УДК 56.074.6:551.733.3(474)

ECOSTRATIGRAPHY - SOME ASPECTS FROM EAST BALTIC PRACTICE

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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.

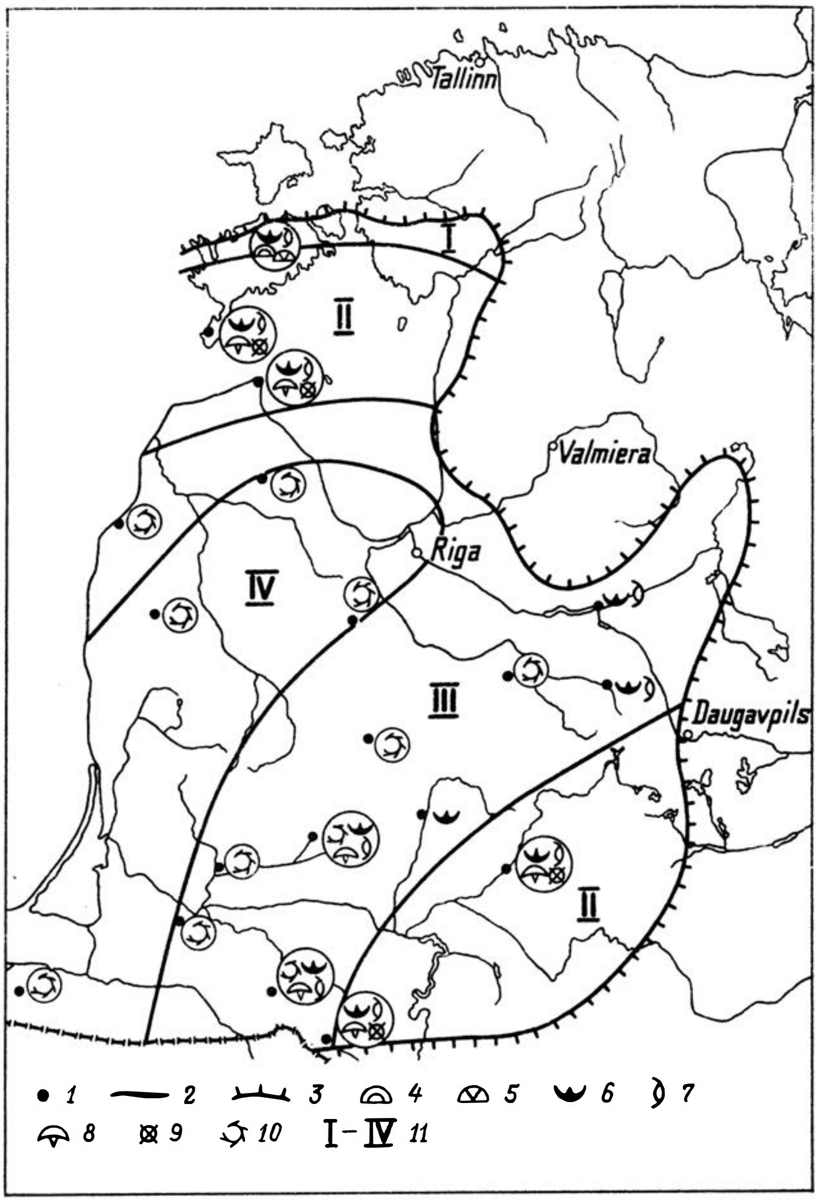

Fig. Facies belts and distribution of dominant fossil groups of the Jaagarahu time (Wenlock East Baltic). 1-boreholes; 2-limit of facies belt; 3-limit of the present distribution of corresponding rocks; 4-stromatoporoids; 5-tabulate corals; 6-brachiopods; 7-ostracodes; 8-trilobites; 9-echinoderms; 10-graptolites;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

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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.