ECOSTRATIGRAPHY, ITS PLACE AND ROLE IN MODERN STRATIGRAPHY

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Translated from "Ekostratigrafiya, yeye mesto i rol' v sovremennoy stratigrafii," in D. L. Kaljo and E. R. Klaamann (Eds.), *Teoriya i opyt ekostratigrafii* (*The Theory and Practice of Ecostratigraphy*) (pp. 9-18): Inst. Geol. AN Eston. SSR, Valgus Press, Tallinn, 1986. The author is with the Department of Geology, Geophysics, and Geochemistry of the USSR Academy of Sciences, Moscow.

There may be good reason for saying, to paraphrase the words of the well-known ecologist Charles Elton [4], that ecostratigraphy is a new name for a very old subject. I do not mean by this that the earlier-existing stratigraphy employed the study of ancient natural assemblages of organisms as an effective instrument in their reconstructions (strictly speaking, no such science is yet in existence), and, moreover, I do not intend to cast aspersions on the new name, or on new terms in general, when there is a logical necessity for them. In the present case, both the early attempts at an ecological approach to the solution of stratigraphic problems and the current demands for essentially new insights into this aspect of paleontological method in stratigraphy are indisputable, and this is of greater interest than the trivial information about "index forms" and even "index associations of forms," which rigidly continues to retain numerous variations of "biozonal stratigraphy" mainly in the groove of purely formalistic procedures.

The apogee of this formalistic trend is the concept of "multiplicity of stratigraphies," accepted as equivalent in value, which has recently been illustrated on an almost triumphal note in the *International Stratigraphic Handbook* [10]. There are no doubts either as to the usefulness of this publication, which has stimulated ideological and pragmatic interest by modern stratigraphers, or to the fair comment of the critic who introduced the *Handbook* to Europe and the USSR [31]. But each of them has demonstrated the excessive pretentiousness of the epithet "international," because national and regional traditions continue very strongly, and the *Handbook* provides no general theory of stratigraphy.

In addition, functions of theory in stratigraphy, we are convinced, have successfully replaced certain historically constituted basic principles, which have sometimes been referred to as "laws," as well as methods of subdivision and correlation adopted from other fields of knowledge (physics, chemistry, and biology) and operatively coordinated with the three-dimensional space-time model. The fundamental value of geology to natural science as a whole once again amounts to the capacity of stratigraphic geology, as an historical science, to provide a real materialistic genre that increasingly permeates the entire field of thought. The formulation of the very concept of geological (and biological) time provides a reference that simply did not exist outside the material documents of geology and paleontology [33, 42, 52, etc.].

The practical work of many investigators, to consider just that published in Russian (Diener [3], Strakhov [49], Librovich [23, 24], Gignoux [6, from the French], Krumbein and Sloss [19, from the English], Stepanov [46], Menner [30], Zubkovich [57], Zhizhchenko [56], Schindewolf [39-40, in German], Sokolov [42, 44], Leonov [22], Krut' [20, 21], Meyen [32, 33], Sadykov [37], Teslenko [51], Yamnichenko [54], Stepanov and Mesezhnikov [47], Kosygin, Salin, and Cherkasov [15], Salin [38], Khalfin [14], Zhamoyda [55], Nikitin and Mozdalevskaya [34], etc.), has convinced us that, with all the varieties of approaches to stratigraphy and research into its rational foundations, only a few principles are fundamental, without which it is not possible to operate any of the stratigraphic trends that claim to be mature.

The vast empirical basis of stratigraphy, dependent for decades and even centuries on these principles and on the generalizations to which they have led, must reinforce the conclusion that we must see in any one of them, those fundamentals that make up the theoretical basis of stratigraphy.

In recent years, the most valuable discussion of a combination of basic stratigraphic principles, united by a logical unity, has been that of Meyen [32, 33]. These principles are not new, although sometimes they have lost the position due to them in the long lists of "laws" and "principles" of stratigraphy of varying caliber and plan, frequently derived from particular stratigraphic operations or discussions of individual investigators, remote from the hunches that they set up as the fundamental bases of science. At one time, it even seemed that some feverish trend arose to multiply these principles for the sake of imparting scientific significance to stratigraphy. However, stratigraphy was not involved in this at all. It is important to free it of excessive rule-making and to demonstrate its simple and fundamentally axiomatic nature, worthy of the place that stratigraphy has firmly occupied in geology.

What do these fundamental precepts in stratigraphy amount to? They express the most simple and clear premises, which must be thoroughly known if we are with the greatest confidence to carry out all those operations in the earth's stratigraphic shell that take account of the temporal and spatial properties of the stratisphere, its mosaic nature, inhomogeneity, and discontinuity. Consequently, it is first necessary to establish the normal chronological succession of geological bodies in actual sections, with their vertical inhomogeneity and discontinuity (this is Steno's classical principle), and, second, to correlate these sequences in geological space, on the basis of similar features in the successions, realizing that this does not always mean simultaneity (this is closest to Huxley's principle of homotaxis). The principle at the root of this procedure in stratigraphy is most important, and it must be agreed upon among those investigators who do not limit it to the homotaxis of only some paleontological assemblages.

However, the spatial mosaic nature, uniformity, and discontinuity inherent in the stratisphere (the various kinds of facies, discrete sedimentary basins, segregated biogeographic provinces, climatic zones, ecological barriers, etc.), inevitably place limitations on the homotaxial series during comparisons (stratigraphic correlation). The most important role in removing these restrictions is played by sections with transitional (inserted) features, extending to complete replacement (extreme kinds of sections) as compared with the stratotype. The stratigraphic subdivision (straton) still retains all of its integrity, whereas the process of correlation reflects and expresses the variety of features of the straton within the framework of corresponding geological synchroneity.

This operation is the principal one in regional and interregional correlation. It alone, getting away from the standard type of stratigraphic boundary (limitotype), will enable us to establish the equivalents of such a boundary in remote sections of the various continents and of different facies origin. In my lectures, especially with respect to many years of work on the Committee for Defining the Silurian-Devonian Stratigraphic Boundary in the late 1960s, I referred to this as the general stratigraphic principle of transfer, or the **"transmission correlation function"** [41, 44]. We must not confuse it with the method of correlating sediments of different facies, for example, with ecologically uniform palyno-assemblages or volcanic-ash deposits. A very detailed discussion of this principle has been given by Meyen [32, 33], who, probably more felicitously, termed his the principle of "chronological interchangeability of features."

At present, I would even find it difficult to name any such general and fundamental principles of stratigraphy as presented above, although in the vast stratigraphic literature, many other principles, rules, and even laws, which could seemingly supplement our list, are often named. It seems, however, that at least most of them, in a limited way, either pass into the above-listed basic principles, or reflect certain particular geological properties of the stratisphere and lithosphere in general, or more likely belong to the procedural bases and methods of stratigraphy.

Up till now, I have used the term "biostratigraphy," but biostratigraphy proper is of the greatest interest not only to stratigraphers and paleontologists, but also to geologists, biologists, and geographers, in a word, to the majority of naturalists. The reason for such interest is simple. First, the record of life in fact permeates the entire history of the earth's stratispheric shell (with a duration of

3500–4000 m.y.), although remnants of its records (trace fossils) are very unevenly distributed and with apparent global problems, which has, as I have stated earlier, given rise to an erroneous view about the fatal incompleteness of this record in geology. Second, the paleontological method in stratigraphy itself has enabled us to create the concept of biological (and in this way, also geological) time, a most important concept in science, to reveal the trend, irreversibility, and unevenness (stage-nature) of the evolutionary process, to develop an hierarchical system of stratigraphic subdivisions, to trace their chronological stability in the geographic environments of the past, and finally, to create a varied geological and paleogeographic cartography, exceptionally important in a practical sense.

The role of paleontology (remains of organisms and manifestations of life systems) in the material characterization of geological bodies in the stratisphere (especially in its Phanerozoic and Proterozoic portions) and in the revelation of the most distinct and significant of its features, used in the fundamental principles of stratigraphy, is so great that frequently the whole of scientific stratigraphy amounts only to a single biostratigraphy, termed stratigraphy proper, and denying even the existence of chronostratigraphy, because the instrument of the latter seems more and more to be paleontological chronology, and not abstract time.

Of course, this skepticism is exaggerated, because in geology, throughout the world, various physical methods of stratigraphy (radiometric, geophysical, lithological, tectonomagmatic, rhythmoclimatic, and generally geocyclic) have been successfully used, and they are very necessary, but there is no doubt that the Phanerozoic biochronological model of stratigraphy remains more and more the most ideal, on the strength of its biological components, which have a high level of evolutionary and ecological differentiation. The Precambrian biota are also very important in themselves for understanding the evolution of life in general, but they only remotely resemble the Phanerozoic forms in this respect, and only during the immediate pre-Cambrian epochs (late Riphean and Vendian). In general, the Precambrian biostratigraphic model is still very crude and has no preference over the historical-geological model, with its physical bases: hence the fundamental difference between the Precambrian and Phanerozoic (and its related Vendian) stratigraphies.

Thus, the general principles of stratigraphy are not completely realized in biostratigraphy, and hence at present biostratigraphy cannot be placed in a single ranking with lithostratigraphy and cyclostratigraphy, even in regional stratigraphy, the most general, and even more so, with purely geophysical stratigraphic schemes. In addition, the marked contrast between biostratigraphy and lithostratigraphy scarcely corresponds to the general interests of stratigraphy, because in the practice of regional stratigraphy (and this is the main sphere of activity of stratigraphers), they have always been closely knit, and only on the general stratigraphic scale (in fact this is also the scale of the chronostratigraphic subdivisions: the zone or chronozone, stage, series, system, and erathem of the eonothem) is abstraction of biological characteristics of the corresponding standard subdivision achieved from its real physical (primarily lithological) basis.

The zone is the principal elemental (but sometimes divisible) unit of this scale, although we must constantly keep in mind that zonal biostratigraphic subdivisions (*lona*, etc.) and beds with a fauna also comprise the main element of regional biostratigraphy. They precisely make up a reference grid for regional correlation schemes and lead to the recognition of such most important stratigraphic subdivisions as horizons or regiostages. Carried away by general and abstract problems of stratigraphic and geological time, we often forget about these fundamental realities of regional stratigraphy, which make up all the stratigraphic standards of the general (that is, the international) scale. In general, there cannot be any other standards for the latter. That is why it is inadmissible to break the logical connection between regional stratigraphy (i.e., regional bio- and lithostratigraphy) and general (i.e., chronostratigraphic) subdivisions.

It may be paradoxical, but the specific nature and fundamental significance of regional stratigraphy that we have understood and seemingly secondarily discovered, when we proceeded to the formulation of the global principles of the International Geological Correlation Program (IGCP) (Budapest, 1965), among which the temporal and spatial correlation of geological phenomena and processes, and also problems of precision and standardization of the global scale, have occupied a central place. On of the significant arguments for such a setting of the problem has been the instructive experiment, with its difficulties and unexpected discoveries, of the International Commission on the Silurian-Devonian Boundary.

As is well known, the final conclusion on the necessity to choose a standard for the boundary between these systems outside their stratotype regions and even their stage subdivisions, has made a profound impression [25, 27, 43, etc.], but the biological principle for resolving such problems in stratigraphy has since become self-evidently universal for the entire Phanerozoic interval, including the Precambrian-Cambrian boundary.

During the past decade, since the establishment of the standard for the Silurian-Devonian boundary at Klonke, Czechoslovakia (International Program 1958-1972), only a single boundary of such rank has been officially accepted for the Phanerozoic interval. However, this unique result of driving the first "golden spike" in the general stratigraphic scale has not turned out to be more important, prospective, and fundamentally new, although the very fact in itself has been extremely significant. The method of international studies with a single objective and following a single program on all the continents, which has enabled us to concentrate on completely new, accurate, and varied biotic, lithofacies and biofacies, and other information organized within the comparatively narrow framework of a restricted interval, could also have determined a new model of approach to the resolution not only of stratigraphic, but also complex historical-geological and historical-biological problems in general.

With the creation of the IGCP, it has become obvious that such studies (based on the Silurian-Devonian boundary) of geological and biological events on the earth, as a means of developing a new geological model for the study of the Phanerozoic Eonathem and of increasing the accuracy of methods of understanding and chronological distribution of its mineral resources, should be continued. Projects with similar objectives have been suggested by investigators in Canada, Poland, USSR, and Sweden. The history of their establishment, ideas, and associations in the general project *Ecostratigraphy*, is well known [2, 26, 28, 29, 43].

Soviet investigators were possibly the best prepared for the new style of studies in the field of biostratigraphy, owing to the brilliant work of Gekker [5] on the paleoecology of ancient basins, which had begun as long ago as the 1920s. Therefore, the idea of continuing intensified stratigraphic-ecological and paleobiogeographical investigations, based on the Silurian-Devonian passage sequence of sediments was approved by the [Soviet] Interdepartmental Stratigraphic Committee in the mid-1970s, and preparation of the appropriate project in the USSR was directed by the present author. Preparation of the project proceeded actively in Europe under the provisional title of "Sequence and Environment." In the autumn of 1974 in Birmingham, on the basis of Sweden's proposal, an international project under the title "Biochronological Correlation at the Level of Ecosystems as Exemplified by the Wenlockian-Gedinnian Interval," or "Ecostratigraphy," was accepted. Under this title, the Soviet portion of the project was also worked out, especially successfully in regard to the regions of the Baltic and Siberian platforms and also Podolia, the Urals, and Central Asia.

The overall objective of the project was the improvement of biostratigraphic methods by correlating sediments of different facies in the ancient basins. Therefore, reconstruction of the time relationships between the ancient ecosystems (the paleoecosystems of Krasilov [17]) on the basis of fossil associations of organic remains (oryctosystems, by the project term) must be carried out not only by paleobiological methods, but also by all other procedures that will enable us to reconstruct the historical-geological process and the various parameters of the life environment and refine the dating of geological events. We must regard as the most significant feature in this approach, not the simple interdisciplinary examination of paleobiological data (even if these relate to typical associations of forms) and lithological information, but the discovery of the connection between them, defining the biofacies meaning of the associations and their transitions in the overall facies and bathymetric profile of the basin, and in its lithofacies structure.

As such work progresses, the facies model of a basin should not be departed from on the grounds of a logical standard, but should be constructed and continuously improved on the basis of the direct and inverse associations between the biotic and all the physical factors marking the dynamics of the habitat. I have become accustomed, perhaps somewhat loosely, to calling the stratigraphy developed in this fashion, basinal, and this term has been retained along with ecostratigraphy, although there is no objection to this, as is clearly seen from the latest works of Estonian and Siberian stratigraphers (Kaljo [11, 12]; Tesakov and Predtechenskiy [50], etc.). The only important paper in this respect on the classification of sedimentary basins was published by Kazanskiy and Betekhtina [13].

The term "ecostratigraphy," as is well known, was introduced by Schindewolf [39], although subsequently [40, etc.] he rejected it. By the term, he understood nothing different from biostratigraphy, with its strict approach to defining the time of existence of species and their associations; this was most likely dependent on facies, and the unusual stratigraphy of the complexes, possibly close to the concept of Palmer's biomere [35]. In fact, in both these cases, we are dealing mainly with monotypic or almost monotypic encroachment of faunas, separated in time but connected by identical conditions. This phenomenon is, of course, ecological, but its significance in overall stratigraphic constructs is not greater than that of recurrent or cryptogenic faunas in general.

The term "ecostratigraphy" was used for a second time by Hedberg [9], but rather in the sense of a stratigraphic construct, based on events in the surrounding environment and unconnected with chronostratigraphy, although both kinds of stratigraphic constructs were assessed by him as of identical importance. On the basis of this argument, Schindewolf in one of his works, caustically remarked that he was terrified by the "odors" that he had caused, and Hedberg did not include this term in his *Handbook* in 1978 [10].

But the "odor" turned out to be viable, and, having undergone a new metamorphosis, it appeared for a third time, when it became necessary to adumbrate this term in the new IGCP project, initiated in Budapest in 1969. Martinsson [26] briefly defined this trend as the "stratigraphy of ecosystems," maximally approaching the chronological ideal through stratigraphic units established facies-wise. After this, the term was finally allowed to run free. Support for ecostratigraphy had begun, although the head of the project himself, Professor Boucot, had written in the preface of his book [1] that the term "ecostratigraphy" had been used only in recent years. In fact, he perceived a new way of working in the field of stratigraphy, discovering connections between the processes of evolution, ecology, biogeography, and taxonomy, and not driving investigators into the narrow cleft of unequivocal stratigraphic parallelism.

Although it has frequently suited biostratigraphers in our local stratigraphic practice to work as casual laborers for the sake of this "identicalness," Soviet paleontologists and stratigraphers have on the whole been very well prepared for stratigraphic studies in the new style. The connection of the concepts "organism and environment" and "environment and life" has always appeared to us to be close, and many have successfully used ecological and biofacies observations, facies and paleogeographic analysis, climatic and biogeographic zonation, the bathymetry of the ancient basins, paleohydrological characteristics, etc., in stratigraphy.

Ecostratigraphy has acquired a special popularity in connection with the creation of the Soviet section of the International Project on *Ecostratigraphy*, done at a special session of the All-Union Paleontological Society on the problem of "Ecostratigraphy and Ecological Systems of the Geological Past" in Leningrad in 1976, and the All-Union Conference on "Ecosystems in Stratigraphy," convened in 1978 in Vladivostok. The latter directly preceded the Conference on "The Theory and Practice of Ecostratigraphy," convened in Tallinn in 1982. A significant role in the ecologization of our stratigraphic concepts was played by Krasilov's book [17], *Evolution and Biostratigraphy*, and numerous recent papers on the ecostratigraphic theme, including critical reviews [8]. We may say, along with Martinsson, that studies in this direction have now acquired the nature of a movement.

However, we must not be deluded. I do not doubt the success of the new trend, but there is still much to be done, primarily to put clear concepts, terminology, and study procedures on a solid footing. In the first place, it would be erroneous to think that ecostratigraphy has brought about a change in biostratigraphy, although it will be asserted that the latter is in chaos so far as its component hypotheses, procedures, terminology, polyglot language, and contradictions are concerned. Stratigraphy based on the paleontological method still remains stratigraphy at heart. Ecostratigraphy is also paleontological. But six years on, I would like once again to repeat that "... the present aspirations of geologists and paleontologists to understand completely the life of the past not simply as a history of individual phyletic groups or as an assemblage of 'index associations'..., but in the form of a system of interassociations, which existed between evolving complexes of organisms and the changing conditions of the life environment (climate, atmospheric composition, solar radiation, landscapes, features of biotas, and the conditions that disrupt some trophic associations), and opening up the routes to the formation of new associations," are completely acceptable [44, p. 7].

We are taking a great deal from ecology and paleoecology, and the process of growth of ecologization of all the earth sciences (and of society also) will be very rapid. But the direction of the science, which is being discussed at present, cannot be limited to simple improvement in paleoecological observations. "Paleoecology is one of the divisions of paleontology" (Gekker [5]), and we are discussing a new trend in geological science (stratigraphy). The geological accent (and this is the accent of reconstructable conditions of past environments) is here fundamentally important. No less important is the concept of the ecological system. It has been selected by us from modern biospherology and has been transformed into the paleoecosystem [16]. But we must know that the science of modern ecosystems has actually been constructed without taking account of the paleontological history of ecosystems, which is vast in its duration; moreover, it has been considered that "... the structure of the ecosystems (modern ones—*B.S.*) originated at a time, about which we cannot judge from paleontological discoveries" (Gilyarov [7]). But is this so? Most probably not, for it is significantly easier for the geologist to substantiate the meaning of biocoenology by the fact that ". . . the greatest aromorphosis in the evolution of the ecological systems was undoubtedly the step from the aqueous to the terrestrial systems." Our idea about the "buffer" ecostratigraphic model of the Pleistocene and Holocene intervals also leads to this conclusion.

From what has been said, it follows that we need a paleontological (geohistorical) understanding of paleoecosystems and a careful development of a specific terminology and a classificatory approach. The projection of phylogeny onto the standard column has provoked great difficulties for us. They will probably be even greater when projecting the evolution of paleoecosystems onto the earth's stratisphere. But it is essential to progress toward this from the elemental systems of the ancient basins, to which the method of actualism is most appropriate [36]. There is no doubt that a paleoecosystems analysis, although also constructed on the remains of formerly completely open and dynamic ecosystems, will truly enable us to achieve maximum detail in basinal ecostratigraphy. But we must be certain about the degree and scale of geographic stability of the detailed ecostratigraphic subdivisions, and their significance for interbasinal correlation.

The idea of unity (continuity) of the biosphere process on the earth (the panbiosphere, as I have suggested; see [45]) must also stand as the basis of ecosystems analysis of the entire stratisphere, and the understanding of the stage-nature of evolution, its uneven course, and critical levels. This problem has become especially topical today, as we in the International Paleontological Association were preparing for the current session of the International Geological Congress with the presentation of a special interdisciplinary symposium on "Fundamental Biotic Events and the History of the Earth and the Extinction of Groups of Fossil Organisms." At the session, we discussed the interrelationships of the structures of marine and continental biota, colonization of the land by plants and animals, and the main events in the history of the earth's organic world and their evolutional consequences.

I suggest that in such a wide range of paleoecosystems analysis (from elemental basinal models to ancient biospheres of the stratified shell of the earth), ecostratigraphy may acquire that basis of logical stability, in which stratigraphy always is still required. Here I understand by the term stability, not the capacity to add a virtually required canon of stratigraphic boundaries, with which we all are all enthusiastically occupied, but that truly natural picture with respect to the stratisphere elements of the crust, within the framework of which the spatial and chronological boundaries of biotic origin will be either disrupted, or will approach ecotones.

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