GLOBAL EVENTS AS A FRAMEWORK FOR ECOSTRATIGRAPHIC CORRELATION

V. A. Krasilov

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In this paper, I propose to discuss certain theoretical premises, concepts, and procedures in ecostratigraphy. Definition of terms are presented as far as possible in accordance with their present usage.

Stratigraphy examines the spatial and temporal ordering of geological bodies.

In **formal** stratigraphy, the study of the arrangement of the strata depends on a number of principles, of which the most important are Steno's principle (the vertical sequence of strata corresponds to the time sequence), the Golovkinskiy-Walter principle (the horizontal sequence of strata transforms into a vertical sequence), and Smith's principle (the species of biofossils are limited to a definite stratigraphic range). No one of these principles alone will explain the changes in stratigraphic features and will not predict relationships of the kind "a bed with feature *A* is always above (younger than) one with feature *B*." In formal stratigraphy, such relationships are established empirically for sections *a, b, c, . . . f* and are then accepted as statistically probable for sections *g, h, i, . . . n*. If sections *o, p, q, . . . v* are later discovered with different relationships between *A* and *B* (from the principles, there is no reason why these relationships cannot be different), then the assumption accepted for *g, h, i, . . . n* must be eliminated as invalid.

Evolutionary stratigraphy, in addition to formal principles, employs certain explanations and resulting predictions, for example: 1) beds with monotypic biofossils in regions remote from one another are asynchronous ("Huxley's rule"); 2) organisms from Bed *A* are descendents of those from underlying Bed *B*, and, consequently, they cannot be found in beds older than *B*; and 3) if species *B* is the ancestor of species *A*, it is always valid to assert that the bed with *A* cannot be below that with *B*.

However, these predictions are valid only within the framework of the classical theory of evolution, which does not embrace the whole gamut of evolutionary phenomena. Thus, prediction (1) is valid if the species gradually migrate from a point center, but invalid if species formation represents a change in a diagnostic feature simultaneously occurring in many populations (recent genetic and paleontological findings conform to such a possibility). Prediction (2) is usually not achieved because, according to the Golovkinskiy-Walter principle, beds replacing one another in a section have formed in adjacent facies zones (geotypes), and, consequently, the stratodeme of Bed *A* has not come from that of the underlying Bed *B*. Prediction (3) is not achieved during iterative form-development, which may occur in asynchronous branching of similar forms from a conservative stem. Moreover, the statement that "*A* is the descendant of *B*" has most commonly been based on the observation that "*A* is above (not below) *B*," and thus involves circular reasoning.

All these considerations lead to the conclusion that no satisfactory stratigraphic theory exists at present. I suggest that it may be developed within the framework of **ecostratigraphy** (an explanation of the ordering of geological bodies on the basis of interaction between evolving systems (organism-environment, biosphere-lithosphere, earth-space, etc.)). **Global geological events** have been generated by such interactions, providing the key organizing role in the development of stratigraphic ordering.

The objection to external stimuli having the leading role in the evolution of the system has deep historical roots: In theological thinking, external influences are regarded as a divine intervention, and the materialistic position has required the exclusion of such factors. At present, these contradictions are already forgotten. According to the second law of thermodynamics, in isolated systems only those processes are possible that lead to an increase in entropy. But according to Boltzmann, nothing less than the universe as a whole may be regarded as an isolated system. The subsystems involved in it in one way or another interact, obtaining a nonentropic stimulus from outside so that the evolution of the system is controlled by some higher level system [2]. Consequently, the cause-and-effect links may be traced "downward," from the evolution of the biosphere to coenogenesis, demogenesis, individual development, and the molecular evolution of the genome, and not in the opposite direction, as in the classical theory of evolution. The discovery of mobile genes and retroviruses transporting and incorporating genes and the exchange of DNA between the nucleus and the cell organelles has made the dynamism and vast adaptive possibilities of the genetic system evident, moving us away from the earlier concept of the nuclear geonome as a virtually closed system.

The connection between cosmic and geological phenomena is achieved mainly through changes in the parameters of the earth's rotation, activation of the global system of faults, and inertial movement of lithospheric blocks. The concept of the influence of geological events on the biosphere has become acceptable in the light of modern views on variation and adaptive strategy as functions of stability (predictability) of conditions [3, 4].

Biological evolution would have been halted at the stage of protobionts, if it were not for impulses from tectonic and climatic processes that, in their turn, were associated with cosmic processes. The duration of the Mesozoic era (lasting, according to the latest radiometric results, from 245 to 65 Ma) is equal to the galactic year. During the last two years in different places (Italy, Spain, Denmark, New Zealand, and the USA, deep boreholes, etc.), a stratum has been discovered on the Mesozoic–Cenozoic boundary, enriched in iridium and other elements of the platinum group. The explanation proposed (the fall of a giant asteroid, which caused atmospheric disturbances destructive to the biota [1]) is unsatisfactory, because iridium has a negligible volatility and could not have been dispersed far from the site of the fall. It is more feasible to suggest the passage of the solar system through a dust cloud (with large amounts of elements of the platinum group), which could have influenced the rate of rotation and the magnetic field of the planet, with various consequences for the biosphere. In any case, the iridium layer marks a global geological event, with which the extinction and replacement of the dominant organisms and the greatest reconstruction of the biosphere as a whole, was directly or indirectly associated. The significance that the iridium layer may have as a global stratigraphic marker depends on our understanding (so far not fully achieved) of the nature of that layer (quite recently, a similar layer has been found near the Eocene–Oligocene boundary).

This example demonstrates that, in the future, the attention of stratigraphers will probably be concentrated on deciphering the global geological events that form the framework of ecostratigraphic correlation. For this purpose, we require the creation of constantly active groups of specialists in different disciplines, who will take upon themselves the organization of interdisciplinary studies and the propagation of information on the results obtained (certain IGCP projects may serve as a prototype for such study programs).

Although the methods of formal stratigraphy are still necessary, the change in style of stratigraphic thinking cannot but affect stratigraphic practice. In our own stratigraphy in the USSR, it has been accepted that we begin with the recognition of groups [*svity*], to which all the available information is linked. The groups or the parts thereof, and groupings of groups (supergroups [*seriya*]) stand out as mapping units (natural geological bodies). In fact, the group usually does not correspond to the definition of a geological body, but consists of a multitude of strata, united on the basis of one or a few macroscopic features (grainsize, color, coal content, etc.). Paleontological, geological, and other features serve as the "stuffing" of the groups and as their informational filling, which may be used for regional correlation and as links to the international stratigraphic scale.

The focus on geological events stimulates us to begin with the recognition of beds (markers) that possess well-defined individual features, easily discernible and suitable for mapping. All the information obtained for the description of a section is linked to the markers (the prototype for such a system is the stratigraphic scheme for the Donbass, worked out in the 1920s by L. I. Lutugin's study group). Subsequently, efforts have mainly been directed toward an interpretation of events, marked by reference horizons, and sections, flowing from this stratigraphic assessment. There is a choice of reference horizons that mark global events and are suitable for broad correlations. The main factors in event interpretation of reference horizons are: 1) facies analysis, 2) reconstruction of paleocoenoses and their systems, and 3) analysis of the repetition (rhythms) and zonation of stratigraphic features.

The facies carries traces of several ecosystems. A differentiated or conformable change in the various elements (e.g., planktic foraminifera and mollusks, and conifer pollen in marine facies) indicates the scale of events, acting selectively (it may be noted, in the benthos only) or on all the ecosystems (in equal measure on the plankton, benthos, and terrestrial biota). Facies restriction, along with an analysis of quantitative ratios and preservation of life forms, plays a decisive role in reconstructing the assemblages and their systems (assemblages are recognized and named on the basis of **dominants** or **determinants**); the description of assemblages contains the following elements: name, author, date of publication, nomenclatorial type (typical taphrogenesis), diagnosis, distribution, and present-day equivalents: cf. [3]). The dynamics of such systems as **catenas** inform us most effectively about the ensuing events.

The rhythmic repetition of features and their stability within a defined stratigraphic interval (**zone**) points to stabilization of ecosystems that control the process of sedimentation. I suggest that zones may be recognized not only on the basis of paleontological, but also any other features, for example, grainsize or color. The traditional groups are essentially such zones.

Interregional and interfacies correlation is achieved on the "marker to marker" principle: for any reference horizon marking a global event in one stratigraphic system, we must discover one (of different composition, with different biofossils, etc.) corresponding to that same event in another stratigraphic system.

I cannot cite any one totally satisfactory example of the application of this procedure; it appears that none such yet exists. I am limited to a series example of ecostratigraphic correlation. The section in the Miocene continental sediments on the west coast of Northern Sakhalin near Duē settlement consists of a number of sandy mudstone cyclothems, with coal seams and plant remains.

Reference horizons (RH): 1) black siltstones with Betulaceae, leaves of *Picea* and *Abies*, and grasses, 2) fine-pebbly conglomerate, 3) black siltstone with *Fagus* and *Hemitrapa*, 4) sandstone with interstratified coal seams and detritus with *Carya*, 5) ferruginized mudstone with *Acer*, 6) ferruginized mudstone with *Acer, Ulmus, Quercus,* and *Castanea*, 7) sandstone with broad-leaved *Populus*, 8) ferruginized mudstone with *Nelumbo*, 9) coal seam with *Hemitrapa* and *Byttneriophyllum*, 10) gastropod siltstone with *Fagus*, and 11) corbicular sandstone (henceforth the horizon numbers are given in parentheses).

Facies: black silt-pelites (1) on a thick sequence of basalts and tuffs, probably deposits of a crater lake, and fanglomerates (2), an assemblage of a wide swampy river-valley with a meandering and migrating channel (3–9), and sediments of a shallow-water marine gulf or lagoon (10–11).

Lithological zones: black silt-pelites, from the base of the section up to (2), coal-bearing cyclothems with arkosic sandstones and black silty mudstones (2–10); non-coaly cyclothems with polymict sandstones (11 and above); phytocoenotic; *Piceeto-Betuletum*, from base of section up to (2), *Fagetum* (3–10), and *Aceretum* (4–7) with *Ulmo-Aceretum* and *Querco-Aceretum* variants.

Interpretation: The *Piceeto-Betuletum* → *Fagetum* → *Aceretum* assemblage reflects a change in the vegetational belts as the relief became smoother; the appearance of *Carya*, and the oaks and chestnuts, indicates amelioration of the climate; RH 6 corresponds to a climatic optimum; the increase in the role of *Fagus* points to downward migration of the belts and cooling (not warming as earlier suggested), because in the present vertical structure, the *Fagus* belt is invariably located above the *Quercus-Castanea* belt.

Correlation: RH 5, 7, and 9-11 are located in adjacent sections (Voyevodskaya Creek valley, Makar'yevka River). A similar section with a number of reference horizons has been described in the Makarovsk region of eastern Sakhalin along the Shakhtnaya River. Here the coal seam with *Bytneriophyllum* and its overlying corbicular sandstone undoubtedly correspond to the above-described RH 9 and 11; the gastropod layer lies significantly lower down in the section and does not correspond to RH 10. The bed with *Quercus, Acer,* and *Carpinus* beneath the main coal-bearing member, we shall correlate with RH 6.

In the classical Miocene sections, climatic events similar to those described in RH 6-10 have been recorded at the Burdigalian-Helvetian (Langian) level. The boundary between the stages may be placed at the sole of the strata with *Globigerinoides sicanus* [5] in the upper part of Zone 8 on Blow's scale. These boundary strata may correspond to one of the RH 7-10 of the western Sakhalin section.

It has frequently been stated that the main premises of ecostratigraphy are not new, and that its constructs are too hypothetical and too complicated in practice. The first statement is, of course, valid because, even in the middle of last century, the boundaries of the eras were plotted on the basis of a change in diversity, which is an ecostratigraphic criterion. The use of ecostratigraphic methods is constantly perceived as vague and present-day theorizing in this field has as its main objective the presentation of theory in accordance with practice. A change in the verifiable hypotheses is an essential condition of the evolution of any science.

And, finally, a word on complexity. As compared with formal stratigraphy, which operates with a virtually unbounded multitude of stratonomic categories, combining local, regional, and international levels, special and general nomenclature, particular and complex bases, etc., into hierarchical systems, and all this into a double package, one for rocks, and the other for time (lower-earlier, upper-late, and seemingly not confused !), the technical arsenal of ecostratigraphy is very simple. Reference horizons, rhythms, and zones are all that are required.

Appendix

An explanation of the most common concepts of ecostratigraphy*:

Assemblage—nonrandom combination of organisms in definite numerical ratios.

Belt—level on a slope with special conditions and assemblages, link in a catena.

Biocoenosis—an assemblage with a definite morphological, trophic, and successional structure.

Catena—series of assemblages, capable of replacing each other during changes in conditions.

Climax (climactic or radical assemblage)—steady state of an assemblage, end member of **coenoseries.**

Cline (geographic)—unidirectional change in the aspect of a population or assemblage in space (in time—**chronocline**).

Coenoseries (also supergroup [seriya], seré)—succession of evolutional phases in an assemblage from pioneer to climactic.

Cyclothem—repetitive sequence of different strata in a geological section.

Deme—component part of terms, denoting particular elemental groupings of organisms (ecodeme, gamodeme, genodeme, etc.).

Determinant—stenobiotypic species, typical of definite kinds of assemblage.

Dominant—numerically predominant species (codominant—one of the dominants, subdominant—a species, numerically following the dominant).

Facies—deposits of a particular structural element in a sedimentary basin (geotope).

Geological body—a separate, genetically and structurally unique mineral mass of definite shape.

Geotope—structural element of a basin, and the site of facies formation.

*These explanations reflect the author's view (Ed.).

Cliseries—change of radical (climactic) assemblages, mainly owing to effect of climate.

Life form (syn, ecobiomorph)—combination of adaptive features, defining the niche (or aspect) of an organism.

Niche—the role of an organism (during its whole life or during a definite phase of evolution) in the functioning of a biocoenosis, and its place in the ecological structure.

Paleocoenosis—a past assemblage, reconstructed on the basis of taphrocoenoses.

Paleoecosystem—reconstructed ecosystem of the past, paleocoenosis and its interacting abiotic factors.

Paleosuccession—sequence of taphrocoenoses in a geological succession, and also changes in paleocoenoses.

Population—space-time combination of individuals of one species (Mendelian—population of nonselective interbreeding organisms; stratopopulation—fossil population from a single stratum; chronopopulation—population of contemporaneous living organisms; coenopopulation—population of a defined biocoenosis).

Reference (marker) horizon—readily distinguishable stratum (grouping of strata) with nonrepetitive features in the section.

Rhythm—regular repetition of a feature or definite succession of strata.

Stratoecotone—boundary beds, combining features of two adjacent stratones.

Syngenesis—evolution of assemblages.

Synusia—combination of similar life forms.

Taphrocoenosis—combination of biofossils from a single stratum or grouping of strata.

Zone—interval in which a particular feature does not undergo marked changes.

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