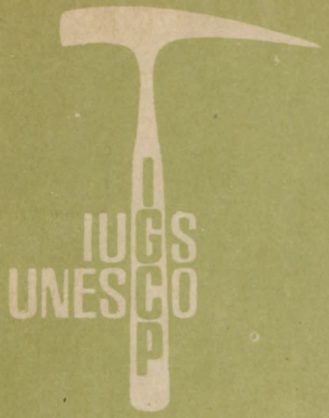

PROJECT
"ECOSTRATIGRAPHY"

ECOSTRATIGRAPHY OF THE EAST BALTIC SILURIAN

Anatol
Simmo
25. märts

Eesti
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Geoloogia Instituut
№ 3

PROJECT
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IUGS
UNESCO
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АКАДЕМИЯ НАУК ЭСТОНСКОЙ ССР
ИНСТИТУТ ГЕОЛОГИИ

ЭКОСТРАТИГРАФИЯ СИЛУРА ПРИБАЛТИКИ

ТАЛЛИН · ВАЛГУС · 1982

IUGS
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PROJECT
"ECOSTRATIGRAPHY"

ACADEMY OF SCIENCES OF THE ESTONIAN SSR
INSTITUTE OF GEOLOGY

ECOSTRATIGRAPHY OF THE EAST BALTIC SILURIAN

TALLINN · VALGUS · 1982

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PREFACE

The development of ecostratigraphy and its ever-growing popularity are characteristic of the stratigraphy of the past decade. We entirely accept B. Sokolov's standpoint who believes that the success of ecostratigraphy is due to "an effort of the present-day geologists and palaeontologists to understand the life in geological past not only as the history of a separate phylum or a set of "guide fossil associations", characteristic of different levels of stratigraphical scale, but as a system of mutual links between evolving communities and changing environmental conditions" (Соколов, 1980). System approach, search for general patterns governing both biotic and abiotic life elements and their application to biochron correlation at the ecosystem level seem to be the most characteristic features of ecostratigraphy. True enough, the content and methods of ecostratigraphy have been a subject of discussions. However, diversity of opinions is rather advantage than disadvantage of ecostratigraphy, since it is just the discussion that has often accompanied and stimulated the development of a branch of science.

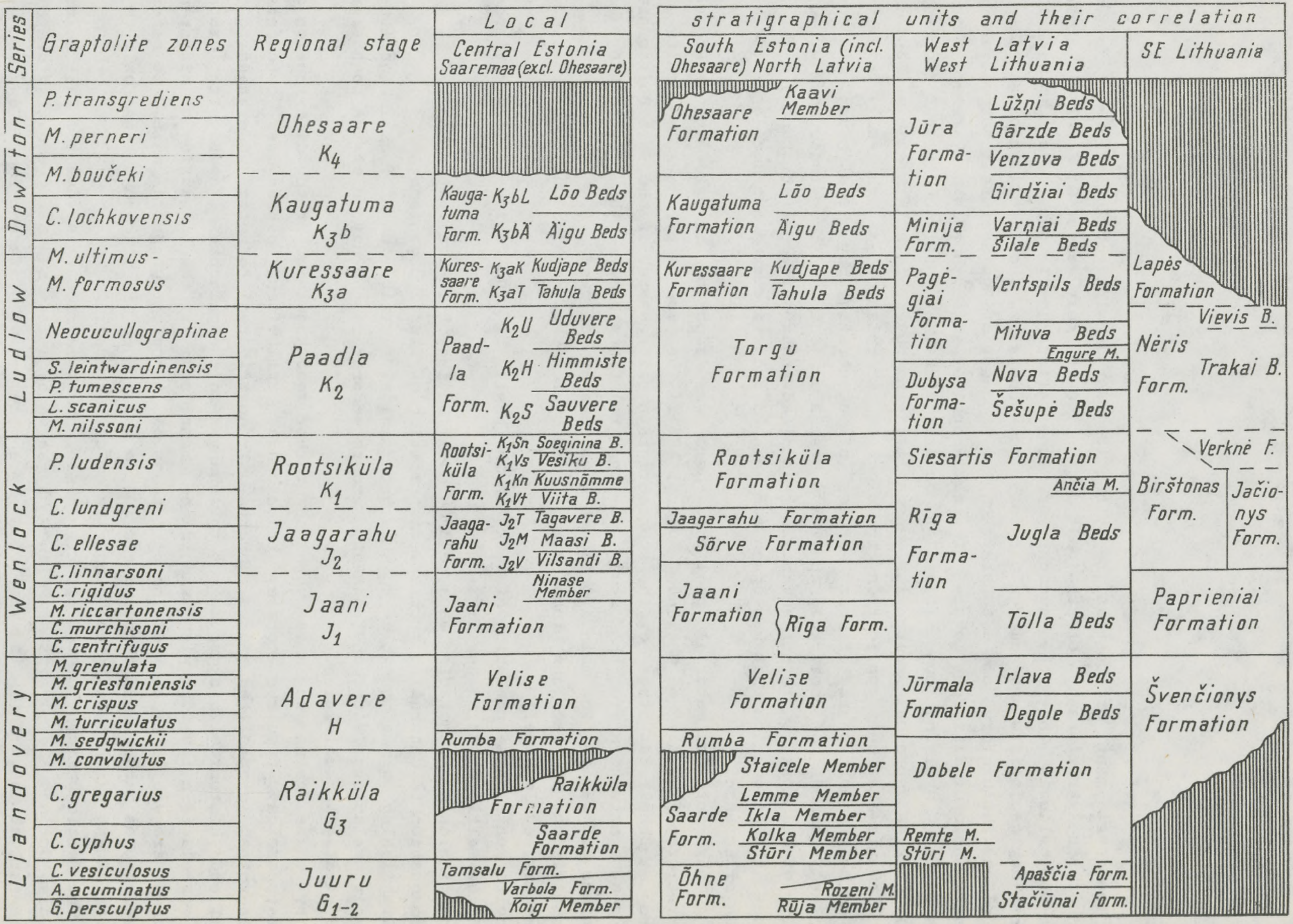
A part of the material published here was reported in brief at the Project Ecostratigraphy Meeting on Gotland, August, 1981. The papers present the results obtained at the first stage of the ecostratigraphical research in the East Baltic area giving much attention to the study of the relations between the distribution of organisms and facies. The main approaches used were as follows:

1) subdivision of sections into litho- and cyclostratigraphical units (formations, members, cyclothems);
2) environmental interpretation of rocks on the basis of the facies-sedimentary model of the Baltic Silurian Basin;
3) compilation of lithofacies maps to show distribution of facies in the basin;
4) biozonation to generalize vertical distribution of fossil organisms;
5) establishing of communities to show geographical distribution of fossil organisms, their relations with environment, and to understand the nature of the boundaries of stratigraphical units.

By these means we have obtained rather good knowledge of the distribution of stromatoporoids, tabulate corals, brachiopods, trilobites, ostracodes, conodonts, chitinozoans, graptolites and vertebrates. It contributes to better understanding of causal and historical background of the changes in the paleobasin. As to stratigraphical correlations the following should be mentioned: if the boundaries of different biozones are coinciding and also with those of lithostratigraphical units, it refers to the facies nature of such boundaries. As a rule, they are diachronous and only to a smaller extent synchronous (the boundaries of cyclothems).

The Baltic pericontinental Silurian basin which embraces besides the East Baltic area also Gotland and a part of Poland may serve as a test basin for ecostratigraphical investigations. This is justified by a wide set of different facies enabling to study deposits from primary dolomites of tidal flat up to mudstones and shales rich

The stratigraphical scheme of the East Baltic-Silurian



in organic matter of the central depression of the basin. The small number of longer hiatuses, rich and well preserved fauna, numerous outcrops and borings create favourable conditions for the elaboration of many problems of ecostratigraphy, especially correlation of the different facies. We think the latter is one of the main tasks of ecostratigraphy. It is also favoured by a long-term stratigraphical study of the area. The current stratigraphical scheme of the East Baltic Silurian is presented here in order to facilitate the orientation of a reader in the names of units, their hierarchy and correlation (Table). Its left side shows the relations between the basic stratigraphical units of the East Baltic Silurian Basin - regional stages - and Silurian standard units, whereas the right side presents the correlation of local stratigraphical units. A regional stage is treated as a chronostratigraphical unit more or less within the limits of which lithostratigraphical or local units, such as formations, members, beds are distinguished in different parts of the basin. In essence the given scheme repeats the unified stratigraphical scheme for the East Baltic (see Решения...., 1978), although the recent studies claim to the introduction of some corrections. Since, for the tasks of the present book the majority of these corrections is not of essential importance, we have introduced only one adjustment: Ventspils Beds (Ludlow) in the area of West-Latvia - West Lithuania are raised from the level of the Paadla Regional Stage to that of the Kuressaare Regional Stage. This correction is proved by a complex of palaeontological evidence obtained through the study of vertebrates, conodonts, chitinozoans and trilobites. In the area of carbonate (shelly) facies the correlation of many East Baltic regional stages with the graptolite standard of the British Isles is only approximate. For this reason the boundaries which are poorly motivated due to the lack of more precise data are given in a broken line. The reader will find in the left side of the scheme the indexes of all stratigraphical units (regional stages and their subdivisions) used in the present book. In the text they will not be dealt with any more. With respect to terminology we beg the reader to consider that frequently occurring term "regional stage" (in Estonian "lade", in Russian "горизонт") is shortened to "stage" for the sake of briefness.

And, at last, we hope that the scheme presented will contribute to correct spelling of names of stratigraphical units of the Silurian of Estonia, Latvia and Lithuania in languages which use the Latin alphabet.

We thank Helle Kukk, Dr. Elga Kurik and Anne Noor for translations and other linguistic help, Ludmilla Lippert and Mare Saare for drawings and different technical assistance.

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ECOSTRATIGRAPHY - SOME ASPECTS FROM EAST BALTIC PRACTICE

D. Kaljo

Up to now there is no unambiguous understanding of the content and essence of ecostratigraphy. The attempts (Hoffman, 1980; Красилов, 1977; Мейен, 1980, etc.) to elucidate its conceptual basis and limits have revealed only more distinctly the multifacetness of ecostratigraphy as "a broad movement among scientists" (Martinsson, 1978). Although the author is thinking that the theory of ecostratigraphy needs further development, and, in view of hitherto opinions the creation of a common theory is undoubtedly possible, he regards the existence of different approaches quite normal. The search for different possibilities is always welcome, especially in case of ecostratigraphy as a working direction which is still in the stage of its development.

Considering the present state of the theory of ecostratigraphy, a comprehensive analysis and generalization are necessary - it is favoured by the accumulation of rather solid material. We hope that the completion of the project "Ecostratigraphy" of the International Geological Correlation Programme which is soon to take place will stimulate our colleagues for the above studies. In the present paper we shall confine ourselves to the presentation of the content and aims of the studies carried out in the East Baltic, in the first place at the Institute of Geology of the Academy of Sciences of the Estonian SSR attempting to show the possibilities they offer as a direction of ecostratigraphy.

In our discussion we shall proceed from the opinion that ecostratigraphy is a part of stratigraphy, to be more exact - a part of biostratigraphy and it has its specific tasks. For that reason ecostratigraphy cannot be identified neither with biostratonomy nor with palaeoecology, although the distribution of fossils in rocks and ecology of fossil organisms serve as its main methods. Ecostratigraphy pursues stratigraphical not biological goals.

On the other hand, we do not think, as some authors do, that the main task of ecostratigraphy is to create a new stratigraphy with its own (special) method and terminology. For example, J. B. Waterhouse (1976) considered ecostratigraphy as the fourth independent category of stratigraphy between litho- and biostratigraphy. He defined it as a study of fossil ecosystems in a chronological and stratigraphical framework, and for that purpose introduced a set of special terminology and classification of units.

The above definition is quite acceptable, however, to our mind the existing stratigraphical codes and guides (e.g. Hedberg, 1976; Жамойда и др., 1977) which comprise different sets of stratons, accept (of course, depending on category to a certain extent) the facial (resp. ecological) principle of determining the boundaries of those units. Consequently, the main task is the improvement of the present stratigraphy by using of data on ecology of fossil organisms and analyses of palaeoecosystems but not its substitution with a new one. To our mind the key of progress in the stratigraphy hides itself in a complex and supple application of different methods (see also Геккер, 1980; another interpretation of ecostratigraphy is not so important in this case). Although ecology, the data about ecological control of the distribution of organisms were used in stratigraphy already long ago, it has been evidently insufficient.

As the main task in ecostratigraphy our working group at the Institute of Geology of the Academy of Sciences of the Estonian SSR regards the elaboration of the methods of so-called basin analyses, especially the correlation of formations of different facies origin (or the crossing of facies boundaries or tracing of synchronous levels) and the improvement of stratigraphical schemes (Кальо, 1979 a).

Our investigations are aimed at solving the following problems:

1. Elucidation of stratigraphical and areal distribution of communities in dependence of facial conditions; compilation of zonal stratigraphical schemes by single groups of organisms (graptolite, ostracode etc. zonations), their correlation.

2. Improvement of sedimentary-facies model and compilation of lithofacies maps (by time intervals or short events) reflecting facies structure and the evolution of the basin.

3. Analyses of palaeoecosystems of basin, their correlation and interpretation from stratigraphical and other points of view.

Our aim is to give an integral treatment of the basin - to describe the evolution of the fauna and environment and to show the result of it, i.e. to characterize the geological structure of the basin proceeding, first of all, from a stratigraphical framework.

Striving for the aim we do not confine ourselves to the application of ecological information only, but take advantage of all the other methods which enable to elucidate different parameters of life environment, to adjust the dating of geological events and reconstruct processes of geological history as stressed B. S. Sokolov in the programme of the Soviet National Working Group of the project "Ecostratigraphy" in 1975.

Speaking about basin analysis as one potential working direction we do not exclude other possible approaches, vice versa, we accept the development of several different methods (resp. approaches) which, this or that way use ecological information. We agree that from ecostratigraphical point of view extensive, purely descriptive taxonomical, lithological, etc. preliminary work is also of necessity. Nihilistic attitude towards the latter favours, by no means, good results. On the contrary, ecostratigraphy requires a real complexity.

On ecosystems in stratigraphy

A. Martinsson (1973) defined ecostratigraphy as a part of stratigraphy which deals with the correlation of fossil ecosystems and their arrangement in a geochronological framework, as well as with the elucidation of the levels of timeplanes through environmentally defined stratigraphical units.

In connection with the above statement there arise two questions: firstly, how to understand the term "fossil ecosystem", and secondly, how to correlate them, i.e. how to solve the most complicated stratigraphical problems with greatly differing facies.

In the following we shall confine ourselves to the first problem as the second one has been discussed elsewhere (Кальо, in press). Let us only note in connection with the latter that alongside other possibilities (e.g. several inorganic effects such as cyclicity, layers of volcanic ash, Krasilov's 1977 suggestion to use synchronous changes of cliseries) we have used the different amplitudes of the facies distribution of fossils based on different degree of ecological tolerance of organisms. It enables to cross facies boundaries correlating biozonations of the different groups.

The main idea of ecosystem was given by Evans (1956) when he wrote that Tansley proposed ecosystem as a name for the interacting system comprising living things together with their nonliving habitat.

Of course, such a simple definition cannot reflect the entire complexity of different ecosystems, but it is important that each ecosystem has its own specific nature unlike the others. If, in order to get a complete idea about an ecosystem, we must know very much (from a list of components up to metabolism and energy flow) then for bringing out its specific nature (sometimes even only preliminary one) we need considerably less.

To our mind just the last matter is of interest for ecostratigraphers who have no possibilities to reveal the majority, let alone all biotic and abiotic components and relations, occurring in ecosystems. Thus, speaking about the usage of ecosystems (or palaeoecosystems) in stratigraphy a detailed description of an ecosystem is of no need; it will be enough to know its main features enabling to reveal its nature, and to define it, i.e. to recognize it among the others.

Having set up the task of the study of a palaeoecosystem on the level of its characterization and definition we do not share the pessimism of some authors but are of opinion that palaeoecosystems may be sufficiently studied and used in Palaeozoic stratigraphy as well.

In proof of the above we should like to present some material on the East Baltic Silurian to show what the most important "living and nonliving" components of some palaeoecosystems look like and how they change in space and time. Firstly let me refer to a series of lithofacies maps of the East Baltic Silurian (Кальо, Юргенсон, 1977). These maps show that nonliving components of ecosystems - nowaday's rocks reflecting environmental conditions of sedimentation, form belts or areas of different composition. Their sequence reflects zonal change in essential characteristic features of the environment - depth, type of bottom, wave energy, chemical composition of water, etc. It is clearly seen from the maps that environmental parameters experience regular mutual changes, and the conditions of the same type localize in certain areas.

Let us reproduce here only one example (Fig. according to Кальо, Юргенсон, 1977, simplified) on the Jaagarahu Stage.

I. Shoal deposits: pure, often well-sorted grained limestones (sparites); organic buildups with stromatoporoids (*Vikingia tenue* Community) and some rugose corals (*Acervularia ananas*). Outside bioherms abundant tabulate (*Halysites junior* Community) and rugose corals (*Microplasma schmidti* and *Kodonophyllum truncatum* Community) and brachiopods (*Stegerhynchus* Community), etc. occur.

Some bioherms are rich in algae.

These rocks have formed in nearshore high energy sea where the water depth does not exceed 20 m (it was about 10 m, prevailingly), water was well lighted and rich in oxygen. The bottom was prevailingly hard, coarse-grained to shingle, mud occurred only in patches; its amount increases towards the open sea, and landwards in the shade of reefs.

II. Open-shelf deposits: prevailingly clayey nodular limestones, to a greater or smaller extent detritic (biomicrites), poorly sorted, in places marls with limestone intercalations. Fauna has a variegated group composition - first of all brachiopods (*Whitfieldella* Community) and ostracodes (*Leptobolbina quadricuspidata, Clavofabella juvenca,* etc.) occur, however, other groups (especially crinoids, corals, bryozoans, trilobites and molluscs) are also rather abundant and diverse.

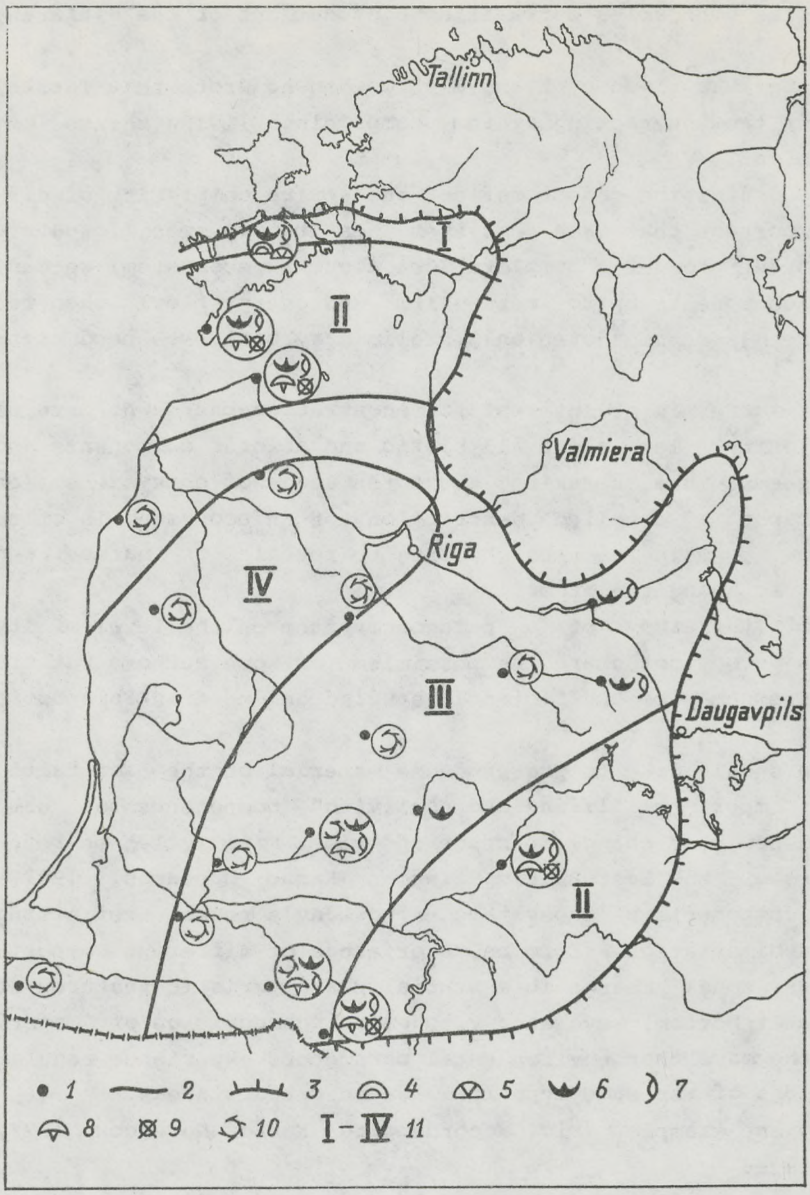

Fig.
Facies belts and distribution of dominant fossil groups of the Jaagarahu time (Wenlock East Baltic).
1-boreholes; 2-limit of facies belt; 3-limit of the present distribution of corresponding rocks; 4-stromatoporoids; 5-tabulate corals; 6-brachiopods; 7-ostracodes; 8-trilobites; 9-echinoderms; 10-graptolites; 11-facies belts described in text. Dominant groups are shown in circles.

These rocks were formed in the shelf sea, up to 180 m in depth (Kaljo, 1978), its water mass belongs to the euphotic zone, however, near the bottom (below wave base) the water activity was insignificant. Still, the content of oxygen was sufficient for abundant bottom fauna. The sea bottom was muddy with sand and rather abundant gravel grains.

III. and IV. Deposits of transitional (slope?) belt and deep basin. In the first one - mainly green marls with rare detritus, in places with limestone intercalations, in the second one - marls (prevailingly gray) and clays (argillites). In the slope belt dominated the association of brachiopods (*Dicoelosia - Skenidioides* Community), ostracodes (podocopids) and trilobites (*Calymene orthomarginata* Community) in places also crinoids and some other benthic groups, and rare graptolites occur.

The number of the latter grew with the depth, at the same time benthos showed decrease in abundance and diversity, and practically disappeared in deep water sediments. Occurred only graptolites with rare brachiopods (lingulids), hyolithids and some others.

These deposits were formed in the low energy deep water area of the basin which, according to oceanographical terminology should be referred to the gentle slope, where the water depth exceed 200 m (Нестор, Эйнасто, 1977; Kaljo, 1978). In the near-bottom layer the oxygen content was low (the content of organic carbon in grey marls is 7 %, in graptolitic argillites up to 18 %). It accounts for the disappearance of the benthos. The bottom was soft and muddy.

Summarizing the data on the second component of an ecosystem - "living things" of the palaeobasin described above, and the data published in a lot of papers, especially in two books - "Facies and fauna of the East Baltic Silurian" (Кальо, ред., 1977) and "Communities and biozones of the East Baltic Silurian" (Кальо, Клааманн, ред. 1982), we can see clearly, as it is already well-known from the world practice in the field of palaeofaunistics and palaeoecology, that the composition of fauna (group, species and trophic composition, distribution of communities) varies within the limits of a basin, it differs with facies belts in dependance of the changes in environmental conditions. In other words, every part (facies) of the basin is characterized by a specific association of organisms.

Generalizing the given data on the living and nonliving components of an ecosystem, we can see that certain parts of the basin are of specific character, which distinguishes them from one another. We think it is possible to treat them as palaeoecosystems.

Boundaries between palaeoecosystems may be transitional or distinct, depending on the rate of changes in the characteristic parametres, at the first place of the lithological composition. To a certain extent distinctness of the boundary depends also on the rank of an palaeoecosystem - usually smaller units (of lower rank) have more distinct boundaries.

In contrast to contemporary ecosystems, palaeoecosystems have also duration and, as we say in geology, lower and upper boundaries. As the boundaries of ecosystems are determined ecologically, then, as a rule, they are diachronous and only in certain cases synchronous, when the change of the environment has been due to a specific reason, e.g. rapid enough change of climate (Красилов, 1977).

It is easy to see that palaeoecosystems are rather similar in character to lithostratigraphical (according to Hedberg's, 1976, guide) or local stratigraphical subdivisions according to the stratigraphical code of the U.S.S.R. (Жамойда и др., 1977). According to the above examples, the ecosystem of shoal inshore belt corresponds to the Jaagarahu Formation, but the ecosystem of open shelf to the Sõrve Formation, the ecosystem of deep sea corresponds to the Riga Formation, etc. Here our viewpoint does not fully coincide with the opinion by V. A. Krasilov (Красилов, 1970) who considered chronostratigraphical, facial and regional stratigraphical units as palaeoecosystems. This conclusion acknowledges boundaries of all given units, among them those of chronostratigraphical ones, facial in essence, only this contradicts to the idea of chronostratigraphy itself.

Therefore I should formulate this in principle correct conclusion with the consideration of the character of boundaries. Palaeoecosystems have natural, more or less distinct, boundaries.

The same type of boundaries (facial) have also local stratons (according to the code of the U.S.S.R., Жамойда и др., 1977), but, not always chronostratigraphical ones (general and regional according to Жамойда и др., 1977). Quite often the boundaries of stages or regional stages do not coincide with those of formations (see Fig. 3 in Holland, 1978).

As already said, we see almost full coincidence of ecosystems with lithostratigraphical units, especially with formations according to Soviet code. The basic difference lies in the estimation of palaeontological and ecological information - as is known, the true lithostratigraphy neglects it, the Soviet code takes it into account but far insufficiently.

In our practice of East Baltic Silurian stratigraphy we consider that local stratigraphical subdivisions (especially formations and members) should have facially (resp. ecologically) defined boundaries. With this we take palaeoecosystems as a basis for those units. V. Krasilov regards the development of the biosphere as a continuous and discontinuous process, which is distributed into several stages. To these stages correspond (in an ideal case) chronostratigraphical units, which, in essence, serve as palaeobiospheres (Красилов, 1970). We entirely acknowledge this interpretation of a chronostratigraphical straton. From above follows that synchroneity not ecological (facial) basis are taken into consideration for the determination of the boundaries of such units. Indeed, here the regional stage which connects synchronous, but being of different facies origin, rocks serves as a good example (Жамойда и др., 1977; Кальо, 1979 б).

Thus, two different interpretations of a palaeoecosystem should be acknowledged - the first one which is based on the internal unity and mutual dependence of the development of environment and biota on the discrete units of these and makes a basis for local or lithostratigraphy, and the second one which takes advantage of the evolution of an ecosystem as a biosphere (sequence of palaeoecosystems) and serves as a basis for chronostratigraphy.

From the above follows that we do not need any special ecostratigraphical units and thus we do not think it necessary to classify ecostratigraphy as a special category of stratigraphy. Instead of it ecostratigraphy may play a very positive role as a method of correlation and basis of stratigraphical units.

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ЭКОСТРАТИГРАФИЯ - НЕКОТОРЫЕ АСПЕКТЫ ИЗ ПРИБАЛТИЙСКОЙ ПРАКТИКИ

Д. Кальо

Главная идея экостратиграфии заключается в усовершенствовании стратиграфии путем использования информации об экологии ископаемых организмов и анализа палеоэкосистем. Существуют разные понимания экостратиграфии; в Институте геологии АН ЭССР целью экостратиграфических исследований является целостное описание седиментационного бассейна, его фаций, геологического строения и эволюции биоты. Для этого изучаются: стратиграфическое и географическое распространение сообществ, их зависимость от фаций, биозонация; составляются литолого-фациальные карты, отражающие последовательное изменение среды; анализируются палеоэкосистемы бассейна, проводится их стратиграфическая интерпретация.

Приведен краткий анализ палеоэкосистем средневенлокского яагарахуского горизонта Прибалтики.

Исходя из разного характера границ местных /литостратиграфических/ и общих /хроностратиграфических/ стратонов, возможны два различных толкования палеоэкосистем. Первое - базирующее на внутреннем единстве и взаимосвязанном изменении среды и распространения биоты, служит основой местной стратиграфии /литостратиграфии/, второе - рассматривающее экосистему как биосферу, а ее развитие как последовательность палеоэкосистем /палеобиосфер/, составляет основу для хроностратиграфии.

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APPLICATION OF SHELF AND SLOPE CONCEPTS TO THE SILURIAN BALTIC BASIN

H. Nestor, R. Einasto

Shelf, slope and depression serve as the basic concepts in oceanography and marine geology. However, unambiguous application of these concepts to the basins of geological past is somewhat complicated. Firstly, it is due to the diversity of situations at recent continental margins. Secondly, it should be considered that present-day situations may prove unrepresentative for the geological past. Particularly great difficulties arise in connection with the application of actualistic concepts to such a distant past as Early Paleozoic. Last years disagreements have been arisen with regards to defining the shelf and slope in the Silurian Baltic Basin. This basin was situated at the western margin of the East European Craton and included North Poland, East Baltic, Gotland and the areas of the present Baltic Sea. The basin was directly connected with the Central-European Hercynian Geosynclinal Basin, the origin of which is still disputable. Some investigators (Berry and Boucot, 1967; Krebs and Wachendorf, 1973; Matthews, Chauvel, Robardet, 1980 and others) supposed that the Mid-European Paleozoic marine basin developed wholly on the continental crust due to intraplate tectonics and the existence of a real ocean in this area, at least during the Early Paleozoic, is fairly problematic. Others (Burrett, 1972; McKerrow, Ziegler, 1972; Johnson, 1973; Ziegler et al., 1977; Tomczyk and Tomczykowa, 1979; Cogne and Wright, 1980; Bard, Burg, Matte, Ribeiro, 1980) assume the presence of a Paleozoic ocean (Rheic, proto-Tethys or paleo-Tethys) in Middle Europe that closed during the Hercynian Orogeny. The last point of view seems quite acceptable for us and we consider the Baltic Basin in Silurian as a marginal sea of this ocean with clearly distinguished shelf, slope and depression environments.

In 1977 the authors of the present paper published a facies-sedimentary model of the Silurian Baltic Basin (Нестор, Эйнасто, 1977).

According to the model, the Baltic Basin was characterized by the lateral succession of 5 macrofacies belts which we have interpreted as follows: 1) littoral-lagoonal belt with argillaceous dolomitic sediments; 2) inshore shoal belt with various sparitic calcarenites, sometimes including reefs; 3) open shelf with nodular micritic calcarenites and thin argillaceous intercalations; 4) basin slope with calcareous mudstones, argillaceous calcilutites or clays; 5) central depression of the basin with graptolitic mudstones. At that predominantly carbonate sediments of the first three facies belts were regarded as shelf deposits, whereas fine-clastic deposits of the fourth and fifth belts distributed mainly within the boundaries of the Baltic Syneclise were already taken for bathyal deposits. More common is the opinion that the shelf included the whole cratonic Baltic Basin up to the Törnquist Line, and the continental slope, if it existed, started from the Törnquist Line. This approach is based on the argument that the phenomena characteristic of the continental slope (gravity slides, slumps, breccias and turbidites) are not established within the boundaries of the Baltic Basin.

However, it seems to us that this approach makes the shelf too wide and it does not coincide with the actualistic shelf conception. According to the fundamental handbook of marine geology by F. P. Shepard (Шепард, 1976) the shelf stretches up to the first clear break in the gradient of the sea bottom profile. The average width of present day shelves is about 75 km, the average depth of their flat part about 60 m, the depth of the shelf edge ranges from 20 to 600 m, being 130 m on an average. Continental slope may be rather wide and within it several terraces may occur. In this case only the uppermost break in the bottom gradient serves as the boundary between the shelf and slope, whereas the other terraces are included to the continental slope. At places the continents may be edged by deeply subsided blocks of continental crust, e.g. Blake Plateau at the eastern coast of Florida, its width is up to 300 km, depth 750-1,000 m. In a wider sense these plateaus are considered as a part of the continental slope, not of the shelf. As a rule, slopes are covered by finer-grain deposits than shelves. Sands are typical of the present-day shelves, muds prevail on slopes. The accumulation of deposits is highly dependent upon the gradient of the slope (Stanley and Unrug, 1972). On a steep slope deposits may be entirely lacking, the thickest deposits are concentrated on the continental rise. Gravity slides, slumps and turbidites are characteristic namely of such slopes. If the bottom is gently sloping the deposits may accumulate in great thickness already on the slope itself as a result of which the slope progrades offshore direction. Deposits are often lacking at shelf edges and on the upper slope.

Let us try to estimate the position of shelf and slope in the Silurian Baltic Basin in the light of these data, starting with the most offshore member of the facies succession, the graptolitic mudstones of the fifth facies belt. Silurian graptolitic shales and mudstones are prevailingly geosynclinal deposits which reach only as tongues to the craton margins. It is reasonable to suppose that typical graptolitic shales represent the main Silurian oceanic deposits. It could be well seen from the schematic geological section compiled by H. Jaeger (1976, Fig. 6) from Sweden through Paleotethys to the Sahara. It shows that at the time when more than 1,000 m of carbonate and clastic sediments accumulated at the margins of Fenno-Sarmatia and Gondwana cratons, the thickness of the complete Silurian sequence was only 50-70 m of monotonous graptolitic shales and "ockerkalk" within Paleotethys from Thyringia to Sardinia (see also Fig. 1B in the present work). It permits to make a conclusion that these were obviously deposits of abyssal plain. On continental margins within the boundaries of continental rise and bathyal the thickness of graptolitic sediments considerably increases in connection with the growing intensity of the accumulation of fine-clastic material towards the source area, however, the basic type of the sediment remains the same. Since graptolitic mudstones accumulated within the boundaries of the Baltic Syneclise on a wide area and during most of Silurian (about 30 million years) we obviously have not to deal with a closed shelf depression, but most likely it was a deep-water continental margin plateau immediately connected with the Gentral European oceanic basin.

Evidently the Paleo-Baltic Basin formed in Early Paleozoic as a result of an incomplete development of rifting in the course of the opening of the Paleotethys (Rheic) Ocean. In this respect the schemes by E. and H. Tomczyk (1979, Figs 2, 3, 4) on the development of the Prototethys Ocean are of interest. According to the first scheme corresponding to the Caradocian the Baltic Basin laid on the extension of the opening Prototethys Ocean and was probably originated by prerift downwarping. Its development probably stopped while a side rift was formed later in the Silurian (see also Fig. 1A in the present work).

The bathyal origin of the axial part of the Baltic Basin is also proved by the history of its development. From North Poland to West Latvia the thickness of the Lower and Middle Llandovery dark graptolitic shales is only 5-15 m while in Central and South Estonia the marginal area of the basin, the thickness of contemporaneous carbonate sediments is up to 10 times greater (see Fig. 1B, 1C and 2). It shows that a depression where subsiding was not compensated with the sediment loading developed here at the initial stage of the Silurian transgression. In the Late Silurian in the course of fulfilling of the depression in North Poland deposited very thick (up to 1,500 m) flysh-

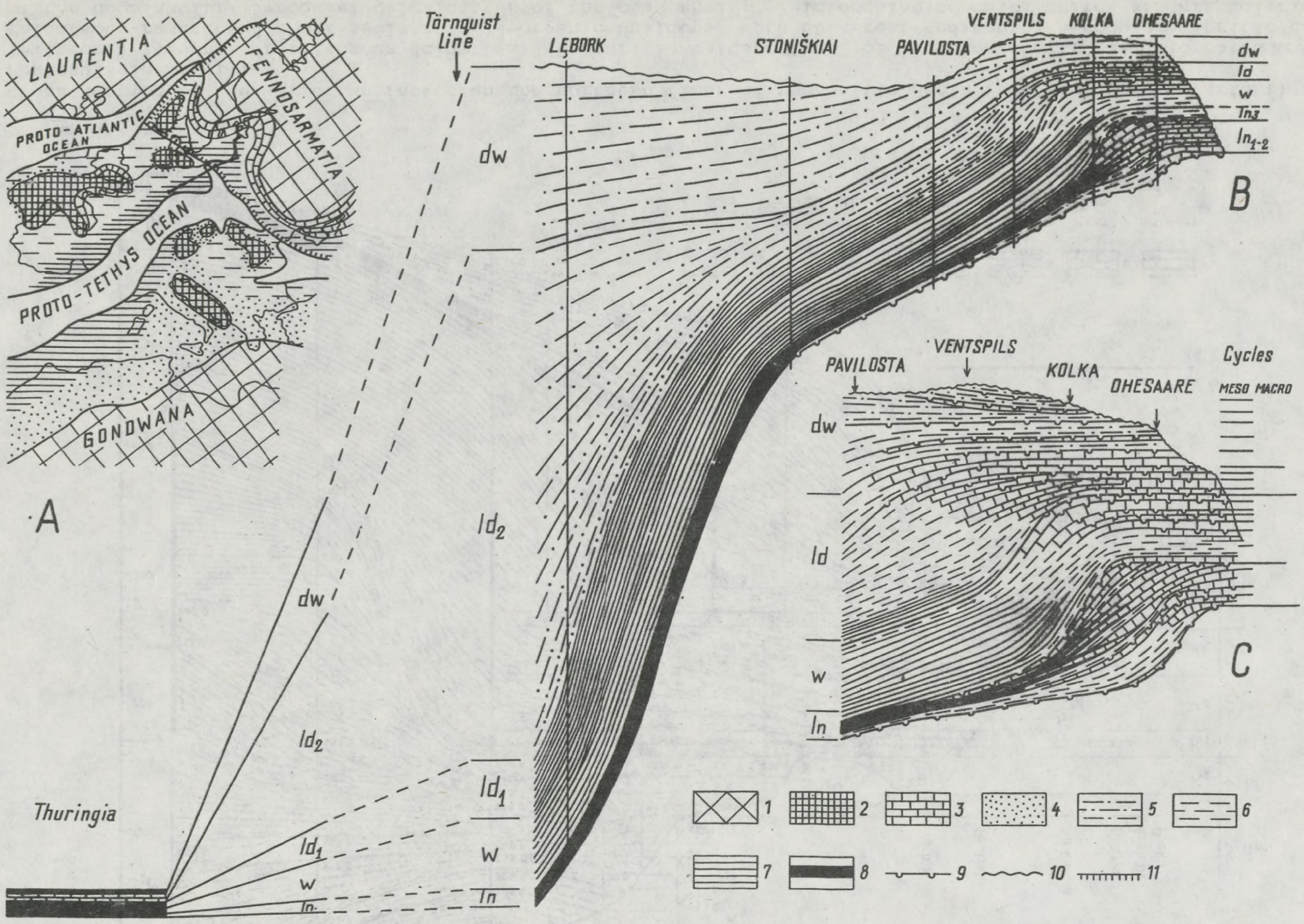

Fig. 1. Middle Silurian paleogeographical situation in Europe after Tomczyk and Tomczykowa (1979) (A) and generalized section across the pericontinental Baltic Basin into Central European Geosynclinal Basin (B, C). 1-cratonic lowland; 2-inter-geosynclinal massifs (microcontinents); 3-carbonate shelf deposits; 4-terrigenous shelf deposits; 5-silty muds of the basin filling phase; 6-pellitic deposits of the slope; 7-graptolitic muds of the depression; 8-shaly graptolitic deposits; 9-hardgrounds; 10-post-Silurian errosion surface; 11-Törnquist Line.

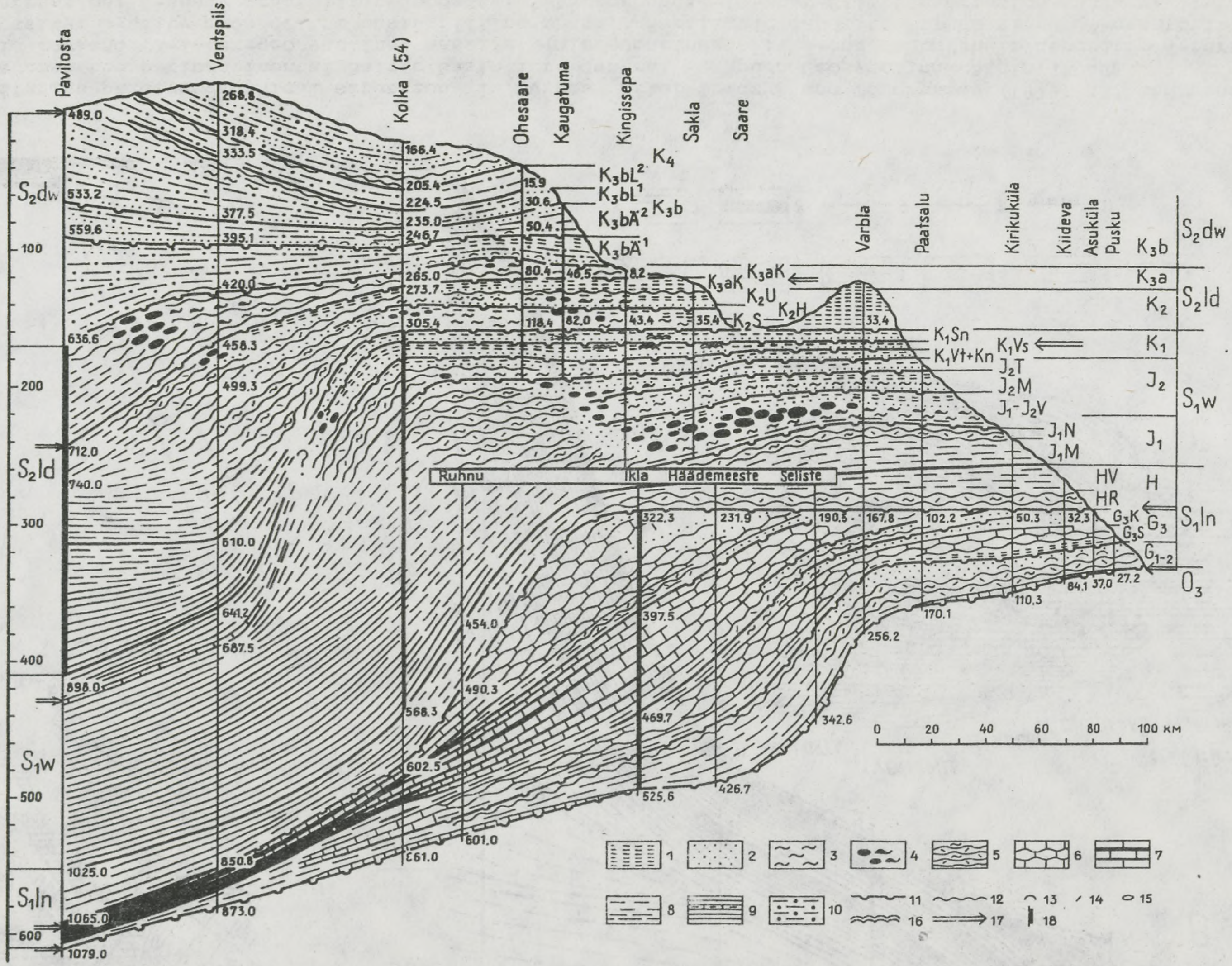

Fig. 2. Cross section of the Silurian facies on the northern flank of the Baltic Basin from West Estonia (right) to Kurzeme Peninsula in Latvia.

1-littoral-lagoonal argillaceous dolomites; 2-sparitic calcarenites of the shoal belt; 3-bioturbated argillaceous-calcareous restricted shelf sediments; 4-organic buildups with back-reef sediments; 5-nodular micritic calcarenites of the open shelf; 6-nodular calcilutites of the open shelf; 7-intercalating calcilutites and graptolitic mudstones of the slope; 8-calcareous mudstones of the slope; 9-graptolitic mudstones of the depression; 10-silty mudstones of the basin filling phase; 11-hardgrounds; 12-post-Silurian errosional surface; 13-brachiopod banks; 14-skeleton detritus; 15-conglomerate; 16-stromatolite layers; 17-boundaries of macrocycles; 18-sections with the maximum thickness of series.

like interlayering graptolitic mudstones and siltstones of Siedlce series that could be interpreted as marginal turbidites.

Thus, the development of the axial part of the Baltic Basin in the Silurian period includes the elements typical of the development of a depression and it can be considered as a tongue of the North European miogeosynclinal depression which extends far into the area of the East European Craton. Regarding this area of the basin as a part of the shelf would be evidently misleading.

On the other hand, the I-III facies belts (lagoons, shoals and open shelf) of our model, forming carbonate platform, could be beyond doubt referred to the shelf. In geological papers the distribution of the shelf is often restricted to the area of carbonate deposits rich in shelly fauna. Interesting parallels can be drawn between the distribution of sediments in the Silurian Baltic Basin and in the north-western part of the present Black Sea. The flat relief of the surrounding area and wide extension of the lagoonal coast, where muds are the prevailing deposits, prevents the transport of terrigenous material to the open shelf of north-western Black Sea. For these purposes the latter is mainly covered with carbonate deposits, 30-80 % of which form shells and their debris (Щербаков и др., 1978). The content of shells decreases abruptly on the continental slope that begins at the depth of 100 m on an average and is covered with argillaceouscoccolite muds. The distribution of skeletal material is more or less similar in the Silurian Baltic Basin, the first - lagoonal belt is relatively poor in it, in the second and third facies belts it plays an important role and in the fourth belt its amount decreases abruptly. F. Shepard (Шепард, 1976), J. Stanley, R. Unrug (1972) and others have also shown that the amount of coarse- and medium-grained material, among this skeltal sand, decreases abruptly with the transition from shelf to slope. The same phenomenon is typical of the eastern coast of the Caspian Sea (Алексина, 1962; Лебедев и др., 1973).

The results obtained through the analyses of the thicknesses of deposits lead to the same conclusion. In the Baltic Basin the thickness of the deposits of the three onshore facies belts grows rather evenly with the depth. A more abrupt increase of thickness takes place on the transition to carbonate-terrigenous muds of the fourth belt. We connect it with the change in the sea bottom gradient at the shelf edge. In favour of the above interpretation speaks the fact that in the onshore sections of the basin the rocks of the I-III facies belts are interbedding rather frequently, whereas the sections of its central part with deposits of the fourth and especially of the fifth facies belt are much more monotonous. This is well known from the section of Wenlock and Ludlow deposits at the northern margin of the Baltic Basin which shows a distinct cyclic change of carbonate facies in Estonian sections as far as Ohesaare boring (Fig. 2). At the same time relatively monotonous argillaceous deposits of the fifth and fourth facies belts accumulated in West Latvia. To our mind it enables to differentiate the northern part of the section as the shelf platform on which the comparatively minor changes in water level gave rise to an extensive facies oscillation that is not reflected in bathyal sections in the central part of the basin due to the relatively abrupt increase in depth.

In the same section, given more generalized in Fig. 1 of the present paper, it becomes evident that the belt of the greatest thicknesses which coincides with the distribution of marls and argillaceous calcilutites of the fourth facies belt migrates gradually towards the basin centre. Evidently it is a reflection of the lenticular deposition of hemipelagic sediments on the flat basin slope that results in the progradation of the slope and migration of the shelf edge towards the central part of the basin.

In favour of the location of the shelf edge between the third and fourth facies belts also speak the evidences obtained through the analyses of the distribution of benthic organisms. If the second and third facies belts are inhabited by a diverse bottom fauna and benthic algae, then in the fourth belt colonial corals, stromatoporoids, algae, bryozoans - all potential reef-building organisms are practically lacking. The disappearance of benthic algae shows that the boundary between the third and fourth facies belts is close to that of the photic zone and thus its absolute depth approaches to the average values of the outer edge of the recent shelves.

These were the most essential considerations that made us restrict the shelf in the Silurian Baltic Basin to the I-III facies belts where the carbonate sedimentation was prevailing.

The concept of the continental slope is not as clear as that of shelf. From the tectonical point of view the continental slope includes the whole subsided part of the continental crust that remains beyond the shelf edge. In these cases when the deep-subsided plateau is situated at the continental margin, continental slope as a purely geomorphological element is actually divided into two independent parts, one of which remains between the shelf and marginal plateau or represents the inner slope of the continental margin sea, while the other lies between the marginal plateau and ocean floor and forms the outer slope of the marginal sea.

It is quite possible that such a complicated situation with two-stage slope was also characteristic of the Silurian Baltic Basin where the first stage roughly coincides with the boundary of the Baltic Syneclise, the other with the Törnquist Line. Speaking of the slope of the Baltic Basin in a narrow sense, we keep in view the first one coinciding with our fourth facies belt. The existence of the second slope behind the Törnquist Line is yet to be proved as there are cases (e.g. the present-day Zambesi-Mosambique Channel Basin - Scrutton, Dingle, 1976) when the marginal block of the continent has subsided to the level of the ocean bottom and the topographical slope is practically lacking between the marginal plateau and ocean floor.

Summarizing the analysis above one may conclude that according to the strict shelf definition of the recent oceanography, that fits the shelf edge with the first clear break in the gradient of the sea bottom profile, it is reasonable to restrict the shelf in the Silurian Baltic Basin with the belt of shelly carbonate sediments in the marginal part of the basin. The central part of the basin within the Baltic Syneclise, where graptolitic mudstones accumulated, has been treated here as a tongue of the North European miogeosynclinal depression. Probably the slope between the shelf and depression had a very low gradient and it was hardly comparable to the continental slopes of the recent oceans. The reason could be the extremely low relief of the Silurian continents and much less depth of the oceans comparing with nowadays.

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ПРИМЕНЕНИЕ КОНЦЕПЦИИ ШЕЛЬФА И СКЛОНА К СИЛУРИЙСКОМУ БАЛТИЙСКОМУ БАССЕЙНУ

Х. Нестор, Р. Эйнасто

. Силурийский Балтийский бассейн располагался на пассивной окрайне континента и открывался непосредственно в Центрально-Европейский геосинклинальный бассейн океанической природы. Такая позиция позволяет интерпретировать Балтийский бассейн в силуре как периконтинентальное море с обособленным шельфом и материковым склоном. Мы считаем, что шельф мог скорее всего совпадать с поясом в основном карбонатной седиментации, который прилегал к пенепленизированному Фенно-Сарматскому материку. Осевая часть Балтийского бассейна с граптолитосодержащими сланцами и аргиллитами может быть рассмотрена как глубоко опущенный блок материковой окрайны, который тектонически относился к материковому склону, но седиментологически представил с собой язык крупной североевропейской некомпенсированной депрессии, проникающей в северо-восточном направлении внутрь Восточноевропейской платформы. Склон бассейна в его более узком, геоморфологическом понимании, вероятно, охватывал пояс седиментации известкого-глинистых илов между шельфовыми карбонатными и граптолитовыми пелитовыми осадками центральной депрессии бассейна. Эррозионные каналы, турбидиты и другие явления, характерные крутым материковым склонам, в Балтийском силурийском бассейне отсутствовали из-за относительно пологого наклона морского дна.

УДК 552.54:549/1/:551.733.3/474.2+486.92/

DISTRIBUTION AND MINERALOGY OF SILT-SIZED TERRIGENOUS MATERIAL IN THE NORTH BALTIC UPPER SILURIAN DEPOSITS

E. Jürgenson

The Upper Silurian section in the North Baltic area consists primarily of biogenic calcarenites and calcilutites interbedded with thin lithocalcirudites and interlayers of marl. Reef-limestones are not uncommon. The content of terrigenous material varies between 3-5 % in reef-limestones and 70-90 % in marls and clays. Most of the terrigenous material is represented by clay fraction with clay minerals, such as illite and chlorite. Grains in silt- and sand-size are commonly minor increasing upwards in the section.

In the course of a general study of the Baltic Silurian carbonate rocks a special study of its terrigenous material (insoluble residue) was carried out (Юргенсон, 1970, 1977). The present study is based on the granulometric and mineralogical investigation of Upper Silurian silt fraction. Samples were collected from 9 boreholes of Western Estonia (Saaremaa, Ruhnu) and South-Western Latvia (Fig.). In order to compare the material with neighbouring areas a series of determinations was made in samples from Lithuania and Gotland. At the author's disposal were some samples from the Silurian sequence of Gotland, kindly given her by Dr. Einar Klaamann and Dr. Sven Laufeld.

250 samples were acidized in the standard manner with 3.5 % HCl. Granulometric analyses were performed by pipetting and sieving. For the mineralogical analyses the clay fraction was washed out and the rest of residues separated into two classes: sand (grains with diameter over 0.1 mm) and silt (0.01-0.1 mm). The presence of sand grains is commonly rare, their content does not exceed 10 %, even in the deposits known as Ohesaare Sandstones from Saaremaa and the Burgsvik Sandstone from Ronehamn, samples analysed by the author of the present paper.

The silt fraction of the insoluble residue varies between 5 % and 90 %. We can calculate the real content of silt fraction of terrigenous material after the identification and exclusion of authigenic minerals (pyrite, chalcedony). The maximum silt fraction in the North Baltic occurs in the Ohesaare Stage as 88-93 % (Fig.). Taking into account the carbonate component the silt content in the whole rock does not exceed 60 %. Calcareous siltstones are known in the Ohesaare Stage from boreholes Ohesaare-2 (4.6-5.2 m) and Kaavi (7.8-8.9 and 17.5-18.0 m) in the thickness of about 0.5-1 m. The carbonate component consists mainly of sparry calcite with skeletal detritus in Ohesaare-2 and dolomite crystals in Kaavi. The calcareous siltstones of Gotland are older and occur mainly in Burgsvik Beds (the stratigraphic nomenclature and correlation used in this paper is that proposed in Решения..., 1978). A. Hadding gives the thickness of Burgsvik Sandstones about 40 m (Hadding, 1941). The content of sand-silt fraction in the total rocks reaches 80 % (after Stel, 1978). In the sample from Ronehamn analysed by author the content of sandsilt fraction in the sandstone was 46.2 %. The silt content in the deposits of the same age in the East Baltic area does not exceed 10-15 % of the total rock.

Local maxima of the silt content occurred in the Kaugatuma Stage in the boreholes of Ohesaare, Kolka and Ventspils (26-37 % of total rock) (Fig.). In Lithuania the maximum of silt content in terrigenous material of Upper Silurian deposits was established, in most cases, in the beds analogous to the Kaugatuma Stage. Further to the south (bore-

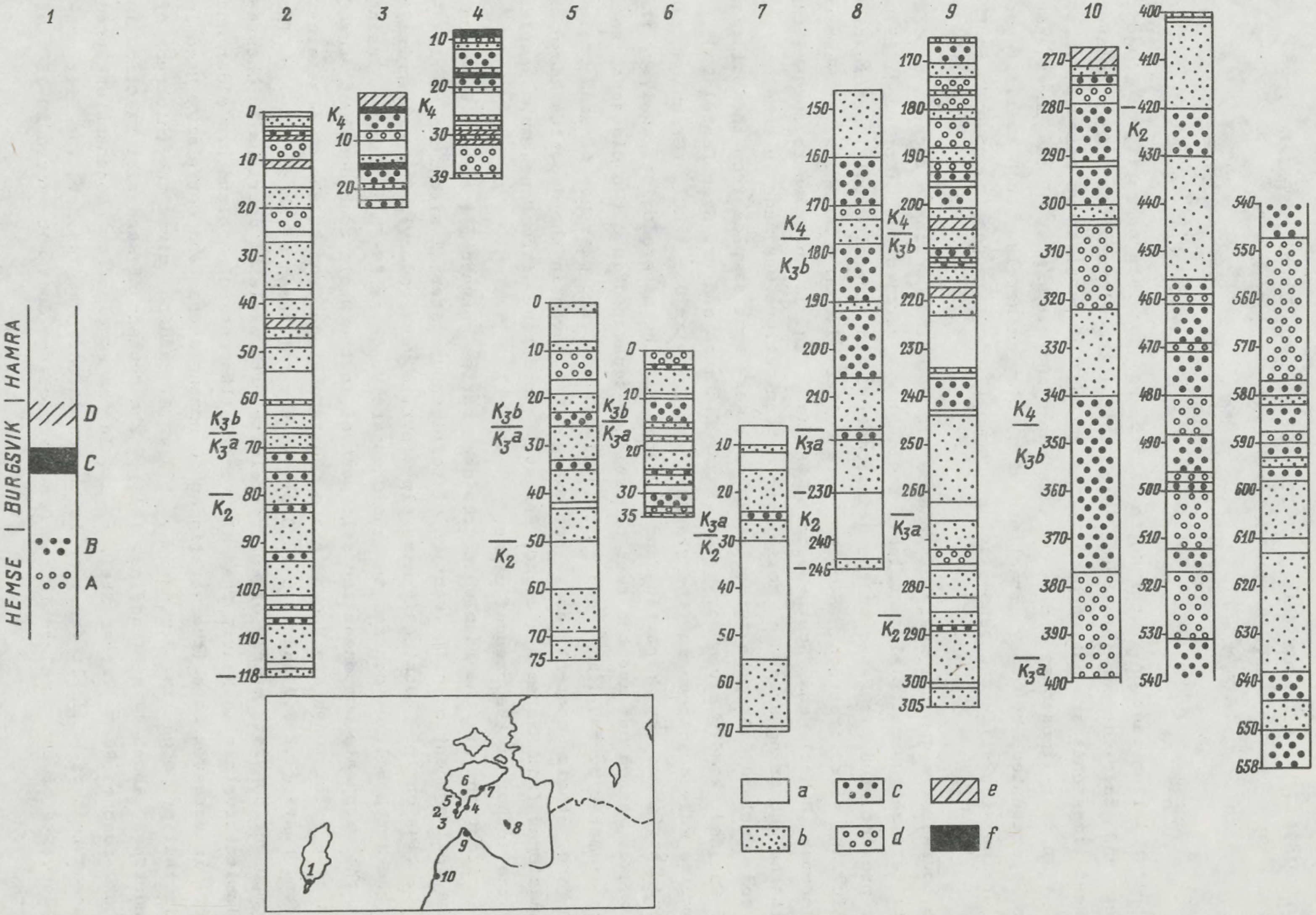

Fig. Location of the sections studied and distribution of the sand-silt-sized fraction in the Upper Silurian carbonate rocks of North Baltic and Gotland.
1 - succession of the samples studied in outcrops of Gotland. A - Ocksarve, B - Hallsarve, C - Ronehamn, D - Lunde. Borings: 2 - Ohesaare, 3 - Ohesaare-2, 4 - Kaavi, 5 - Kaugatuma, 6 - Vaivere, 7 - Tulpe, 8 - Ruhnu, 9 - Kolka, 10 - Ventspils.
The content of sand-silt-sized fraction in terrigenous material: a - less than 10 %; b - 10-20 %; c - 20-30 %; d - 30-50 %; e - over 50 %; f - calcareous siltstone beds.

hole Virbalis 875.5 m) the maximum occurs in calcareous marls corresponding to the Paadla Stage.

There is no definite relationship between grain size and amount of terrigenous material. We can preliminarily distinguish two main types of the accumulation of sand-silt-sized material. The first type is connected with an intensive accumulation of terrigenous material (20-80 %). These are the argillaceous limestones and marls of transgressive character distributed mainly in the lower part of the Paadla Stage, in the Kuressaare Stage and in the lower part of the Ohesaare Stage. The second type of accumulation exists in limestones containing terrigenous material moderately (15-30 %); these are the coarse crystalline limestones, particularly some lithocalcarenites of regressive character occurring in the upper part of the Paadla Stage, in the Kaugatuma Stage and some uppermost beds in the Ohesaare Stage (Ventspils 271.0 m).

According to the granulometric analysis carried out by pipetting and direct measurements made under the microscope, the most frequent diameter of the silt grains is 0.03-0.08 mm. The material is coarser in the calcareous siltstones, with median grain size of Ohesaare siltstone 0.05-1.0 mm and Burgsvik Sandstone 0.08-0.115 mm (after Stel, 1978). The silty ooidal limestones from the upper part of the Burgsvik Beds contain quartz grains with diameter about 0.05 mm (Hadding, 1941). Biocalcarenitic limestone with ooids at the boundary of Burgsvik and Hamra Beds, analysed by the author, in a sample from Lunde contained quartz grains with diameter about 0.8-1.2 mm.

The mineralogical identification of the sand-silt-sized fraction was carried out under a microscope; the grains were mounted in immersion-liquids. The light and heavy minerals were not separated with bromoform (Юргенсон, 1976). More than 500 light and 100 heavy mineral grains were counted in each sample. The relative frequencies (percent) of different minerals were computed separately for the light and heavy fractions. It must be noted that heavy minerals are concentrated mostly in the smaller size fractions (< 0.05 mm).

The light mineral fraction of the terrigenous material accounts for about 98-99 % of the total number of silt grains in most of the samples studied. Of this total, the light fraction less than 1-2 percent is composed of mica (muscovite, chlorite). The content of quartz and feldspar varies between 30-40 % and 60-70 %. In most cases the quartz prevails. In the sandclass the content of quartz is higher, reaching 99 %. The index of maturity (quartz: feldspar) varies in the Upper Silurian terrigenous material from 1.5 to 4.7, increasing in younger deposits. More remarkable concentrations of silt are often characterized by a high index of maturity (over 3), only in samples with a notable content of mica (biotite, muscovite) the values of indexes are moderate (1-3).

Quartz grains are mostly subangular or angular. Rounded grains occur as a rule in the sand class. Inclusions of gas and rutile, and traces of solution and overgrowths of chlorite are typical of quartz grains. The wavy extinction is not rare. Grains with microcrystalline texture were found in the Kuressaare and Kaugatuma Stages.

Feldspars are represented mainly by orthoclase. Grains of plagioclase occur sporadically. In general the grains of feldspar are subangular and moderately or strongly weathered. Grains with traces of solution and secondary overgrowths are known from the terrigenous material of the Paadla Stage.

Muscovite is common in many of the samples as well rounded colourless flakes. Chlorite is represented by greenish flakes, partly allothigenous, partly occurring as a weathering product of biotite. Fragments of extremely fine-granular siltstone are present in many samples of the Upper Silurian terrigenous material (boreholes of Kaugatuma, Tulpe, Ventspils). The diameter of the siltgrains does not exceed 0.02 mm and they are cemented mostly by silicious material, which is sometimes weakly phosphatic. The diameter of the siltstone particles varies between 0.03-0.06 mm. In the Burgsvik Sand-

Table

Average content of heavy non-opaque minerals in the silt-sized terrigenous material of Upper Silurian rocks of borehole sections from Saaremaa, Ruhnu, North-West Latvia, and outcrops of Gotland

	Ohe-saare	Ohe-saare-2	Kaavi	Kauga-tuma	Vai-vere	Tulpe	Ruhnu	Kolka	Vents-pils	Ock-sarve	Hall-sarve	Rone-hamn	Lunde
Paadla Stage										Hemse Beds			
1. Number of samples	14	-	-	7	13	-	7	9	10	3	3	-	-
2. Heavy mineral fraction	2.6	-	-	0.8	1.0	-	0.5	1.1	2.1	0.6	7.8	-	-
3. Zircon	11.3	-	-	41.2	23.4	-	30.7	32.5	38.8	39.0	60.0	-	-
4. Garnet	8.1	-	-	23.0	26.1	-	25.4	29.2	14.3	32.7	8.5	-	-
5. Tourmaline	2.4	-	-	13.4	8.4	-	19.1	14.0	7.0	5.3	1.7	-	-
6. Titaniferous minerals	12.0	-	-	8.8	9.8	-	15.9	10.4	6.4	9.2	12.8	-	-
7. Amphiboles-pyroxenes	1.8	-	-	1.9	0.8	-	0.9	0.3	0.5	1.1	0.6	-	-
8. Corundum	19.1	-	-	0.6	0.6	-	3.0	0	0.7	0	0	-	-
9. Biotite	35.6	-	-	9.5	26.5	-	2.9	10.6	31.0	11.6	15.4	-	-
0. Et al.	9.7	-	-	1.6	4.4	-	2.2	3.0	1.3	1.1	1.0	-	-
	100.0	-	-	100.0	100.0	-	100.0	100.0	100.0	100.0	100.0	-	-
Kuressaare Stage												Burgsvik Beds	
1. Number of samples	20	-	-	7	6	8	3	13	7	-	-	3	3
2. Heavy mineral fraction	1.3	-	-	1.3	1.2	1.6	1.9	1.1	0.9	-	-	1.0	0.4
3. Zircon	14.8	-	-	42.2	16.0	14.1	20.0	27.3	43.5	-	-	12.6	34.0
4. Garnet	11.0	-	-	16.1	7.6	7.3	19.2	11.3	16.6	-	-	0	10.0
5. Tourmaline	3.0	-	-	7.9	3.7	8.6	15.2	3.7	7.7	-	-	1.9	2.0
6. Titaniferous minerals	21.8	-	-	10.8	5.4	4.2	22.4	12.0	10.3	-	-	3.0	12.2
7. Amphiboles-pyroxenes	0.2	-	-	1.6	0.5	0.3	0.8	2.1	1.9	-	-	0	1.7
8. Corundum	15.5	-	-	0.5	0.2	0.1	0	1.0	0.7	-	-	0	0
9. Biotite	29.1	-	-	20.5	66.5	65.3	21.6	33.4	15.9	-	-	72.5	40.0
0. Et al.	4.6	-	-	0.4	0.1	0.1	0.8	9.2	3.4	-	-	0	0.1
	100.0	-	-	100.0	100.0	100.0	100.0	100.0	100.0	-	-	100.0	100.0

Table (continued)

	Ohesaare	Ohesaare-2	Kaavi	Kaugatuma	Vaivere	Tulpe	Ruhnu	Kolka	Ventspils	Ocksarve	Hallsarve	Ronehamn	Lunde
Kaugatuma Stage													
1. Number of samples	32	10	–	13	–	3	5	19	14	–	–	–	–
2. Heavy mineral fraction	1.7	1.8	–	1.5	–	1.9	1.0	2.4	2.2	–	–	–	–
3. Zircon	6.8	14.0	–	20.0	–	27.8	33.2	17.6	19.8	–	–	–	–
4. Garnet	7.2	7.5	–	14.7	–	21.2	20.8	9.4	11.5	–	–	–	–
5. Tourmaline	2.5	4.4	–	6.9	–	9.9	11.4	6.3	7.2	–	–	–	–
6. Titaniferous minerals	6.6	5.4	–	6.3	–	10.6	19.3	6.0	7.7	–	–	–	–
7. Amphiboles-pyroxenes	0.4	0.6	–	1.2	–	1.7	1.5	0.1	0.3	–	–	–	–
8. Corundum	0.2	0.3	–	0.1	–	0	0.3	3.9	0	–	–	–	–
9. Biotite	71.5	66.2	–	50.0	–	28.8	10.8	55.5	52.9	–	–	–	–
0. Et al.	4.8	1,6	–	0.8	–	0	2.7	1.2	0.6	–	–	–	–
Ohesaare Stage													
1. Number of samples	–	13	23	–	–	–	4	24	8	–	–	–	–
2. Heavy mineral fraction	–	1.1	3.2	–	–	–	1.3	2.5	1.9	–	–	–	–
3. Zircon	–	29.3	15.6	–	–	–	22.4	27.3	18.0	–	–	–	–
4. Garnet	–	19.5	12.1	–	–	–	11.7	11.6	7.8	–	–	–	–
5. Tourmaline	–	5.0	6.0	–	–	–	9.8	6.9	5.5	–	–	–	–
6. Titaniferous minerals	–	17.8	5.0	–	–	–	15.3	7.3	5.7	–	–	–	–
7. Amphiboles-pyroxenes	–	1.6	0.2	–	–	–	0.3	0.3	0.4	–	–	–	–
8. Corundum	–	0.4	0.2	–	–	–	0	3.3	0.2	–	–	–	–
9. Biotite	–	21.1	58.8	–	–	–	35.8	36.4	61.4	–	–	–	–
0. Et al.	–	5.3	2.1	–	–	–	4.7	6.9	1.0	–	–	–	–
	–	100.0	100.0	–	–	–	100.0	100.0	100.0	–	–	–	–

stone of Ronehamn siltstone fragments were noticed in the sand class (diam. 1.0-1.2 mm) composed of quartzouse grains with diameter 0.05-0.08 mm (15 % of the light fraction). The first-mentioned siltstone fragments are well rounded and most likely of allochthonous origin. The siltstone fragments in Burgsvik Sandstone seem to be more compactly cemented particles of autochthonous origin.

The non-opaque heavy mineral suite observed in samples taken from the Upper Silurian silt-sized terrigenous material is characterized by a biotite-zircon-garnet-tourmaline association (Table). The content of biotite prevails in most samples taken from the central part of the Paadla Stage (excluding boreholes of Kaugatuma, Kolka, Ruhnu). In the Kuressaare Stage it prevails only in samples taken from boreholes more closely situated to the probable shore line (Vaivere, Tulpe). The amount of biotite is higher in the Kaugatuma Stage and in the Ohesaare Stage (Kaavi and Ventspils) not including the uppermost beds of the sequence. There is much biotite in samples taken from the Burgsvik Beds. Brown-coloured biotite is more common in the deposits of the Paadla Stage, the greencoloured variety is more frequent in younger deposits. Many of the flakes of biotite are attacked by weathering. Abundant bleached biotite has been noticed in the deposits of the Kuressaare Stage which has entirely lost colour.

The highest precentages of zircon in the Upper Silurian are found in the Paadla Stage (Table) where the maximum values reach 60-70 %. 60 % of zircon was also noticed in the samples from the upper part of the Hemse Beds of Gotland. The zircons studied were of two types: slightly rounded colourless fragments and idiomorphic crystals. Fragmental rounded zircons are more common and distributed throughout all the size classes whereas the idiomorphic crystals are rare and confined to the upper limits of the silt size grains.

As a rule the garnet is less abundantly distributed in the Upper Silurian than zircon. Most frequently it varies between 10-20 %. Only in the boreholes of Vaivere and Ruhnu does garnet prevail over zircon in some samples from the Paadla and Kuressaare Stages. The highest content of garnet in the analysed samples of Gotland occurred in the Hemse Beds from Ocksarve. The grains of garnet are very often subangular with traces of solution; the colourless or yellowish grossular is most widely distributed. Rare grains of brown andradite have been also found.

Tourmaline is a minor component of the heavy mineral association, the average content usually does not exceed 10 %. The amount of tourmaline is higher in the Paadla Stage in boreholes of Ruhnu, Kolka and Kaugatuma. Most tourmalines occur as subangular prismatic grains with a pleochroism from green to brown. Blue-coloured varieties are rare and they are known only from the Ohesaare Stage.

Titaniferous minerals are represented by rutile, brukite, anatas, titanite and leucoxene. Most common of them are rutile, titanite and leucoxene, the latter as a weathering product of ilmenite and rutile. The average amount of titaniferous minerals varies from 4.2 to 22.4 %, it seems to have local concentrations in the boreholes of Ruhnu and Ohesaare. The rutile and brukite are represented mainly by reddish brown little prismatic grains (0.01-0.05 mm).

The occurrence of amphiboles and pyroxenes is in most cases sporadic. Average content does not exceed 2 %. Of the amphibole group the green hornblende is most common. The pyroxenes are represented mainly by augite and hypersthene; diopside was identified in the deposits of the Ohesaare Stage.

The average content of corundum may reach 19.0 % among the non-opaque heavy minerals of Upper Silurian deposits. In the former investigations it was noted (Юргенсон, 1977) that corundum is concentrated in the Upper Wenlock deposits in the north-western part of the Silurian sedimentation basin (Ohesaare, Kipi) where the maximum content reaches up to 80 % of the heavy mineral fraction. The average abundance of corundum is considerably high in the section of Ohesaare, even in the Paadla and Kuressaare Stages, and decreases at the lower boundary of the Kaugatuma Stage. The analyses from samples of Gotland do not indicate corundum in Ludlow. However, it is present in the terrigenous material of the Slite and Högklint limestones. Corundum occurs as colourless angular grains with relatively high diameters compared with zircon, garnet and other heavies.

The rest of the non-opaque heavy fraction is represented by staurolite, disthene, epidote, sillimanite, apatite and monacite. Staurolite and disthene are commonly present in transgressive deposits at the lower boundary of the Kuressaare Stage and the Ohesaare Stage. The appearance of these minerals is mainly connected with the beginning of megacycles of sedimentation. Disthene occurs in slablike little grains, colourless or pale bluish. Staurolite was found as prismatic grains, slightly rounded, pleochroic from dark brown to yellowish-grey.

The presence of epidote and sillimanite is of occasional character. Grains of epidote are well rounded pale green, and weakly pleochroic. Sillimanite was mainly identified in the Ohesaare Stage as little prismatic grains.

The presence of apatite and monacite in the insoluble residue of carbonate rocks depends on the activity of the solution process. Dissolvable in dilute hydrochloric acid the preservation of phosphatic minerals depends mostly on the duration of solution and lithologic character of the rocks analysed. It is certain that we cannot account for the absolute amounts of these minerals in such cases.

Based on the accumulated evidence reported in this paper some general conclusions may be derived. The Upper Silurian rocks in the North Baltic and Gotland are considerably rich in silt-sized terrigenous material, which concentrations occur on several levels as lenses and layers of calcareous siltstones. The distribution of the latter is limited and strictly depends on local hydrodynamic conditions. Owing to that fact they cannot be taken as a very reliable correlation criteria.

The mineralogical composition of silt concentrations may be of two kinds: 1. high value of maturity index accompanied with much micas (muscovite, biotite, chlorite) and a moderate suite of non-opaque heavy minerals and 2. lower value of maturity indexes, moderate content of micas and a more numerous suite of heavies. The total content of terrigenous material is higher in the first case.

Comparison of heavy mineral suites might afford a basis for correlation when there has been a major change in conditions of sedimentation (transgression, regression).

The non-opaque heavy minerals have long been used as valuable indices to provenance or source areas. Their usefulness is greatly reduced in our case, because many of them are most likely to be derived from older sedimentary rocks. The heavy mineral suites observed in samples taken from the deposits in the North Baltic and Gotland contained nearly the same minerals but in varying frequencies. It seems very likely that a great part of the silt fraction was derived almost entirely from one and the same source area, though the quantity and coarseness of the silt fraction is greater in the deposits of Gotland.

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РАСПРЕДЕЛЕНИЕ И МИНЕРАЛЬНЫЙ СОСТОВ АЛЕВРИТОВОЙ ФРАКЦИИ ТЕРРИГЕННОГО МАТЕРИАЛА В ВЕРХНЕСИЛУРИЙСКИХ ОТЛОЖЕНИЯХ СЕВЕРНОЙ ПРИБАЛТИКИ

Э. А. ЮРГЕНСОН

Исследован гранулометрический и минеральный составы алевритовой фракции верхнесилурийских карбонатных отложений Западной Эстонии и Северо-Западной Латвии. Для сравнения приведен ряд данных из соответствующих отложений Литвы и острова Готланд. Максимальная концентрация алевритовой фракции установлена в Северной Прибалтике в даунтоне, в охесаареском горизонте /рис./, на острове Готланд - в известковом алевролите слоев Бургсвик /лудловский ярус/.

Минеральный состав терригенного материала Северной Прибалтики и Готланда мало отличается между собой. В основном варьируются количество и частота встречаемости отдельных минералов. Прозрачные аллотигенные минералы тяжелой фракции представлены биотит-циркон-гранат-турмалиновой ассоциацией /табл. 1/. Можно предполагать, что большинство терригенного материала происходит из одного и того же источника, распологавшегося, видимо, ближе к Готланду, чем Прибалтике, так как его количество и размер зерен в первом районе больше.

УДК 563.67+563.713:551.733.3 /474+486.92/

CORAL REEFS OF BALTIC SILURIAN (STRUCTURE, FACIES RELATIONS)

E. Klaamann, R. Einasto

According to recent ideas the Baltic Silurian basin was a typical Early Paleozoic pericontinental sea. At the time of its maximum distribution the sea cut deep into the peneplaned Fenno-Sarmatian continent. As a result of the continental uplift the sea gradually retreated to the south-west, towards the Central-European Hercynian Geosynclinal Basin (Walter, 1972; Нестор, Эйнасто, 1977; Кальо, Юргенсон, 1977). Representing a near-equatorial shallow platform-sea, the Baltic Silurian basin offered favourable conditions for the development of tabulate corals, stromatoporoids, rugose corals, bryozoans and calcareous algae capable of constructing the frame of various organic buildups: bioherms, biostromes, banks, and more seldom small bioherm complexes, further conditionally called reefs. These buildups are mostly unstratified small bodies 3-5 m, rarely 10 m high, some tens of metres across and are enclosed in well-bedded biodetritic, biomorphous and pelletal limestones poor in terrigenous admixture. They are less numerous in nodular muddy bioclastic limestones. These relations show a comparatively wide facial range of the development of organic buildups: from shoal barriers (overwhelming majority of buildups) to extensive open shelf, incl. (in press). Thus, shoal and shelf reefs can be distinguished in the Baltic Silurian basin. Applying facial analysis it was established that shoal sedimentary barriers with reefs developed in the highest energy wave activity zone. Being narrow (to 10 km) they ran many hundred kilometres. In addition to characteristic carbonate sediments the formation of chains of different organic buildups resembling modern reef barriers evidently took place just in this part of the basin. However, genetically authentic barrier reefs did not exist here. Unlike, e.g. the Great Barrier Reef of Australia running along the steep outer margin of the Coral Sea shelf, most of the Paleobaltic Silurian organic buildups developed within the stable shelf basin at the gentle slope of the sea bottom. Thereby, they resemble the patch reefs particularly numerous in the wide southern part of the eastern shelf of Australia between the continent and the Great Barrier Reef.

At times, the Silurian shoal barriers and associated organic buildups were very extensive (Fig. 1). E.g., the Wenlock and Middle Ludlow bioherms form distinct shoal barriers from Gotland through Saaremaa and the southern Baltic to Volyno-Podolia, i.e. within a distance of approx. 1,500 km (Эйнасто и др., 1980). During recurrent transgressions and regressions the shoal barriers removed considerably. The most favourable conditions for the formation of organic buildups existed at the regressive phases of the basin development. This is evidenced by the regular position of the shoal reefs in sedimentary cycles: the reefs are underlain by nodular open-shelf limestones and overlain by lagoonal primary dolomites (see Nestor, Einasto in this book, Fig. 2).

Middle Wenlock and Middle Ludlow were the epochs of the maximum reef development. In between these epochs the shoal facies belt, most suitable for the reef formation, migrated in the East Baltic for a distance of 300 km but on Gotland and in Podolia only for 15-40 km. Supposedly, this difference indicated the presence of a much steeper continental slope in the latter.

Further from the shoal barrier towards the outer shelf edge the shelf reefs were located. More precisely, they occupied the central part of the shelf, and probably its

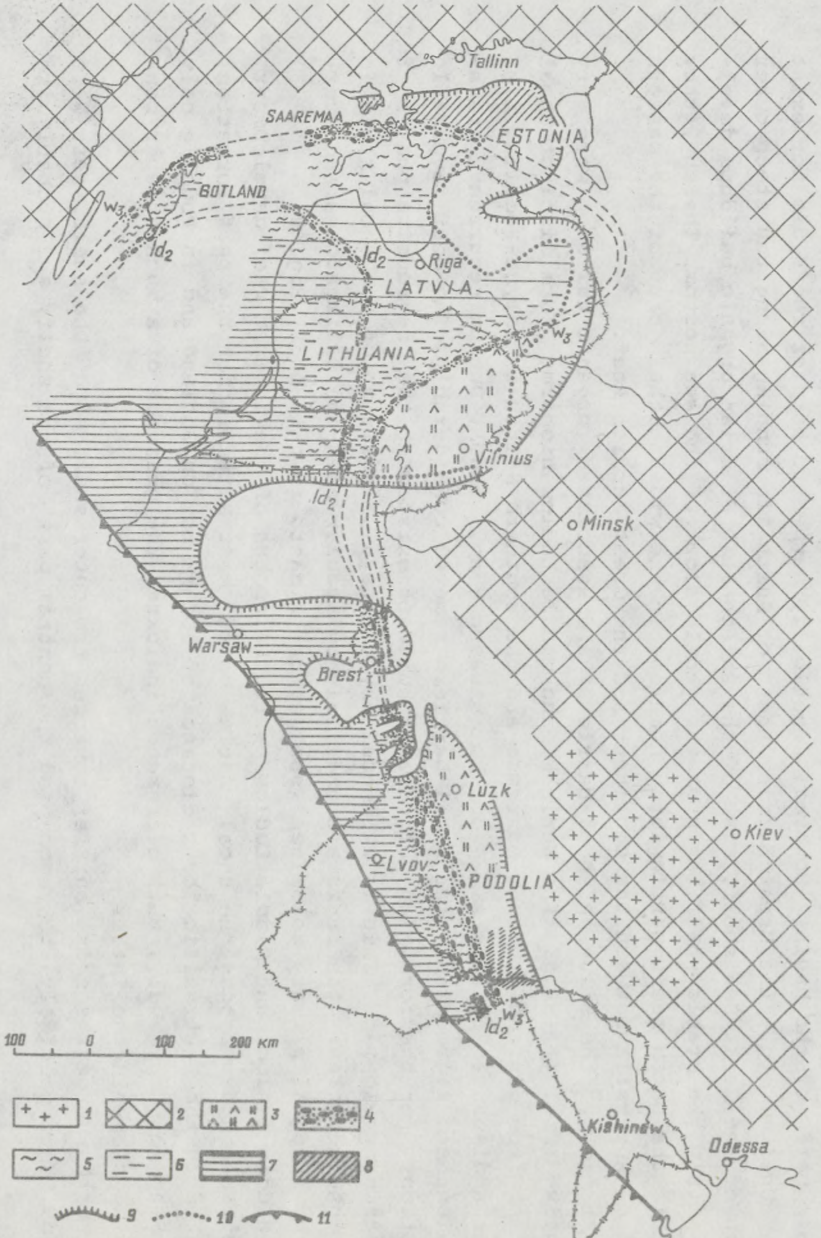

Fig. 1. The Wenlock (w_3) and Middle Ludlow (ld_2) bioherms form distinct shoal barriers from Gotland to Volyno-Podolia (from Эйнасто и др., 1980).
1 - Ukrainian Shield, 2 - Fenno-Sarmatian continent, 3 - lagoonal dolomites and gypsum, 4 - calcarenites and organic buildups of the shoal facies belt, 5 - nodular limestones of the open shelf belt, 6 - marls of the slope belt, 7 - graptolite mudstones and shales, 8 - outcrop area of the Silurian rocks, 9 - limit of the present distribution of Silurian rocks, 10 - contour of complete thickness of Jaagarahu Beds (Wenlock), 11 - Törnquist Line.

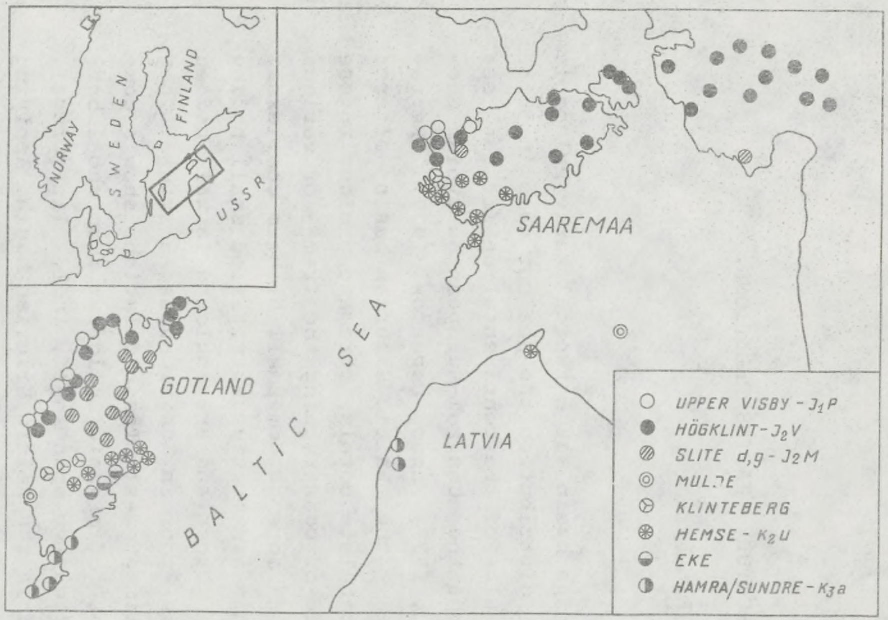

Fig. 2. Distribution of the Silurian organic buildups in Gotland and East Baltic.
Explanation of stratigraphical indexes - see table in Preface. The distance between Gotland and East Baltic is reduced.

elevated portions (dome or bar-shaped structures). The shelf reefs were small bodies (biostromes, bioherms) varying from some metres to some tens of metres in diameter, and consisting mainly of dendroid or bush-shaped tabulates. Stromatoporoids were rare. These organic buildups are most similar to the modern patch-reefs.

These are general considerations of the reef development in the Silurian Paleobaltic basin. Further, we shall present more specific data by analysing the Wenlock and Ludlow on Gotland and in the East Baltic from the comparative aspect.

The earliest Wenlock reefs on Gotland are known from the Upper Visby Marls (Fig. 2), formed in the inner area of the open shelf. They are small buildups of knoll, cone or lens-shaped composed chiefly of tabulate corals (halysitids, favositids) and heliolitids, i.e. of an assemblage characterized by a higher tolerance to muddy substrate (Manten, 1971; Stel, 1978). The maximum height of the buildups is 3.5 m but frequently they are much smaller. V. Jaanusson (1979) having studied them in detail called these unstratified bodies knolls and mounds. He supposed that on forming they rised only slightly from the sea bottom. By our identifications in these buildups predominates favositid *Angopora hisingeri* associated with *Planalveolites foughti*, *Heliolites decipiens*, *Stelliporella* sp., rare *Catenipora* and fairly small stromatoporoid coenostea. The skeletons of the associated species did not constitute more than 10-15 % of the volume of buildups.

Buildups of the same habit, structure and analogous facies relations have been established in the nodular clayey limestones of the Jaani Stage (the Paramaja Formation) at the base of the Silurian cliff on Saaremaa (Fig. 2).

On Gotland the Early Silurian reef development culminated in Högklint time. Huge algal-stromatoporoid-coral buildups up to 20 m high and several hundred metres long often take their beginning from the very base of the Högklint Beds. They are well exposed in the NW cliffs of Gotland and thoroughly studied by many authors (Hadding, 1950; Rutten, 1958; Manten, 1971; Eriksson, Laufeld, 1978; Stel, 1978, etc.). By K. Mori (1968) the main reefbuilder was the stromatoporoid *Vikingia tenue*, in the inter-reef areas dominated *Densastroma pexisum* and *Simplexodictyon simplex*. Of tabulates *Favosites mirandus* is associated with reefs. C.-O. Eriksson and S. Laufeld (1978) have demonstrated that the Högklint reefs occupied a belt 10 km wide and almost parallel to shore line.

An analogous reef assemblage is known from the East Baltic (Fig. 2). However, in this region it appears somewhat later in comparison with Gotland. In the Ninase Member of the Jaani Stage (Клааманн, 1977) the equivalent of Högklint "a" with reefs of *Vikingia* is lacking. Instead of them there occur small bryozoan bioherms (1-2 m in diameter). Stromatoporoid reefs are also absent in the overlying part of the Jaani Stage. *Vikingia* reefs appear in the basal portion of the Jaagarahu Stage, in the Vilsandi Beds. Jaagarahu reefs are huge: 10-16 m high and several km across (Аалоэ, 1970). The main reefbuilders are *Vikingia tenue* and stromatolites; *Favosites mirandus*, *Coenites juniperinus* and colonial rugose coral *Acervularia ananas* are rarer. The Early Jaagarahu reefs form a long chain running through the whole northern part of Saaremaa, and continuing in the mainland of Estonia and to the SSW of it. Borings have shown that the reefs represent a belt at least 10 km in width. Unfortunately, most of the organic buildups in the territory of Estonia are heavily dolomitized and, therefore it is hardly possible to identify the reef-forming organisms even on the group level. It seems that to the east of the western coast of Saaremaa the role of the calcareous algae, halysitids and solitary rugose corals increases and that of *Vikingia tenue* decreases.

By lithological characters (see Jaanusson, 1979) the deposits enclosing Högklint bioherms are mainly sparite limestones; so, they may be considered according to the facies model of the basin (Нестор, Эйнасто, 1977) as belonging to the shoal belt. To this conclusion seems to contradict the presence in Högklint reefs of *Dicoelosia verneuliana* which has been taken as an indicator of the quiet-water environment in Wales and Welsh Borderland (Hurst, 1975). One can evidently agree with J. Stel (1978) who pointed out that not all *Dicoelosia*-species had the same facies range. However, the absence of *D. vernuiliana* in *tenue*-reefs of the East Baltic may indicate that these buildups, occupying somewhat higher stratigraphical position, were perhaps located closer to the shore than the reefs of analogous species content on Gotland.

The next reef level well defined in the whole northern part of the Silurian Baltic basin occurs on Gotland in the Slite Beds, particularly in Slite "d" and "g", and on Saaremaa in the Maasi Beds of the Jaagarahu Stage (Fig. 2). By their shape these buildups may be called biostromes. They are flat bodies full of halysitids, teciids, favositids, auloporids and rugose corals. Stromatoporoids are of secondary significance. In the coral assemblage *Halysites junior* and *Thecia confluens* predominate but dendroid *Barrandeolites bowerbanki*, *Palaeofavosites collatatus*, *Pf. tersus*, *Subalveolites sokolovi*, *Heliolites decipiens*, *Aulopora enodis*, tetracoral *Microplasma schmidti*, etc. are also numerous. Large bioherms with *Halysites junior* are developed only in the very south-western part of the region (Stora Kalsö Island). As to their facies position the *junior-confluens*-reefs are shoal ones. Upwards of the Slite Beds in the Wenlock of Gotland the organic buildups of three stratigraphical levels are known to us. These come from (1) Halla "b", (2) the Mulde Beds, and (3) the middle of the Klinteberg Beds (Fig. 2).

Common features for these buildups are: small size, peculiar species content, and the absence of direct analogs of them in the Wenlock of the East Baltic. Halla bioherms (Hörsne outcrop) differ from the others in large number of small dendroid and encrusting tabulates and bryozoans: *Parastriatopora priva*, *Thecia expatiata*, *Coenites juniperinus*, *Palaeofavosites asper*, *Desmidopora acuminata*, etc. Judging by the first three species, these buildups may be situated on the level of the uppermost part of the Maasi Beds in the East Baltic. Taking into account the small size of Halla coelenterates and bryozoans, the morphology of their colonies, and analogous position in modern reefs of similar adaptions, it can be supposed that the bioherms built by above-mentioned organisms were located in the onshore side of shoal barrier or in the outshore of a lagoon (Клааманн, 1982).

From the Mulde Beds only one organic buildup (Blåhäll outcrop) is known. It is a thin (0.25 m) biostrome consisting of dendroid proporids (heliolitids), not identified on species level so far. It is enclosed in monotonous mudstone full of unjoined meshes of halysitids (*Halysites laticatenatus*) and hemispheric colonies of *Favosites gothlandicus*. The enclosing rock seems to suggest this biostrome as the most open sea buildup in the Baltic Silurian, formed at the outer margin of the open shelf.

The bioherms of shoal facies belt occur at Klinte and Hunninge (the Klinteberg Beds). Of the reefbuilders dominate *Halysites klintebergensis* and *Palaeofavosites tersus*, partly also thin dendroid corals and bryozoans, closely resembling those in the bioherms of the Halla Beds at Hörsne.

The second maximum of reefbuilding in the Baltic Silurian basin took place in the Ludlow, particularly in Hemse and Paadla times when bioherms and biostromes were equally well developed on Gotland and in the East Baltic. However, the reefs of these regions reveal some differences. E.g., on Gotland the bioherms analogous to those of Early Paadla time, and consisting of *Thecia swindereniana*, *Subalveolites*, *Densastroma podolicum* and a rich assemblage of other stromatoporoids, are not established. But almost identical are the assemblages of reef-forming coelenterates in the Uduvere Beds and those of the Hemse Beds on the Östergarn Peninsula and in Linde area. In this assemblage predominate massive or encrusting stromatoporoids (*Plectostroma*-species, *Syringostromella borealis*, *Lophiostroma*, etc.). Between them occur gatherings of cylindric tabulates *Laceripora cribrosa* and *Parastriatopora coreaniformis* and bushes of syringoporids. If in the East Baltic the buildups of this content are represented by thin (approx. 1 m high) biostromes, those on Gotland reach the thickness of 4-5 m. Being enclosed in well-bedded limestones these biostromes might possibly develop in shoal environment.

The organic buildups in the Eke Beds of Gotland are known to us from the localities surrounding Laubackar (Hallsarve, Källstäde, Botvide). The moundlike bodies consist of marls and contain numerous small mushroom shaped or encrusting colonies of alveolitids and heliolitids. Stromatoporoids are of secondary significance. The facies position of Eke reef in unclear. Abundant encrusting alveolitids which in the East Baltic Silurian are mostly connected with lagoonal facies belt call for location of these buildups in the near-shore though quietwater part of sea (onshore side of shoal barrier?).

On Gotland the uppermost Silurian is represented by the Hamra and Sundre Beds which are also rich in buildups (Fig. 2). The number of reefbuilding species is limited but the individuals are numerous. Most important are stromatoporoids among which encrusting coenostea dominate (*Plectostroma scaniense*, *Parallelostroma typicum*, *Lophiostroma schmidti*). Tabulate corals *"Palaeofavosites" moribundus*, *Favosites similis*, alveolitids and syringoporids are of note. All of these coelenterates are known in the Silurian of Gotland from the Eke Beds and overlying ones. In Estonia this kind of bioherms is not known though the majority of species are frequent in the uppermost part of the Paadla Stage and above it. But in West Latvia the buildups of almost identical species content have been discovered by boring (Ventspils core). These buildups are the youngest by their age in the East Baltic Silurian (Ventspils Formation, the topmost Ludlow). Evidently, in the northern Baltic the regression of the sea at the end of the Ludlow (in Kuressaare time) was so rapid that the most favourable conditions for reef building occurred already southwards the territory of Estonia.

In conclusion it can be said that during the whole Wenlock and Ludlow reefs were characteristic of the northern part of the Paleobaltic. They are especially abundant on Gotland where at least 9 levels with reefs of different age have been preserved. Suggesting general regression of the basin, they replaced regularly each other towards the south and south-west. The coincidence of the succession on Gotland and in Estonia shows the presence of reef belts situated roughly parallel to the shore line. This succession was partly interrupted at the end of the Wenlock at the time of Silurian maximum regression (in Rootsiküla time) when reef formation took place only on Gotland (evidenced by buildups in the uppermost Halla Beds, the Mulde and Klinteberg Beds).

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КОРАЛЛОВЫЕ РИФЫ В СИЛУРИЙСКОМ БАССЕЙНЕ БАЛТИКИ
/СТРОЕНИЕ, ФАЦИАЛЬНАЯ ПРИУРОЧЕННОСТЬ/

Э. Клааманн, Р. Эйнасто

Органогенные постройки /биогермы, биостромы - условно названные как рифы/ приурочены в силуре Балтоскандии к двум фациальным зонам: 1/ к подвижноводной отмельной зоне /преобладающее большинство/ и 2/ к открытому шельфу.

Отмельная зона представлена детритовыми криноидными и ракушечно-детритовыми известняками, с которыми ассоциируются кораллово-строматопоровые биогермы. Внутренняя сторона зоны, в основном с водорослевыми биогермами, сложена илисто-детритовыми, битуминозными глинистыми известняками и мергелями, переходящими в сторону берега в однородные доломитовые мергели. Органогенные постройки отмели являются наиболее крупными в силуре Балтоскандии и отличаются заметно линеарным распространением /в частности биогермы слоев Хёгклинт и яагарахуского горизонта/ /рис. 1/.

Рифы открытого шельфа небольшие, напоминающие т.н. лоскутные рифы, бугры или возвышения дна современных морей. Они вероятно, лишь немного возвышались над дном силурийского моря. В разрезе подобные постройки заключены в комковатых известняках и мергелях. Сложены они плоскими колониями фавозитид, корковидными альвеолитидами, толстостенными хализитидами и кустистыми сирингопоридами /постройки Верхних мергелей Висбю, мергелей Хемсе, вентспилской свиты лудлова и др./.

В течение почти всего силурийского периода органические постройки были особенно полно представлены в северной части Палеобалтики - в частности в районе Готланда, где сохранились следы по меньшей мере восьми разновозрастных рифов /рис. 2/.

Биогермы и биостромы силура Балтоскандии формировались в регрессивных фазах развития бассейна. Максимумы рифообразования были в среднем венлоке и среднем лудлове. В течение этого интервала времени наиболее подходящая для рифостроителей отмельная зона мигрировала в пределах Прибалтики около 300 км, а на Готланде и в Подолии лишь 15-40 км /рис. 1/. Думается, что в двух последних регионах материковый склон был заметно более крутым и стабильным.

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THE BALTIC MIDDLE SILURIAN STROMATOPOROID SUCCESSION

H. Nestor

Although a remarkable number of regional taxonomical and biostratigraphical papers has been published on the Silurian stromatoporoids during last decades, there does not still exist a formal zonal stromatoporoid standard for any region. The Baltic area offers good opportunities for elaborating such a standard for stromatoporoid stratigraphy due to relatively detailed researches covering Silurian outcrop areas on both sides of the Baltic Sea (Рябинин, 1951; Нестор, 1964, 1966, 1970; Nestor, 1979; Mori, 1968, 1969, 1970, 1978).

The aim of the present paper is to summarize the existing data on the distribution of stromatoporoids in the Baltic middle Silurian (Wenlock). The main attention is paid to the species distributed both in the East Baltic and Gotland sequences.

General remarks on the stromatoporoid distribution

Due to their relatively narrow ecological ranges stromatoporoids are distributed in Silurian rocks rather unevenly. The richest and the most diverse stromatoporoid assemblage occurs in the sparitic, biomicritic and argillaceous limestones of shallow water genesis, distributed in the border areas of the Baltic Silurian sedimentary basin. According to the generalized facies-sedimentary model of the basin (Нестор, Эйнасто, 1977) these rocks formed in the high energy shoal environments and in the moderate to low-energy open-shelf environments (Nestor, 1977). In the territory of Gotland and Estonian outcrop areas such conditions prevailed almost throughout the whole Silurian period. These areas offer the best possibilities for following the succession of stromatoporoid faunas in the shallow water optimal conditions. As for the Estonian sequence its stromatoporoid succession is not so complete as in the Gotland sequence. There are several gaps in the stratigraphical distribution of stromatoporoids caused by the presence of tongues of lagoonal or restricted-shelf deposits (various dolomitic sediments) in which stromatoporoids are lacking. The latter are more common for the Wenlock-Ludlow boundary beds, i.e. for the Jaagarahu, Rootsiküla and Paadla Formations. In the Gotland area Silurian sediments accumulated almost without exception in the normal-marine environments and therefore they contain a very rich stromatoporoid fauna.

Towards the centre of the Baltic Basin biomicritic nodular limestones of the open shelf are replaced with marlstones, considered as deposits of a relatively gentle basin slope (Нестор, Эйнасто, 1977) and the latter, in turn, with graptolite bearing mudstones and shales of the axial depression of the gulf-like basin. As a rule, the latter facies do not contain stromatoporoids. Therefore stromatoporoids are lacking in the middle Silurian of Latvia, West Lithuania and Scania. The transition belt from the shelf limestones to the slope mudstones is characterized by improverished fauna of comparatively long-range species of stromatoporoids, giving a specific succession of deeper water assemblages. Such lateral differentiation of stromatoporoid fauna was earlier mentioned by K. Mori (1970), who noticed that in western Gotland marls and marly limestones include only a few species of stromatoporoids, which all belong to the comparatively long-ranging ones, while the rich and diverse stromatoporoid fauna in massive reef limestones and in surrounding stratified limestones of eastern Gotland changes more rapidly. In the present paper two parallel successions of zonal assemblages have been distinguished (Table 1): one for shallow water, another for deeper water deposits. Actually there does not exist any distinct boundary between these contemporaneous lateral assemblages and partly deeper water species occur also together with the shallow water ones, gradually replacing each other.

Composition of the zonal standard

The most wide-spread species of stromatoporoids were preferred for outworking of the zonal standard, given in Table 1. The medium column of the table lists all species common for the corresponding stratigraphical units of the Estonian and Gotland sequences, presented in the left and right columns of the table, correspondingly.

According to the recent stratigraphical scheme regional stages of Estonia are subdivided into beds or formations (Аалоэ и др., 1976). It enables a more detailed correlation of sequences than earlier. Unfortunately in Estonian sections stromatoporoids occur and are studied rather unevenly. The names of the stratigraphical units which are not characterized by stromatoporoids yet, have been shown in Table 1 in square brackets. Species are distributed in sections rather sparsely and mostly they do not offer any possibility for tracing exact boundaries between the stromatoporoid biozones. Conventionally the latter are considered coincidental with the boundaries of the local topostratigraphical units. If the unfit of the boundary is obvious or if its position is very obscure, it is shown in Table 1 by the broken line. If in the table the column of the shallow water zonal assemblages is divided into two parts by double line then on such stratigraphical levels there do not exist stromatoporoid species common for both the East Baltic and Gotland areas and the species listed on both sides of the double line occur only in the corresponding area.

Table 1

The Baltic middle Silurian stromatoporoid communities and species common for Estonia and Gotland

Estonia		Communities and common species			Gotland	
		Shallow water		Deeper water		
Rootsiküla	[Soeginina Vesiku] Kuusnõmme Viita	Araneosustroma stelliparratum	Parallelostroma tenellum	„Pycnodictyon" densum Actinostromella aff. vaiverensis	Klinteberg	Mulde
Jaagarahu	[Tagavere]	not studied	Labechia conferta Stelodictyon striatellum Clathrodictyon vesiculosum		Halla	
	Maasi	Ecclimadictyon astrolaxum E. macrotuberculatum Simplexodictyon validum		Densastroma pexisum Clathrodictyon simplex	Slite	
	Vilsandi	Vikingia tenuis V. vikingi Syringostromella yavorskyi			Tofta Högklint	
Jaani	[Ninase] Paramaja	Stromatopora impexa „Pseudolabechia" hesslandi Clathrodictyon linnarssoni			U. Visby	

Succession of stromatoporoid communities

Detailed data on the distribution of stromatoporoid species in localities of Gotland and Estonia have been presented in the special papers (Mori, 1968, 1970; Нестор, 1966, 1970; Nestor, 1979) and they are not repeated here. Additional data are commented below if necessary.

The *Stromatopora impexa* Community

On Gotland the earliest stromatoporoids hitherto known are these of the Upper Visby Marls. It is remarkable that almost all the Upper Visby species occur also in similar nodular limestones and marls of the Estonian Jaani Formation, exposed in the cliffs of the northern coast of Saaremaa (Liiva, Panga, Suuriku) immediately below the lower boundary of the Ninase Member. Some of these species such as *"Pseudolabechia" hesslandi* and *Clathrodictyon linnarssoni* have not been described in the author's earlier paper (Нестор, 1966) due to some taxonomical difficulties. Now their presence is well established in the Estonian sequence.

Actually the most common stromatoporoid species in the Upper Visby Beds and Jaani Formation are *Densastroma pexisum* and *Clathrodictyon simplex*, but these species have a wider stratigraphical and ecological range, and are considered here as the main representatives of the Lower Wenlock deeper water stromatoporoid assemblage (p. 44). At the same time such rather wide-spread species as *Stromatopora impexa*, *Clathrodictyon linnarssoni* and *"Pseudolabechia" hesslandi* are mostly confined to the Upper Visby and Jaani levels and could be treated as the zonal assemblage of a more shallow-water faunal succession. A few specimens of these species have also been reported from the basal part of the Högklint Beds. Therefore the upper boundary of the *Stromatopora impexa* Zone may actually lay within the limits of the Högklint Beds and may coincide with the boundary between its "a" and "b" or even "b" and "c" units. In the Estonian sequence the boundary probably coincides with the base of the Jaagarahu Stage.

Hitherto species typical of the *Stromatopora impexa* Community have not been reported from the other regions.

The *Vikingia tenuis* Community

Vikingia tenuis is the most common species in the Högklint and Tofta Beds of Gotland, particularly in the massive reef limestones of the former and in the Spongiostroma Limestone of the latter. In Estonia the same species occurs abundantly in reef limestones and associated rocks in the Vilsandi Beds of the early Jaagarahu age. In places *Vikingia tenuis* is accompanied by *Vikingia vikingi* and *Syringostromella yavorskyi*. In Estonia the latter species was not earlier separated from *Vikingia tenuis* but as the latter examination of the collection has confirmed, it definitely occurs in Jaagarahu locality besides *V. tenuis*. On Gotland a few specimens of *Vikingia tenuis* have also been recorded from the uppermost part of the Visby Beds and from the lower part of the Slite Beds (Mori, 1968). Thus there is a certain overlap of the stratigraphical ranges of the zonal stromatoporoid species and the both boundaries of the *Vikingia tenuis* Zone could be fitted with the boundaries of the topostratigraphical units only conventionally.

The *Vikingia tenuis* Community is apparently rather specialized ecologically and it is mainly restricted to the reef facies. At the same time it has a rather narrow stratigraphical range, as it has not been recorded neither from the small Upper Visby patch reefs below, nor from the reefs of the Slite Group higher in the sequence. Therefore the opinion about different age of the *Vikingia tenuis* Community in Gotland and Estonian sequences, expressed earlier by Kaljo (Кальо, 1970, p. 198) on the basis of the indirect correlations of the outcrop sections, does not evidently have enough ground. The data obtained through the investigation of tabulate corals (Клааманн, 1977) and chitinozoans (V. Nestor, 1982) confirm the same.

The elements of the fauna with *Vikingia tenuis* have not been recorded from other regions. Some similar species (*Vikingia demshynensis*, *"Pseudolabechia" nikiforovae*) occur in the Restevo and Demsha Beds of the Kitaigorod Stage of Podolia (Большакова, 1973), which are roughly contemporaneous to the *Vikingia tenuis* Zone but are represented by different lithofacies.

The *Ecclimadictyon astrolaxum* Community

Rather thick and variable Slite Group of Gotland contains diverse stromatoporoid fauna. Unfortunately most of the stromatoporoid species in the Slite Group occur in a single or in very few localities and therefore are not of interest as zonal forms. Only such species as *Stromatopora* cf. *psudotuberculata*, *Ecclimadictyon astrolaxum*, *E. macrotuberculatum*, *Densastroma podolicum*, *D. pexisum*, *Simplexodictyon simplex* are more wide-spread. The latter four are of rather wide stratigraphical range and are therefore of less interest. Therefore *Ecclimadictyon astrolaxum* is the most characteristic species for the stratigraphical interval considered. In Estonia it is rather abundant in some outcrops (Tôre, Sepise) of the Maasi Beds of middle Jaagarahu age.

According to the data by K. Mori (1968) *Ecclimadictyon astrolaxum* occurs both in the lower and in the upper parts of the Slite Group while many other species are restricted to one of the parts. Unfortunately at the present time the data are too scanty for a more detailed subdivision of the Slite Group by stromatoporoids.

Besides *Ecclimadictyon astrolaxum* there are some other species common for the Slite and Maasi Beds. *Ecclimadictyon macrotuberculatum* and *Simplexodictyon validum* are more notable. Evidently specimens of the latter species were described by K. Mori (1968) as representatives of *Clathrodictyon* cf. *argutulum* and *Diplostroma yavorskyi*. Both stratigraphical units contain also *Densastroma pexisum* and *Simplexodictyon simplex* of wide stratigraphical range.

One of the characteristic features of the stratigraphical interval considered is very diverse fauna of the representatives of *Ecclimadictyon* and some related genera. The same phenomenon has been observed in many other regions, particularly in the Arctic areas, the Urals, Siberia, Central Asia where the so-called "Wenlockian fauna" of stromatoporoids contains abundantly representatives of *Ecclimadictyon*, *Neobeatricea* and *Actinodictyon*. Obviously the middle Wenlock was one of the ages of nearly cosmopolitic distribution of certain stromatoporoid species. Unfortunately identification of the species of *Ecclimadictyon* and related genera is very difficult and they are of less correlative significance than many other stromatoporoids.

The *Densastroma pexisum* Community

In many parts of the Upper Visby and Slite Beds the most common stromatoporoid species are *Densastroma pexisum* and *Simplexodictyon simplex*. A few specimens of these species occur also in the Högklint Beds. In the Upper Visby Marls these species occur partly together with the representatives of the *Stromatopora impexa* Community (Snäckgardsbaden, Vattenfallet, Kneippbyn, Högklint). In Slite Marls in the western part of Gotland (Westergarn, Klinteby) these species are the only representatives of stromatoporoids. In the Lerberget Marls of Stora Karlsö *D. pexisum* and *Clathrodictyon simplex* have been met together with the specific forms *Ferestromatopora insularis* and *Plumatalinia densa*. It is reasonable to suppose that *Densastroma pexisum* and *Clathrodictyon simplex* inhabited the most deep water marginal areas of stromatoporoid settlement during the whole early Wenlock time. Towards the shore stromatoporoid fauna gradually enriched with more short-range species, while the role of deeper water elements decreased respectively. Consequently, the fauna with *Densastroma pexisum* may be treated as a deeper water equivalent of the shallower water *Stromatopora impexa* - *Vikingia tenuis* - *Ecclimadictyon astrolaxum* succession.

In Podolian sequence *Densastroma pexisum* has been mentioned from the Chercha Beds of the Kitaigorod Stage (Богоявленская, 1976). In the same beds and lower, in the Demsha Beds *Clathrodictyon microstriatellum* occurs, which is very similar and even may be conspecific with *Clathrodictyon simplex*. Presumably the major part of the Kitaigorod Stage roughly coincides with the range of the *Densastroma pexisum* Community and is also ecologically comparable.

The *Labechia conferta* Community

In the East-Baltic area stromatoporoids are insufficiently known from the upper part of the Wenlock (*nassa/ludensis* Zones of the graptolite succession). Hitherto there are no data on their occurrence in the Tagavere Beds (upper Jaagarahu) and very few evidence in the Viita Beds (lower Rootsiküla). In the shallow water sequence of Gotland the stromatoporoid succession is more complete. Here the fauna with *Ecclimadictyon astrolaxum* is directly followed by the *Labechia conferta* Community, which occurs in the Halla Beds. Stromatoporoids of this stratigraphical level mostly occur in coral and reef limestones and are even partly connected with oolitic limestones. *Labechia conferta* is the most common species in the Halla Beds. *Clathrodictyon striatellum* (= *Stelodictyon* Bogoyavlenskaya, 1969), *Clathrodictyon vesiculosum* and *Stromatopora antiqua* are the other species, typical of that part of the sequence.

Although some of the Halla species also occur in the sequence lower (*Ecclimadictyon macrotuberculatum* in the Slite Beds) and higher (*Stelodictyon striatellum* in the Klinteberg Beds at Klinte), as the whole, the *Labechia conferta* Community is comparatively distinct.

It is remarkable that all the most common species of the Halla Beds (*L. conferta, Cl. vesiculosum, S. striatellum*) have been described by H. Nicholson (1886-1891) from the Wenlock Limestone of the Welsh borderland (Dudley, Ironbridge, Much Wenlock, Dormington). Thus the correlation of the Halla Beds and the Wenlock Limestone is well supported by stromatoporoids. More difficult is the question whether the *Labechia conferta* Zone corresponds to the whole extent of the Wenlock Limestone section or only to some part of it. Relying merely upon the scanty stromatoporoid data the first possibility seems more likely as the known stromatoporoid fauna of the Wenlock Limestone looks rather unitary and does not contain typical representatives of neither Slite nor Klinteberg faunas of Gotland.

In Podolian sequence *Labechia conferta* is common in the Muksha Beds (Богоявленская, 1976 and author's data). On the same stratigraphical level I have identified *Stelodictyon striatellum* (loc. Bagoviza).

Consequently, *Labechia conferta* Zone is discernable in different regions of Europe and it roughly coincides with the Halla Beds in Gotland, the Wenlock Limestone in Britain and the Muksha Beds in Podolia.

The *Parallelostroma tenellum* Community

On Gotland the *Labechia conferta* Community is succeeded by those of the *Parallelostroma tenellum*. Taxonomical content and distribution of the fauna with *Parallelostroma tenellum* are rather badly delimited. *P. tenellum* itself is distributed in the middle and upper parts of the Klinteberg Beds and occurs in the outcrops of the middle part of the island. Some other species specific to the Klinteberg Beds (*Plumatalinia balticivaga, Actinostroma botvaldavikense*) have been known by a few specimens from a limited number of localities. Quite a lot of the Klinteberg species pass over into above laying limestones of the Hemse Group. Those are *Syringostromella borealis, Stromatopora venukovi, Parallelostroma typicum, Stromatopora carteri, Clathrodictyon convictum, Ecclimadictyon robustum*, suggesting great affinity of the Klinteberg stromatoporoid fauna to the succeeding Ludlovian ones. True enough, *Stromatopora carteri* is one of the species erected on the basis of the material from the Wenlock Limestone of the Welsh borderland, but exact identification of that species is extremely complicated as very similar forms are distributed from Wenlock to Givet.

The *Araneosustroma stelliparratum* Community

In Estonian sequence *Parallelostroma tenellum* has not been found yet. In the local stromatoporoid succession his position is probably occupied by the *Araneosustroma stelliparratum* Community. The latter species itself, earlier described as *Clathrodictyon ? stelliparratum* is most common in the Kuusnõmme Beds of the Rootsiküla Stage, but a few specimens have also been found from the Paadla Stage (Нестор, 1966). The fauna with *Araneosustroma stelliparratum* is scanty. Besides *A. stelliparratum* it only contains *Ecclinadictyon robustum* and *Densastroma podolicum* of a comparatively wide stratigraphical range.

It seems that the *Araneosustroma stelliparratum* Community is a lateral equivalent of the *Parallelostroma tenellum* Community and it probably inhabited a more restricted, near-shore part of the sea. Such opinion is supported by new data concerning the distribution of stromatoporoids in a section of the Southern part of Novaya Zemlya (Нестор, 1982, in press). There, in the section of peninsula Khatanzei *Parallelostroma tenellum* and *Araneosustroma* ex gr. *stelliparratum* have been found together in the upper part of the Klenov Formation, represented by interlayering lagoonal and normal-marine carbonate deposits.

The *"Pycnodictyon" densum* Community

The *Labechia conferta* and *Parallelostroma tenellum* Community were treated as succeeding shallow water stromatoporoid communities. Their lateral, deeper water analogue may be the *"Pycnodictyon" densum* Community (probably synonym of *Densastroma*), which occurs in the Mulde Marls of Gotland and also passes over into the Hemse Marls. Besides *"Pycnodictyon" densum* *Actinostromella* aff. *vaiverensis* is another common species for Mulde and Hemse Marls. These two fine-reticulate stromatoporoids are most frequent in outcrops of the western part of Gotland, whereas other species are found there in a very few specimens.

In the deeper water succession the *"Pycnodictyon" densum* Community replaces the *Densastroma pexisum* Community stratigraphically. Both have rather wide stratigraphical range corresponding to three or more stromatoporoid zones in the shallow water succession.

The distinction of the fine-reticulate species of *Densastroma pexisum* and *"Pycnodictyon" densum* Community is rather complicated, especially when the material is recrystallized. Therefore in Estonian sequence *"Pycnodictyon" densum* was not distinguished. Probably specimens of this species were earlier linked with the species *Densastroma podolicum.*

Summary

The present paper distinguishes five successive stromatoporoid communities spread in the shallow water sections of the Baltic Silurian Basin, in the stratigraphical interval corresponding to the Wenlock Series by now accepted correlations. In the ascending order they are: *Stromatopora impexa*, *Vikingia tenuis*, *Ecclimadictyon astrolaxum*, *Labechia conferta* and *Parallelostroma tenellum* Communities. However, there is a possibility that the last community already belongs to the lowermost Ludlow. Potentially these communities may serve as a basis for a zonal stromatoporoid standard of the Baltic and adjacent regions. In the same stratigraphical interval in deeper water, marginal areas of the distribution of stromatoporoids two communities - *Densastroma pexisum* and *"Pycnodictyon" densum* are distinguished.

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ПОСЛЕДОВАТЕЛЬНОСТЬ СТРОМАТОПОРАТ В СРЕДНЕМ СИЛУРЕ БАЛТИКИ

Х. Э. Нестор

В мелководных разрезах Балтийского силурийского бассейна в стратиграфическом интервале по принятой в настоящее время корреляции соответствующем венлоку, выделено пять последовательных сообществ строматопорат. Снизу вверх это сообщества *Stromatopora impexa*, *Vikingia tenuis*, *Ecclimadictyon astrolaxum*, *Labechia conferta*, *Parallelostroma tenellum*. Не исключено, что последнее из них имеет уже раннелудловский возраст. Потенциально эти сообщества могут служить основой для зонального стандарта строматопорат в Балтийском и соседних регионах.

В более глубоководных разрезах распространяются сообщества *Densastroma pexisum* и *"Pycnodictyon" densum*, причем первое из них соответствует зонам *S. impexa*, *V. tenuis* и *E. astrolaxum*, вторая - зонам *L. conferta* и *P. tenellum* в мелководной последовательности.

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THE SUCCESSION OF BRACHIOPODS AS A TOOL FOR CORRELATION IN THE SILURIAN OF THE EAST BALTIC

M. Rubel

Fossil taxa can be grouped together in relation to their sequential occurence as observed in studied sections, for instance, into zonal schemes. They may also be arranged into various communities based on their spatial coexistence. When considered separately, these two arrangements represent either purely temporal or purely environmental aspects of stratigraphical study respectively.

It is difficult to define such as time and environment in a strict sense. But according to the main thesis of this paper it is necessary to estimate temporal and environmental factors separately. Moreover, it must be done in a certain order. Thus, if one observes differences in content of fossils from two exposures then it is difficult to say immediately whether the differences are temporal or environmental. But, as soon as dating of the exposures is possible, some paleogeographical conclusions can be achieved, and only then. Because of this the temporal aspect must be ranked first in all kinds of stratigraphical correlations, including ecostratigraphical ones.

Any stratigraphical events in the Baltic Silurian as well as in many other regions may be dated easily relative to existing stratigraphical scales, and the necessity of analysing the different aspects in a astrict order may therefore seem to be puzzling. However, if one wants to improve on the existing scales then it must be done not only through elucidation of temporally controlled successions of taxa as a first step, but also independently of the existing scales.

The Upper Silurian example discussed below shows that only a minor part of the brachiopods forms such a well defined temporal succession that can be used unambiguously in intraregional correlations.

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Material

The distribution of 74 brachiopods was studied in 16 borings located throughout the East Baltic region (see Table 1). Their succession in the borings was also checked by their occurrence in the outcrop area on the Island of Saaremaa. Range charts of the species in each section are stored at the Institute of Geology, Tallinn.

Table 1. Frequency of brachiopod occurrence and washed samples, and stratigraphy in the borings

A - percentage of intervals with brachiopods from the total interval studied.

B - percentage of washed samples from the total number of samples with brachiopods.

C - stratigraphy: D - Downton, L - Ludlow, W - Wenlock.

M - number of identified species or taxa.

Q - studied interval of the boring in meters.

No.	Boring	A	B	C	M	Q
1.	Paadla	80	0	L	4	0.0 - 10.0
2.	Kingissepp	62	7	L+D	11	0.0 - 26.0
3.	Kaugatuma	63	18	L+D	20	0.0 - 71.0
4.	Ohesaare-1	59	0	W+L+D	43	0.0 - 330.0
5.	Kolka-54	48	0	L+D	32	170.0 - 470.0
6.	Kolka-4	37	0	L+D	34	180.0 - 520.0
7.	Ventspils	23	11	L+D	32	270.0 - 640.0
8.	Piltene-1	18	0	W+L+D	28	418.0 - 827.5
9.	Pavilosta	44	5	L+D	34	487.5 - 800.0
10.	Ezere	33	17	L+D	27	925.0 - 1130.0
11.	Pašaltuonis-94	32	0	L	25	1100.0 - 1270.0
12.	Girdžai-50	11	40	L	27	950.0 - 1110.0
13.	Geluva-99	52	0	W+L+D	43	644.0 - 1020.0
14.	Virbalis	37	0	W+L+D	35	705.0 - 1155.0
15.	Kalvarija	57	100	W	25	695.0 - 850.0
16.	Dubovskoje	12	100	D	15	979.0 - 1312.0

Systematic notes

The following list of species or their groups gives the basis for the study. Each taxon has a code number, and those occurring in less than five sections have their code number in brackets. The references quoted give the authority on which the identification of the various species is based.

1 - *Shaleria* sp. sp.: = *Brachyprion ezerensis* - Рыбникова, 1966: 80, Pl.1:9,10; 1967: 193, Pl.21:1,2; = *B. costatula* - Рыбникова, 1966: 85, Pl.2:1-3; 1967: 194, Pl.20:1-3; = *Shaleria* aff. *ornatella* - Bassett & Cocks, 1974: 17; = *S. delicata* - Harper & Boucot, 1978: 161, Pl.34:11-25,29.

(3) - *Rhipidium tenuistriatum*: Bassett & Cocks, 1974: 23, Pl.6:1-4, Pl.7:1.

4 - *Aegiria grayi*: Bassett, 1974: 91, Pl.20:8-15; = *Plectodonta aknistensis* - Рыбникова, 1967: 188, Pl.19:1-2.

5 - *Glassia obovata*: = *G. rotunda* - Рыбникова, 1967: 201, Pl.23: 2; = *G. minuta* - ibid.: 203, Pl.23:3; = *G.* sp. - ibid.: 202, Pl. 23:4.

(7) - *Anastrophia deflexa*: Bassett & Cocks, 1974: 22.

(8) - *Kozlowskiellina deltidialis*: Bassett & Cocks, 1974: 38, Pl. 11:1.

9 - *Atrypa reticularis*: Алихова и др., 1954: 42, Pl.25:3; Bassett % Cocks, 1974: 28, Pl.9:2; = *A. reticularis dzwinogrodensis* - Рыбникова, 1967: 208, Pl.24:4-6; = *A. reticularis* aff. *tajnensis* - ibid.: 209, Pl. 24:7; = *A. dzwinogrodensis* - Рубель, 1970: 37, Pl. 19:1-12, Pl.20:1, 12-21, 23.

10 - *Resserella* sp. sp.: = *Parmorthis elegantula* - Алихова и др., 1954: 35, Pl.22:1,2; = *Resserella concavoconvexa* - Рубель, 1963: 134, Pl.5:1-7; = *R.* cf. *concavoconvexa* - Рыбникова, 1967: 172, Pl.14:5; = *R. canalis* - Walmsley & Boucot, 1971:

497, Pl.97:1,4-7, Pl.98:1,2, Pl.100:4; Bassett & Cocks, 1974: 10; = *R. elegantula* - Walmsley & Boucot, 1971: 499, Pl.91:5, Pl.96:1-4, Pl.17:2,3; Bassett & Cocks, 1974: 10; = *R. basalis* - Walmsley & Boucot, 1971: 501, Pl.91:7-10, Pl.98: 7, Pl. 99:2-6, Pl.100:3,5; Bassett & Cocks, 1974: 10.

11 - *Dicoelosia biloba*: Rubel, 1971: 55, Pl.9:26-31, Pl.10:1-17, non Pl.10:18-22; Bassett & Cocks, 1974: 11; non Рыбникова, 1967: Pl.15:1; = *D. oklahomensis* - ibid.: 175, Pl. 14:7,8; Rubel, 1971: 57, Pl.9:32, Pl.10:23-40.

12 - *Isorthis crassa*: Hurst & Watkins, 1978: 96, Pl.2:27; = *I. parvulus* - Рыбникова, 1967: 180, Pl.16:10, non Pl. 16:7-9; = *I. (Arcualla) crassa* - Walmsley & Boucot, 1975: 80, Pl.7:16-23; = *I. (Protocortezorthis) slitensis* - ibid.: 65, Pl. 3:9-11; = *Levenea muldensis* - ibid.; 92, Pl. 10:1-11.

13 - *Dalejina hybrida*: Bassett & Cocks, 1974; 11; = *Rhipidomelloides hybrida* - Рубель, 1963: 145, Pl.7:7-15; = *R. tripartita* - ibid.: 143, Pl.6:10-13, Pl.7:1-6, = *R.* cf. *hybrida* - Рыбникова, 1967: 176, Pl.15:5-7.

14 - *Cyrtia exporrecta*: Алихова и др., 1954: 38, Pl.23:2; Рыбникова, 1967: 212, Pl. 25:1; Рубель, 1970: 56, Pl. 35:1-11; Bassett & Cocks, 1974: 35; = *C. trapezoidalis* - Рубель, 1970: 57, Pl.36:1-15, Pl.38:1-5.

15 - *Skenidioides lewisii*: Рыбникова, 1967: 169, Pl. 4:1, non Pl.14:2-4; Bassett, 1972: 35, Pl.5:10, Pl. 6:1-12; non Рубель, 1963: 128, Pl. 3:1-10.

(16) - *Plectodonta* sp.

(17) - *Atrypina barrandii*: = *Plectatrypa barrandi* - Алихова и др., 1954: 37, Pl.22:8.

18 - *Clorinda* sp. sp.: = *C. rotunda* - Bassett & Cocks, 1974: 25, Pl.5:7; = *Atrypa ? dormitzeri* - Hede, 1917: 17, Pl. 1:15-19; Bergman, 1980: Fig.2:E.

19 - *Gypidula galeata*: Рубель, 1970: Pl.11:11-14; Bassett & Cocks, 1974: 24, Pl.5:8; = *G. magna* - Рыбникова, 1967: 183, Pl.17:4,5; Рубель, 1970: 21, Pl.11:1-10, Pl. 12:1-14.

20 - *Delthyris elevata*: Рыбникова, 1967: 214, Pl. 25:2,3; Рубель, 1970: 62, Pl.38:6-11; Bassett & Cocks, 1974: 37, Pl.10:6.

(21) - *Striispirifer plicatellus*: Boucot, 1963: 696, Pl.100: 8,14,15; Bassett & Cocks, 1974: 37; = *Hedeina plicatella* - Brunton & Cocks, 1967: 172, Pl.3:1-5; = *H. crispa* - ibid.: 171, Pl.2:28-33; = *Striispirifer* sp. - Рубель, 1970: 61, Pl.40:9, 10; = *Macropleura* sp. - ibid.:61, Pl.40:11; = *Striispirifer crispus* - Bassett & Cocks, 1974: 37; = *S. striolatus* - Bassett & Cocks, 1974: 37.

(22) - *Visbyella visbyensis*: Walmsley et al., 1968: 307, Pl.60: 1-9; Рубель, 1963: 137, Pl.5:8-16; Bassett & Cocks, 1974: 11.

23 - *Strophonella euglypha*: = *S. podolica* - Рыбникова, 1966: 87, Pl.2:9-11; = *S.* cf. *podolica* - Рыбникова, 1967: 194, Pl.21: 3-5; = *Strophoprion euglypha* - Harper & Boucot, 1978: 96, Pl.15:6,7, Pl. 16:1-4,6,7,11.

(25) - *Lanceomyonia* sp.

26 - *Isorthis canaliculata*: Walmsley & Boucot, 1975: 93, Pl. 10: 12-18; Hurst & Watkins, 1978: 95; Bassett & Cocks, 1974: 10; = *Platyorthis ovalis* - Пашкевичюс, 1962: 33, Pl.1,2; = *P.* cf. *ovalis* - Рубель, 1963: 149, Pl.1:1-4; = *Isorthis usari* - ibid.: 150, Pl.7:16-23; = *I. orbicularis ovalis* - Рыбникова, 1967: 178, Pl. 16:4-6; = *I. parvulus* - Рыбникова, 1967: 180, Pl.16:7-9, non.Pl.16: 10; = *Levenea canaliculata* - Walmsley & Boucot, 1975: 93, Pl.10:12-18.

27 - *Dayia navicula*: Рыбникова, 1967: 211, Pl. 24:10,11; Bassett & Cocks, 1974: 31; Рубель, 1977: 217, Pl. 1:8; = *D. bohemica* - ibid.: 215, Pl.3:1-3, Pl.4:1-11.

28 - *Protochonetes minimus*: Bassett & Cocks, 1974: 22; = *Chonetes gotlandicus* - Hede, 1917: 16, Pl.1:14.

(29) - *Strophochonetes cingulatus*: Muir-Wood, 1962: 40, Pl.2: 10;11; Bassett & Cocks, 1974: 21; Bergman, 1980: Fig. 2: F.

30 - *Protochonetes stonishkensis*: = *Strophochonetes stonishkensis* - Рыбникова, 1967: 198, Pl.22:1-3.

31 - *"Brachyprion" kurzemensis*: Рыбникова, 1966: 82, Pl. 1: 11-14; 1967: 194, Pl.22:9-12.

32 - *Microsphaeridiorhynchus nucula*: Bassett & Cocks, 1974: 27; = *"Camarotoechia" nucula* - Рыбникова, 1967: 199, Pl.22:8,9; = *"C" sp.* - Рыбникова, 1967:199.

34 - *Protochonetes piltenensis*: Рыбникова, 1967: 196, Pl.22:4; = *P.* aff. *ludloviensis* - ibid.: 195, Pl.22:5-7.

35 - *Homoeospira baylei*: Рубель, 1970: 43, Pl.24:12,14, Pl. 34: 1-20; Bassett & Cocks, 1974: 33; = *Rhynchospirina baylei* - Рыбникова, 1967: 217, Pl.25:13-15; = *Homoeospira* cf. *bouchardi* - Рубель, 1970: 45, Pl.23:7-10, Pl.34:21, Pl.24:13, 15-19.

36 - *Atrypoidea prunum*: Copper, 1977: 21, Pl. 3:5-9, Pl.5:6-10; = *Lissatrypa* sp. - Алихова и др., 1954: 42, Pl.26:1-2; = *L. prunum* - Рыбникова, 1967: 208, Pl.24:2, 3; = *Atrypella prunum* - Рубель, 1970: 40, Pl.22:1-15, Pl.23:1-6; = *Atrypoidea saaremaaensis* - Copper, 1977: 23, Pl.5:1-5.

37 - *Delthyris magna*: Рубель, 1970: 63, Pl.38:12-14; = *D. pyramidalis* - Рыбникова, 1967: 213, Pl.25:6-10.

38 - *Shaleria "dzwinogrodensis"*: = *Brachyprion dzwinogrodensis* - Рыбникова, 1966; 83, Pl.2:4-8; 1967: 194, Pl.20: 4-8.

(39) - *Parastrophinella* sp.

40 - *Morinorhynchus orbignyi*: = *Schellwienella* sp. - Рыбникова, 1966: 88, Pl.1:7,8; 1967: 195, Pl.21:6,7; = *Morinorhynchus crispus* - Bassett & Cocks, 1974: 20, Pl. 4: 1-8; *M. adnatus* - Bassett & Cocks, 1974: 21, Pl.4:9-12.

(41) - *Craniidae*

(42) - *Shagamella minor*: = *S. ludloviensis* - Boucot & Harper, 1968: 168, Pl.29:4-12; = *S.* cf. *ludloviensis* - Bassett 1977: 164, Pl.43:26-29.

(43) - *Eomartiniops ludloviensis*: Рыбникова, 1967: 215, Pl.25:11,12.

44 - *Leptaena* sp. sp.: = *L. depressa* - Bassett & Cocks, 1974: 14; = *Rugoleptaena venzavensis* - Рыбникова, 1966: 76, Pl.1:1-3; = *Leptaena altera* - Рыбникова, 1966: 78, Pl.1:4-6; = *Leptagonia venzavensis* - Рыбникова, 1967: 192, Pl.18:1-3; *L. altera* - ibid.: 193, Pl.18:4-6; = *Leptaena rhomboidalis* - Bassett & Cocks, 1974: 14, Pl.2:7-8.

45 - *Eospirifer radiatus*: Алихова и др., 1954: 38, Pl.23:1; Рыбникова, 1967: 213, Pl.25:4,5; Рубель, 1970: 59, Pl.35:12-18; Bassett & Cocks, 1974: 35.

46 - *Lingulidae*

48 - *Howelella* sp. sp.: = *H. elegans* - Рубель, 1970: 64, Pl.39:18-24, Pl.40:12; Bassett & Cocks, 1974: 38, Pl.10:5; = *H. nucula* - Рубель, 1970: 65, Pl.39:13-17; = *H. cuneata* - ibid.: 66, Pl.39:1-12; = *H. angulata* - ibid.: 68, Pl.40: 1-5; = *H.* cf. *subinsignis* - Bassett & Cocks, 1974: 38.

(49) - *Sphaerirhynchia wilsoni*: Schmidt, 1954: Abb.6.

(50) - *Stegerhynchus diodontus*: Рубель, Розман, 1977: 227, Pl. 7: 7-10, Pl.8,9, Pl.10:1; = *Ferganella diodonta* - Bassett & Cocks, 1974: 26, Pl.8:2.

51 - Pentameridae gen. et sp. indet.

52 - *Orbiculoidea* sp.

(54) - *Whitfieldella* sp.: Bassett & Cocks, 1974: 34; = *W. upsilon* - Rubel, 1970: 50, Pl.30:18-27, Pl.31, Pl.32:18,19.

55 - *Craniops* sp. sp.

(56) - *Coelospira pusilla*: Bassett & Cocks, 1974: 32, Pl.9:4; = *C. baltica* - Рыбникова, 1967: 209, Pl.24:8-9.

58 - *Didymothyris didyma*: Рубель, Модзалевская, 1967: 239, Pl.1:1-13, Pl.3:1-20; Рубель, 1970: 52, Pl.27, Pl.28: 11-15, Pl.30:1-17; = *D. biohermica* - Рубель,

Модзалевская, 1967: 242, Pl.2:11-20; Рубель, 1970: 54, Pl.28: 1-10; = *D. katriensis* - Рубель, Модзалевская, 1967: 243, Pl.1:14-17, Pl.2: 1-10; Рубель, 1970: 54, Pl.29: 1-17.

(61) - *Stegerhynchus pseudobidentatus*: Рубель, Розман, 1977: 230, Pl.10:2-7; = *Camarotoechia (?) pseudobidentatus* - Рыбникова, 1967: 200, Pl.23:1.

(62) - *Protochonetes striatellus*: Muir-Wood, 1962: 50, Pl.3: 6,7, Pl.8:1,2; Böger, 1968: Figs 1-6, 9-11; Bassett & Cocks, 1974: 22.

63 - *Salopina conservatrix*: Walmsley et al., 1969: 505, Pl. 77:15-22, Pl.78:1-11; Bassett & Cocks, 1974: 9.

(64) - *Boucotinskia sulcata*: Brunton & Cocks, 1967: 180; Bassett & Cocks, 1974: 38, Pl.11:2; = *Hedeina crispa* - Boucot, 1957: 324, Pl.2:9,10.

66 - *Septatrypa subaequalis*: Bassett, 1979: 202, Figs 63-64; = *S. secreta* - Рыбникова, 1967: 205, Pl.23:7,8.

(68) - *Resserella sawddensis*: = *R.* cf. *sabrinae* - Bassett, 1972: Pl.11:11, 13, 14; = *R. sabrinae sawddensis* - Hurst, 1975: 323, Pl.2:12-16.

(69) - *Protozeuga bicarinata*: Bassett & Cocks, 1974: 32, Pl.9:3; Рубель, 1977: 213, Pl.2:1-6; = *P. carinata* - ibid. :214, Pl.2:7-9.

(71) - *Pholidostrophia (Mesopholidostrophia) laevigata*: Bassett, 1977: 155, Pl.42-12.

(76) - *Nucleospira pisum*: Bassett & Cocks, 1974: 35.

(80) - *Eoplectodonta* sp. sp.: = *Sowerbyella transversalis* var. *lata* - Алихова и др., 1954: 36, Pl.22:6,7; = *Eoplectodonta transversalis* - Bassett & Cocks, 1974: 13; = *E. duvalii* - ibid.: 13.

(87) - *Coolinia* sp.

(88) - *Conchidium biloculare*: Bassett & Cocks, 1974: 24.

(89) - *Brachyprion* (*Protomegastrophia*) *semiglobosa*: = *B.* (*P.*) cf. *semiglobosa* - Harper & Boucot, 1978: Pl.38:3-8; = *B.* (*P.*) sp. - ibid.: Pl.37:1-11, Pl.38:9.

(94) - *Leptostrophia filosa*: Bassett & Cocks, 1974: 15.

(95) - *Plagiorhyncha depressa*: = *Septatrypa* (?) *subanaloga* - Рыбникова, 1967: 206, Pl. 23:9; = *Plagiorhyncha cordata* - Bassett & Cocks, 1974: 28; Bergman, 1980: Fig. 2:A.

(97) - *Leangella* sp. sp.: = *L. scissa* - Рыбникова, 1967: 186, Pl. 18:7-10; = *L. segmentum* - Bassett & Cocks, 1974: 13.

(99) - *Cyrtia laevis*: Рубель, 1970: 58, Pl.37:1-10.

(100) - *Ptychopleurella* sp.

(101) - *Rhynchotreta cuneata*: Bassett & Cocks, 1974: 25; Рубель, Розман, 1977: 214, Pl. 1:1-3; = *R. gracilis* - ibid.: 216, Pl.2:1-4, Pl.3:1-6.

(102) - *Estonirhynchia estonica*: = *Sphaerirhynchia* (*Estonirhynchia*) *estonica* - Schmidt, 1954: 236, Fig. 1-5,7,9-12.

(104) - *Stegerhynchus borealis*: Рубель, Розман, 1977: 222, Pl.6:4,5; = *Ferganella borealis* - Bassett & Cocks, 1974: 26; = *Stegerhynchus estonicus* - Рубель, Розман, 1977: 220, Pl. 4:7-10, Pl.5; Pl.6:1-3, Pl.7:1-6.

(105) - *Antirhynchonella linguifera*: = *A.* cf. *linguifera* - Рубель, 1970: 25, Pl.12:15-18.

(106) - *Janius barrandi*: Bassett & Cocks, 1974: 36, Pl.10:3-4; = *J. schmidti* - Boucot, 1963: 699, Pl.101:1-6; = *Howelella cuniculi* - Рубель, 1970: 67, Pl.40:6-8.

(107) - *Meristina obtusa*: = *Meristella (?) podolica* - Алихова и др., 1954: 39, Pl.23:3; = *Meristina tumida* - Рубель, 1970: 47, Pl.26:1-5,11, non Pl.26:6-10: Bassett & Cocks, 1974: 34, Pl.9:10.

(108) - *Ancillotoechia bidentata*: Bassett & Cocks, 1974: 27; Рубель, Розман, 1977: 234, Pl.11:4-8.

(109) - *Collarothyris canaliculata*: Рубель, Модзалевская, 1967: 245, Pl.4:1-18; = *Didy-*

mothyris ? collaris - Рубель, 1970: 55, Pl.29:18-22, Pl.33:14-17.
(110) - *Quadrithyris sinuata*: Рубель, 1970: 69, Pl.23:11-14.

Temporal aspect

The correlative value of fossils is determined by their rate of evolution and environmental limitations of distribution. In order to estimate the correlative value of species or any taxa it is necessary to know their total range and occurrence in the sections studied (McCammon, 1970).

There are two main approaches to estimate the total range of taxa: (1) relative to existing stratigraphical scales, and (2) with respect to their mutual vertical position (Blank, 1979). The latter method is used here because such a succession of biostratigraphical events can be plotted before any kind of correlations are made, and therefore the succession can be used for the correlation of sections.

In theory, species intervals that are successive (i.e. not overlapping) in the same order in all sections studied, and successions of which can be arranged mutually without contradictions, form the standard (Rubel, 1978) or the most likely sequence (cf. Hay, 1972). The standard for the Upper Silurian brachiopods, based on the 16 Baltic sections, appears as follows:

					$\underline{E}$	27	36	9	13	$\underline{E}$	20	32	40	35	34	26	$\underline{31}$	$\underline{37}$	$\underline{38}$
				$\underline{D}$	45	27	36	9	13	19	20	32	40	35	34	$\underline{26}$	E		
			$\underline{C}$	12	45	27	36	9	13	19	20	32	40	35	$\underline{34}$	D			
		$\underline{B}$	15	12	45	27	36	9	13	19	20	32	40	$\underline{35}$	C				
	$\underline{A}$	14	15	12	45	27	36	9	13	$\underline{19}$	$\underline{20}$	$\underline{32}$	$\underline{40}$	B					
	66	14	15	12	45	27	36	9	13		A								
N_i:	6	8	9	12	8	11	12	14	12	9	12	14	10	13	13	14	6	13	11

Each row of the standard represents a unique association of the species, that is a time interval of their potential or actual coexistence. The relative total range of each species is determined by the number of rows in which each is written. Thus, the species 27, 36, 9, 13 occupy the whole time interval considered. At the same time the first and last occurrences of other species according to the standard form contacts between their immediately succeeding total ranges. Such datum planes are denoted here by the letters A to E. The notation N_i denotes the number of sections in which a given species was found. The species included in the standard have the best correlative value for the correlation of the Upper Silurian sections studied in that they allow correlations to be unambiguous. They may be taken as a pure time scale for the same sections in the sense of Leibniz (Rubel, in press).

Taxa 1, 44, 46, 48, 51, 52, 55 are not included in the standard because they are as yet not studied in detail and because of this their ranges are equal to the considered time interval, or even longer. The species occurring in five or less sections were not taken into consideration because of their poorly known distribution with respect to the studied sections.

The remaining species constitute the so-called contradictory species and their relationships to the species in the standard include some information relating to the environmental factors (see below).

Correlation

The use of the standard for stratigraphical correlation lies in the plotting of the datum planes A to E in every section studied according to the first and last occurrences of the standard species (text-Fig. 1 and Table 2).

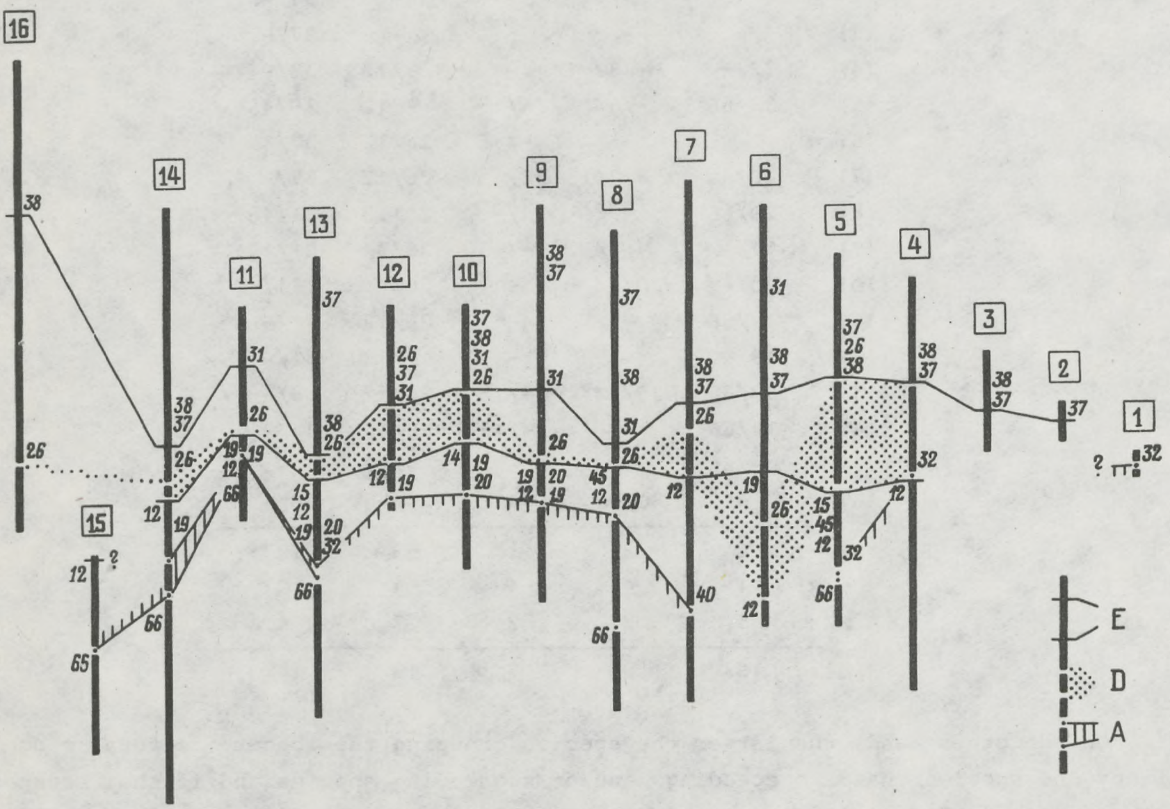

Fig. 1. Correlation of sections (1) to (16) by the datum planes A, D and E. The code numbers of species on the right side of the columns denote their appearance, and those on the left sides indicate their disappearance.

From these datum planes only three that can be traced most easily are drawn in text-Fig. 2. The intervals for the datum planes B and C, both dated by only two species (respectively, 35/14 and 34/15) and often overlapped by the intervals of the preceeding or succeeding datum planes, have little independent correlative value.

Of the three traceable datum planes A, D and E, D has the most restricted interval in the sections. Because of this only plane D was chosen for further analysis. It is dated by occurrences of two species: 12 = *Isorthis crassa* and 26 = *I. canaliculata*, both occurring also in sections on the Island of Gotland (see: Hurst and Watkins, 1978: Fig. 5). These successive species were considered by Hurst and Watkins (1978) as biological species with a complicated intraspecific structure. The use of the concept of biological species for the classification of fossil brachiopods often leads to many complications. However, it is accepted here and used for groups of brachiopods that can be differentiated clearly on the basis of morphology. Such an approach has at least one obvious advantage: it leads to an increase in the number of common species in sections and, therefore, to an increase of unconditional prerequisites for any kind of stratigraphical correlation.

Table 2. Species used for extraction of the datum planes A to E in the sections (1) to (16), and the traceability of the datum planes (lower part of table)

	A	B	C	D	E
(1)	32/-	-	-	-	-
(2)	-	-	-	-	37/-
(3)	-	-	-	-	37/-
(4)	32/-	-/14	-	-/12	37/-
(5)	32/66	-/14	34/15	-/12	38/45
(6)	-	-	-/15	26/12	37/19
(7)	40/-	-/14	34/15	26/12	37/-
(8)	20/66	-	34/-	26/12	31/45
(9)	19/-	-/14	-/15	26/12	31/19
(10)	20/-	30/14	-	26/-	38,31/-
(11)	19/66	-	-	26/12	31/-
(12)	19/-	-	-	-/12	31/-
(13)	32/66	35/14	-/15	26/12	38/-
(14)	19/66	-	-/15	26/12	37/-
(15)	-/66	-	-	-/12	-
(16)	-	30/-	-	26/-	38/-
x/-:	6	2	1	2	10
-/x:	1	4	4	4	0
x/x:	5	2	2	7	4
Σ:	12	8	7	13	14

On the other hand, the larger the species grouping the longer its total range. But if any one species has a preceeding and/or succeeding species and if their respective appearances (and disappearances) do not coincide in time (cf. Shaw, 1964; Hay, 1972) then the possibilities of plotting the succession by means of them does not depend on their duration.

The requirement of having a preceeding and succeeding species restricted the use of the standard here, so that only its medial part works sufficiently well. Further refinement of the standard for Baltic Silurian brachiopods can be extended only into older beds, but there are no obstacles for its extension in both directions by means of corresponding data from other regions.

Environmental aspect

The position of species in the standard expresses their purely temporal relationships according to their known total ranges in the area studied. But it is usually impossible to discover such a position unambiguously for all species because all relationships needed are not yet examined in the sections, or sometimes the actual distribution of species makes it impossible (see Rubel, 1978). The latter case is related to the environmental limitations of species distribution and is illustrated below.

Such a distribution is assumed for two contradictory species: 58 = *Didymothyris didyma* and 27 = *Dayia navicula*. According to the known relationships, species 58 must preceed species 27 and coexist at least with species 19, 20, 32, 40 and 35. It is impossible to carry out these requirements in the standard. There are two ways to eliminate the contradictions: to exclude species 27 from the standard or to exclude the use of species 58. As species 27 occurs in many more sections than 58, then the latter was excluded from further study. Similar exclusions were made with species 10, 11, 18, 4, 5, 23, 28, 30 and 63 too.

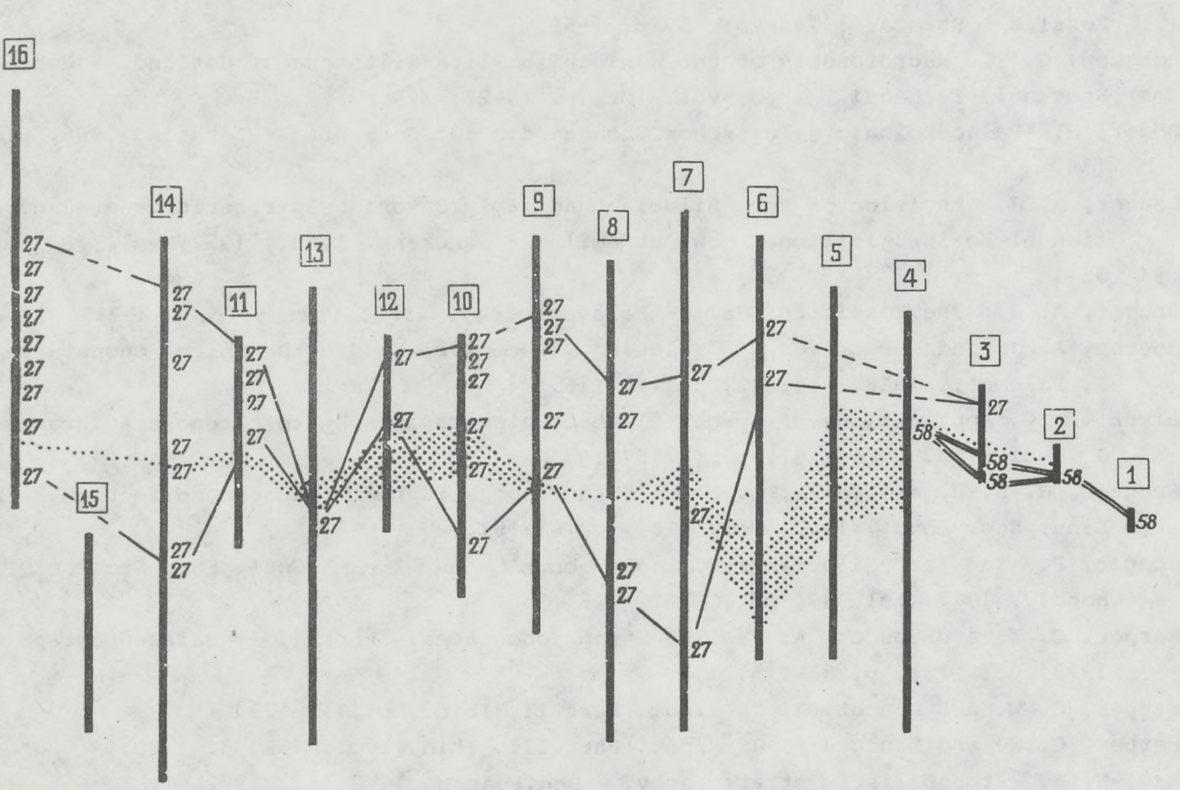

Fig. 2. Occurrence of the species 27 and 58.

Text-Fig. 2 explains the possible reason for the contradiction between species 58 and 27: due to their quite different ecological positions that probably reflect only short transgressive conditions in sections (6) and (3), neither temporal nor environmental coexistence of these species can be deduced in any sections (cf. Rubel, 1978, Text-Fig. 2).

Therefore, the contradictions that arose during the composing of the standard may already indicate relationships that can be interpreted in terms of environmental factors (ecology, biogeography, migrational rates, etc.). But, as there are many reasons for the contradictions then it is not easy to say for every case which of them is operating.

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ПОСЛЕДОВАТЕЛЬНОСТЬ БРАХИОПОД КАК ИНСТРУМЕНТ КОРРЕЛЯЦИИ СИЛУРА ПРИБАЛТИКИ

М. Рубель

В целях оценки значения брахиопод при корреляции удаленных и разнофациальных разрезов было изучено распределение 77 видов верхнесилурийских брахиопод в разрезах 14 скважин Прибалтики. Их корреляционная значимость выводилась, с одной стороны, оценкой относительной длительности полных интервалов существования установленных таксонов и, с другой, встречаемостью таксонов по изученным разрезам. Если в первом случае мы получим чисто временные соотношения между таксонами, то во втором определенную роль играло наличие подходящей среды для тех или других брахиопод.

Полные интервалы существования оценивались на основе взаимоположений таксонов в частных разрезах. Оказалось, что из всех рассмотренных только полные интервалы 19 широкораспространенных видов могут быть упорядочены так, чтобы их последовательность не дала при корреляции изученных разрезов противоречивых результатов.

На основе таких корреляций можно показать, что многие, в том числе и широкораспространенные брахиоподы, имеют в удаленных разрезах сдвинутые во времени неполные интервалы существования. В то же время именно по непримененным при корреляции видам легче всего установить характерные для тех или других фаций сообщества брахиопод.

УДК 565.393:551.733.3(474)

WENLOCK AND LATE SILURIAN TRILOBITE ASSOCIATIONS OF THE EAST BALTIC AREA AND THEIR STRATIGRAPHICAL VALUE

Reet Männil

So far little attention has been paid to Silurian facies-controlled trilobite associations. Among the few exceptions are the papers on British Wenlock trilobite associations by A. T. Thomas (1979), trilobite ecology in the Ludlow of the Welsh Borderland by D. G. Mikulic and R. Watkins (1981) and the trilobite associations of the Thornton Reef in Illinois and in Paleozoic carbonate buildups by D. G. Mikulic (1976, 1980). A comparison of the trilobite associations presented in these papers with the East Baltic Silurian ones shows a taxonomic and morphologic similarity between those from related lithofacies of different regions, and evidences of their value in stratigraphic correlations.

Generally trilobites are of wide environmental range occurring from basinal graptolite mudstones up to the shoal biohermal limestones. At the same time their species are highly sensitive to facial conditions and their diversity and abundance remarkably differ in different environmental zones. The studied East Baltic Silurian trilobites come predominantly from the subsurface. In accordance with this the distribution pattern, demonstrated herein, is based mainly on the beds relatively rich in trilobites.

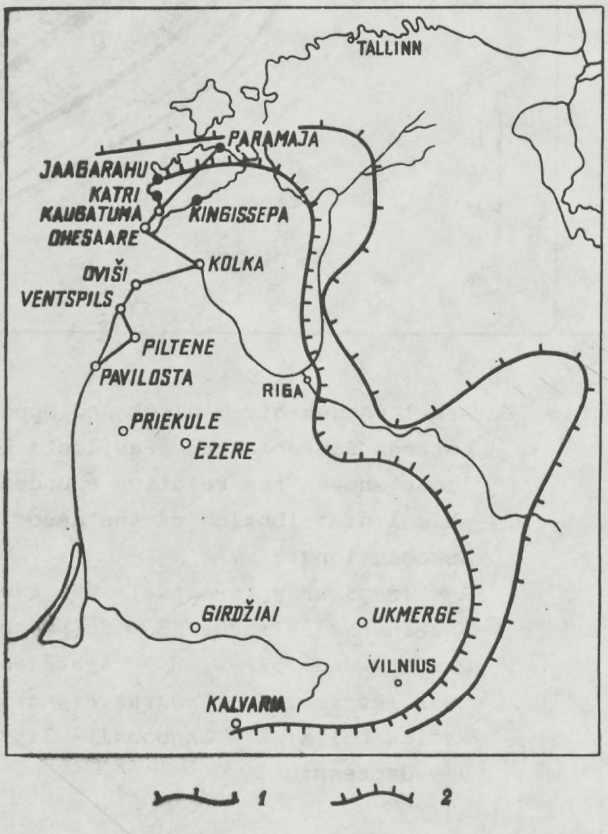

Fig. 1
Outcrops (dots) and borings (circles) studied.
1 - limit of the present distribution of the middle Wenlock deposits; 2 - contour of complete thickness of corresponding rocks.

This paper presents an example of the environmental control on trilobite distribution in the Wenlock and Late Silurian on the basis of a cross-section from Paramaja cliff to Pavilosta boring (Figs 1, 2). In the section (Fig. 2) mainly the areal distribution of the species is shown (the vertical ranges are given approximately) as well as the vertical and areal distribution of the twelve recognized associations. This model is based on the following facies belts (according to Nestor and Einasto, 1977): lagoon-littoral (I), shoal (II), open shelf (III), slope (IV) and depression (V). Facial interpretation of studied sections was performed by R. Einasto, thicknesses of stages and series are given according to Kaljo et al. (Кальо, 1970), Gailite et al. (Гайлите и др., 1967), Sarv (Сарв, 1977), etc.

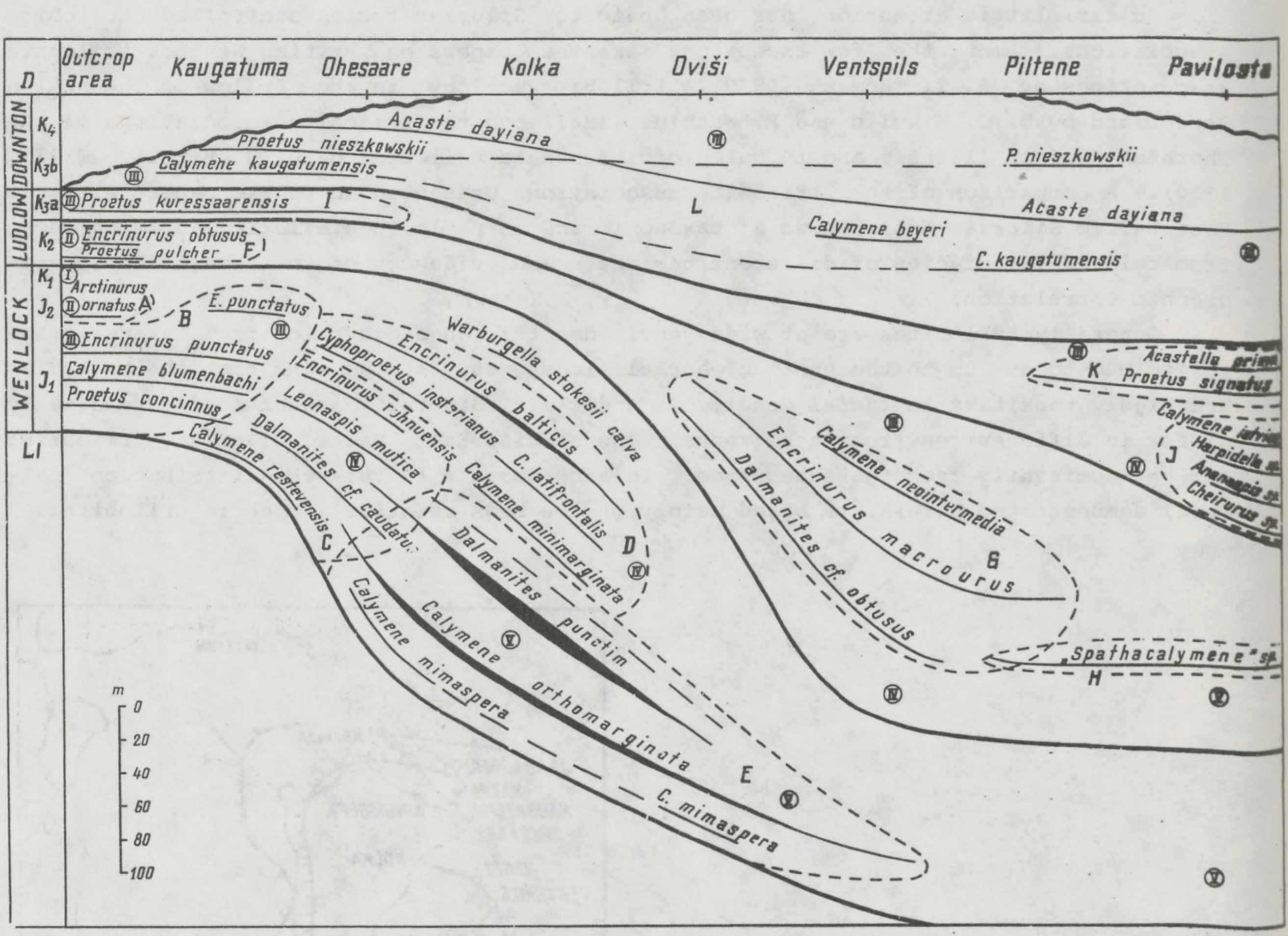

Fig. 2. Areal ranges of Wenlock and Upper Silurian trilobite species and associations between Saaremaa and Pavilosta boring (West Latvia). The thickness of range lines shows the relative abundance of the species; the areal and stratigraphical distribution of the associations is contoured by dotted line.

Associations:

A - *Arctinurus ornatus;* B - *Encrinurus punctatus:* C - *Leonaspis mutica:* D - *Encrinurus balticus;* E - *Calymene orthomarginata;* F - *Proetus pulcher;* G - *Encrinurus macrourus;* H - *"Spathacalymene",* I - *Proetus kuressaarensis;* J - *Calymene latvica;* K - *Proetus signatus;* L - *Acaste dayiana.*

Facies belts: I - lagoonal - littoral, II shoal, III - open shelf, IV - slope, V - depression.

Associations

Wenlock. In the East Baltic Wenlock five trilobite associations have been recognized. They are treated in more detail in a forthcoming paper (Männil, 1982). From nearshore area in the direction of the open sea the associations are arranged as follows:

A. *Arctinurus ornatus* association occurs in nearshore reefs. It is of a rather restricted distribution and is nearly monospecific, as the nominal species (sporadically abundant) is accompanied only by rare specimens of *Calymene*.

B. *Encrinurus punctatus* association occurs in light-grey calcareous marls of the transitional area from the open shelf to the slope. It consists of *E. punctatus*, *Calymene blumenbachi*, *Proetus concinnus osiliensis*, *Bumastus* cf. *barriensis* and *Harpidella elegantula* and is best developed in the type area of the Jaani Formation (Paramaja cliff) on the northern coast of Saaremaa. This association is comparable with *Proetus/Warburgella* association in British Wenlock (Thomas, 1979).

C. *Leonaspis mutica* association is restricted to the grey marls of the slope facies belt. It is represented by *Leonaspis mutica*, *Calymene restevensis* (= *C. mimaspera livonica* Männil, 1977), *Dalmanites* cf. *caudatus* and *Encrinurus ruhnuensis*. It must be noted that in all studied sections *C. restevensis* partially precedes other species of this association, being one of the rare Early Wenlock trilobites in the East Baltic. As the association closely overlaps with lateral ones its recognition is often rather difficult.

D. *Encrinurus balticus* association is developed in greenish-grey marls of the slope facies belt. The most common species are *E. balticus*, *Cyphoproetus insterianus* and *C. latifrontalis*, accompanied by rare specimens of *Calymene minimarginata* and *Dalmanites* sp.

E. *Calymene orthomarginata* association is the most offshore one, occurring in dark-grey mudstones of the inner part of the depression facies area, often containing fragments of graptolite rhabdosoms. This association, low in diversity, consists of abundant *Dalmanites punctim*, *C. orthomarginata* and *Calymene mimaspera* (which appears by analogy with *Calymene restevensis* already in the Early Wenlock). Towards the central part of the basin the amount of other species decreases and finally the association becomes monospecific, being represented only by nominal species (in Ventspils boring).

This association is comparable with *Dalmanites/Raphiophorus* association in British Wenlock (Thomas, 1979). In the latter the calymenids of nodulosa-type (= *Tapinocalymene* Siveter, 1980) are of the same morphotype as the most deep-water calymenids of the East Baltic, having long preglabellar area, wide and long proximal part of fixed cheek relative to the glabella, etc. (*C. latigenata*, *C. orthomarginata*, *"Spathacalymene"* sp.).

Generally the East Baltic Wenlock trilobites are quite closely comparable with contemporaneous British trilobites, however their diversity is much lower. Such genera as *Trimerus*, *Schizoproetus*, *Decoroproetus*, *Raphiophorus*, *Radnoria* and the representatives of the *Delops/Miraspis* association have never been recorded from the East Baltic. This is evidently caused by more homogenous environmental conditions and by restricted collections from deep-water deposits in the East Baltic.

Ludlow. In the East Baltic Ludlow the following six trilobite associations are recognized.

F. *Proetus pulcher* association. It occurs in the shoal limestones of the Paadla Formation, is low in diversity and abundance. *Proetus pulcher* is the dominant, associated with rare specimens of *Encrinurus obtusus* and *Calymene* sp.

G. *Encrinurus macrourus* association is developed in the grey marls of Dubysa and Engure Formations of the slope facies belt of the Paadla stage and consists mainly of

E. macrourus, Dalmanites cf. *obtusus* and *Calymene neointermedia*.

H. "*Spathacalymene*" association. It is the most offshore association in Ludlow, occurring in the dark-grey marls of the inner part of the depression facies belt. It is mainly monospecific, as besides the nominal species only rare remains of *Dalmanites* sp. and *Calymene* cf. *neointermedia* have been found.

I. *Proetus kuressaarensis* association is low in diversity, occurs in clayey nodular limestones of the open shelf of the outcrop area of the Kuressaare Formation (Kudjape Member). It consists mainly of two species: *P. kuressaarensis* and *Calymene flabellata*.

J. *Calymene latvica* association occurs in greenish-grey marls of the slope facies belt of the Pagegiai Formation of the Kuressaare Stage. It is highly diverse and abundant. The association is represented by rather deep-water, mainly undescribed species: *Cheirurus* sp., *Ananaspis* sp., *Harpidella* sp., *Coniproetus* sp., *Calymene latvica, Proetus* cf. *signatus, Acastella* cf. *prima*, etc.

K. *Proetus signatus* association occurs in grey calcareous marls of the transitional area between the open shelf and slope facies belt of the same formation. The nominal species is dominant, associated with *Acastella prima, Encrinurus* sp., *Harpidella* sp. and *Calymene* sp.

On the whole, the offshore Ludlow trilobite associations of the East Baltic are taxonomically (by the presence of *Dalmanites* cf. *obtusus, Harpidella* sp., *Leonaspis* sp., *Ananaspis* sp.) quite similar to Ludlow association of mudstone and laminated shale facies in Welsh Borderland (Mikulic and Watkins, 1981).

Downton. In the studied area Downton deposits belong mainly to the open shelf belt. In accordance with this, their trilobite fauna is rather monotonous and represented mainly by species of genera *Calymene, Proetus* and *Acaste*. The most characteristic species with wide horizontal distribution are *Acaste dayiana* and *Proetus nieszkowskii* (obviously occurring both in the Kaugatuma and the Ohesaare Stages). Thus, the whole Downton trilobite fauna has been trated as *Acaste dayiana* association (L.). Additional trilobites are of somewhat more restricted lateral and vertical ranges, among them the relatively common *Calymene kaugatumensis* and *C. schmidti* (Kaugatuma Stage) and *Calymene conspicua* (Ohesaare Stage).

Correlational comments

A number of trilobite species and their associations, distinguished in the East Baltic Wenlock and Late Silurian, are known from similar lithofacies in other regions, yielding important data for correlation.

The most offshore Wenlock associations of *Calymene orthomarginata* and *Encrinurus balticus* are probably endemic. Outside the East Baltic their members are so far known only from erratic boulders in the territory of the German Democratic Republic (Schrank, 1970, 1972). More onshore species are of wider distribution. Thus, *Calymene restevensis*, which marks the base of the Wenlock of the East Baltic, has been described from the Restevo Beds of Podolia (Балашова, 1975). The *Encrinurus punctatus* association is of the widest geographical distribution. Most species of this association occur in Högklint, Mulde and Slite Beds of Gotland (Lindström, 1885; Hede, 1960; Tripp, 1962; Bruton, Jaanusson, Owens, Siveter, Tripp, 1979), in Wenlock of England: *Bumastus barriensis* in Woolhope and Barr Limestones (Thomas, 1978); *Proetus concinnus* in Woolhope Limestone, Coalbrookdale Formation, Much Wenlock Limestone and Lower Elton Beds (Thomas, 1978); *Calymene blumenbachi* in Much Wenlock Limestone (Shirley, 1933) and in Woolhope Limestone Formation (*C. blumenbachi* subsp. n., Sivester, 1980, pl. 100, Figs 12, 14, 16). It should be noted that the latter subspecies is probably identical with morpha of *C. blumenbachi* from Paramaja cliff. All the species of the *E. punctatus* association, known from the East Baltic, have been also found in the upper part of Restevo Beds, Demshin

Beds and lower part of the Vrublevets Beds of Podolia (Балашова, 1975; L. Konstantinenko, personal communication).

Arctinurus ornatus, occurring in reefs of the Jaagurahu Stage, has been found in Tofta and Slite Beds of Gotland (Hede, 1960). The slope facies marls of the upper part of the same stage have yielded *Warburgella stokesii calva*, which is closely related to *W. stokesii* from the topmost Coalbrookdale Formation and Much Wenlock Limestone of England as well as from Halla unit "b" of Gotland (Thomas, 1978).

A representative of the uncommon genus "*Spathacalymene*" occurs in the Ludlow deep-water deposits (*scanicus* and *tumescens* graptolite Zones) in South-West Latvian cores. Up to the present this genus is known only from Upper Mielnik Beds of North-East Poland. "*Spathacalymene*" *brevis*, the species most similar to the Latvian one occurs in the *Cucullograptus aversus* and *Saetograptus leintwardinensis* Zones (Tomczykowa, 1970).

In onshore direction the "*Spathacalymene*" range partially coincides with the range of the *Encrinurus macrourus* association, which extends from the *scanicus* Zone almost up to the *lauensis-ctenophora* ostracode Zone. Members of this association have been long known from the Hemse Marls of Gotland (Lindström, 1885; Schmidt, 1859). It should be noted that *Dalmanites* cf. *obtusus*, which is rather frequent in Latvian borings but occurring mainly as indeterminate fragments, seems to be closely related to (if not identical with) *Dalmanites myops*, the most abundant species in mudstone, laminated shale and bioturbated siltstone facies of the Middle and Upper Elton and Lower Bringewood Beds in the Welsh Borderland. There is also *Calymene neointermedia* in the Upper Leintwardine Beds of the same region (Mikulic & Watkins, 1981). *Encrinurus macrourus* is known also from the Mielnik Beds of Poland (Alberti et al., 1982) and probably from Sokol Beds of Podolia (Konstantinenko, personal communication).

Encrinurus obtusus from the shoal facies of the Paadla Formation is known from the Hemse and Eke Beds of Gotland (Hede, 1960; Schrank, 1972).

The species of the most deep-water, *Calymene latvica* association of the Kuressaare Stage has obviously not been found in other areas so far. The main members of the subsequent *P. signatus* association - *P. signatus* and *Acastella prima* are of wider geographical distribution. They occur outside the East Baltic also in Burgsvik, Hamra and Sundre Beds of Gotland and Upper Sieldce and Lower Podlasie Beds (*formosus* and *ultimus* graptolite Zones) of Poland (Tomczykowa, 1962; Alberti et al., 1982), and apparently also in Grintshuk of Podolia.

The trilobites from the outcrop area of the Kuressaare Stage show generally low abundance and are evidently of more restricted distribution. However, *P. kuressaarensis* has been founded from Grintshuk Beds of Podolia and a species closely related to it (*P. pulcher* subsp. sensu Schrank, 1972) from the Sundre Beds of Gotland (according to H. Alberti's unpublished data).

In Downton of the East Baltic *Acaste dayiana* is of maximum areal and vertical distribution. This species associated with *Calymene beyeri* (s.l.) characterizes Lower Podlasie and Upper Rzepin Beds in Poland (Tomczykowa & Witwicka, 1974; Alberti et al., 1982), and together with *Proetus scalicus* the Skala Stage in Podolia (Балашова, 1968). The latter is closely related to another typical species of the East Baltic Downton - *Proetus nieszkowskii*.

From the above follows that trilobite species occurring in similar lithofacies have quite coeval stratigraphical ranges in rather distant sections. Trilobites occurring in the open shelf and slope facies belts are of widest geographical distribution, thus being the most valuable for stratigraphical correlations. These are mainly the representatives of the *Encrinurus punctatus*, *E. macrourus* and *Proetus signatus* associations.

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ВЕНЛОКСКИЕ И ВЕРХНЕСИЛУРИЙСКИЕ АССОЦИАЦИИ ТРИЛОБИТОВ ПРИБАЛТИКИ

Рээт Мяннил

Трилобиты в целом отличаются широкой фациальной амплитудой, но отдельные их виды приурочены к определенным литофациям, где образуют более или менее четкие ассоциации. В венлоке и верхнем силуре Прибалтики выделены двенадцать трилобитовых ассоциаций, замещающих друг друга в пространстве и времени /рис. 2/.

За пределами Прибалтики многие виды и некоторые ассоциации встречаются в аналогичных литофациях того же стратиграфического интервала. Наиболее широко распространены представители открытошельфовых и склоновых ассоциаций, прежде всего ассоциация *Encrinurus punctatus* в венлоке и ассоциации *E. macrourus* и *Proetus signatus* в лудлове.

УДК 565.33:551.733(474+486.92)

ON OSTRACODE ZONATION OF THE EAST BALTIC UPPER SILURIAN

L. Sarv

Ostracodes are of great significance in the classification and correlation of the East Baltic Upper Silurian. Here special attention has been paid to the index-species which serve as a basis for the establishment of the ostracode zonation. The data for the present paper come from the borings of Stoniškiai, Virbalis, Kunkoiai, Ezere, Ventspils (pers. comm. by L. Gailite), Piltene-1, -31 and -32, Kolka-4 and -54, Ohesaare and Kaugatuma (see Fig. presenting more important ones of them).

For the first time ostracode zones of the Upper Silurian of the East Baltic were proposed by L. Gailite (Гайлите, 1964, 1965; Гайлите и др., 1967) using the sections of West Latvia. The distinguished subdivisions were defined more precisely in her later works (Гайлите, 1978; Гайлите и Ульст, 1974). D. Kaljo (1978) supplemented the zonation mainly on the basis of the Estonian data. The most important ostracode zones of the East Baltic Upper Silurian and their approximate analogous units on Gotland are given in the Table.

Analysing ostracode zonation of the East Baltic Upper Silurian we used also data obtained by A. Martinsson (1967) on ostracode successions in the Silurian of Sweden, and by E. Tomczykowa, E. Witwicka (1972) and B. Žbikowska (1973) on the Upper Silurian ostracode zones of North Poland.

Craspedobolbina lietuvensis Zone

The first Upper Silurian ostracode zone with *Craspedobolbina lietuvensis* has been determined in West Latvia and Lithuania in the Kolka-4, Virbalis and Kunkoiai and less distinctly in the Ventspils boring (see Гайлите, Ульст, 1974; Сарв, 1977). With this zonal species associate *Craspedobolbina percurrens*, *Beyrichia snoderniana*, *Paraparchites gregarius*, *Silenis* ex. gr. *subtriangulatus*. Stratigraphical position of the zone is still indistinct. L. Gailite compares it with the *Neodiversograptus nilssoni* and *Lobograptus scanicus* Zones, evidently increasing its extent. According to D. Kaljo (1978) the *C. lietuvensis* Zone corresponds to the uppermost Wenlockian and only to a part of the *N. nilssoni* Zone. Such a conclusion is more acceptable as it is confirmed by the distribution of *Beyrichia snoderniana* on Gotland, in the Halla and Mulde Beds (= uppermost Wenlock) and the lowermost Hemse Beds (Martinsson, 1962, 1967).

Evidently the topmost part of *C. lietuvensis* range overlap with the interval of the distribution of *Amphitoxotis curvata*. In the East Baltic the latter species occurs only in sections of the Kunkoiai and Virbalis borings. In Gotland *A. curvata* occurs in the lower part of the Hemse Beds, containing numerous graptolites (*Neodiversograptus nilssoni*, *Saetograptus chimaera*, etc.; Martinsson, 1967). It enables to correlate the interval with *A. curvata* in the East Baltic approximately with the topmost beds of the *N. nilssoni* and part of *Lobograptus scanicus* Zones.

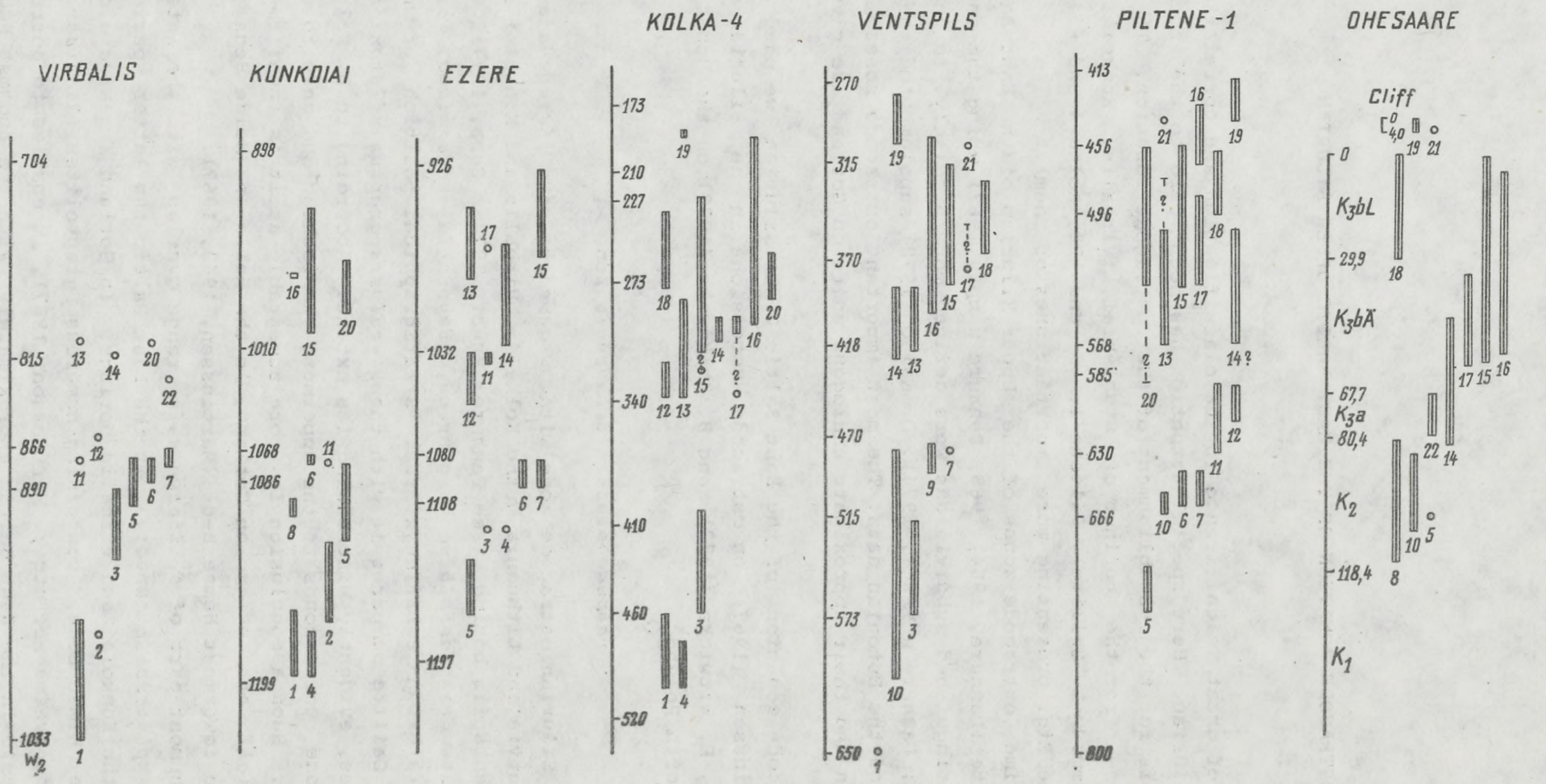

Fig. Distribution of zonal ostracode species in the main boring sections of the East Baltic Upper Silurian. 1 - *Craspedobolbina lietuvensis*, 2 - *Amphitoxotis curvata*, 3 - *Craspedobolbina ezerensis*, 4 - *Beyrichia snoderniana*, 5 - *Hammariella pulchrivelata*, 6 - *Neobeyrichia ctenophora*, 7 - *Neobeyrichia lauensis*, 8 - *Neobeyrichia nutans*, 9 - *Neobeyrichia scissa*, 10 - *Hemsiella hemsiensis*, 11 - *Hoburgiella tenerrima*, 12 - *Undulirete balticum*, 13 - *Neobeyrichia alia*, 14 - *Hemsiella margaritae*, 15 - *Neobeyrichia buchiana*, 16 - *Macrypsilon salterianum*, 17 - *Frostiella groenvalliana*, 18 - *Nodibeyrichia tuberculata*, 19 - *Nodibeyrichia jurassica*, 20 - *Hemsiella maccoyiana*, 21 - *Dizygopleura opportuna*, 22 - *Plicibeyrichia numerosa*.

Craspedobolbina ezerensis Zone

The following zonal species *Craspedobolbina ezerensis* occurs in sections of Virbalis, Ezere, Ventspils and Kolka-4 together with *Microcheilinella lacrima, Primitiopsis ezerensis, Pseudorayella acuta, Hammariella pulchrivelata.* It is of comparatively restricted vertical distribution but almost all accompanying species existed during a fairly long time. Only *Hammariella pulchrivelata* occupies in a number of sections a short interval but on different levels. For instance, in the Ezere boring it is found below the *C. ezerensis* Zone, in the Virbalis boring - together with *C. ezerensis, Hemsiella anterovelata* and *Neobeyrichia ctenophora - N. lauensis,* in the Ohesaare boring and on Gotland together with *Neobeyrichia nutans.* How far *H. pulchrivelata* occurs together with two zonal species (*C. ezerensis, N. ctenophora*) obviously of different ages it would be better not to use it as an index-species.

Craspedobolbina ezerensis does not occur anywhere together with *Amphitoxotis curvata,* however, their being of almost the same age is not excluded either. In the Kolka-4 boring *C. ezerensis* appears immediately after *C. lietuvensis.* In the Virbalis boring there is a noticeable interval between them, but the range of *C. ezerensis* is evidently restricted there. *A. curvata* has been also found in the Virbalis boring, however, only one specimen and in the topmost beds of the interval of distribution of *C. lietuvensis.*

The above Early Ludlow zonal species are known only from the sections of West Latvia and Lithuania. According to D. Kaljo and E. Jürgenson (Кальо и Юргенсон, 1977) this is the area of the transitional (=slope) facies belt of marls and clays with limestone nodules, being formed in rather offshore conditions. The above-mentioned zonal and some accompanying species were, evidently, tied to this facies belt and only rather rare occur in other ones. Therefore, they are not found from more northern sections of the East Baltic (Piltene-1, Kolka-54, Ohesaare, Kaugatuma).

Neobeyrichia ctenophora - N. lauensis Zone

The zone *Neobeyrichia ctenophora - Neobeyrichia lauensis* follows immediately above the zone *C. ezerensis* in the Central and South East Baltic. It embraces a fairly small interval (up to 20 m) in the Piltene and Ezere borings and is seldom found in the Virbalis and Ventspils borings. In the latter together with *N. ctenophora* L. Gailite has identified *Neobeyrichia scissa.* They are accompanied by *Hemsiella hemsiensis, Hammariella pulchrivelata, Microcheilinella lacrima, Primitiopsis ezerensis* but in the Virbalis and Kunkoiai borings also by *Hoburgiella tenerrima.*

On Gotland *N. lauensis* and *N. scissa* mark the upper part of the Hemse Beds (Martinsson, 1967). *N. ctenophora* is there of wider vertical distribution occurring also in the overlying Eke, Hamra and Sundre Beds. In the Virbalis and Kunkoiai borings together with *Neobeyrichia ctenophora and N. lauensis* there are found *Hoburgiella tenerrima* and *Scaldianella personata,* rather wide-spread species in the overlying beds.

Neobeyrichia lauensis does not occur in sections of the Saaremaa Island. A probable find of *N. ctenophora* has been made from Kõrkküla outcrop (Paadla Stage, Uduvere Beds).

Neobeyrichia nutans Zone

The zone contains a rich association of ostracodes with species characteristic of the Hemse Beds: *Hemsiella hemsiensis, Beyrichia eteliana, B. grogarniana, Calcaribeyrichia simplicior, Neobeyrichia nutans,* and numerous species of wider vertical distribution (Сарв, 1971) occurring in the upper part of the Paadla Stage in the Ohesaare boring (Uduvere Beds).

A. Martinsson (1967) treated *Neobeyrichia nutans* together with *Hammariella pulchrivelata* as an index-species for the middle part of Hemse Beds. In the Southern East Baltic this species occurs in the Kunkoiai boring in a short interval above the zone *Amphitoxotis curvata*, but below the occurrences of *Neobeyrichia* cf. *ctenophora* which approximately corresponds to the level of distribution of *Neobeyrichia nutans* on Gotland. In the Ohesaare boring the interval of the distribution of this species is wider and embraces the whole middle and upper parts of the Paadla Formation. However, *N. nutans* is lacking in the upper part of the Pagēgiai Formation of central and Southern East Baltic (Гайлите и Ульст, 1974) and cannot serve as a zonal species there. It may serve as a zonal species only for sections of the Saaremaa Island where it together with *Hemsiella hemsiensis*, *Moorea bisculata* and other species characterizes the middle and upper parts of the Paadla Stage.

Absence of *N. ctenophora* and *N. lauensis* in sections of the Saaremaa Island and scarcity of *N. nutans* in sections of the Central and Southern East Baltic can be explained by facies zonality of the basin - first two species are distributed in offshore, the latter more often in nearshore facies.

Undulirete balticum and *Plicibeyrichia numerosa* Zones

L. Gailite (Гайлите и Ульст, 1974) has distinguished both *Neobeyrichia nutans* and *Hoburgiella anterovelata* as of the same age zonal species. The latter is evidently conspecific with *Hoburgiella tenerrima* identified from the Eke, Hamra and Sundre Beds on Gotland. *H. anterovelata (=tenerrima)* is known in the sections Piltene-1 and Ezere, rarely also from the Virbalis and Kunkoiai sections. Frequently it occurs together with considerably wide-spread *Undulirete balticum*, which has also been proposed as zonal species (Kaljo, 1978). In the Northern East Baltic the *U. balticum* Zone is replaced by *Plicibeyrichia numerosa* Zone.

Age relations between species *Neobeyrichia ctenophora* and *N. lauensis*, *N. nutans*, *Hoburgiella tenerrima* and *Undulirete balticum* are as follows. In the section of the Piltene-1 *H. tenerrima* appears somewhat earlier than *U. balticum* but not before the disappearance of *N. lauensis* and *N. ctenophora*. In the Virbalis boring *H. tenerrima* occurs in the same sample together with the last specimens of *N. lauensis* and *N. ctenophora*, whereas *U. balticum* is found somewhat higher in the section. In the Ezere boring *H. tenerrima* is met in a short interval together with the last specimens of *U. balticum*. *Neobeyrichia nutans* is older than *N. lauensis* and *N. ctenophora* but the upper part of its distribution coincides with the range of the latter.

Hemsiella margaritae - *Neobeyrichia alia* Zone

L. Gailite (Гайлите и Ульст, 1974) determined *Hemsiella margaritae* and *Neobeyrichia alia* as zonal species within the Minija Formation of the Central and South East Baltic. However, *H. margaritae* has rather noticeable intraspecific variation and it is doubtless closely related to *H. loensis* and *H. maccoyiana*. Thus the scope of *H. margaritae* is treated differently by different researchers. Vertical distribution of this species is wide. It has been determined in many sections already in the topmost beds of the Pagēgiai Formation (Stoniškiai, Kolka-54, Ventspils) but in the majority of cases in the lower half of the Minija Formation. In the Northern East Baltic it occurs in the Kuressaare Stage and in the lower half of the Äigu Beds of the Kaugatuma Stage (Сарв, 1968, 1971).

Neobeyrichia alia is of the same age as *H. margaritae* and of analogous vertical distribution: the uppermost beds of the Pagēgiai and the lowermost beds of the Minija Formations in the sections of the Stoniškiai and Ventspils borings but in the Virbalis, Ezere, Piltene-1 and -31, Kolka-4 sections it occurs only in the Minija Formation. An exception is the Piltene-1 boring where *N. alia* has evidently been identified in one sample from the lowermost beds of the Jūra Formation (Гайлите и др., 1967).

In sections of the Virbalis, Ezere and Piltene-1 *Hemsiella margaritae - Neobeyrichia alia* appear immediately after the zonal species *Undulirete balticum* but in the Kolka-4 boring (Гайлите и Ульст, 1974) *N. alia* occurs together with *U. balticum* whereas *H. margaritae* appears somewhat later. The above serves as an evidence of inconstancy of the lower boundary of the zone *H. margaritae - N. alia*.

Frostiella groenvalliana Zone

Species characterizing the former zone occur together with *Frostiella groenvalliana* which, besides the sections of the North East Baltic (Ohesaare and Kaugatuma borings), is rarely found also in the sections of the Stoniškiai, Ezere and Ventspils borings but in the section of the Piltene-1 boring L. Gailite determined a similar species *Frostiella lebiensis*. Distinction of *F. groenvalliana* in the role of a zonal species (Kaljo, 1978) for the lower part of the Kaugatuma Formation and its analogs (the Minija Formation) is justified as this species, despite its scarcity in the East Baltic, is known from the Upper Silurian of Southern Sweden, England and Canada. In the East Baltic together with it for the first time appear such wide-known species as *Neobeyrichia buchiana, Macrypsilon salterianum, Hemsiella maccoyiana*.

Nodibeyrichia tuberculata Zone

The following *Nodibeyrichia tuberculata* Zone is more constant in the whole East Baltic. On the Saaremaa Island this species characterizes the Lõo Beds of the Kaugatuma Formation, in North-West Latvia it is distributed in masses in the lower part of the Jūra Formation which therefore are considered synchronous with the Lõo Beds. The zone is established in the Piltene-1 and -32, Kolka-4 and -54, Ventspils borings and also in some sections of the Southern East Baltic (Stoniškiai boring; Сарв, 1967).

Nodibeyrichia jurassica Zone

The top of the East Baltic Silurian is considered by L. Gailite (Гайлите, 1965) *Nodibeyrichia jurassica* Zone. In the Piltene-1 boring the zone occupies the upper part of the Jūra Formation with the thickness of 43 m. Approximately of the same extent is this zone in the Piltene-32, Kolka-4 and -54, Ventspils borings. The *Nodibeyrichia jurassica* Zone in North-West Latvia and on the Saaremaa Island corresponds to the Ohesaare Stage. The distribution of zonal association besides index-species (*Dizygopleura opportuna, Juviella piltenensis, Kloedenia leptosoma* and some others) permits to assume that in the Ohesaare stratotype section the beds of *Nodibeyrichia jurassica* age, despite their relatively small thickness (6 m), contain the whole complex of characteristic ostracode species.

The above shows that differences in the distribution of zonal ostracode species in various areas of the Late Silurian Baltic basin existed in the Ludlow and, partially, in the Downton time. Thus the determination of zonal ostracode species for different areas of the mentioned basin will be expedient. The present paper gives such species separately for the North East Baltic and for the Central and South East Baltic areas (see Table).

Table. The ostracode zones in the Upper Silurian of the East Baltic

Group	Series	Regional Stratigraphy		Ostracode zones (Гайлите, 1965-1978; Kaljo,1978;emend.)			Gotland (Martinsson, 1967)	
		Stage	Graptolite zone	North East Baltic	Central and South East Baltic		Stratigraphy	Ostracode succession
Upper Silurian	Downton	Ohesaare		*Nodibeyrichia jurassica*	*Nodibeyrichia jurassica*	Jūra Formation		*Kloed-Nodi plicul*
		Kaugatuma		*Nodibeyrichia tuberculata*	*Nodibeyrichia tuberculata*			
				Frostiella groenvalliana	*Hemsiella margaritae – Neobeyrichia alia*	Minija Formation		*groenvall-leb-kies maccoy-regn*
		Kuressaare	*Monocl. ultimus M. formosus*	*Plicibeyrichia numerosa*	*Undulirete balticum*		Sundre Hamra Burgsvik	*juvens-regn* *semilaq* *tenerr*
	Ludlow	Paadla	*Monogr. balticus*	*Neobeyrichia nutans*	*Neobeyrichia ctenophora – N. lauensis*	Pagēgial Form.	Eke	*lau-sciss*
			Monocl. tauragensis		*Craspedobolbina ezerensis*	Dubysa Formation	Hemse	*pulchri-nut*
			L. scanicus					*haidby*
			N. nilssoni					*curv-rob*
		Rootsiküla	*M. ludensis*		*Craspedobolbina lietuvensis*			

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К ЗОНАЛЬНОМУ РАСЧЛЕНЕНИЮ ВЕРХНЕГО СИЛУРА ПРИБАЛТИКИ ПО ОСТРАКОДАМ

Л. Сарв

Остракодовые зоны верхнего силура Прибалтики установлены Л. К. Гайлите (1964, 1965, 1978; Гайлите и др., 1967; Гайлите и Ульст, 1974) в разрезах Западной Латвии и Литвы. Объем этих зон уточнен Д. Л. Кальо/Kaljo, 1978/; им же выделены некоторые новые зоны, в основном, в разрезах Эстонии.

В данной статье проведены ревизия верхнесилурийских остракодовых зон и переоценка их стратиграфической и корреляционной значимости на основе исследования 12-и буровых разрезов (см. рис.). Показана целесообразность выделения в разнофациальных отложениях некоторых участков разреза параллельных, более-менее одновозрастных остракодовых зон.

Раннелудловские зональные виды *Craspedobolbina lietuvensis* и *C. ezerensis* известны только из разрезов Средней и Южной Прибалтики. Там же распространяются позднелудловские *Neobeyrichia ctenophora* - *N. lauensis* (см. табл.). Лудловские отложения Северной Прибалтики характеризуются зональным видом *Neobeyrichia nutans*. Разные остракодовые зоны выделены и в раннедаунтонских отложениях: в Северной Прибалтике зоны *Plicibeyrichia numerosa* и *Frostiella groenvalliana*, в Средней и Южной Прибалтики - зоны *Undulirete balticum* и *Hemsiella margaritae* - *Neobeyrichia alia*. Позднедаунтонские отложения Прибалтики содержат такие широкораспространенные зональные виды, как *Nodibeyrichia tuberculata* и *N. jurassica*.

УДК 56.016:591.52:551.733.33(474)

LATE SILURIAN SHALLOW AND DEEP WATER CONODONTS OF THE EAST BALTIC

V. Viira

The present paper deals with the zonation of the East Baltic Upper Silurian conodonts and their facies dependence. A large number of samples were studied for to characterize all facies belts from near-shore up to basin one. They come from 7 borings of Saaremaa (Ohesaare, Kaugatuma, Kingissepa, Sakla) and North-West Latvia (Kolka-54, Ventspils, Pavilosta) and also from more than 30 localities of Saaremaa (Fig. 1). Published information is available only on conodonts from Kolka-4 (Гайлите, Ульст, 1974) and Ohesaare boring (Вийра, 1977), on the Upper Silurian spathognathodians (Вийра, 1982 a), and the apparatus *Ctenognathodus murchisoni* (Вийра 1982 б).

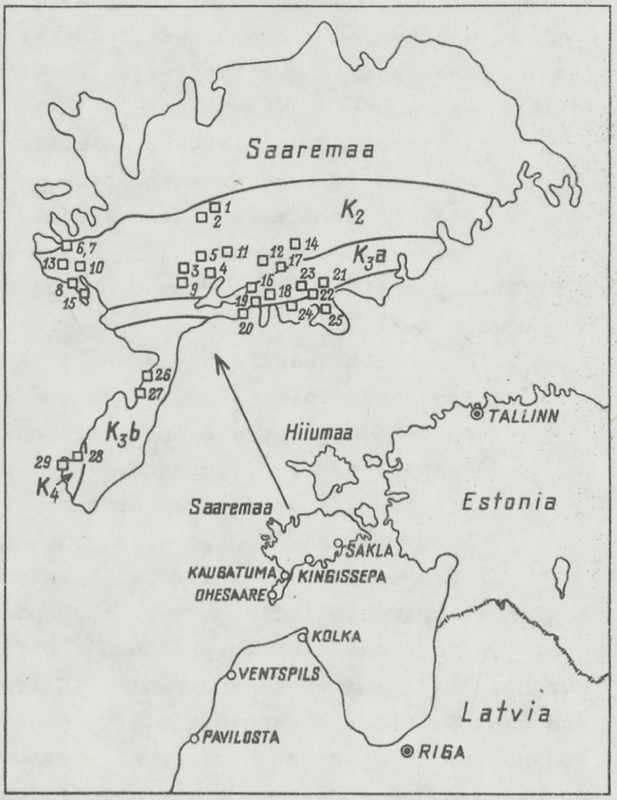

Fig. 1
Location map of outcrops (quadrangles) and borings (circles). Explanation of locality numbers see in Fig. 3.

General distribution

Ludlow and Downton conodont faunas show high abundances and rather low diversity. They are characterized by bar and blade elements, whereas platform elements appear to be of very limited distribution. Carbonate deposits of the shelf area contain the richest fauna where the prevalence of multielement genera *Ozarkodina* and *Oulodus* is typical of the given region. The Ludlow part of the section is rich in the longranging apparatuses *Ozarkodina confluens, O. e. excavata, Oulodus siluricus.* In the East Baltic they appear gradually beginning with the Lower Wenlock but the largest gatherings occur just in the Ludlow. The Downton contains besides *O. confluens* also abundant *O. s. eosteinhornensis* and *Oul. elegans.* On Gotland different *Ozarkodina* and *Oulodus (=Hindeodella* and *Ligonodina)* also occur nearly in the same quantity as in Estonia (Jeppson, 1969, 1972, 1974).

Two distinct changes are observable in stratigraphic range of the Upper Silurian conodonts of the northern East Baltic. The first is expressed by replacement of the Upper Wenlock shallow water *Ctenognathodus murchisoni* association with a rich Ludlow fauna containing *O. confluens, O. e. excavata* and *Oul. siluricus.* These apparatuses are known already from the underlying Wenlock deposits but in specific condition of the Rootsiküla time they were rare or lacking. The second change is more distinct. It is defined by the appearance of conodonts of the *eosteinhornensis* Zone. Besides the index-species *O. s. eosteinhornensis, Oul. elegans* makes its first appearance on this level. The named two taxa in association with *O. confluens* form the rich Downton fauna. All three apparatuses occur up to the uppermost beds of the Silurian.

Taxonomic notes

In the northern East Baltic at the present stage of study the following apparatuses and their component elements have been identified.

1. *Ozarkodina excavata excavata* (Branson et Mehl):
   Spathognathodus inclinatus inclinatus (Rhodes),
   Ozarkodina media Walliser,
   Neoprioniodus excavatus (Branson et Mehl),
   Hindeodella equidentata Rhodes,
   Plectospathodus extensus Rhodes,
   Trichonodella excavata (Branson et Mehl).

The apparatus ranges from the Jaani Stage (Lower Wenlock) into the Kuressaare Stage (uppermost Ludlow).

2. *Ozarkodina confluens* (Branson et Mehl):
   Spathognathodus primus (Branson et Mehl),
   Ozarkodina typica Branson et Mehl,
   Neoprioniodus bicurvatus (Branson et Mehl),
   Hindeodella confluens (Branson et Mehl),
   Plectospathodus flexuosus Branson et Mehl,
   Trichonodella symmetrica (Branson et Mehl).

Most characteristic part of the apparatus is its spathognathodontan element *S. primus.* On the basis of morphological differences in *S. primus* 5 morphotypes (Klapper, Murphy, 1974) and three subspecies (Helfrich, 1975) have been established. In the northern East Baltic 6 chronological subspecies: *S. primus bucerus* (Wenlock), *S. primus densidentatus* (Uppermost Wenlock), *S. primus retroversus* (Uppermost Wenlock), *S. primus cornidentatus* (Ludlow), *S. primus ambiquus* (uppermost Ludlow) and *S. primus nasutus* (Downton) have been proposed (Вийра, 1982 a). *O. confluens* makes its first appearance in the lowermost beds of the Jaagarahu Stage (Wenlock) and is present up to the end of the Silurian.

3. *Ozarkodina steinhornensis eosteinhornensis* (Walliser):
   Spathognathodus steinhornensis eosteinhornensis Walliser,
   Ozarkodina typica denckmanni Ziegler,
   Neoprioniodus arisaigensis Legault,
   Hindeodella priscilla Stauffer,

Plectospathodus alternatus Walliser,

Trichonodella symmetrica (Branson et Mehl).

The characteristic element is *S. s. eosteinhornensis* in which 4 varieties are distinguished (Виира, 1982 а). The apparatus occurs in the Kuressaare, Kaugatuma and Ohesaare Stages.

4. *Ozarkodina* sp. S :

Neoprioniodus ? sp. S Viira, 1977,

Ligonodina sp. S Viira, 1977,

Trichonodella sp. S Viira, 1977.

Undescribed apparatus, evidently containing six robust elements. The apparatus is restricted to the lower half of the Paadla Stage.

5. *Oulodus siluricus* (Branson et Mehl):

Lonchodina walliseri Ziegler,

Lonchodina greilingi Walliser,

Neoprioniodus multiformis Walliser,

Ligonodina silurica Branson et Mehl,

Trichonodella inconstans Walliser.

The complete apparatus is illustrated by Chlupaĉ, Křiž und Schönlaub (1980, Table 17, Fig. 20). In the East Baltic Silurian it ranges from the Jaagarahu Stage up to the uppermost beds of the Paadla Stage.

6. *Oulodus elegans* (Walliser):

Lonchodina detorta Walliser,

Ozarkodina ortuformis Walliser,

Neoprioniodus williamsi Legault,

Ligonodina elegans Walliser,

Trichonodella inconstans Walliser.

The apparatus occurs in the Kuressaare, Kaugatuma and Ohesaare Stages.

7. *Ctenognathodus murchisoni* (Pander):

Spathognathodus murchisoni (Pander),

Ligonodina sp. n. L Viira, 1977,

Lonchodina ? sp. n. N Viira, 1977,

Trichonodella sp. n. V Viira, 1977.

The apparatus is described and illustrated in the paper on the Upper Wenlock shallow water conodonts (Виира, 1982 б). *C. murchisoni* is a guide fossil for the Rootsiküla Formation.

Besides the above named ones elements of the following apparatuses have been found:

Distomodus dubius (Rhodes),

Pelekysgnathus dubius Jeppsson,

Kockelella variabilis Walliser,

Polygnathoides siluricus Branson et Mehl.

Names of conodonts interpreted by formal taxonomy are given in inverted commas.

Associations

In the East Baltic Wenlock and Upper Silurian the environmental types of conodonts are distinguished: lagoonal, shoal-shelf and slope ones. Terms come from facies belts of the Silurian Paleobaltic Basin (Нестор, Эйнасто, 1977). From the shallow inshore towards the continental slope the associations are as follows: (1) *Ctenognathodus*, (2) *Ozarkodina* and *Oulodus*, (3) *Kockelella* and *Polygnathoides*.

Lagoonal type is represented by *Ctenognathodus* association known from the Upper Wenlock so far. Besides lagoon it occurs also in the transitional area to the shoal belt (Вийра, 1982 б). Typical representative of this association is *Ctenognathodus murchisoni*, other conodonts are rare. *O. confluens* with a spathognathodontan element *"S." primus retroversus* occurs sometimes.

Shoal-shelf type of conodonts is mostly represented by *Ozarkodina* and *Oulodus*. These two multielement genera are distributed in the whole mentioned area. The shoal belt is rich in *O. confluens* association, which is rather common in the open shelf as well. It occurs in detritic, nodular and clayey limestones. The *O. e. excavata* association is more characteristic of the open shelf belt of Ludlow age but it is found also in the shoal belt. However, *O. e excavata* does not occur in Downton and its ecological niche is occupied by the *O. s. eosteinhornensis* association. These two associations are characterized by a wider facies affiliation as compared with the *O. confluens* association and they may occur also in clays and marls of the slope belt.

Conodonts of the multielement genus *Oulodus*, being frequent in the shoal and open shelf belts, are mostly represented by species *Oul. siluricus* (Ludlow) and *Oul. elegans* (Downton). *Oul. siluricus* has nearly the same ecological position as *O. confluens*. *Oul. elegans* is more connected with the *O. s. eosteinhornensis* association.

Offshore part of the basin (slope facies belt) was inhabited by the association of *Kockelella variabilis* and *Polygnathoides siluricus* in Ludlow.

Zonation

The abundance of conodonts decreases from the shallow part of the basin towards the open sea. Such a situation is especially characteristic of Ludlow conodonts. Simultaneously with decreasing of their number a taxonomic change takes place: in offshore facies platform conodonts appear. Therefore we have presented two zonal schemes: one for shallow and the other for deeper water sediments (Table).

Table

Northern East Baltic Upper Silurian conodont zones

SERIES	Regional stratigraphic scheme		SHELF AREA		BASIN AREA
			Zone	Subzone	Zone
DOWNTON	OHESAARE		eosteinhornensis	remscheidensis	eosteinhornensis
	KAUGATUMA	LÕO		canadensis	
		ÄIGU		eosteinhornensis s. str.	
LUDLOW	KURESSAARE	KUDJAPE		aff. scanica	
		TAHULA			
	PAADLA	UDUVERE	D. dubius – „Belodus" sp.		siluricus
		HIMMISTE	Ozarkodina sp. S – O. confluens cornidentatus		
		SAUVERE			
WENLOCK	ROOTSIKÜLA	SOEGININA	Ctenognathodus murchisoni		sagitta
		VESIKU			
		KUUSNÕMME			
		VIITA			

Zones with *sagitta*, *eosteinhornensis* and *siluricus* were established in the Carnic Alps by O. Walliser (1964), later on they are recognized in many parts of the world. Other Upper Silurian zones of the northern East Baltic are local. They are assemblage zones presumably. Subzones of the *eosteinhornensis* Zone are based on the replacement of different *"Spathognathodus" s. eosteinhornensis* morphotypes.

An important guide fossil is *"Spathognathodus"* aff. *snajdri*. Among conodonts identified as *"S."* aff. *snajdri* two morphological types similar to *"S." snajdri* and *"S." crispus* are established. In literature both they are interpreted as zonal ones whereas *"S." crispus* is considered stratigraphically younger than *"S." snajdri* (Walliser, 1964; Helfrich, 1975; Chlupač, Kříž, Schönlaub, 1980). In our material there is no clear succession of the above species. E.g. in 15 kg of sample dissolved from Karala locality among hundred specimens of *"S."* aff. *snajdri* both element types occurred. Thus for ascertaining the position of *"S." snajdri* and *"S." crispus* we mark our forms in the open nomenclature.

"S." aff. *snajdri* ranges from the lower part of the Paadla Stage up to lowermost Kaugatuma Stage. It has been identified in all studied sections of northern East Baltic, including more offshore ones, but also in a number of localities of the Saaremaa (Fig. 2, 3). The lower limit of the *"S."* aff. *snajdri* range is recognized in the studied borings on the following levels: Sakla 33.2 m, Kingissepa 39.2 m, Ohesaare 113.3 m, Kolka 289.8 m, Ventspils 464.2 m, Pavilosta 622.7 m. Relative to the lower boundary of the Paadla Stage in above sections the species appears step by step higher towards the central part of the basin. The upper limit of the *"S."* aff. *snajdri* range is more uniform. The latest specimens occur in the lowermost part of the Äigu Beds: Kaugatuma 28.9 m, Ohesaare 61.2 m, Kolka 253.6 m, Ventspils 406.0 m, Pavilosta 604.0 m.

Shelf zones

Ctenognathodus murchisoni Zone

The base of the *murchisoni* Zone (Вийра, 1982 б) is defined by the appearance of *C. murchisoni*. The fauna of the zone is dominated by index-species. *O. confluens* is represented by subspecies with a spathognathodontan element *"S." primus retroversus*. *O. sagitta bohemica* and *O. e. excavata* are rare.

The zone corresponds to the Rootsiküla Formation (excl. lowermost part).

The stratotype for the zone is Vesiku outcrop.

Ozarkodina sp. S - *O. confluens cornidentatus* Zone

The zone is defined primarily on the ranges of the *Ozarkodina* sp. S apparatus. The base of the zone is determined by the first appearance of *Ozarkodina* sp. S or *O. confluens cornidentatus*. The latter subspecies appears in Fig. 2 given borings on levels: Ohesaare 118.0 m, Kaugatuma 81.2 m, Kingissepa 43.3 m, Sakla 34.1 m, Kolka 304.2 m.

The zone is rich in two nominate species. *O. e. excavata* and *Oul. siluricus* are frequent. *"S."* aff. *snajdri* first appears in this zone.

The zone covers the Sauvere and Himmiste Beds and the lower part of the Torgu Formation. It may be distinguished in the near-shore and shelf areas only. The stratotype of the zone is Roopa cliff.

Distomodus dubius - *"Belodus"* sp. Zone

The zone is characterized by the occurrence of *Distomodus dubius*, *Pelekysgnathus dubius* and *"Belodus"* sp. Its lower boundary is marked by the first appearance of *D. dubius* or *"Belodus"* sp., in case the former is lacking. The base of the zone lies in borings (Fig. 2) as follows: Ohesaare 106.5 m, Kaugatuma 57.5 m, Kingissepa 35.0 m, Sakla 19.9 m, Kolka 294.6 m.

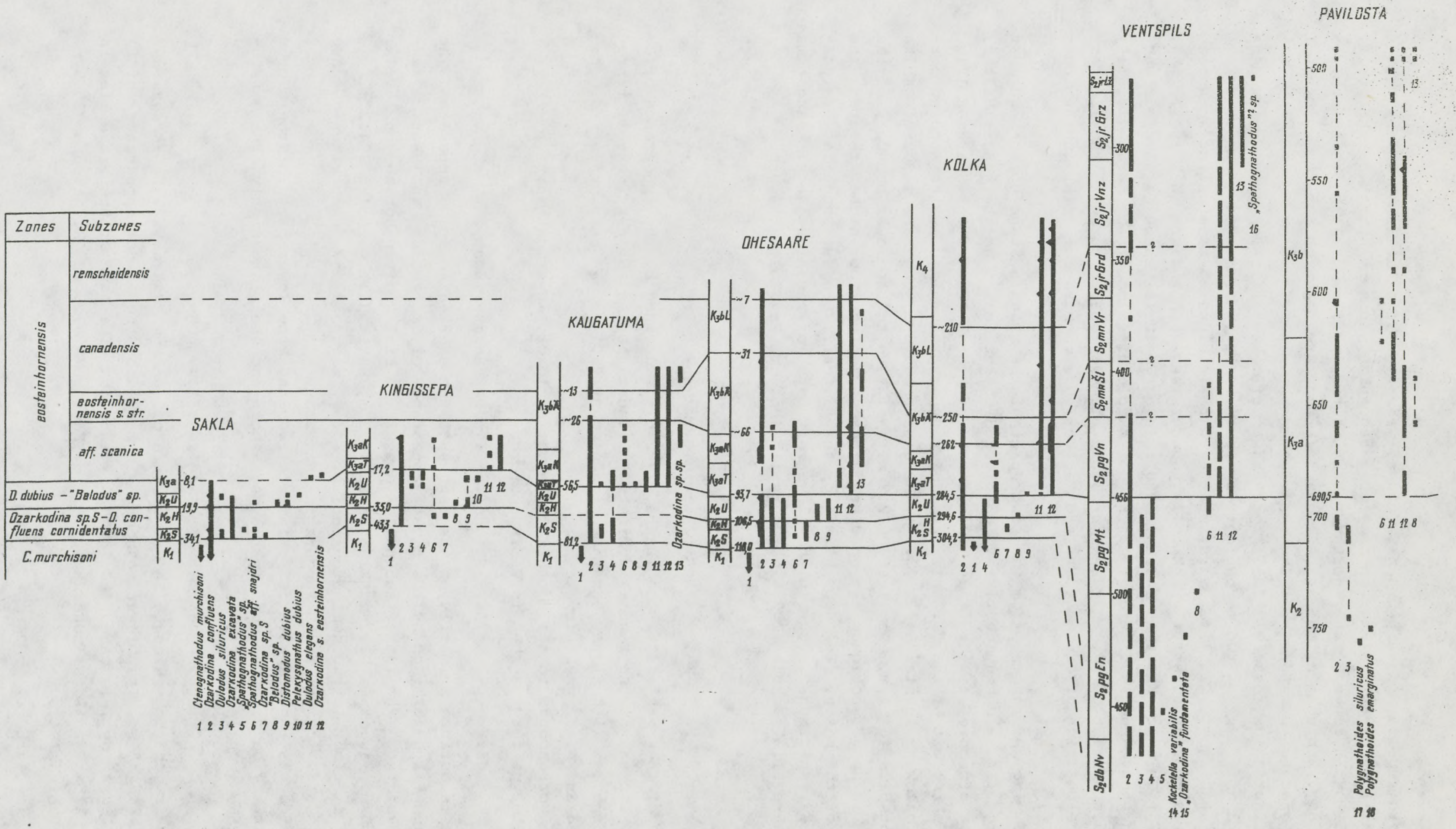

Fig. 2. Correlation of the Upper Silurian boring sections in the northern East Baltic by conodonts. Stratigraphical subdivisions of the Ventspils core: S_2dbNv - Nova Beds of the Dubysa Formation, S_2pgEn - Engure Member, S_2pgMt - Mituva Beds, S_2pgVn - Ventspils Beds, all three the Pagėgiai Formation, S_2mnŜl - Ŝilale Beds and S_2mnVr - Varniai Beds of the Minija Formation, S_2jrGrd - Girdẑiai Beds, S_2jrVnz - Venzova Beds and S_2jrGrz - Gārzde Beds of the Jūra Formation.

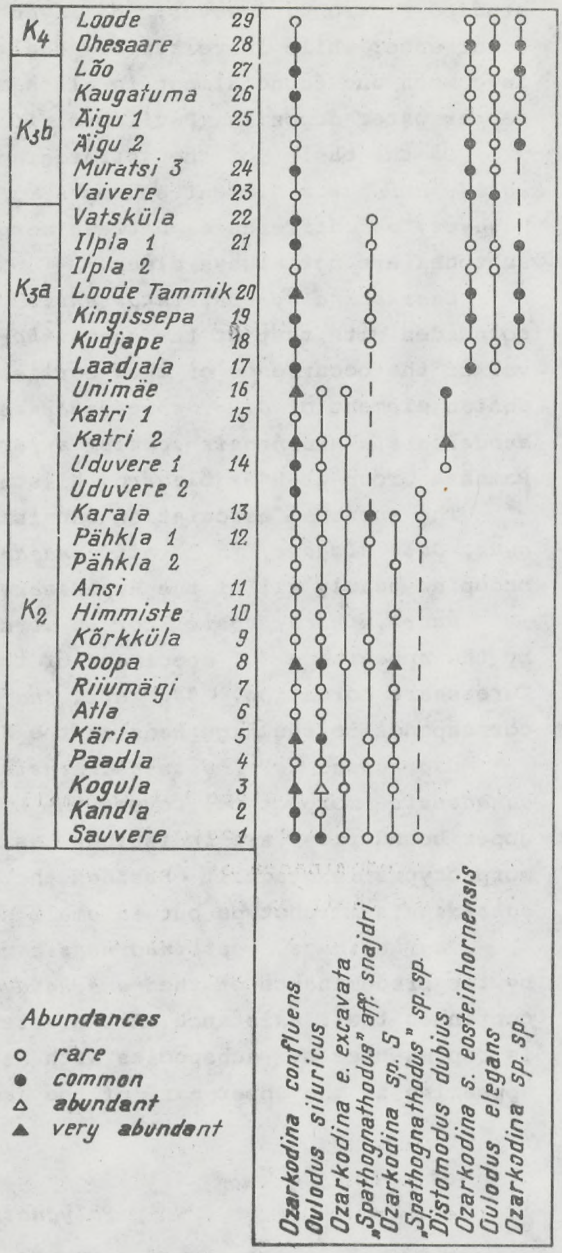

Fig. 3. Distribution of selected conodonts in the Upper Silurian localities of Saaremaa.

Besides the two index species the zone contains *P. dubius, O. confluens cornidentatus, O. e. excavata, Oul. siluricus*. All these conodonts disappear at the upper boundary.

D. dubius - *"Belodus"* sp. Zone occupies the Uduvere Beds and upper part of the Torgu Formation. The zone has been determined in the sections of the shelf area.

The stratotype of the zone is Unimäe abandoned quarry.

Ozarkodina steinhornensis eosteinhornensis Zone

In the East Baltic the lower boundary is well distinguished by the appearance of numerous specimens of all zonal apparatus elements and those of usually accompanying it *Oul. elegans*. The third, more frequent apparatus is *O. confluens* with two spathognathodontan elements on subspecies level *"S." primus ambiquus* and *"S." primus nasutus*. Besides them there occur *"S."* aff. *snajdri* (in the lower subzone) and undescribed new apparatus of *Ozarkodina* (at least two taxa).

The *eosteinhornensis* Zone reaches the uppermost beds of the Silurian section of the northern East Baltic. In the East Baltic basin it has been identified in all the studied sections. However, the investigations revealed a difference in the frequency of occurrence: while in relatively shallow water sections (Kaugatuma, Ohesaare, Kolka) it is common and found almost in all samples, in places even in great abundances, then in deeper water deposits (Pavilosta) it is rare and occurs, by no means, in all samples.

On the basis of the stratigraphical distribution of morphotypes of the *"S." s. eosteinhornensis* element subzones are distinguished in the shelf deposits (Виира, 1982 a). However, as differences between morphotypes have transitional character the limits of subzones are not always clear.

Ozarkodina s. eosteinhornensis aff. *O. s. scanica* Subtone. The lower boundary coincides with that of the *eosteinhornensis* Zone. The subzone corresponds to the interval of the occurrence of the earliest morphotype. By its morphology the spathognathodontan element of *O. s. eosteinhornensis* aff. *O. s. scanica* is similar to that of *Hindeodella steinhornensis scanica* apparatus described by L. Jeppsson (1974) from the Öved. Ramsåsa Group at Bjäsjölagård, Klinta and Tullesbo in Skåne.

The subzonal association consists besides the index-species of *O. confluens ambiquus, Oul. elegans, "S."* aff. *snajdri, Ozarkodina* sp. Stratigraphically the subzone occupies nearly all of the Kuressaare Formation (except ots uppermost part).

Ozarkodina s. eosteinhornensis s. str. Subzone. The lower boundary is determined by the appearance of specimens of the typical subspecies in the topmost part of the Kuressaare Formation. *"S."* aff. *snajdri* terminate within this subzone. The subzone corresponds to the Äigu Beds of the Kaugatuma Formation.

Ozarkodina s. eosteinhornensis canadensis Subzone. This subzone determined by *canadensis* morphotype, covers the Lõo Beds of the Kaugatuma Formation. The lower and upper boundaries are indistinct as the appearance of *canadensis* and *remscheidensis* morphotypes is gradual. Besides the index morphotype there can also be found the *remscheidensis* morphotype but in small numbers.

Ozarkodina s. eosteinhornensis remscheidensis Subzone. The subzone is distinguished by the predominance of the *remscheidensis* morphotype at which the *canadensis* morphotype continues their existence. A characteristic feature of this subzone is that *O. confluens* is represented by subspecies with a spathognathodontan element *"S." primus nasutus* appearing in the upper part of the *canadensis* Subzone.

Basin zones

Polygnathoides siluricus Zone

This zone is defined on the occurrences of the index-species in two sections: Pavilosta (Latvia), depth 756.0 m (2 specimens) and Vidukle (Lithuania), depth 1166.2 m (1 specimen). Besides the index-species *"P." emarginatus* (Pavilosta, depth 750.3 m) and *D. dubius, P. dubius* (Vidukle, depth 1166.2 m) have been identified. The last two give reason for correlation the *siluricus* Zone with the *D. dubius* Subzone of the shelf area, at least with a part of it.

Ozarkodina s. eosteinhornensis Zone

The zone was described above in more detail. In general the conodont complex is analogous with that of the shelf area. However, offshore deposits finds of all conodonts, also of the index-species, are comparatively rare. Thus reliability of drawinf zonal boundaries depends, first of all, on the frequency and sizes of samples.

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ВЕРХНЕСИЛУРИЙСКИЕ МЕЛКОВОДНЫЕ И ГЛУБОКОВОДНЫЕ КОНОДОНТЫ ПРИБАЛТИКИ

В. Вийра

Верхнесилурийские конодонты Северной Прибалтики анализированы на основе богатой коллекции, происходящей из разрезов 7 буровых скважин и более чем 30 обнажений /рис. 1, 2, 3/. Рассмотрено распределение конодонтов в зависимости от фациальной зональности Палеобалтийского бассейна. Сообщество *Ctenognathodus* распространено в лагунной и отмельной, сообщества *Ozarkodina* и *Oulodus* в отмельной и открытошельфовой зонах. Конодонты склоновой зоны представлены сообществом *Kockelella* и *Polygnathoides*.

На основании фациального распределения конодонтов приведено две зональные схемы: для шельфа и для бассейновой части /табл./. Первая содержит зоны *C. murchisoni*, *Ozarkodina* sp. S - *O. confluens cornidentatus*, *D. dubius* - *"Belodus"* sp. и *O. s. eosteinhornensis* /с четырьмя подзонами/. Схема бассейновой части содержит зоны *sagitta*, *siluricus* и *eosteinhornensis*.

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CORRELATION OF THE EAST-BALTIC AND GOTLAND SILURIAN BY CHITINOZOANS

V.-K. Nestor

Taxonomy and distribution of chitinozoans in the Silurian of Gotland have been studied by A. Eisenack (1962, 1964 etc.), P. Taugourdeau and B. Jekhowsky (1964) and especially by S. Laufeld (1974, 1979 etc.). Chitinozoans of the corresponding part of the East Baltic Silurian have been mainly studied from the Estonian borings at Ohesaare, Ruhnu, Varbla, Kipi, Kaugatuma, etc. and also from a number of the borings in West Latvia - Pavilosta, Ventspils and Kolka. A part of these materials (Мяннилъ, 1970; Nestor, 1975; Нестор, 1982а, 1982б, 1982в), as well as some data based on the outcrops (Eisenack, 1968; 1970 etc.) have been published earlier.

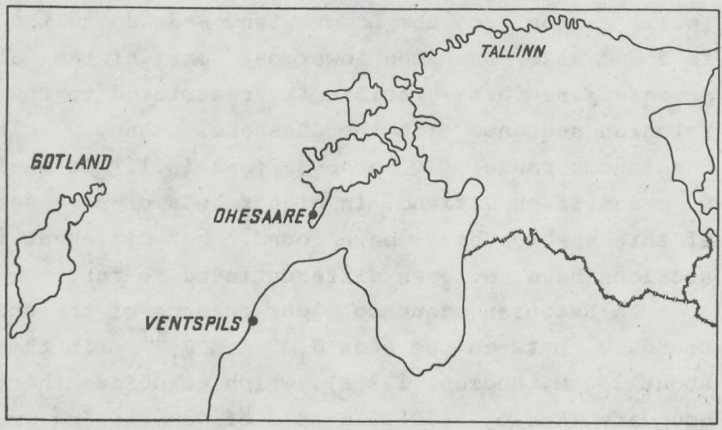

Fig. 1
Location of the main boreholes.

Location of the main boreholes is shown in Fig. 1. The Ohesaare and Ventspils borings were selected as the key sections since the relations between chitinozoa and graptolite zonation are better known. The succession of selected chitinozoan species in the Silurian of Gotland and the corresponding part of the Ohesaare boring are given in Fig. 2. Graptolites from the Ohesaare boring, including those from samples dissolved on chitinozoans, were identified by D. Kaljo (Кальо, 1970). The ranges of the selected chitinozoan species in the boundary beds of the Wenlock and Ludlow in the sections of Ventspils boring and Gotland are shown in Fig. 3. In the Ventspils section graptolite zones are given according to R. Ulst, though these data are still unpublished.

The author expresses her sincere gratitude to R. Ulst and D. Kaljo for the supply of graptolite data and H. Nestor for critical reading of the manuscript.

The comparison of the stratigraphical ranges of chitinozoan species in the Silurian of the East Baltic and Gotland (Laufeld, 1974, 1979) permits the following conclusions to be made.

The Lower Visby Marls of Gotland are usually correlated with the uppermost beds of the Adavere Stage (=Regional Stage, see this book, p. 6) (Martinsson, 1967; Кальо, 1970, etc.). Laufeld (1974) recorded *Margachitina margaritana* from the topmost part of the Lower Visby Beds in Buske and about 8 m below the Lower Visby - Upper Visby boundary in Irevik 3. The appearance of *M. margaritana* in Estonian sections marks the base of the Jaani Stage (Мянниль, 1970; Нестор, 1982a). Therefore it is possible that the uppermost part of the Lower Visby Beds corresponds to the lowermost beds of the Jaani Stage.

In the Upper Visby Marls excluding some topmost meters (Laufeld, 1974, 125) there occurs *Angochitina longicollis*, a characteristic species for the Velise Formation of the Adavere Stage and for the lowermost beds of the Jaani Stage (Мянниль, 1970; Нестор, 1982a). In the latter *Angochitina longicollis* associates with some other species (*Gotlandochitina* n. sp. 1, G. n. sp. 2 etc.) and this part of the sequence has been distinguished as a local zonal unit J_1^{I} (Нестор, 1982a), which in the Ohesaare section coincides with the graptolite zone of *C. murchisoni*. Therefore we may assume that the main part of the Upper Visby Beds corresponds to the same stratigraphical interval.

Conochitina proboscifera is the dominant species in the Lower Wenlockian Beds of Estonia. The beds with abundant *C. proboscifera* above the range of *Angochitina longicollis* and gotlandochitinas are distinguished as a local zonal unit J_1^{II} (Нестор, 1982a). Its upper boundary is marked by almost complete disappearance of *Conochitina proboscifera* and abundant appearance of *Conochitina* cf. *claviformis*. In the Ohesaare section this interval roughly coincides with the graptolite zone of *M. riccartonensis*. It is notable that on Gotland, according to S. Laufeld (1974, 1979) *C. proboscifera* (s.l.) ranges from the Lower Visby Beds up to the top of the Högklint Beds, and species is found also from the lowermost part of the Slite Beds. Only the distribution of *C. proboscifera* forma gracilis is restricted to the Upper-Visby Beds and Högklint "a". In Estonian sequence (in the Ohesaare, Ruhnu, Varbla, Kipi, Tõlla and Pulli sections) the continuous range of *C. proboscifera* (s.l.) is analogous to the range of *C. proboscifera* f. *gracilis* on Gotland. In higher beds of some sections only single scattered specimens of this species have been found, but different formas of *C. proboscifera* in Estonian sections have not been differentiated so far.

In Estonian sequence clear changes of the chitinozoan assemblage take place at the boundary between the beds J_1^{II} and J_1^{III} in the Ohesaare section (at the depth of about 330 m, Нестор, 1982a), which coincides there with the Lower- and Middle-Wenlockian boundary (Кальо, 1970). Instead of *Conochitina proboscifera C.* cf. *claviformis*[x] appears there in great numbers. Possibly this stratigraphical level can also be traced on Gotland, at the boundary of the subdivisions "a" and "b" of the Högklint Beds. Högklint "b" and "c" are characterized by *Desmochitina densa* and *Conochitina mamilla* (subdivision b), *C. flamma* and *C. leptosoma* (b, c) and *Desmochitina acollaris* (c) (see Laufeld, 1974, 1979). The uppermost part of the Jaani Stage includes also *Conochitina* cf. *mamilla*, which is an index-species of the beds J_1^{III} and by *Desmochitina acollaris* which first occurs in the beds J_1^{IV} (Нестор, 1982a). This allows to correlate beds J_1^{III} and J_1^{IV} correspondingly with the subdivisions "b" and "c" of the Högklint Beds. In the Ohesaare core this part of the Jaani Stage contains graptolites (Кальо, 1970). *Pristiograptus sardous* occurs in beds J_1^{III} (327-331 m) and *Monograptus flexilis* in beds J_1^{IV} (311.7-8 m).

In the middle part of the Wenlock the rapid renewal of the chitinozoan assemblage took place. *Clathrochitina clathrata*, *Gotlandochitina martinssoni* and *Linochitina cingulata* appear one after another in the succeeding subdivisions of the Slite Beds (d, e)

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[x] *C. claviformis* has not been identified by S. Laufeld (1974) on Gotland but we consider that part of specimens included by him to the species *C. leptosoma* (Fig. 29-B), *C.* aff. *proboscifera* and probably also *C.* aff. *elegans* (the latter from Klinteberg to middle Hemse) may belong to that species.

and in the lowermost beds of the Jaagarahu Stage in the Ohesaare core (see Laufeld, 1974: 126; Нестор, 1982a, b). It allows to correlate roughly these parts of sequences of both areas.

Succession of the appearance of *Conochitina argillophila*, *C. pachycephala* and *Gotlandochitina tabernaculifera* in the uppermost Wenlock is the same in the Ohesaare boring and on Gotland. In the upper part of the Jaagarahu Stage in the Ohesaare core at the depth of 172.6 m the first representatives of the genus *Sphaerochitina* appear. The Estonian species of *Sphaerochitina* differ from the sphaerochitinas in the Halla and Mulde Beds on Gotland, but it seems likely that the first appearance of this genus in both areas indicates a close age of these beds. The Rootsiküla Stage contains only scattered

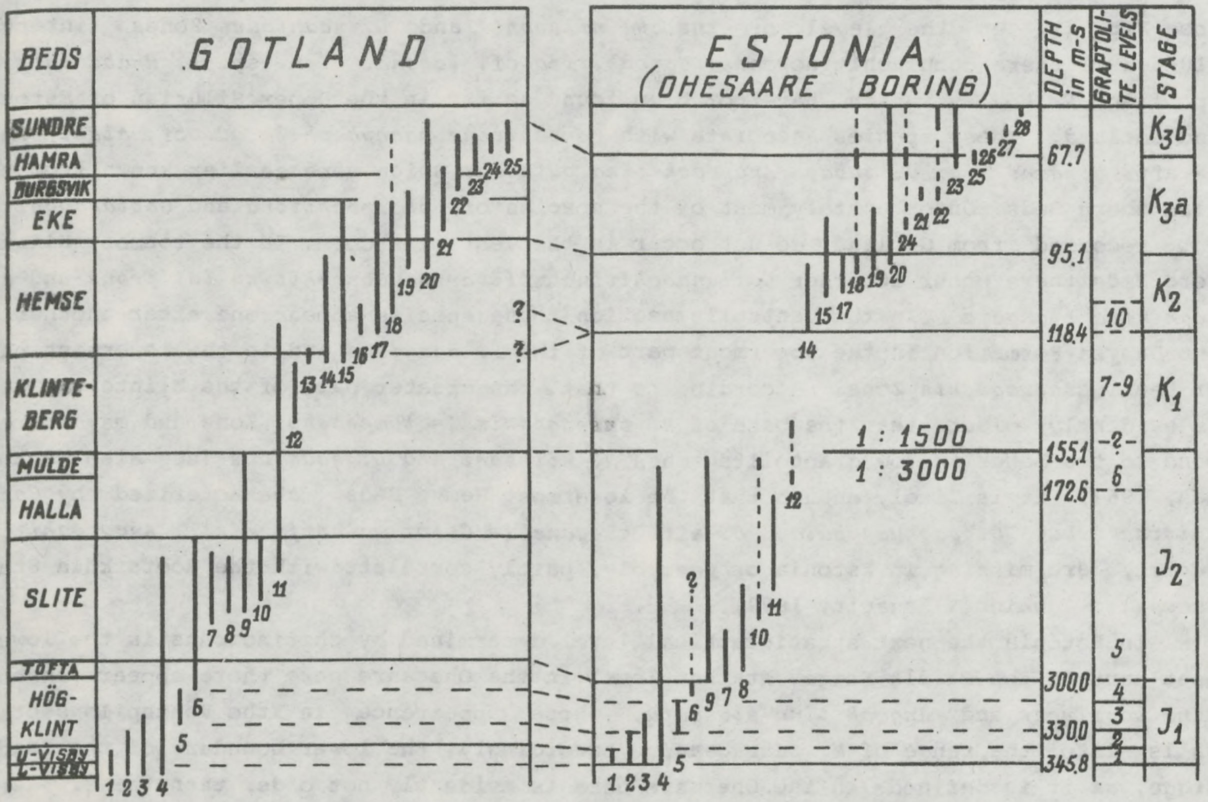

Fig. 2. Stratigraphical ranges of selected chitinozoan species in Silurian of Gotland (Laufeld, 1974) compared with Estonian.

I Chitinozoan species: 1 - *Angochitina longicollis* Eisenack; 2 - *Conochitina proboscifera* Eisenack; 3 - *Desmochitina densa* Eisenack; 4 - *Margachitina margaritana* (Eisenack); 5 - *Conochitina mamilla* Laufeld; 6 - *Desmochitina acellaris* Eisenack; 7 - *Clathrochitina clathrata* Eisenack; 8 - *Gotlandochitina martinssoni* Laufeld; 9 - *Linochitina cingulata* (Eisenack); 10 - *Conochitina argillophila* Laufeld; 11 - *Conochitina pachycephala* Eisenack; 12 - *Gotlandochitina tabernaculifera* Laufeld; 13 - *Gotlandochitina militaris* Laufeld; 14 - *Conochitina latifrons* Eisenack; 15 - *Angochitina elongata* Eisenack; 16 - *Ancyrochitina desmea* Eisenack; 17 - *Conochitina lauensis* Eisenack; 18 - *Angochitina echinata* Eisenack, 19 - *Eisenackitina philipi* Laufeld; 20 - *Eisenackitina lagenomorpha* (Eisenack); 21 - *Conochitina granosa* Laufeld; 22 - *Conochitina intermedia* Eisenack; 23 - *Sphaerochitina sphaerocephala* Eisenack; 24 - *Pterochitina pervivelata* Eisenack; 25 - *Gotlandochitina villosa* Laufeld; 27 - *Ancyrochitina fragilis* Eisenack; 28 - *Eisenackitina* cf. *elongata* Eisenack.

II Graptolite levels: 1 - *C. murchissoni* Zone; 2 - *M. riccartonensis* Zone; 3 - *P. sardous* Subzone; 4 - interval with *M. flexilis*; 5 - interval with *M. flemingii* and its subspecies; 6 - interval with *G. nassa*; 7-9 - interval presumably corresponding to the *M. ludensis*, *N. nilssoni* and *L. scanicus* Zones; 10 - interval presumably corresponding to the *M. tauragensis* Zone.

specimens and only in its lower part, that do not enable the correlation with the Gotland sequence. It should be noted that the index-species of the Klinteberg Beds *Gotlandichitina tabernaculifera* in Estonia occurs already in the uppermost beds of the Jaagarahu Stage.

Graptolites are rare in the upper part of the Wenlock of the Ohesaare core. According to finds of *M. flemingii* and its subspecies (see Кальо, 1970; Нестор, 1982b) the so-called "*flemingii* Beds" have been distinguished (interval 174-302 m). *G. nassa* is found in the Ohesaare boring at the depth of 166.4 m and also in the Ruhnu core (pers. comm. by D. Kaljo, see Нестор, 1982b).

The correlation of the Wenlock and Ludlow boundary beds in the East-Baltic and Gotland is based on the section of the Ventspils boring in West Latvia. In this section R. Ulst has established Ludlow graptolite zones up to the *M. tauragensis* Zone (incl.) (see Fig. 2). On the level of the *N. nilssoni* and *L. scanicus* Zones (interval 610-662 m) there occur chitinozoans: *Conochitina* cf. *lagena*, *C.* n. sp. 1, *Rhabdochitina* sp. 1 and *R.* sp. 2, which have not been found so far in the Upper Silurian of Estonia and Gotland. These species associate with *Conochitina pachycephala*, *C.* cf. *claviformis* (= aff. *elegans ?*), *C. tuba*, *Ancyrochitina gutnica*, which were earlier known from the Klinteberg Beds. Unfortunately most of the species of *Sphaerochitina* and *Gotlandochitina*, recorded from Gotland, do not occur in the Ventspils core. In the topmost Klinteberg Beds there occur together *Gotlandochitina militaris*, *Conochitina latifrons* and *Angochitina elongata*. In the Ventspils section these species appear one after another in the Dubysa Formation in the uppermost part of the *L. scanicus* and in the lowermost part of the *M. tauragensis* Zone. According to that, the greater part of the Klinteberg Beds is evidently older than the base of *M. tauragensis (= tumescens)* Zone and may correspond to the Lower Ludlow graptolite zones *N. nilssoni* and *L. scanicus* (see also Martinsson, 1967). It is likely enough that the lowermost Hemse Beds, characterized by *Conochitina tuba*, *C. pachycephala*, *C.* aff. *elegans* (= *C.* cf. *claviformis)*, *Ancyrochitina desmea*, are missing in Estonia or possibly, partly correlate with the Rootsiküla Stage (see also Jenkins & Legault, 1979).

In Estonia the next stratigraphical level determined by chitinozoans is the lowermost part of the Paadla Stage. At that level in the Ohesaare core there appear *Conochitina latifrons* and *Angochitina elongata*, whose appearance in the Ventspils section falls into the range of *M. tauragensis*. Accordingly, the lower boundary of the Paadla Stage, as it is defined in the Ohesaare core is evidently not older than the *M. tauragensis* Zone. Therefore, in Estonian sections beds, corresponding to the Lower Ludlow graptolite zones *N. nilssoni* and *L. scanicus* are either missing or correlate with a certain part of the Rootsiküla Stage.

In the lower - middle part of the Hemse Beds *Conochitina lauensis* and *Angochitina echinata* make their appearance and *Conochitina tuba*, *C. pachycephala*, *C.* aff. *elegans* and *Ancyrochitina desmea* disappear. In the section of Ventspils analogous changes take place within the interval of about 535-570 m, in the topmost beds of the Dubysa Formation and lowermost part of the Pagegiai Formation.

Unfortunately the lower and middle beds of the Paadla Stage in the Ohesaare core contain a reduced number of species. Besides *Conochitina latifrons* and *Angochitina elongata* there occur only *Ancyrochitina* cf. *diabolus* and *Sphaerochitina* sp. Though appearance of *Conochitina lauensis* at the depth of 110.5 m is noteworthy, these data are still not sufficient for exact correlation of the Hemse Beds and the Paadla Stage. Interval of the possible position of the base of the Paadla Stage in the Hemse Beds is given in Fig. 2.

According to S. Laufeld (1974, 127) chitinozoan assemblage of the uppermost part of the Hemse Beds and the lower part of the Eke Beds differ a little from one another.

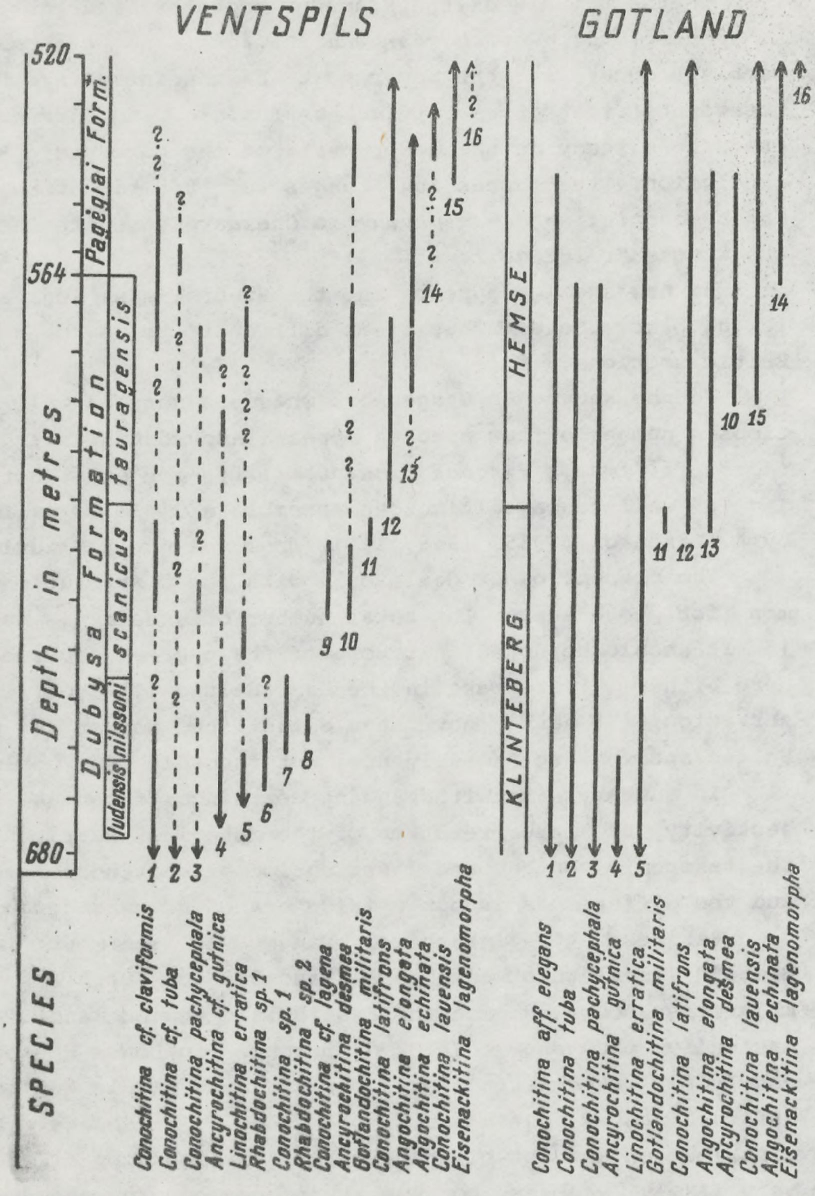

Fig. 3. The succession of selected chitinozoan species in Wenlock-Ludlow boundary beds of the Ventspils section and Gotland.

Sphaerochitina acanthifera appearing in the lowermost Eke Beds, has not been found in the East Baltic. This species proved to be facies-controlled to a very great extent (S. Laufeld, 1974:123, 127). The Eke Beds are mainly characterized by *Eisenackitina lagenomorpha, E. philipi, Conochitina lauensis, C. granosa* and *Angochitina elongata.* Still, the first species appears already in the uppermost Hemse Beds but is represented there by untypical specimens (see Laufeld, 1974: 82). Similar untypical form of *E. lagenomorpha* appears in the Ventspils boring from the depth of 516 m (one dubious specimen already at 532 m) and occurs in Ohesaare in the interval of 95.1 - 99.5 m, corresponding to the uppermost part of the Paadla Stage. The Eke assemblage occurs also in the Ohesaare section, but *Conochitina lauensis* is there mainly restricted to the Paadla Stage and *Eisenackitina philipi* to the lowermost Kuressaare Stage with certain overlap of the ranges.

The upper boundary of the Eke Beds is characterized by disappearance of *Conochitina lauensis* and *Angochitina elongata. Eisenackitina philipi* occurs also in the lower part of the Burgsvik Beds. According to S. Laufeld (1974:127) the Burgsvik Beds represent a short time interval with very rapid sedimentation and fossils occurring are greatly dependent on facies.

In the Hamra Beds there appear together *Sphaerochitina sphaerocephala, Pterochitina pervivelata, Gotlandochitina villosa* and *Eisenackitina oviformis*. Analogous assemblage occurs in the upper part of the Kuressaare Stage in the Ohesaare core. It is noteworthy that *Pterochitina pervivelata* and *Eisenackitina oviformis* are present in Ohesaare already in the lower part of the Kuressaare Stage, at the depth of 89.3 m. In conclusion, the succeeding ranges of *Eisenackitina philipi, Conochitina granosa* and *Sphaerochitina sphaerocephala* in Ohesaare core are the most characteristic features of the Kuressaare Stage.

No new species appear in the Sundre Beds; only gradual disappearance of taxa is taking place there. Thus it is difficult to make a certain comparison with the East Baltic sections.

In the Kaugatuma Stage of Ohesaare core as well as in the other East Baltic sections a number of new species appear: *Ancyrochitina fragilis, Eisenackitina* cf. *elongata, E. filifera, Fungochitina pistilliformis* etc., not recorded from Gotland but forming a well-known chitinozoan assemblage of the so-called Beyrichia Limestone described by A. Eisenack (1955, 1968, 1971) from the upper Silurian erratic boulders.

The present paper deals only with the distribution of more essential species, common for both areas. The total number of species is much greater than is given in Fig. 1. It should be noted that some of the species recorded from Gotland and not mentioned here either (1) are rare in the East Baltic (2) occur with some doubt, due to bad preservation; (3) have not been established so far. On the other hand, some of the East Baltic species are probably new, not recorded from Gotland up to now.

In summary, notwithstanding certain differences, probably caused partly by subjectivity of interpretation of the material, partly by ecological reasons, in general the taxonomic content and distribution of chitinozoans of both areas are rather similar and the differences in our opinion are of no considerable influence on the correlation.

Besides, stratigraphical ranges of the most important chitinozoan species in Britain (Aldridge et al., 1979) and Belgium (Verniers, 1981) also indicate certain similarities compared with the East Baltic and Gotland. Though these data are given schematically, they show clear difference in Lower Wenlock *(Conochitina proboscifera, C. acuminata, Angochitina longicollis)* and Middle Wenlock *(Linochitina cingulata, Conochitina tuba, C. gutta* etc.) chitinozoan assemblage. Finding out species of worldwide distribution and establishing sure relationships of their ranges with graptolite zones very likely enables to use chitinozoans for age determination in shelly sequences, where graptolites are lacking.

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КОРРЕЛЯЦИЯ РАЗРЕЗОВ СИЛУРА ПРИБАЛТИКИ И О-ВА ГОТЛАНД ПО ХИТИНОЗОЯМ

В. Нестор

Сравнение данных распространения хитинозой в силурийских разрезах Эстонии /скв. Охесааре/, Латвии /скв. Вентспилс/ и острова Готланд позволяет сделать следующие корреляционные выводы:

1. Основная часть мергелей Висбю и слои Хёгклинт соответствуют яанискому горизонту - зонам *Conochitina proboscifera* и *C. claviformis* /Нестор, 1982а, б/.

2. Последовательное появление видов *Clathrochitina clathrata*, *Linochitina cingulata* и др. как в яагарахуском горизонте, так и в слоях Слите позволяет грубо сопоставить эти части разреза /см. рис. 2/.

3. Поскольку в Эстонии роотсикюлаский горизонт охарактеризован хитинозоями слабо, эта часть разреза сопоставима с готландским через скв. Вентспилс /см. рис. 3/, где пограничные слои венлока и лудлова содержат и граптолиты.

4. Наличие *Conochitina lauensis*, *Eisenackitina lagenomorpha* и др. в слоях Хемсе и в паадласком горизонте позволяет сопоставить эти части разреза /см. рис. 2/.

5. Последовательность видов *Eisenackitina philipi*, *Conochitina granosa* и *Sphaerochitina sphaerocephala* характерна для курессаареского горизонта и слоям Эке, Бургсвик, Хамра и Сундре.

УДК 566:551.733.3(474)

VERTEBRATE ZONES IN THE EAST BALTIC SILURIAN

T. Märss

Several attempts have been made to subdivide the Silurian and the lowermost part of the Devonian using various vertebrates: osteostracans (Bölau, 1949), heterostracans and osteostracans (White, 1950), and thelodonts/(Gross, 1947, 1967; Каратаюте-Талимаа, 1968, 1974 (in Гайлите, Ульст, 1974), 1978; Turner, 1973/. As these zonal schemes were largely based on the material from outcrops representing only small parts of the continuous sections the zonations appeared to be insufficient for a detailed correlation within a paleobasin and/or for an interregional correlation.

Recent study of rich material from 17 borings and 9 outcrops of the East Baltic area demonstrates the great stratigraphical value of vertebrates. Nine zones (Fig. 1, 2) are established in an interval from the Lower Wenlock (in Estonia) to the Upper Downton (in Latvia). Here the Downton/Ditton boundary has been used according to H. W. Ball and D. L. Dineley (1961). The lower limit of a biostratigraphical zone is

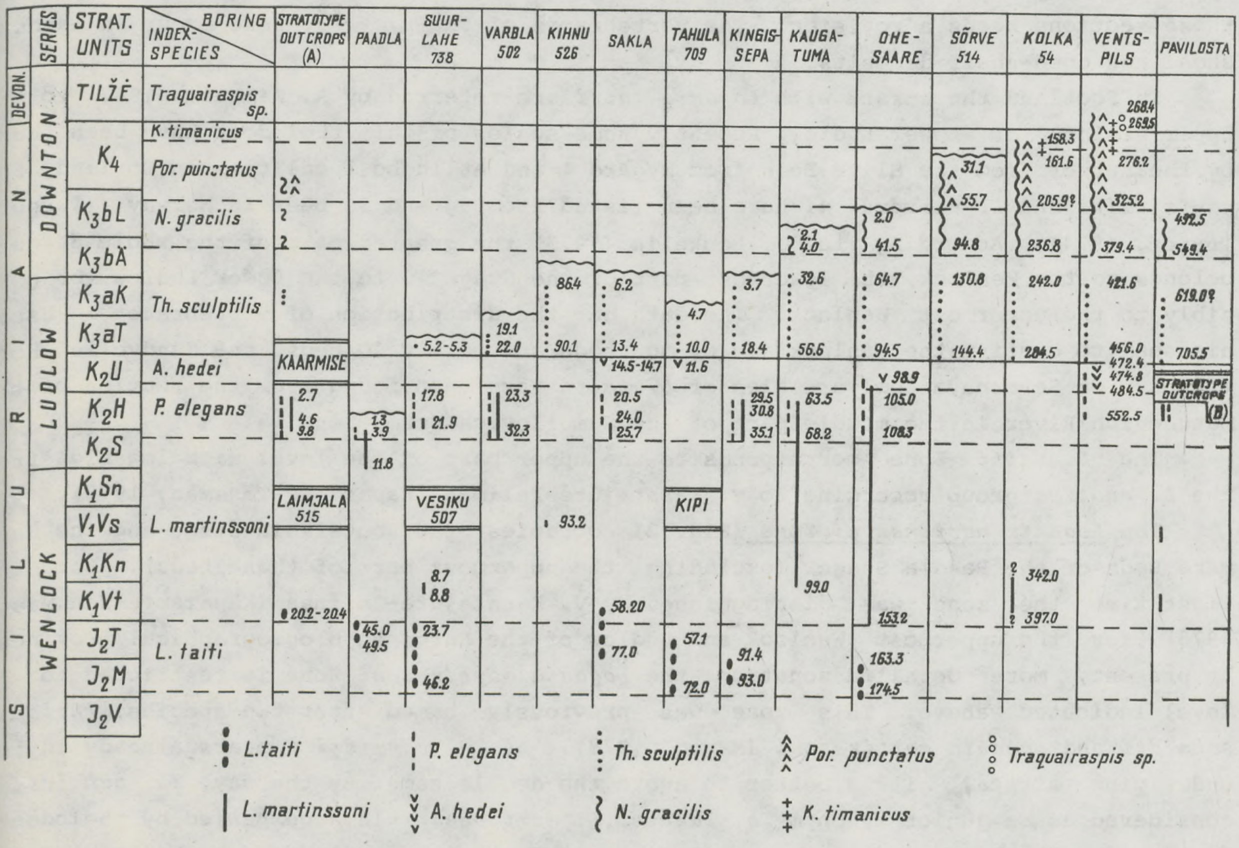

Fig. 1. The tailzones of index-species in borings and outcrops. For indexes of stratigraphical subdivisions see Table in Preface.
Vertebrates were used for establishing of the lower boundary of the Kuressaare Stage, but not those of other ones.

defined by the earliest occurrence of the index-species (Hedberg, 1976). Usually the index-species extends into the succeeding zone. The representatives of various vertebrates (thelodonts, acanthodians, a heterostracan, an osteichthyid) are used as index-species.

Vertebrate zones

In Estonia the earliest known vertebrates, i.e. thelodont and acanthodian scales have been discovered from the Late Llandovery Rumba Formation, and from the upper part of the Early Wenlock Jaani Stage (Fig. 2). The latter contains conodont *Ozarkodina sagitta rhenana* (Walliser) (Viira, personal communication). The scarcity of vertebrates has not enabled to distinguish the zones on these levels. Higher up in sections the vertebrate fossils are more numerous but in the earliest, *Logania taiti* zone they are still rare.

The *Logania taiti* Zone (Fig. 2) corresponds to the Maasi (except their base) and Tagavere Beds of the Jaagarahu Stage, the Wenlock of Estonia. Though the scales of *Logania* are known from the upper part of the Jaani Stage, they cannot be referred with certainty to those of *L. taiti*. In view of this, the lower limit is defined by the earliest appearance of scales which definitely belong to *L. taiti*. Of the other species, *Thelodus laevis*, *Thelodus* sp. ind., Osteostraci gen. et sp. ind. and *Saarolepis oeselensis?* are represented. The acanthodians of *Nostolepis striata* and *Gomphonchus sandelensis* type are known from the Vesiku-507 boring, where the zone has a maximum thickness (22.5 m). In the Sakla and Laimjala-515 borings *L. taiti* ranges above the upper boundary of the zone (Fig. 1) (to our mind stratigraphy of the Wenlock part of these sections needs a revision). The vertebrates of the *L. taiti* Zone occur in lagoon, shoal and open-shelf deposits.

In Scotland the strata with *Logania taiti* are referred by A. Ritchie (1967) to the Upper Wenlock or Lower Ludlow. Recently some scales of this thelodont have been found by the author from the Slite Beds from Nygård 1 and Atlingbo localities on Gotland. *Logania taiti* and *L. martinssoni* have been listed from 9g and 10 beds in Norway (Turner, Turner, 1974). According to J. Bockelie (1973) tne greater part of the whole Stage 9 belongs to the Wenlock, the lowermost part of the Stage 10 to the Lower Ludlow, or possibly to the uppermost Wenlock. The data on the distribution of vertebrates in Estonia seem to confirm the Wenlock age of 9g beds and partly 10 beds, the Sundvollen Formation. On Severnaya Zemlya scales of *L. taiti* have been found from the section of the Matusevich River in the middle part of the Samoilovich Formation.

The *L. taiti* Zone corresponds to the upper part of the level with loganids from the *L. scotica* group according to V. Karatajūtė-Talimaa (Каратаюте-Талимаа, 1978).

The *Logania martinssoni* Zone (Fig. 2) occupies the Rootsiküla Stage and the Sauvere Beds of the Paadla Stage (excluding the uppermost part of these beds). For the first time the zone was distinguished by V. Karatajūtė-Talimaa (Каратаюте-Талимаа, 1978) for the uppermost Wenlock and Ludlow of the European biogeographical province. At present, more detailed zonation, the *Logania martinssoni* Zone is restricted to the level indicated above. This zone was previously named after two species, *Thelodus schmidti* and *Logania martinssoni* (Мярсс, 1978). As *Th. schmidti* appears already in the underlying strata, it is better to avoid the double name. By the way, *Th. schmidti* is considered as a junior synonym *Th. laevis*. *L. martinssoni* is accompanied by thelodonts *Th. laevis*, *Th.* cf. *marginatus*, osteostracans *Tremataspis schmidti*, *T. milleri*, *Oeselaspis pustulata*, *Thyestes verrucosus* and anaspid *Saarolepis oeselensis*. In the Laimjala-515 and Sakla borings in the Viita Beds only scales of *L. taiti* occur. The whole listed vertebrate assemblage (except *L. taiti*) ranges into the succeeding zone. The maximum thickness of the strata corresponding to the *Logania martinssoni* Zone is 44.9 m in the Ohesaare boring. Facial distribution of *L. martinssoni* coincides with that of *L. taiti*.

Outside Estonia *L. martinssoni* is listed from the Halla Beds of Gotland (Martinsson, 1966; Gross, 1967, 1968a), and from 9g and 10 beds of the Ringerike district, Norway (Turner, Turner, 1974). The identification of *L. martinssoni* from the beds 9g needs a revision. From the Mortimer outcrop area, (loc. 3:4 of Silurian Subcommission localities), the Middle Eltonian of Welsh Borderland have been found both *L. martinssoni* and *Thelodus laevis*. In the Canadian Arctic they occur in the Upper Wenlock and Lower Ludlow of the Prince of Wales Island (Turner, Dixon, 1971; Dixon, Williams, Turner, 1972), in North Timan in the Velikoretskaya Formation (Ludlow) (Коссовой, Каратаюте-Талимаа, 1977), and in the Ust-Spokoinaya Formation, Ludlow of Severnaya Zemlya (author's identifications).

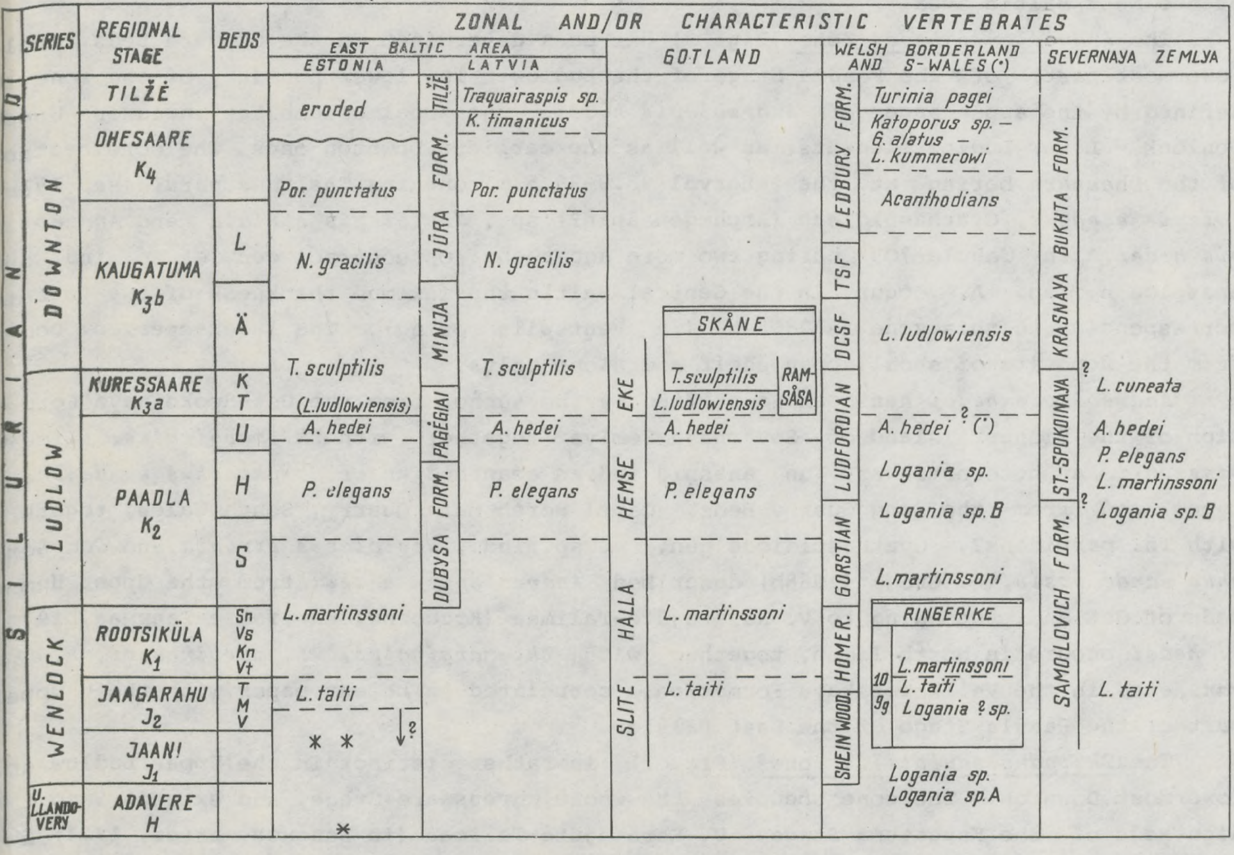

Fig. 2. Subdivision of Silurian deposits based on vertebrates. * - finds of single scales of *Thelodus* sp. and *Gomphonchus* sp., ** - the same + *Logania* sp. DCSF - Downton Castle Sandstone Formation, TSF - Temeside Shale Formation. Stratigraphy and (partly) paleontological data after Ball, Dinely, 1961; Turner, 1973; Turner, Turner, 1974; Kaljo, 1978; Holland, 1980; Гайлите, Ульст, 1974; Меннер и др., 1979; Пашкевичюс, 1979.

The Phlebolepis elegans Zone (Fig. 2) evidently occupies the topmost part of the Sauvere Beds, Himmiste Beds and lowermost part of the Uduvere Beds of the Paadla Stage. Ch. Pander (1856) in his description of *Phlebolepis elegans* gave for type-locality "Rootsikülle". Numerous samples from stratotype outcrops and from the cores of more than 10 boreholes representing the same stage, have not revealed a single scale from the Rootsiküla level. Maximum thickness of the strata corresponding to the *Phlebolepis elegans* Zone is 68.0 m in the Ventspils boring. The other thelodonts, osteostracans, anaspid and acanthodians coincide with those of the preceding zone. However, *Th. marginatus* has been identified from the *P. elegans* Zone with certainty (and not with some doubt as in the preceding zone). *Phlebolepis* n. sp., and osteostracans *Tremataspis mammillata* and *Dartmuthia gemmifera* make their first appearance in this zone. Index-species ranges into the succeeding zone. Facial range of *Phlebolepis elegans* is somewhat wider than those of *L. taiti* and *L. martinssoni*. It has been found in the deposits of lagoon, shoal, open-shelf and slope belts of the Paleobaltic Silurian basin.

The *Phlebolepis elegans* Zone has been established in the Paadla Formation (Ludlow) of Estonia in numerous boring sections, in the Pagėgiai Formation of Latvia in the Kolka-4 (= Lužni) boring (see Гайлите, Ульст, 1974). In the Ventspils boring (at the depth 484.5-552.5 m) the zone corresponds to the most of the Dubysa Formation and the lower part of the Pagėgiai Formation. The Kuba Beds in the Mikhailovsk section, western slope of the Central Urals, and a part of the Ust-Spokoinaya Formation of the October Revolution Island, Severnaya Zemlya may be equivalent to the *Phlebolepis elegans* Zone of the East Baltic area.

The *Andreolepis hedei* Zone (Fig. 2) has been determined in the Uduvere Beds (excl. lowermost part) of the Paadla Stage of the Ludlow. The lower boundary of the zone is defined by the appearance of *Andreolepis hedei*. The zonal assemblage includes Upper Wenlock - Lower Ludlow elements, as well as the earliest Downton ones. The core section of the Ohesaare boring at the interval 98.9-99.5 m contains *Thelodus parvidens*, *Phlebolepis elegans*, Cyathaspidinae (Archegonaspis?) sp., *Nostolepis striata* and *Andreolepis hedei*. In Tahula-709 boring two more agnathans: Osteostraci gen. et sp. ind. and Anaspida n. sp. A. occur. In the Central Baltic the maximum thickness of the strata corresponding to this zone is 28.5 m (in Ventspils boring). The index-species comes from the deposits of shoal, open shelf and slope belts.

Andreolepis hedei has been identified by the author from the Ust-Spokoinaya Formation of the Pioneer Island of Severnaya Zemlya together with *Th. marginatus*, *L. martinssoni*, a heterostracan, an anaspid and an acanthodian of *Gomphonchus sandelensis* type, and from the Long Quarry Beds, Capel Horeb Main Quarry, South Wales, together with Th. parvidens?, Cyathaspididae gen. et sp. ind., *Nostolepis striata* and *Gomphonchus sandelensis*. W. Gross (1968b) described *Andreolepis hedei* from the Upper Hemse Beds of Gotland. According to V. Karatajūtė-Talimaa (Коссовой, Каратаюте-Талимаа, 1977) *A. hedei* occurs in North Timan, together with *Th. marginatus*, *L. martinssoni*, *P. elegans*, etc. in the Velikoretskaya Formation, correlated in recent paper with the upper part of the Paadla Stage of the East Baltic.

The *Thelodus sculptilis* Zone (Fig. 2) is rather distinct in the Upper Ludlow and lowermost Downton. The zone occupies the whole Kuressaare Stage, and extends into the Äigu Beds of the Kaugatuma Stage. V. Karatajūtė-Talimaa (in Гайлите, Ульст, 1974) for the first time distinguished this zone in Latvia in the section of the Kolka-4 boring at the base of the Minija Beds. Later on, however, she has not mentioned the zone. But, as *Th. sculptilis* appears in many borings at the same level and is abundant, it is worth using this thelodont as an index-species. The maximum thickness of the strata occupied by the zone is known in the Pavilosta boring, Latvia, (more than 155 m). Northwards the thickness decreases. In the lower part of the zone the fish assemblage is very variable and abundant. Almost at the same level with *Th. sculptilis* appear in Ohesaare boring thelodonts *Th. traquairi*, *Logania cuneata* and *L. ludlowiensis*. In the lowermost part of the zone in the Sakla boring appears *Katoporus tricavus*, and in Varbla-502 boring *Logania cuneata*. Scales of an acanthodian which may belong either to *Gomphonchus hoppei* or *Poracanthodes porosus* (see Gross, 1971) have been found in many borings. Somewhat higher occurs *Th. admirabilis*. A number of forms, such as Cyathaspidinae (*Archegonaspis*?) sp., Osteostraci gen. et sp. ind., *Nostolepis striata* and *Gom-*

phonchus sandelensis range into the *Thelodus sculptilis* Zone from the preceding one. More characteristic of the zone are *Th. sculptilis, Th. admirabilis, L. ludlowiensis* and the acanthodian of the uncertain systematic position (*Gomphonchus hoppei* or *Poracanthodes porosus*). The lower boundary of the zone can be defined by the appearance of these forms (except *Th. admirabilis*). There is an interval before the succeeding zone (up to 69.6 m thick in the Pavilosta boring), poor in the characteristic vertebrates. *Th. sculptilis* has been found in deposits of all facies belts of the Baltic basin except the depression one. It is especially numerous in the first two nearshore belts. In the other regions of the East Baltic *Thelodus sculptilis* has been found in the upper part of the Upper Ludlow Pagėgiai Formation and at the base of the Minija Formation, Downton of Lithuania (Virbalis boring, depth 843.6 m), and Latvia (Kolka-4, depth 336.5-338.6 m; Engure, depth 468.5-471.5 m) see Каратаюте-Талимаа, 1978; it is also known from borings Sutkai-89, depth 839.7-875.1 m, and Jurbarkas-36, depth 1034.0-1062.1? m (Karatajūtė-Talimaa, pers. comm.). The scales of *Th. sculptilis* have been discovered by the author also from the Upper Ludlow of the Kunkoiai section (depth 1055.1 m) Lithuania, and from the Demid Beds (Downton) of the Mikhailovsk section, West Urals. Gross (1967) noted *Th. sculptilis* from Ramsåsa Beds, South Sweden.

V. Karatajūtė-Talimaa (Каратаюте-Талимаа, 1978) distinguished an assemblage with *Logania ludlowiensis* for the Early Downton of European biogeographical province. This assemblage is characteristic of the Lower Downton of Britain. However, the first finds of *Logania ludlowiensis* are recorded from the Lower Wenlock (Turner, 1973). Evidently, in the Wenlock and Ludlow of Welsh Borderland, a number of *Logania*-species occur (see Fig. 2). This is confirmed by finds of *L. martinssoni* in the Mortimer Forest outcrop area, Middle Eltonian (see above) and *Logania* sp. B in the Sunnyhill Quarry, Upper Bringewoodian. Scales similar to those of *Logania* sp. B and *L. ludlowiensis* (but not identical with the latter ones) have been found from the uppermost beds of the Samoilovich Formation or the lowermost beds of the Ust-Spokoinaya Formation of Severnaya Zemlya (collections of V. Karatajūtė-Talimaa). Five scales of *Logania ludlowiensis* have been found on Gotland Källstede locality in the Eke Beds, together with corals. In the Kuressaare Formation of Estonia, upper part of the Pagėgiai Formation of Lithuania and Latvia, also in boulders of North German lowland *L. ludlowiensis* is rare, and so it is difficult to use this thelodont as an index-species.

The *Nostolepis gracilis* Zone is approximately equivalent to the upper half of the Kaugatuma Stage (Fig. 2). The acanthodians are especially characteristic of the zone. Rare specimens of *Thelodus parvidens* occur together with *Nostolepis gracilis, N. striata,* and *Gomphonchus sandelensis*. In the Ohesaare and Ventspils borings *Th. traquairi, Katoporus tricavus,* heterostracans *Tolypelepis undulata* and *Strosipherus indentatus* appear at this level. *Nostolepis gracilis* ranges into the succeeding zones. This acanthodian occurs in the first four facial belts.

The vertical distribution of Silurian acanthodians in the North and Central East Baltic shows, that besides thelodonts some representatives of this group may be well used for biostratigraphical purposes. They are especially valuable for the lower part of the Downton where the thelodonts and other vertebrates are rare. W. Gross, V. Karatajūtė-Talimaa and S. Turner have indicated in their papers a Downton level rich in acanthodians. This level, by author, corresponds in Latvia and Lithuania to the upper part of the Minija and lower part of the Jūra Beds, in Britain partly to Holdgate sandstones containing only acanthodians. For the middle part of the Baltic Downton V. Karatajūtė-Talimaa (Каратаюте-Талимаа, 1978) distinguished an assemblage with *Katoporus tricavus*. However, finds of *K. tricavus* are so rare that it is hardly possible to use this thelodont as a zonal species.

The *Poracanthodes punctctus* Zone (Fig. 2) corresponds to the uppermost beds of the Kaugatuma and to the greater part of the Ohesaare Stage. The establishment of the lower boundary of the zone is sometimes complicated, as it is not always easy to tell the difference between *Poracanthodes punctatus* and the acanthodian of uncertain systematic position (*Poracanthodes porosus* or *Gomphonchus hoppei*). The strata at the depth of 325.2-276.2 m of the Ventspils boring, and at the depth of 205.9(?)-161.6 m of the Kolka-54 boring represent the zone entirely. The index-species ranges into the succeeding zone. The zone is characterized by a very variable and rich vertebrate assemblage. It includes, on the one hand, species, which occur in the Kuressaare Stage, and on the other hand species, ranging into the Devonian. Thus, beginning with the Lõo time in Estonia, the assemblage with *Por. punctatus* includes *Goniporus alatus*, *Gomphonchus hoppei*, *Lophosteus superbus* and *Tylodus deltoides*. In the uppermost part of the zone all the *Thelodus* species disappear. *Poracanthodes punctatus* has been found from the deposits of lagoon, shoal and open shelf facial belts.

The zone evidently corresponds to the upper part of the *Katoporus tricavus* assemblage level distinguished by V. Karatajūtė-Talimaa (Каратаюте-Талимаа, 1978).

The *Katoporus timanicus* Zone occurs in the Upper Downton of Latvia (Fig. 2) and North Timan. It corresponds to the *Katoporus lithuanicus* Zone of Lithuania, established by V. Karatajūtė-Talimaa (Каратаюте-Талимаа, 1978). The author of the present paper has identified scales of *K. timanicus* from four samples of the Ventspils boring (depth 276.2-269.5 m), and from the Kolka-54 boring (depth 161.6-158.3? m). Zonal assemblage contains besides the index-species a small number of thelodont scales, fragments of heterostracans, numerous acanthodian scales and remains of osteichthyid *Lophosteus superbus*, and sceletal fragments of *Tylodus deltoides*. They are all known from the preceding *Poracanthodes punctatus* Zone. *Katoporus timanicus* and associated species have been found from deposits of lagoon, shoal and open-shelf belts.

Vertical distribution of *Logania kummerowi*, distinguished by W. Gross (1967) as zonal species for the assemblage lacking *Thelodus parvidens*, is not fully known. V. Karatajūtė-Talimaa (see Гайлите, Ульст, 1974) identified from the Kolka-4 boring together with *Katoporus* sp. (? *lithuanicus*) also *Logania kummerowi ?* and *Traquairaspis* sp. ind. The first one of these three species occurs somewhat lower in the section. V. Karatajūtė-Talimaa (Каратаюте-Талимаа, 1978) changed in the Kolka-4 boring the identification of the *Logania kummerowi ?* to *L. borealis ?* and noted (p. 180) that some scales of *Logania borealis ?* in the number and size of lateral spines are reminiscent to the scales of *L. kummerowi*. In the Nida and Stoniškiai borings, Lithuania, *L. kummerowi* appears earlier than *K. lithuanicus*. According to the data from the Ventspils boring, two types of *Logania* scales can also be distinguished, and *L. kummerowi* occurs higher the monolithic scales of *K. timanicus*. By S. Turner (1973, p.566) the *Goniporus - Katoporus* assemblage, containing *L. kummerowi*, is distributed in conglomerates of the Upper Red Downton Group. Higher, in the "Psammosteus" Limestones Group this fauna is associated with *Traquairaspis pococki*. Evidently, we are dealing with two species of *Logania*: (1) *Logania cuneata*, which is of wide vertical distribution (ranging from the Kuressaare Stage into the lowermost beds of the Tilžė Stage) and (2) *Logania kummerowi* with a limited stratigraphical distribution (from the uppermost beds of the Ohesaare Stage up to the lowermost beds of the Tilžė Stage incl.). As biozones of *L. kummerowi*, *K. timanicus* and *K. lithuanicus* possibly coincide, but *K. timanicus* is geographically more widespread (North Timan, Latvia, evidently also in Britain, see Turner, 1973, Fig. 7c), the last has been chosen as an index-species. As to *Logania borealis ?* indicated by Karatajūtė-Talimaa (Каратаюте-Талимаа, 1978), it must be considered as junior synonym of *L. cuneata*.

The *Traquairaspis* Zone has been distinguished in the Upper Downton by E. White (1950). In the Ventspils boring *Traquairaspis* sp., *Tesseraspis ?* sp. and *Turinia pagei* are associated with *Logania cuneata, L. kummerowi, Goniporus alatus*, etc., the Silurian forms of preceding zone. The *Traquairaspis* Zone has not been completely studied by the author so far.

Facies and cyclic distribution of vertebrates

The facies distribution of Silurian vertebrates is rather wide. The majority of species has been found from lagoon, shoal and open-shelf deposits, but some of them /*Phlebolepis elegans, Logania* sp. ind., *Thelodus parvidens, Th. sculptilis, Th. admirabilis*, Cyathaspidinae *(Archegonaspis ?)* sp., *Nostolepis striata, N. gracilis, Gomphonchus sandelensis, Andreolepis hedei*/ also from the slope facies belt which increases the correlative value of these vertebrates. It must be taken into account that from the Late Downton slope facies we have a small number of samples. Thus, data on the distribution of some species are incomplete, e. g. those of the *Poracanthodes punctatus* Zone. And so is the case with the assemblage of the *Andreolepis hedei* Zone (lagoon deposits corresponding to the latter are not known).

The comparison of the environmental changes during the Silurian in Estonia (see diagram by Эйнасто et al., 1978) with the vertical distribution of vertebrates has revealed an interesting coincidence between the appearance of many new genera and species and transgressions of higher rank. This coincidence is especially clear by the maximum phase of Ludlow transgression during the Uduvere time when first elements of a new, Downton vertebrate fauna appear. The next transgression of a higher rank took place in the Downton in the Kaugatuma time. This transgression is connected with the appearance of vertebrates ranging into the Devonian. The data from the Wenlock are more limited, particularly from its lower part. But the appearance of *Logania martinssoni* in the Early Viita (Late Wenlock) and *Phlebolepis elegans* in Late Sauvere (Early Ludlow) time seem to confirm this rule. As to *L. taiti*, it might appear even during an earlier transgression in the Late Llandovery or Early Wenlock. It must be kept in mind that it is not always possible to fix exactly the first appearance of a new vertebrate species in transgressive deep-water rock where scales are highly scattered (Мярсс,Эйнасто, 1978). G. Lindberg (Линдберг, 1978, p. 19) writes about the influence of the change of phases of transgression and regression on the evolution of fish and fish-like animals as follows: "We have a full right to consider a sudden transgression after a long lowering of the ocean level as one of possible reasons for the existence of stages in the development of organic world". Recently it has been demonstrated that extensive transgressions in the Silurian have been caused by fluctuations of the level of the world ocean (see Антошкина et al., 1976). Thus, if G. Lindberg's presumption is valid, the appearance of new contemporary vertebrate genera and species must have taken place in vast territories.

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ЗОНЫ ВЕРТЕБРАТ В СИЛУРЕ ПРИБАЛТИКИ

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Для выяснения последовательности и предела распространения видов бесчелюстных и рыб в силуре и силуре - нижнем девоне Северной и Центральной Прибалтики с большой детальностью опробовались разрезы 17 буровых скважин /рис. 1/. Начиная с яагарахуского горизонта, нижнего венлока до тильжеского горизонта нижнего девона установлено 9 зон позвоночных. Нижние границы зон определены по первому появлению вида - индекса.

Самая нижная, зона *Logania taiti* соответствует маазиским /без основания/ и тагавереским слоям яагарахуского горизонта Эстонии /рис. 2/. Зона *Logania martinssoni* охватывает роотсикюлаский горизонт и саувереские слои паадлаского /за исключением верхов этих слоев/. Зона *Phlebolepis elegans* занимает, вероятно, верхи сауверехских, химмистеские и низы удувереских слоев паадлаского горизонта. Зона *Andreolepis hedei* выделяется в удувереских слоях /без низов/ паадлаского горизонта. Зона *Thelodus sculptilis* охватывает весь курессаареский и большую часть эйгуских слоев каугатумаского горизонта. Зона *Nostolepis gracilis* выделена в верхах эйгуских и в лыоских /за исключением самых верхов/ слоев каугатумаского горизонта. Зона *Poracanthodes punctatus* охватывает верхи каугатумаского и большую часть охесаареского /без верхов/ горизонтов. Зону *Katoporus timanicus* можно выделить в верхах охесаареского горизонта. *Traquairaspis* sp. /зона *Traquairaspis* sp./ определено в разрезе скв. Вентспилс в низах тильжеского горизонта. В полном объеме она не изучалась.

Большинство видов силурийских вертебрат связано с лагунными, отмельными и открытошельфовыми отложениями. Некоторые виды найдены и из отложений склоновой зоны. Однако, необходимо иметь в виду, что в верхнем даунтоне мы не имеем отложений склоновой зоны, а в лудлове /в удувереских слоях/ - лагунной зоны, и поэтому данные о фациальном распределении некоторых видов не полны.

УДК 56.074.6:551.733.3 /474/

Экостратиграфия - некоторые аспекты из прибалтийской практики. Д. Кальо. В кн.: Экостратиграфия силура Прибалтики. Таллин, АН ЭССР, Ин-т геол., 1982, р. 9 - 15 /англ., рез. русск./.

Основная задача экостратиграфии заключается в разработке методики т.н. бассейнового анализа, в частности, корреляции разнофациальных отложений путем преодоления фациальных границ и трассирования синхронных уровней через весь палеобассейн. Местные и региональные стратиграфические подразделения отражают палеоэкосистемы. Их распространение и замена во времени и пространстве составляет основной каркас для стратиграфии бассейна. 1 рис. Библ. 20 назв.

УДК 551.461.8:551.733.3 /474/

Применение концепции шельфа и склона к силурийскому Балтийскому бассейну. Нестор Х., Эйнасто Р. В кн.: Экостратиграфия силура Прибалтики. Таллин, АН ЭССР, Ин-т геол., 1982, р. 17 - 24 /англ., рез. русск./.

Балтийский бассейн силура интерпретируется как периконтинентальное море с обособленным шельфом и материковым склоном. Склон в его геоморфологическом понимании, вероятно, охватывал пояс седиментации известково-глинистых илов между шельфовыми карбонатными и граптолитовыми пелитовыми осадками центральной депрессии бассейна. 2 рис. Библ. 18 назв.

УДК 552.54:549/1/:551.733.3 /474.2+486.92/

Распределение и минеральный состав алевритовой фракции терригенного материала в верхнесилурийских отложениях Северной Прибалтики. Юргенсон Э. В кн.: Экостратиграфия силура Прибалтики. Таллин, АН ЭССР. Ин-т геол., АН ЭССР, 1982, р. 25 - 33 /англ., рез. русск./.

Изучены гранулометрический и минеральный составы алевритовой фракции верхнесилурийских карбонатных отложений Западной Эстонии и Северо-Западной Латвии. Для сравнения приведены данные по соответствующим отложениям острова Готланд. Максимальная концентрация алевритовой фракции установлена в Северной Прибалтике в охесаареском горизонте /даунтон/, на Готланде - в известковом алевролите слоев Бургсвик /лудлов/. 1 табл., 1 рис. Библ. 6 назв.

УДК 563.67+563.713:551.733.3 /474+486.92/

Коралловые рифы в силурийском бассейне Балтики /строение, фациальная приуроченность/. Клааманн Э., Эйнасто В. В кн.: Экостратиграфия силура Прибалтики. Таллин, АН ЭССР, Ин-т геол., 1982, р. 35 - 41 /англ., рез. русск./.

Органогенные постройки приурочены в силуре Балтоскандии к двум фациальным зонам /отмель, открытый шельф/ и восьми стратиграфическим уровням. Они формировались в регрессивных фазах развития бассейна. Максимумы рифообразования были в среднем венлоке и среднем лудлове. В течение этого интервала времени наиболее подходящая для рифостроителей отмельная зона мигрировала в пределах Прибалтики около 300 км, а в районе Готланда и Подолии лишь 15-40 км на запад или юго-запад. Предполагается, что в двух последних районах материковый склон был более крутым и стабильным. 2 рис. Библ. 15 назв.

УДК 563.713:551.733.31 /474.2+486.92/

Последовательность строматопорат в среднем силуре Балтики. Нестор Х. В кн.: Экостратиграфия силура Прибалтики. Таллин, АН ЭССР, Ин-т геол. АН ЭССР, 1982, р. 43 - 50 /англ., рез. русск./.

В разрезах венлокских мелководных отложений Прибалтики выделено пять последовательных сообществ строматопорат, которые могут служить основой для разработки зонального стандарта по этой группе кишечнополостных в Балтийском и соседних районах. 1 табл. Библ. 17 назв.

УДК 551.7.02/03:564.82/85:551.733.3 /474/

Последовательность брахиопод как инструмент корреляции силура Прибалтики. Рубель М. В кн.: Экостратиграфия силура Прибалтики. Таллин. АН ЭССР, Ин-т геол., 1982, р. 51 - 62 /англ., рез. русск./.

Изучалось распределение 77 видов верхнесилурийских брахиопод в разрезах 14 скважин Прибалтики. Их корреляционная значимость определялась оценкой относительной длительности полных интервалов существования таксонов и их встречаемости в изученных разрезах. Оказалось, что из всех анализированных только полные интервалы 19 широкораспространенных видов могут быть упорядочены так, чтобы их последовательность не дала при корреляции разрезов противоречивых результатов. Многие таксоны, в том числе и широкораспространенные, имеют в удаленных разрезах сдвинутые во времени интервалы существования. 2 рис. Библ. 40 назв.

УДК 565.393:551.733.3 /474/

Венлокские и позднесилурийские ассоциации трилобитов Прибалтики и их стратиграфическое значение. Мянниль Рээт. В кн.: Экостратиграфия силура Прибалтики. Таллин, АН ЭССР, Ин-т геол., 1982, р. 63 - 70 /англ., рез., русск./.

В венлоке и верхнем силуре Прибалтики выделено 12 трилобитовых ассоциаций, замещающих друг друга во времени и пространстве. Наиболее широко распространены представители открытошельфовых и склоновых ассоциаций, в венлоке ассоциация *Encrinurus punctatus*, в лудлове - ассоциации *E. macrourus* и *Proetus signatus*. 2 рис. Библ. 25 назв.

УДК 565.33:551.733 /474+486.92/

К зональному расчленению верхнего силура Прибалтики по остракодам. Сарв Л. В кн.: Экостратиграфия силура Прибалтики. Таллин, АН ЭССР, Ин-т геол., 1982, р.71 - 78/англ., рез. русск./.

Ревизия верхнесилурийских остракодовых зон Прибалтики показала целесообразность выделения в разнофациальных отложениях параллельных, более-менее одновозрастных зон. В лудлове таких зон 5, в даунтоне - 7. Рассматривается распространение зональных и некоторых ассоциирующих с ними видов в верхнем силуре острова Готланд. 1 табл. 1 рис. Библ. 11 назв.

УДК 56.016:591.52:551.733.33 /474/

Позднесилурийские мелко- и глубоководные конодонты Прибалтики. Вийра В. В кн.: Экостратиграфия силура Прибалтики. Таллин, АН ЭССР, Ин-т геол., 1982, р. 79 - 88 /англ., рез. русск./.

Анализируется распространение верхнесилурийских конодонтов в разрезах 7 буровых скважин и более 30 обнажений. Выявлен фациальный контроль распределения, о чем свидетельствует наличие лагунных, отмельных, открытошельфовых и склоновых ассоциаций. Это обуславливает необходимость создания двух параллельных местных зональных схем по конодонтам - одной для отложений шельфа, другой - для более глубоководных отложений. 3 рис. Библ. 12 назв.

УДК 56.016:551.733.3 /474+482.96/

Корреляция силура Прибалтики и острова Готланд по хитинозоям. Нестор В.-К. В кн.: Экостратиграфия силура Прибалтики. Таллин, АН ЭССР, Ин-т геол., 1982, p. 89 - 96 /англ., рез. русск./.

По распространению хитинозой в разрезах буровых скважин Охесааре /Эстония/, Вентспилс /Латвия/ и обнажений острова Готланд сделаны следующие корреляционные выводы: большая часть мергелей Висбю и слои Хёгклинт соответствуют яанискому горизонту, слои Слите - яагарахускому, слои Хемсе - паадласкому, слои Эке, Бургсвик, Хамра и Сундре - курессаарескому горизонту Эстонии. 3 рис. Библ. 19 назв.

УДК 567:551.7.022.2 /474.2+474.3/

Зоны вертебрат в силуре Прибалтики. Мярсс Т. В кн.: Экостратиграфия силура Прибалтики. Таллин, АН ЭССР, Ин-т геол., 1982, p. 97 - 105 /англ., рез. русск./.

Изучением распределения агнат и рыб в непрерывных разрезах силура Эстонии и силура - нижнего девона Латвии в интервале от нижнего венлока до верхнего даунтона выявлено 9 зон позвоночных, позволяющих коррелировать разрезы Прибалтики, Швеции, Норвегии, Англии, Северного Тимана, Северной Земли и Среднего Урала. 3 рис. Библ. 33 назв.

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