarkable concentrations. The cross-bedding is expressed in the alternation of the layers with different debris content. In the lower part of the Suurjõgi Member, about 1 cm thick sharply angular pieces of kerogenous argillite occur. They are most typical of the Hundikuristik and, to a lesser extent, in the Mäekalda section. In both sections, the uppermost, 4—10 cm thick layer is cemented with pyrite, forming the so-called pyrite layer. The thickness of the Suurjõgi Member, both in the Hundikuristik and Mäekalda sections, is 0.90 m.

The upper boundary is distinct: the sandstones of the Suurjõgi Member are covered by the dark-brown kerogenous argillites («Dictyonema shales») of the Türisalu Formation.

The textural (Table 1) and mineral features (Table 2) of the rocks have been studied throughout the whole terrigenous part of the section, except the interlayers of kerogenous argillites.

The both boundary units (the Ülgase and Kallavere Formations) are similar: (1) in high mineralogical maturity expressed by prevalence of quartz in the group of light minerals as well as by zircon—tourmaline—rutile association in the group of nonopaque allothigenous heavy minerals; (2) in features of the authigenic mineralization from which especially typical are secondary overgrowths and phosphatic pellicles on some detrital minerals, despite that they differ by intensity in the vertical range. Thus secondary overgrowths on detrital feldspar grains are more common in the deposits of the Kallavere Formation, especially in the rocks of the Suurjõgi Member, whereas the Ülgase ones have less than 5 per cent of grains with limped overgrowths. Phosphatic pellicles on detrital minerals (commonly on quartz, zircon, ilmenite and rutile) are more typical of the deposits of the Kallavere Formation yielding always more than 10 per cent of this kind of grains.

In addition, all the lithostratigraphical units have some special characteristics in the texture and in the group of nonopaque allothigenous heavy minerals;

Table 2

Mineral composition of the boundary beds in the coarse silt fraction (0.1—0.05 mm), %

Minerals or their groups	Mäekalda-86																			
	Samples																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
The content of light minerals (sp. gr. <2.89)																				
Quartz	58.5	94.0	89.4	97.7	91.7	98,7	94.3	97.3	97.0	97.3	96,7	93.0	89.6	94.0	97.3	96.7	96.7	95.7	86.1	88,3
Feldspars	38.4	4.0	8.3	0.7	8.3	1.3	5.7	2.7	3.0	2.7	2.0	5.3	7.1	4.9	2.7	3.3	3.3	4.3	13.3	11.7
Micas	1.5	0.7	2.3	1.3	—	—	—	—	—	—	—	1.0	1.8	0.9	—	—	—	—	0.6	—
Authigenous	1.6	1.3	—	0.3	—	—	—	—	—	—	1.3	0.7	1.5	0.2	—	—	—	—	—	—
The content of the main groups in heavy fraction (sp. gr. >2.89)																				
Ilmenite	11.7	6.9	28.7	4.7	9.4	2.4	8.2	19.2	15.2	17.2	19.2	23.3	10.4	20.7	41.7	36.1	36.4	36.0	8.4	1.0
Leucoxene	25.9	22.7	25.0	12.6	9.8	4.5	9.9	9.1	14.3	11.9	8.3	27.3	9.5	7.9	6.1	14.0	5.9	1.2	1.0	0.4
Non-opaque allothigenous	14.5	39.1	17.4	10.9	17.9	5.9	12.2	43.2	19.8	43.2	54.5	45.0	26.9	48.4	38.3	33.7	45.3	58.8	6.6	1.6
Micas	5.2	0,5	—	1,1	—	—	0.5	0.5	0.4	—	0.8	1,1	0.2	2.2	2.3	—	—	—	—	—
Authigenous	42.7	30.8	18.9	70.7	63.2	87.2	69.2	28.0	50.3	27.7	17.2	3.3	53.0	20.8	11.6	16.2	12.4	4.0	84.0	97.0
The content of non-opaque allothigenous heavy minerals in group																				
Zircon	25.1	47.4	15.5	23.6	21.9	12.7	14.7	44.5	42.6	55.4	69.0	46.1	59.5	78.4	69.3	63.4	70.8	80.5	68.2	52.9
Tourmaline	58.3	44.1	67.0	46.2	51.1	57.3	55.4	11.7	29.6	19.7	8.3	38.6	23.4	17.4	9.9	16.4	8.8	3.4	7.0	11.8
Titano-minerals (rutile, titanite etc.)	15.6	5.2	16.5	29.2	25.3	28.2	29.9	40.9	25.9	24.0	18.6	9.3	12.6	0.8	16.8	15.9	10.8	9.6	21.6	29.4
Garnet	0.6	0.9	1.0	0.9	1.2	0.9	—	1.6	—	0.9	3.1	4.2	4.5	2.9	1.0	2.2	9.2	6.5	1.6	—
Apatite	—	—	—	—	—	0.9	—	—	0.9	—	—	—	—	—	1,5	—	—	—	—	—
Disthen	—	—	—	—	—	—	—	—	0.9	—	0.3	—	—	—	—	0.5	—	—	—	—
Unstable (pyroxene, amphibole, epidote)	0.4	2.4	—	0.1	0.5	—	—	1.3	0.1	—	0.7	1.8	—	0.5	1.5	1.6	0.4	—	0.8	5.9
The content of authigenous heavy minerals in group																				
Anatase	34.7	43.7	65.1	1.0	4.1	1.3	11.4	3.7	5.7	12.0	1.1	20.9	3.1	6.6	—	1.1	9.1	—	—	—
Pyrite	54.7	52.9	31.2	93.9	94.9	96.9	86.1	76.8	82.2	78.6	84.0	71.9	77.3	60.8	—	60.3	12.1	—	28.2	—
Iron oxide and hydroxide	7.1	0,5	—	3.6	0.1	0.7	1.4	12.5	0.2	—	2.1	3.4	12.6	13.5	80.3	1.1	27.3	16.0	71.8	18.3
Glauconite	2.9	2.9	3.7	—	—	—	—	0.1	—	—	—	0.3	—	1.1	0.1	—	—	—	—	3.6
Carbonates	0.6	—	—	—	0.9	0.7	0.4	2.5	3.6	—	8.5	1.2	5.2	0.8	—	21.6	—	—	—	78.1
Phosphates («collophane»)	—	—	—	1,5	—	0.4	0.7	4.4	8.3	9.4	4.3	2.3	1.8	17.2	19.6	15.9	51.5	84.0	—	—

(1) the Ülgase and Maardu rocks are moderately sorted whereas the Suurjõgi ones are well sorted;

(2) the allothigenous grains of the Ülgase silt- and sandstones are subrounded and rounded as the grains of the Kallavere Formation are well-rounded and (seldom) rounded;

(3) in the triplet zircon—tourmaline—rutile of the Kallavere Formation the former prevail always whereas in the rocks of the Ülgase Formation tourmaline has prevalence, particularly in its lower part (up to sample 8).

Thus, the lithostratigraphical units (the Ülgase Formation, the Maardu and Suurjõgi Members) can be recognized on the basis of the textural and mineral characteristics of their rocks. Additionally, twofold subdivision on the ground of the mineralogical composition of the Ülgase Formation is turned to be more important, than it has been known previously (Менс, 1984).

Acritarchs. From the ten samples studied on acritarchs (Fig. 1), the lower three taken from the Tiskre Formation are barren. The samples from the Ülgase and Kallavere Formations contained quite well-preserved acritarchs in different quantities. By taxonomic composition two acritarch assemblages can be distinguished, one representing the Ülgase Formation, and the other — the lowermost Maardu Member.

The acritarch assemblage of the Ülgase Formation is rich both in the number of specimens and species diversity; the highest number of species was observed in samples A-0493 and A-0495. This assemblage contains mostly new species of the genera *Timofeevia*, *Stelliferidium*, *Cymatiogalea*, *Impluviculus*, *Leiofusa*, *Cristallinium*, *Vulcanisphaera* and *Veryhachium*. The formerly described forms *Stelliferidium cortinulum* (Deunff), Deunff Gorka et Raischer, ? S. *glabva* Martin, *Vulcanisphaera turbata* Martin, *Leiofusa stoumonensis* Vang., *Cristallinium cambriense* (Slavikova) Vang., *C. randomense* Martin and *Veryhachium dumontii* Vang. have been reported on Upper Cambrian sections in some places (Martin, Dean, 1981; Vanguestaine, 1973). The acritarch assemblage of the Ülgase Formation of the Mäekalda section is similar to the assemblages observed in the Ülgase, Turjekelder and Suhkrumägi sections and can be correlated to the *Olenus* Zone (Волкова, 1982; Волкова, Менс, 1988).

The acritarch assemblage of the lowermost part of the Maardu Member differs from that of the Ülgase Member in an abrupt disappearance of most species of the genera *Timofeevia*, *Cristallinium*, *Vulcanisphaera*, *Leiofusa*, *Veryhachium* and *Impluviculus*, and the appearance of diacrodiids, among which *Acanthodiacrodium angustum* (Downie) Combaz, *A. comptulum* Rasul and *Dasydiachrodium ornatum* Combaz are known only from the Tremadocian rocks (Martin, 1982; Rasul, 1979; Волкова, Менс, 1988). Among the transient genera, mostly new species appear: *S.* aff. *fimbria*, *C. cuvillieri* (Deunff) Deunff and *C. cristata* (Downie).

Conodonts were studied from twenty one samples through the section of the Ülgase and Kallavere Formations (Fig. 1). Conodonts are extremely rare in the Ülgase Formation except sample 6 containing *Phakelodus tenuis*, and sample 10 with two specimens of *?Proconodontus*. Samples 13—20 from the sandstones of the Kallavere Formation contained numerous conodonts, prevailingly species of the genus *Cordylodus* (Fig. 2).

Samples 13 and 14 from the base of the Maardu Member contained few poorly preserved specimens of *Cordylodus proavus*, represented mostly by alpha morph and also by specimens with the typical outline and a high basal cavity, but having secondary tips (Viira et al., 1987).

In sample 15, and upwards, the genus *Cordylodus* is represented by an increasing number of specimens, and by higher variability and diversity of species. By the shape of basal cavity two types of *Cordylodus* rounded

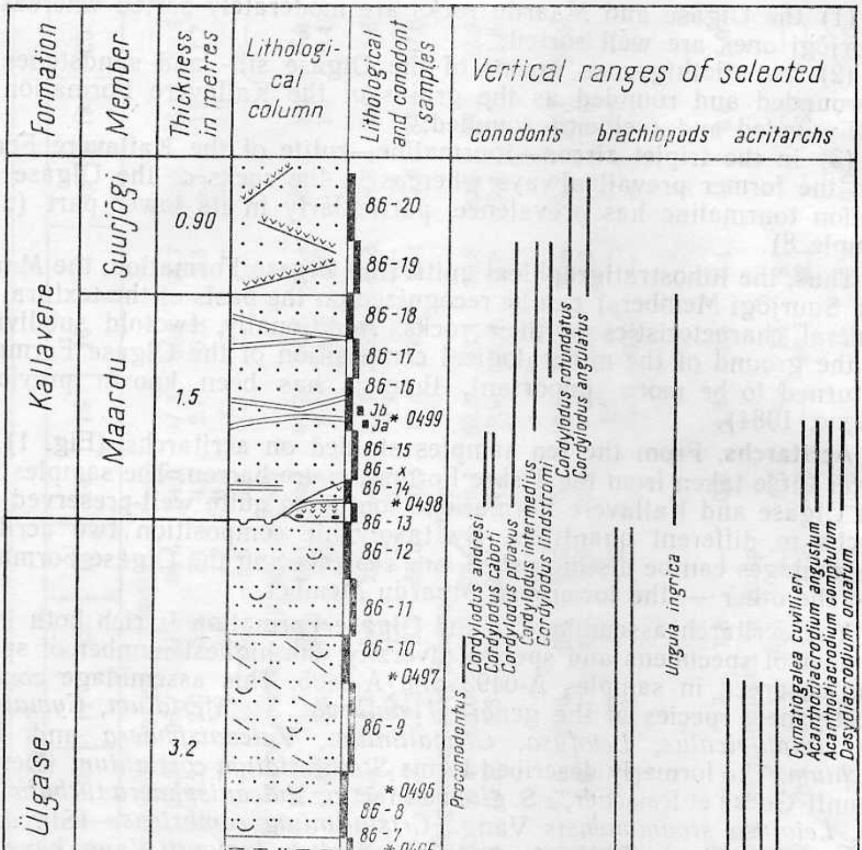
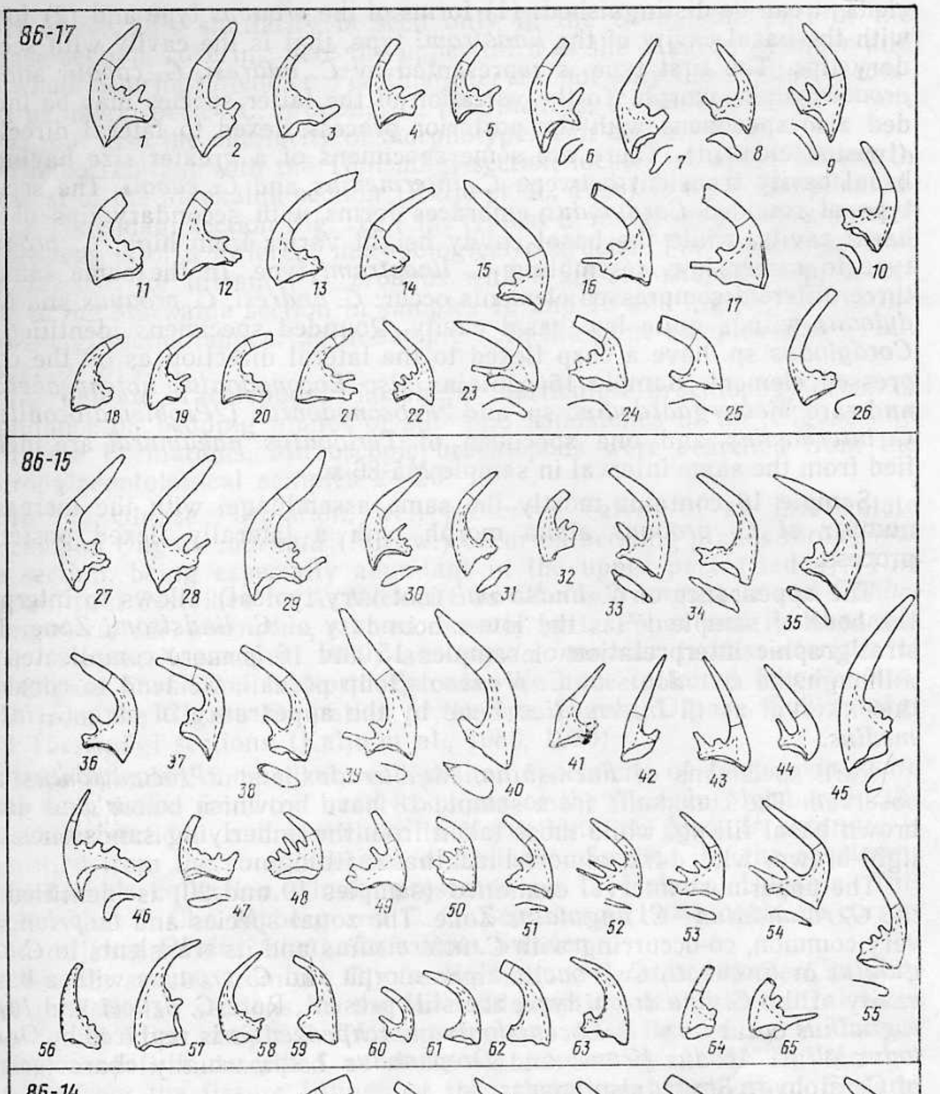


Fig. 1. A. The Mäekalda section of the Cambrian-Ordovician boundary beds. In the graph of samples the asterisk indicates the location of acritarch samples. B. Location of stratigraphic sections discussed in the text: T — Tõnismägi, M — Mäekalda, H — Hundikuristik, S — Suhkrumägi. Legend: *1* — sandstone, *2* — siltstone, *3* — argillaceous rock, *4* — kerogenous argillite («Dictyonema shale»), *5* — phosphatic pebbles, *6* — brachiopod coquina («Obolus conglomerate»), *7* — valves and detritus of inarticulate brachiopods, *8* — discontinuity surface, *9* — clint.

Fig. 2. Rounded specimens of *Cordylodus* from samples 86—14, 86—15 and 86—17 of Mäekalda section. ▶



1—10. *Cordylodus lindstromi* Druce et Jones, specimens Cn1230—Cn1239. 11—17, 26. *Cordylodus intermedius* Furnish, Cn1240—Cn1247. Some specimens with basal cavity transitional to *C. caboti* or *C. angulatus*. 18—22, 46—55, 75—78. *Cordylodus proavus* Müller alpha morph, Cn1248—Cn1267. 23—25. *Cordylodus* aff. *drucei* Miller, Cn1268—Cn1270. 27—40, 66—74. *Cordylodus proavus* Müller with basal cavity of *lindstromi*-type, Cn1271—Cn1293. 41—44. *Cordylodus* sp., Cn1294—Cn1297. 45, 79. *Cordylodus intermedius* Furnish with basal cavity of *caboti*-type, Cn1298, Cn1299. 56—59. *Cordylodus andresi* Viira et Sergeyeva, Cn1300—Cn1303. 60—63. *Cordylodus primitivus* Bagnoli, Barnes et Stevens, Cn1304—Cn1307. 64, 65. *Cordylodus caboti* Bagnoli, Barnes et Stevens, Cn1308, Cn1309.

element can be distinguished: (1) forms of the *proavus* type and (2) forms with the basal cavity of the *lindstromi* type, that is the cavity with secondary tips. The first type is represented by *C. andresi*, *C. caboti*, and *C. proavus* alpha morph. To the variation of the latter species may be included also specimens with the posterior process flexed to lateral direction (twisted element). There are some specimens of a greater size having a basal cavity transient between *C. intermedius* and *C. caboti*. The second type of rounded *Cordylodus* embraces forms with secondary tips of the basal cavity, while the basal cavity height varies from high, *C. proavus* type to rather low, resembling *C. lindstromi* type. In the same sample, three different compressed elements occur: *C. andresi*, *C. proavus* and *Cordylodus* with a quite low basal cavity. Rounded specimens identified as *Cordylodus* sp. have a cusp flexed to the lateral direction as on the compressed element. Sample 15 contains also *Eoconodontus notchpeakensis*, and rare *Westergaardodina* sp. and *?Proconodontus* (*?Problematoconites*). *C. intermedius* and one specimen of *Teridontus nakamurai* are identified from the same interval in sample Mä-86-x.

Sample 16 contains mostly the same assemblage, with the increased number of *C. proavus* alpha morph with a laterally flexed posterior process.

The appearance of *C. lindstromi* (not very typical) allows to interpret the base of sample 17 as the lower boundary of *C. lindstromi* Zone. The stratigraphic interpretation of samples 15 and 16 is more complicated — although the conodonts of *C. proavus* group prevail, we tend to consider this interval as *C. intermedius* Zone by the appearance of rare *C. intermedius*.

Rare specimens of *Furnishina*, *Muellerodus* and *?Proconodontus* are observed. The conodonts from sample 18 have brownish colour and dark-brown basal filling, while those taken from the underlying sandstones are light-brown, with dark, almost black basal filling.

The uppermost interval examined (samples 19 and 20) is identified as the *C. rotundatus—C. angulatus* Zone. The zonal species and *C. prion* are very common, co-occurring with *C. intermedius* and its transients to *C. angulatus* or *C. caboti*. *C. proavus* alpha morph and *C. proavus* with a basal cavity of the *C. lindstromi* type, are still present. Rare *C. drucei* and *Iapetognathus* occur as well. *Eoconodontus notchpeakensis* is replaced by *Oneotodus altus*. *Acodus firmus* and *Drepanodus* ? sp., usually characteristic of Ceratopyge Stage, also appear.

The conodont sequence of Mäekalda is comparable to the sequence in Suhkrumägi, Ülgase and Tõnismägi sections, which are located not far from Mäekalda (Fig. 1B) and have been studied palaeontologically.

The Suhkrumägi section is located a bit more than 1 km north-east of Mäekalda (Kaljo et al., 1986). Here, the Maardu Member contains rare opaque conodonts of dark-brown colour. For this reason, by comparison of conodonts of these two sections, the shape of the basal cavity cannot be used as the main diagnostic feature of *Cordylodus* species. However, the conodont assemblage of the two samples from the basal part of the Maardu Member in the Suhkrumägi section can be correlated with the assemblage in samples 13—16 of the Mäekalda section. The occurrence of *Teridontus nakamurai* at this level in both sections is important. In other regions of the world, this species is rather common in the interval *C. proavus* Zone — Fauna F (Miller, 1980), but in the East Baltic *T. nakamurai* is known only from these two sections. The Suurjõgi Member is in both sections characterized by the conodonts of the *C. rotundatus—C. angulatus* Zone.

The conodont sequence in the Ülgase section, located at about 15 km east of Mäekalda, seems to be most similar to that of the Mäekalda section (Хейнсалу et al., 1987).

However, this similarity is seen only in the *Cordylodus*-part of the Ülgase section, covering here the upper third of the Maardu Member and the whole Suurjõgi Member. For this interval, not only the similar succession of index-species *C. proavus*, *C. intermedius*, *C. lindstromi*, *C. rotundatus*, but also the similarity of morphotypes can be observed.

The correlation with the Tõnismägi section located at about 1.5 km to the west of the Mäekalda section (Kaljo et al., 1988) is more complicated. In the Tõnismägi section Fig. 1B, T the typical *C. lindstromi* is missing and *C. proavus* is of a different morphological character. For the comparison we may use, for instance, *C. proavus* with a zig-zag-shaped cusp, occurring in the Mäekalda section in samples 15 and 16 and higher, and in the Tõnismägi section appearing in sample 7. In the same samples also *C.* aff. *drucei* is present.

Inarticulate brachiopods. Phosphatic inarticulate brachiopods occur in abundance on bedding planes of silt- and sandstones of the Ülgase and Kallavere Formations. Microscopic brachiopods were searched from the micropalaeontological samples 2—20.

In the Ülgase Formation, well preserved valves of an inarticulate brachiopod *Ungula inornata* (Mickw.) occur on bedding planes throughout the section, being especially abundant in the upper part (Bed 4). This species, first described by A. Mickwitz as *Obolus triangularis* and *Obolus triangularis* var. *inornatus*, revised recently by L. Popov and K. Khazanovitch (Попов, Хазанович, 1989) as *Ungula inornata*, is characteristic of the Ülgase Formation in North Estonia. We have collected *Ungula inornata* from the Ülgase Formation of the Iru, Jägala, Ülgase, Suhkrumägi and Tõnismägi sections (Kaljo et al., 1986, 1988).

Rare rounded, most likely redeposited specimens of *Ungula inornata* have been found from the basal coquinas of the Maardu Member, in the Mäekalda section, and elsewhere in North Estonia. Also, *U. inornata* is identified from the conglomerates of Dalarna, Sweden, by the specimens from Holm's collection, kindly presented by L. Holmer, Uppsala. This implies that J. Chr. Moberg and C. O. Segerberg (1906) could be correct in identifying *Obolus triangularis* from Sweden.

Another species from the Ülgase Formation, *Ceratreta tanneri*, is quite rare in Estonian sections. In the Mäekalda section, a single ventral valve was found from sample 6. This species was first figured by V. Tanner (1911) and first described as *Acrotreta tanneri* by A. A. Th. Metzger (1922) from the fissure fillings of the crystalline basement of Finland. A. Martinsson (1968) assigned this species to the genus *Ceratreta* Bell and suggested the Upper Cambrian age of the topotypic material (since then interpreted as Lower Cambrian). However, this time his conclusion was based on indirect observations and no direct evidence could be provided.

The recent examination of an unpublished German manuscript and the collections of A. Öpik (deposited in the Chair of Geology, Tartu State University) allowed to identify the specimens documented as *Acrotreta* (Öpik, 1929, S. 13), as *Ceratreta tanneri*. The manuscript and the collection labels indicate that the specimens recorded by A. Öpik originate from the temporary excavation near the Hundikuristik section, i. e. only 1 km north of the present Mäekalda roadcut, where the siltstones of the Ülgase Formation were exposed in 1930s.

L. Popov reports *Ceratreta tanneri* from the base of the Ladoga Formation in Syas River (Kaljo et al., 1986, Fig. 3) and from the Ülgase Formation of some sections in North Estonia (pers. comm.). During the WOGOGOB meeting in July 1988, L. Holmer (pers. comm.) provided interesting data about the Västanå section near Borensberg, Sweden, where *Ceratreta tanneri* is found in association with *Phakelodus tenuis*, *Wester-*

gaardodina, and other Upper Cambrian conodonts from the interval with Peltura *scarabeoides* (Bed 3 in Westergård, 1922, Fig. 17), while the overlying beds contain *Cordylodus proavus* and, upwards, *Rhabdinopora flabelliformis*. At the same time, sample 6 from Mäekalda, is referred to the *Olenus* Zone by acritarch correlation. Thus, by this quite incomplete evidence *Ceratreta tanneri* occurs in the Upper Cambrian, ranging from the *Olenus* to the *Peltura scarabeoides* Zone.

Rare specimens of *Oepikites* sp., found on bedding planes, were too poorly preserved for specific identifications. However, L. Popov (pers. comm.) has reported *Oepikites fragilis* from the Ülgase Formation of the Mäekalda section.

The pebbles at the base of the Ülgase Formation contain the fragments of an unidentifiable obolid species. Similar fragments have been recorded from the base of the Ülgase Formation of the Ülgase and Jägala sections. A single, almost complete brachial valve found in the Jägala section represents a new species, probably of the Middle Cambrian origin.

The basal coquina of the Maardu Member consists almost exclusively of the valves of *Ungula ingrica* (Eichwald). This species was first described by E. Eichwald (1829, S. 274) and later mixed up with *Obolus apollinis* (Eichw.) by A. Mickwitz (1896). The comprehensive explanation of this mix-up is given elsewhere (see Хейнсалу и др., 1987, 161—163).

It is noticeable that the coquina does not contain the valves of *Schmidtites celatus* (Vern.), usually present in «Obolus conglomerate». Such a monospecific accumulation of thick *Ungula* valves may indicate facial distribution of brachiopods and/or hydrodynamic conditions of the basin. In the upper part of the Maardu Member, the specimens of *Ungula ingrica* are sparsely distributed. L. Holmer (pers. comm.) has provided the latex casts of the brachiopods from 12 Swedish localities, identified as *Ungula ingrica*. In Sweden, *Ungula ingrica* occurs in the basal conglomerates of the lowermost Ordovician.

The sandstones of the Suurjõgi Member contain rounded brachiopod shell fragments and debris of phosphatic inarticulates, mostly unidentifiable in species level. The rock structure and the roundness of the brachiopod shell fragments indicate significant redeposition of the bioclastic material in hydrodynamically active environment. Therefore, some rare identifications of poorly preserved *Ungula ingrica* and *Schmidtites celatus* are of a low stratigraphic value.

Thus, the presence of disconformity within the studied boundary interval, makes the definition of the Cambrian-Ordovician boundary impossible. However, the Mäekalda section is an important sequence for the cooccurrence of acritarchs, conodonts and inarticulate brachiopods, adding valuable information to the correlation of terrigenous sections.

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KAMBRIUMI JA ORDOVIITSIUMI PIIRIKIHID MÄEKALDA LÄBILÕIKES (TALLINN)

Kiirtrammitee rajamisel tekkinud Mäekalda läbilõike alumises, terrigeenses osas paljanduvad liivakihid, aleuroliidid ja savid kuuluvad Tiskre, Ülgase ning Kallavere kihistusse. On esitatud nende settekehade mineraloogilise ja paleontoloogilise (akritarhide, konodontide, lukuta brahhiopoodide) uurimise tulemused.

Кайса МЕНС, Вийве ВИЙРА, И. ПААЛИТС, И. ПУУРА

КЕМБРИЙСКО-ОРДОВИКСКИЕ ПОГРАНИЧНЫЕ ОТЛОЖЕНИЯ РАЗРЕЗА МЯЭКАЛДА (ТАЛЛИНН)

Дана минералогическая и палеонтологическая (акритархи, конодонты, беззамковые брахиоподы) характеристика нижней — терригенной части разреза Мяэкалда, начиная с алевролитов тискреской свиты нижнего кембрия и завершая разнозернистыми песчаниками суурйыгиской пачки каллавереской свиты нижнего ордовика.

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A. RÕÕMUSOKS

ÜBER DIE DIVERGENZ DER *LEPTAENIDAE* (*BRACHIOPODA*) IN DER VIRU- UND HARJU-ZEIT IN BALTOSKANDIA

In den letzten Faunenlisten des estnischen Ordoviziums, die in unseren Arbeiten (Рыымусокс, 1963; 1970) abgedruckt sind, figurieren von den *Leptaenidae* nur drei Gattungen — *Leptaena* Dalman 1828, *Kiaeromena* Spjeldnaes 1957 und *Bekkeromena* Rõõmusoks 1963. Inzwischen haben wir festgestellt, daß in der Viru- und Harju-Serie Estlands eigentlich mehrere neue Gattungen vorkommen. Deshalb wollen wir annehmen, daß das paleobaltische Bassin die eine Urheimat der Leptaeniden sein könnte. Überhaupt aber spricht das für eine bedeutende Radiation oder Divergenz der Leptaeniden während der Viru-Zeit in der ganzen baltoskandischen Provinz. Eine andere Frage ist aber, welche Rolle hier die Immigrationen spielten. Die Vertreter dieser neuen Gattungen wurden früher nur zur Gattung *Leptaena* gezählt. Neben den wenigen schon bekannten Arten (s. Bekker, 1921; Öpik, 1930; Ораспыльд, 1956) gibt es in diesen Gattungen auch viele neue Arten, die alle in unserer bald erscheinenden Monographie näher beschrieben werden. Bemerkenswert ist noch, daß die wahre *Leptaena* in den estnischen ordovizischen Schichten eigentlich nicht vorkommt, da von der *Leptaena rugosa* Dalman, dem Generotyp, ausgehend (s. Spjeldnaes, 1957; Bergström, 1968) unsere *Leptaena*-artigen Formen in die neue Gattung *Similoleptaena* (s. unten) gehören. Für einen Vergleich mit den letzteren sind hier die Fotos von *L. rugosa* aus den Dalmanitina-Schichten Västergötlands beigefügt (Taf. IV, Fig. *1—3*). Entsprechende Exemplare hatte Prof. V. Jaanusson (Stockholm) dem Verfasser liebenswürdigerweise zugesandt.

TAFEL I

Fig. *1—6*. *Estonomena estonensis* (Bekker) aus der Kukruse-Stufe, Viivikonna-Formation, Kiviõli-Formationsglied. *1*, *2* — Ventralklappe (Br 1315), Küttejõu; × 1. *3* — ein Fragment der Ventralklappe (Br 1316), Küttejõu; × 3. *4* — Ventralklappe (Br 218; Öpik, 1930, Taf. XIII, Fig. 152), Käva; × 2. *5* — Area (Br 216; Öpik, 1930, Taf. XIII, Fig. 150), Kohtla; × 1. *6* — Brachialklappe (Br 219; Öpik, 1930, Taf. XIII, Fig. 153), Vanamõisa; × 2.

Fig. *7*. *Estonomena linda* sp. n. (Holotyp, Br 1317) aus der Uhaku-Stufe, Kõrgekallas-Formation, Tallinn, Lasnamägi; × 2.

Fig. *8*. *Astamena flexuosa* sp. n. (Abdruck, Br 1343) aus der Jõhvi-Stufe, Spitham; × 2,2.

TAFEL II

Fig. *1—3*. *Septomena juvenilis* (Öpik) aus der Kukruse-Stufe, Viivikonna-Formation. *1* — Ventralklappe (Holotyp, Br 207; Öpik, 1930, Taf. XI, Fig. 140), Käva. *2* — Brachialklappe (Br 1319), Küttejõu. *3* — Ventralklappe (Br 212; Öpik, 1930, Taf. XII, Fig. 145), Kohtla. Alle × 2.

Fig. *4*, *5*. *Septomena crypta* (Öpik) aus der Kukruse-Stufe, Viivikonna-Formation, Peetri-Formationsglied. *4* — Ventralklappe (Holotyp, Br 221; Öpik, 1930, Taf. XVI, Fig. 182), Adra; × 1,5. *5* — Brachialklappe (Br 1322), Humala; × 1,3.

Fig. *6—8*. *Astamena inaequalis* sp. n. *6* — Ventralklappe (Holotyp, Br 1346), Jõhvi-Stufe, Anija; × 2. *7*, *8* — Idavere-Stufe, Vasavere-Formation. *7* — Brachialklappe (Br 1344), Aluvere; × 3,6. *8* — Ventralklappe (Br 1345), Sõjamägi; × 2.

Fig. *9*. *Astamena flexuosa* sp. n. Ventralklappe (Holotyp, Br 1330), Jõhvi-Stufe, Oandu-Fluß, Aru; × 1.