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VARIABILITY OF CARPATHIAN ICHTHYOFAUNA (PALAEOGENE) IN THE LIGHT OF THE STATISTICAL RODIONOW'S METHOD

(2 Figs.)

Zmienność ichtiofauny paleogenu Karpat w świetle statystycznej metody Rodionowa

(2 fig.)

Abstract. The variation in time of ichthyofauna biocoenosis of Menilite Beds was checked by means of a statistical method described by Rodionow. This method made possible the detection of statistically homogeneous section on account of biocoenosis composition as well as correlation between profiles. The trends of ecological changes within the deep-water and shallow-water assemblages of ichthyofauna are discussed.

INTRODUCTION

Ichthyofauna is undoubtedly an important element of the biocoenosis of geosynclinal basins, but the value of ichthyofauna assemblages as an index of bathymetric conditions in ancient marine basins is notable only since beginning of the Cainozoic Era. Numerous genera living recently appeared at that time, and they are forms with known ecological requirements, providing a proper basins for this type of examinations. However, aboundant occurrence and an adequate state of preservation of their remains are necessary.

Such a situation is met with the geosyncline of the Outer Carpathians, but only in formations that are of non-flysch character (uppermost Eocene? — Oligocene). One of such formations, the Menilite Beds, developed as clayey-siliceous shales with intercalations of sandstones or sometimes of cherts and marls. The other formation containing aboundant fish remains is represented by the calcareous pelagic Jasło shales. These shales are important key indicating that the Krosno-Menilite Beds represent facies found in the same basin (Jucha, Kotlarczyk, 1961; Bieda et al., 1963).

The recent examinations have confirmed the views by Jerzmańska and Kotlarczyk (1968), that the well preserved fish specimens occur almost exclusive in shales, that are characterized by quiet, non-terrygenic sedimentation. In other rocks only fish bones or scales are met with. The fish-bearing shales have a thickness of a few mm and occur repeatedly in the Menilite Beds profile, forming intercalations (laminae) among other rocks.

An important conclusion was arrived at (see Jerzmańska, Kotlarczyk, 1968), that fossil thanatocoenosis in the range of every individual bed represent closely determined ecologic fish assemblages (neritic-sublittoral or bathypelagic) and correspond to almost pure biocoenosis. In the above mentioned paper the autochtonous character of fish assemblages was substantiated. Investigating fish assemblages in a sequence of laminae one can note the qualitative variation of biocoenosis in time.

In lower part of the Menilite Beds exposed at Jamna (see Fig. 1) a bathypelagic assemblage was found in 13 levels starting from the bottom of the exposure. A neritic-sublittoral assemblage was found in 11 higher levels. On this basis it has been concluded that the basin was shallowing during sedimentation of the beds containing the sampled fish levels.

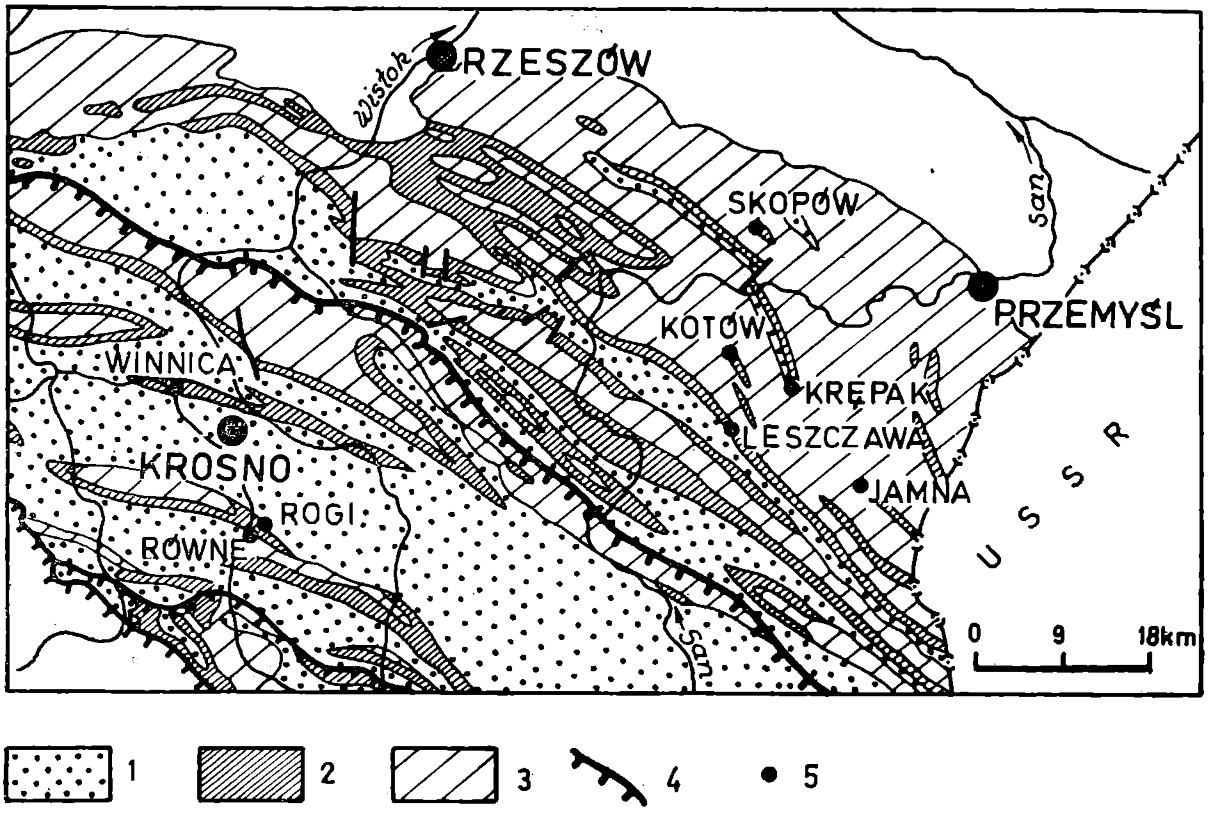

Fig. 1. The distribution of localities with ichthyofauna on the background of geological structure of Eastern Polish Carpathians (according to S. Sokołowski, 1963): 1 — Krosno Beds (Oligocene — Aquitanian?); 2 — Menilite Beds (Upper Eocene? — Oligocene); 3 — measures of Lower Paleogene and Cretaceous; 4 — overfaults; 5 — localities with ichthyofauna

Fig. 1. Rozmieszczenie stanowisk z ichtiofauną na tle budowy geologicznej polskich Karpat Wschodnich (wg S. Sokołowskiego, 1963): 1 — warstwy krośnieńskie (Oligocen — Akwitan?); 2 — warstwy menilitowe (Górny eocen? — Oligocen); 3 — utwory dolnego paleogenu i kredy; 4 — nasunięcia; 5 — stanowiska z ichtiofauną

This example shows, that with unmethodical collecting of fauna from exposures one can obtain a mixed neritic-bathypelagic assemblage. In most papers on fish remains in the Carpathian flysch the lists of genera show such mixed assemblages. The lists of this type, however, may give information concerning the genera present in a given outcrop but will not give information concerning the life conditions of the necton. Such lists do not have a stratigraphical meaning because the Tertiary ichthyofauna is fairly uniform.

From the hitherto published papers, only that by Jerzmańska (1969) brings some data on the composition and distribution of homogeneous ecologic assemblages in the Menilite Beds of the Northern Carpathians. However, the majority of sampled localities the fish collections represent a total sample, coming from many levels, the content of which was not registrated separately. Such collection can be taken as representative for a tested biocoenosis recte thanatocoenosis only under condition that the fish assemblages were remained unchanged in time at any given place in the basin. On the base of rich observation material contained mainly in Jerzmańska's papers an examinations of homogeneity of determined ecologic assemblages on the area of part of menilite basin was carried out (Jerzmańska, Kotlarczyk, Krawczyk, 1973).

This new stage of quantitative studies of Carpathian ichthyofauna gave an important statement, that within a qualitatively homogeneous ecologic assemblage statistical differences occur between individual fish-bearing localities (even if they are closely spaced). This leads (assuming an unchanging biocoenosis in time) to an unlike conclusion, that different necton assemblages had been living in the same basin for a long time period. More substantiated is, however, a presumption that quantitatively homogeneous biocoenosis was changing its composition in time and that the impossibility of assigning the fish assemblages from individual localities to one population results from comparing collections representing various stages of biocoenosis development and various time intervals.

However, other statistical methods are required to prove this conclusion and first of all the methodical sampling of profiles and collecting of fossils from every fish level separately. It should be pointed, that in the Carpathians collecting of suitably large material by means of this method is not so simple. At present the authors have in their disposal two long and two short profiles elaborated in details (Fig. 2). These are as follow: the profile at Jamna (Jerzmańska, Kotlarczyk, 1968), the sections in Rogi and Równe (the last two profiles represent the lower but not lowest part of the Menilite Beds) and also the Kotów's profile (from the lowest part of the Menilite Beds).

The intention of this article is to demonstrate the Rodionow's method (1965, 1968, 1972) of statistical separation of geological objects on the base of assemblages of attributes as well as to use the method for a study of ichthyofauna.

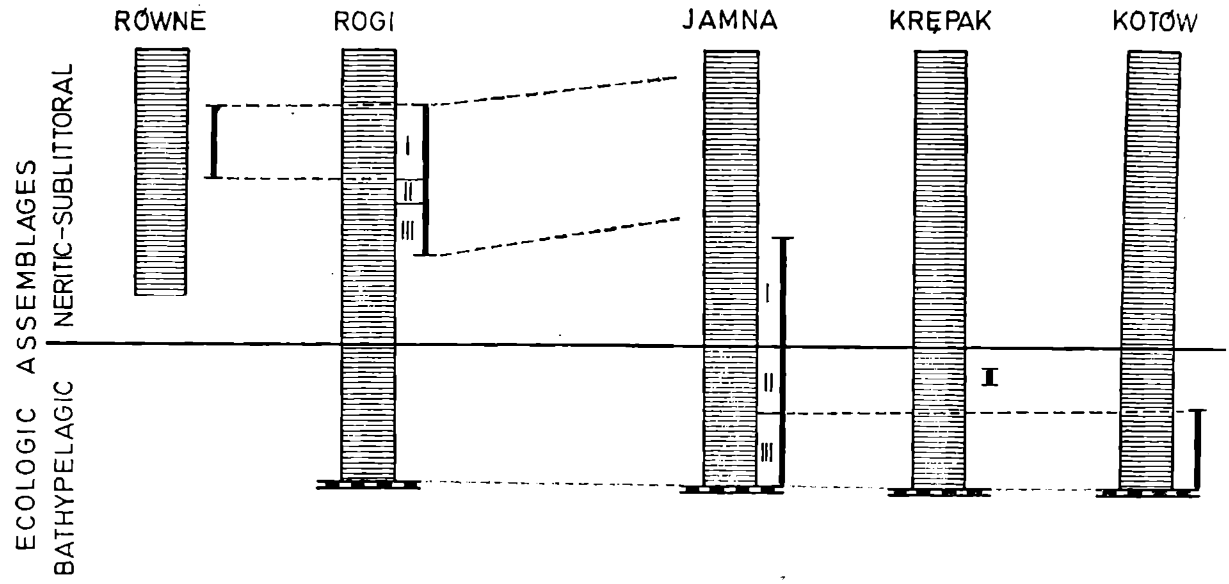

Fig. 2. The correlation of ecological assemblages using the Rodionow's method

Fig. 2. Korelacja zespołów ekologicznych za pomocą metody Rodionowa

I. PARTITION OF THE PROFILES INTO HOMOGENEOUS SECTIONS

The menilitic fish biocoenosis existing in the Carpathian basin determines the general population, changing in time and space under the influence of many factors as: physical and chemical environmental conditions (temperature, salinity, gas saturation), geographic and geological conditions (basin depth, sea currents, natural obstacles between the basins, sedimentation), biological factors (evolution, procreation and mortality, migrations) and others. The variability is registered in the deposit by thanatocoenoses closely corresponding to the fish biocoenosis (the eventual differences can appear as a result of elimination of rare genera of biocoenosis from the thanatocoenosis content). Then every level with fish gives a more or less proper picture of the population content at given time (short interval of time).

Every exposure of a layer with fish represents a point t belonging to a discrete set T of all possible points. On the above mentioned set the multidimensional random variable Ξ_t is put. Such variable is here regarded as a model of complex of properties (the properties are adequate to fish genera) in point t. Thus every fish genus is determined with uni-dimensional random variable ξ_j, and hence the random variable composed of m genera has the following formula

$$\Xi_t = \{\xi_{t1}, \xi_{t2}, \dots, \xi_{tj}, \dots, \xi_{tm}\}. \qquad (1)$$

The variable, in every point, has a concrete value, characterized by a distribution function $F_t(x)$.

The discrete set T of points t, on which m-dimensional random variable Ξ_t is put will be a mathematical model (Ξ^T) of fish population in the Menilite Beds. The model makes possible to answer the two main questions:

1. is it possible in the individual examined profiles to prove the heterogeneity (variation) of fish population in the time period fixed by arranged sequence of layers containing fish?,
2. is there a similarity (homogeneity) between individual profiles of the Menilite Beds, or between parts of profiles (spacial variation)?

The mathematical basis for solving the problem can be found in the method suggested by Rodionow. Briefly the procedure is as follows:

The homogeneity of geological object Ξ^T containing n discrete points t (or its part — subset Ξ^A, belonging to the set Ξ^T) will be proved if for all $t', t'' \in T$ (or accordingly $t', t'' \in A$) the equality

$$F_{t'}(\mathrm{X}) - F_{t''}(\mathrm{X}) = 0 \quad \text{for all } \mathrm{X} \in X, \tag{2}$$

where: X — set of all X, is satisfied.

The inequality at least for one pair $t', t'' \in T$ (or A) will be a picture of the object heterogeneity:

$$|F_{t'}(\mathrm{X}) - F_{t''}(\mathrm{X})| > 0 \quad \text{for at least one } \mathrm{X} \in X. \tag{3}$$

Practically, in order to satisfy the conditions mentioned above one must know the function $F_t(x)$ of multi-dimensional random variable Ξ_t, corresponding to every point $t \in T$. Assuming that the distribution of unidimensional random variables ξ_{tj} is normal for the nearest environment of point $t \in T$ (Vistelius, 1960 — the "local" part of examined object) the normal distribution of multi-dimensional random variable was adopted; then the density function of m-dimensional random variable can be expressed as:

$$f(\mathrm{X}; \Theta_t, \textstyle\sum_{t\pi}) = \frac{1}{(2\pi)^m \sqrt{|\sum_t|}} \exp\left[-\frac{1}{2} \{\mathrm{X} - \Theta_t\} \sum\nolimits_t^{-1} \{\mathrm{X} - \Theta_t\}' \right], \tag{4}$$

where: $\Theta_t = \{\theta_{t1}, \theta_{t2}, \ldots, \theta_{tj}, \ldots, \theta_{tm}\}$ — a vector formed by expected values of random variables ξ_{tj}, $\sum_t$ — covariance matrix.

The equation (2) can be now replaced by another equation:

$$f(\mathrm{X}; \Theta_{t'}, \textstyle\sum_{t'}) - f(\mathrm{X}; \Theta_{t''}, \sum_{t''}) = 0 \quad \text{for all } \mathrm{X} \in X. \tag{5}$$

The mentioned expression is equivalent with simultaneous satisfaction of two equations:

$$\Theta_{t'} - \Theta_{t''} = \{0, 0, \ldots, 0\} \quad \text{for all } t', t'' \in T, \tag{6}$$

$$\textstyle\sum_{t'} = \sum_{t''}. \tag{7}$$

From the above it arises, that if the set Ξ^T is homogeneous, then for an arbitrary pair of subsets ΞA_S, ΞA_K containing n_s and n_k elements the equality

$$\frac{1}{n_s} \sum_{t \in A_s} \Theta_t - \frac{1}{n_k} \sum_{t \in A_k} \Theta_t = \{0, 0, \ldots, 0\} \quad \text{for all } A_s, A_k \in T \tag{8}$$

is satisfied.

The inequality (3) can be replaced with another inequality:

$$|f(X; \Theta_{t'}, \textstyle\sum_{t'}) - f(X; \Theta_{t''}, \textstyle\sum_{t''})| > 0 \quad \text{for at least one } X \in X. \tag{9}$$

In practice, as Rodionow has proved, the above shown requirements for proving homogeneity may be weakened by additional relatively strong restrictions, which are usually satisfied for the geological objects:

a. uni-dimensional random variables $\xi_{t1}, \xi_{t2}, \ldots, \xi_{tj}, \ldots, \xi_{tm}$ forming a model Ξ_t of the local set parts can be taken as independent for all $t \in T$; considering this, the matrix $\sum_t$ changes into a diagonal matrix;

b. the diagonal elements of the matrix $\sum_t$ are equal for all $t \in T$, what means, that every uni-dimensional random variable ξ_{tj} have the same dispersions for all $t \in T$.

The adoption of these assumptions simplifies the construction of statistic criterium.

If one takes a presumption that $\sum_{t'} = \sum_{t''}$ for all $t', t'' \in T$, the inequality (9) will be equivalent to an expression:

$$\Theta_{t'} - \Theta_{t''} \neq \{0, 0, \ldots, 0\} \quad \text{for at least one pair } t', t'' \in T. \tag{10}$$

In the heterogeneous geological objects the boundaries between their homogeneous parts will occur, for instance: dividing the set Ξ^T into two non-intersecting subsets ΞA_1, ΞA_2 one makes a partition of the second order $(h = 2)$—r^2, obtaining a whole class of subsets Ξ^A. The boundary between the subsets is univocally determined and it is a division r^2 of the second order belonging to the set of divisions R^2.

Then if the set Ξ^T is heterogeneous, the set of divisions R^2 contains at least one element (r^2), for which:

$$\frac{1}{n_1}\sum_{t \in A_1} \Theta_t - \frac{1}{n_2}\sum_{t \in A_2} \Theta_t \neq \{0, 0, \ldots, 0\}. \tag{11}$$

where: n_1, n_2 — frequences of suitable subsets A_1 and A_2, which nowhere intersect.

The expression (11) was a base for forming a function used as an homogeneity index of the set:

$$\delta(r^2) = \frac{1}{n_1}\sum_{t \in A_1} \Theta_t - \frac{1}{n_2}\sum_{t \in A_2} \Theta_t. \tag{12}$$

In the case of geological objects Ξ^T of n elements t, arranged linearly (as in a case of our profiles with fish levels) there is only $n-1$ variants of second-class divisions (r_0^2).

Thus in order to check the hypothesis of homogeneity of such a set one should check $n-1$ null hypotheses

$$H_0: \quad \delta(r_0^2) = \{0, 0, \ldots, 0\} \quad \text{for all } r_0^2 \in R_0^2. \tag{13}$$

Our m-dimensional function given on the set of divisions R_0^2 takes on a form:

$$\delta(r_0^2) = \frac{1}{k}\sum_{t \in A_k} \Theta_t - \frac{1}{n-k}\sum_{t \in \bar{A}_k} \Theta_t, \tag{14}$$

where A_k — set of arranged meanings t from 1 to k, $\bar{A}_k$ — set of meanings t from $k+1$ to n (completion of the set to T).

Procedure of calculations

In order to check the null hypothesis of object homogeneity we can utilize Rodionow's (1965) statistical criterion:

$$v(r_0^2) = \frac{n-1}{n(n-k)k} \sum_{j=1}^{m} \frac{\left[(n-k)\sum\limits_{t=1}^{k} x_{tj} - k \sum\limits_{t=k+1}^{n} x_{tj}\right]^2}{\sum\limits_{t=1}^{n} x_{tj}^2 - \frac{1}{n}\left(\sum\limits_{t=1}^{n} x_{tj}\right)^2}, \tag{15}$$

where: x_{tj} — the result of measurement of attribute quantity of number j in point t.

The above function, given on the set of divisions R_0^2, in a case when the null hypothesis is real, behaves like random variable having a distribution χ^2 with m degrees of freedom. Then the hypothesis of homogeneity of arranged set (profile) will be accepted if:

$$v(r_0^2) \leqslant \chi^2_{q,m} \quad \text{for all } r_0^2 \in R_0^2.$$

However, if

$$v(r_0^2) > \chi^2_{q,m} \quad \text{for at least one } r_0^2 \in R_0^2,$$

the hypothesis is rejected.

In case of larger number of quantities $v(r_0^2)$ higher than the critical quantity, the boundary of division of such heterogeneous but arranged set (profile) should be placed in a point where the quantity of the coefficient $v(r_0^2)$ is maximal. This coefficient expresses the maximal differentiation of the complex of attributes because it corresponds to a maximum of probability function. Subsequently we check in such a way the two new subsets. The calculation procedure is finished at a moment of division of the whole heterogeneous, arranged set into homogeneous subsets. This process of dichotomic division of the set Ξ^T into subsets Ξ^{T_α} on the base of maximal quantity of the criterion $v(r_0^2)$ can lead, however, to a distinction of the so-called false boundaries between neighbouring parts Ξ^{T_α} and $\Xi^{T_{\alpha+1}}$ of the set — dividing the homogeneous element. The next stage of the procedure is the detection and elimination of these false boundaries.

The boundary will be false in the case when the null hypothesis is true and has a form:

$$H_0: \quad \Theta_a - \Theta_{a+1} = \{0, 0, \ldots, 0\}, \tag{16}$$

and it is true if:

$$H_1: \quad \Theta_a - \Theta_{a+1} \neq \{0, 0, \ldots, 0\}. \tag{17}$$

In order to check the hypothesis, Rodionow proposes a criterion analogous to (15):

$$v(T_a, T_{a+1}) = \frac{n_a + n_{a+1} - 1}{n_a n_{a+1}(n_a + n_{a+1})} \sum_{j=1}^{m} \frac{[n_{a+1} \sum\limits_{t \in T_\alpha} x_{tj} - n_a \sum\limits_{t \in T_{\alpha+1}} x_{tj}]^2}{\sum\limits_{t \in T_\alpha \cup T_{\alpha+1}} x_{tj}^2 - \dfrac{1}{n_a + n_{a+1}} (\sum\limits_{t \in T_\alpha \cup T_{\alpha+1}} x_{tj})^2}. \tag{18}$$

The boundary between subsets T_a and T_{a+1} is false, if:

$$v(T_a, T_{a+1}) \leqslant \chi^2_{q,m}.$$

In such a manner all boundaries in the sequence are checked.

The above method of checking the homogeneity of arranged sets and division of heterogeneous sets into homogeneous parts is very effective in case when we investigate the variation of many attributes. However, it requires the use of computers. Because in our problems the number of attributes was no more than 15, the small computer "Elka-22" made in Bulgaria was used for calculations.

The Rodionow's method shown above is a proper statistical basis for solving the first of the two problems indicated in the introduction.

During the first stage of examinations the method was checked in order to prove the heterogeneity of fish assemblage in the Jamna profile, in which the bathypelagic assemblage in the lower part of the profile and the neritic-sublittoral assemblage in the upper part were distinguished. The output material and the results of calculations of the index v_k $(k = 1, 2, \ldots, n-1)$ are shown in Table 1.

In the first stage of calculation, the profile containing 24 fish beds arranged according to the time parameter from the youngest to the oldest bed was divided by maximal quantity of $v_k = 34{,}682$ into two most different parts on the boundary between the layers with marks C6 and D1. The critical value of χ^2 with 15 degrees of freedom and a significance level 0,05 had been distinctly exceeded.

In the second stage the homogeneity of two sections formed by a division was checked. The upper part of the profile — between layers D1 and G3 — is not divided, because for any tested boundary between the layers the quantity of index v_k was not larger than the critical value $\chi^2_{0,05;8} = 15{,}507$. However, the lower part of the profile is divided into subsections along the boundary between the layers C5 and C4 (compare Table 1). The index v_k equal 26,850 is here larger than the quantity $\chi^2_{0,05;9}$ that amounts 16,919.

In the third stage the calculations were carried out in order to show the homogeneity of the two new subsections. The part C5-C6 does not require further division, while in the part A1-C4, a single layer — C4 — distinctly differs from the others.

In the fourth stage the homogeneity of the part A1-C3 had been confirmed: the index v_k is smaller than the quantity $\chi^2_{0,05;7}$.

As a result three boundaries were distinguished in the studied profile and two among them were detected within the range of the bathypelagic ecologic assemblage.

Then the detected boundaries were checked by means of the method of comparing the neighbouring sections described above (Table 1a). The comparison of a section C5-C6 with the section C4 has proved, that the boundary placed here in the second stage is false; the boundaries D1-C6 and C4-C3 had been confirmed.

The first boundary, recognized before by geological reasoning, corresponds to a change of bathypelagic assemblage into the neritic-sublittoral one. The following genera do not pass above this boundary: *Eomyctophum*, *Scopeloides*, *Vinciguerria*, *Centriscus* and *Palimphyes*. However, above the boundary there are the following genera: *Glossanodon*, *Palaeogadus*, *Syngnathus*, *Hipposyngnathus*, *Serranus*, *Trachinus*. From calculations it results that the strongest influence on the determination of the boundary discussed have the genera occurring uniformely in a large time interval (even if the genera are not numerous). Such genera are: *Vinciguerria*, *Palaeogadus*, *Glossanodon*, *Serranus*, *Centriscus* and *Scopeloides*. The lesser influence have the genera limited to the smaller time interval like *Eomyctophum* and *Capros* (it represents an admixture here). An influence of genera: *Syngnathus*, *Hipposyngnathus*, *Trachinus*, *Palimphyes*, *Ammodytes* (admixture) is almost corruptible. This is due to the fact that such genera tend to occur singly in some of the layers (the used method is specially sensitive for that). The presence of numerous assemblage of shallow-water genera *Trachinus*, *Hipposyngnathus* and *Syngnathus* in one layer (E1) is not completely clear (maximum of shallowing of the basin?).

The influence of individual genera for determination of boundaries is somewhat different, if we take under consideration the subsections. In the case discussed the boundary between C4-C6 and D1-G3 is marked first of all by the influence of genera *Vinciguerria*, *Scopeloides*, *Eomyctophum*, *Palimphyes*, *Centriscus*, *Capros*, occurring in a series of layers on one side of the boundary, and to a smaller degree the boundary is influenced by genera: *Palaeogadus*, *Glossanodon* and *Serranus*.

The establishment of the second boundary by the Rodionow method is very important because this boundary lies within a uniform bathypelagic

Tabela 1a

Elimination of false boundaries in the Jamna profile
Eliminacja granic fałszywych w profilu Jamnej

j	Genus	$\frac{n_{\alpha+1}\sum_{t\in T_\alpha} x_{tj} - n_\alpha \sum_{t\in T_{\alpha+1}} x_{tj}^{\;\;2}}{\sum_{t\in T_\alpha \cup T_{\alpha+1}} x_{tj}^2 - \frac{1}{n_\alpha + n_{\alpha+1}}\left(\sum_{t\in T_\alpha \cup T_{\alpha+1}} x_{tj}\right)^2}$			
		A - B	B - C	B,C - D	A - B,C
1	Clupea	2,21	6,00	0,71	22,58
2	Glossanodon	15,98	-	-	35,18
3	Palaeogadus	19,58	-	-	42,89
4	Lepidopus	51,68	2,23	248,28	40,27
5	Syngnathus	4,33	-	-	9,69
6	Hipposyngnathus	4,33	-	-	9,69
7	Serranus	15,60	-	-	34,35
8	Trachinus	4,33	-	-	9,69
9	Eomyctophum	193,43	2,13	271,41	230,13
10	Scopeloides	162,84	0,46	230,10	259,08
11	Palimphyes	130,96	1,50	154,18	130,25
12	Vinciguerria	131,08	0,64	29,95	278,32
13	Centriscus	-	6,00	18,00	130,25
14	Capros	-	6,00	46,71	130,25
15	Ammodytes	-	-	9,64	-
$\sum$		736,35	24,96	1008,98	1362,62
$\frac{n_\alpha + n_{\alpha+1} - 1}{n_\alpha n_{\alpha+1} / n_\alpha + n_{\alpha+1}}$		0,042	0,333	0,026	0,028
v_k		30,897	8,320	26,163	38,344
m		12	8	9	14
$\chi^2_{m;0,05}$		21,026	15,507	16,919	23,685

assemblage. This boundary was overlooked in previous studies. The statistically detected heterogeneity of the bathypelagic assemblage is linked with:

1. the presence of skeletons of the *Eomyctophum* genus[1] only above the boundary,

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[1] However, the presence of scales of this genus which was proved in lower levels can not be a base to precise the number of individuals as well as to take into consideration the *Eomyctophum*

Tabela 1

Partition of the Jamna profile into homogeneous sections (on the basis of fish present in particular evels)l

Podział profilu Jamnej na odcinki jednorodne (na podstawie ryb występujących w poszczególnych poziomach)

t	Level	Number of individuals collected															Partition into homogeneous sections												
		Clupea	Glossanodon	Palaeogadus	Lepidopus	Syngnathus	Hipposyngnathus	Serranus	Trachinus	Eomyctophum	Scopeloides	Palimphyes	Vinciguerria	Centriscus	Capros	Ammodytes	Stage I			Stage II			Stage III			Stage IV			Distinguished sections
																	v_k	m	$\chi^2_{m;0,05}$	v_k	m	$\chi^2_{m;0,05}$	v_k	m	$\chi^2_{m;0,05}$	v_k	m	$\chi^2_{m;0,05}$	
1	G3	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	2,656	15	24,996	1,893	8	15,507							A
2	G1	1	6	0	0	0	0	0	0	0	0	0	0	0	0	0	3,553			3,016									
3	F2	0	4	0	1	0	0	0	0	0	0	0	0	0	0	0	4,711			4,795									
4	F1	2	4	2	2	0	0	0	0	0	0	0	0	0	0	0	7,230			5,229									
5	E3	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	8,380			8,279									
6	E2	4	0	0	2	0	0	0	0	0	0	0	0	0	0	0	10,261			11,852									
7	E1	1	40	0	9	2	17	1	62	0	0	0	0	0	0	0	21,088			5,661									
8	E0	2	0	0	1	0	0	1	0	0	0	0	0	0	0	0	22,496			5,476									
9	D3	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	22,313			7,687									
10	D2	2	9	3	2	0	0	0	0	0	0	0	0	0	0	0	26,793			5,650									
11	D1	0	5	2	1	0	0	1	0	0	0	0	0	0	0	0	34,682												
12	C6	1	0	0	2	0	0	0	0	2	1	1	0	0	0	0	33,962			14,006	9	16,919	5,000	5	11,070				B
13	C5	1	0	0	8	0	0	0	0	9	9	0	5	0	0	0	29,881			26,850									
14	C4	0	0	0	1	0	0	0	0	1	3	0	4	1	1	0	23,593			21,784			19,463	8	15,507				C
15	C3	0	0	0	1	0	0	0	0	0	4	0	1	1	0	0	23,008			19,117			18,733			10,106	7	14,067	D
16	C2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	22,188			14,389			10,739			5,364			
17	C1	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	21,616			12,057			7,954			4,874			
18	B6	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	23,016			11,508			7,903			6,428			
19	B5	0	0	0	1	0	0	0	0	0	0	0	8	7	0	0	13,652			9,407			6,703			5,136			
20	B4	7	0	0	0	0	0	0	0	0	0	0	4	1	0	0	12,192			7,758			5,621			5,336			
21	B3	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	10,374			6,721			6,031			4,478			
22	B2	3	0	0	1	0	0	0	0	0	0	0	1	3	0	1	3,416			3,482			3,063			2,456			
23	A2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1,771			1,398			2,557			2,043			
24	A1	0	0	0	1	0	0	0	0	0	0	0	2	0	0	0													

2. a notable increase of the *Scopeloides* genus and simultaneous disappearance of the *Centriscus* genus.

For methodical reasons analogical calculations were executed, taking the assemblages of fish present in different lithological complexes as elements of the model. In the case of the Jamna profile the complexes in question represent: A — clayey siliceous shales, brown, with green intercalations; B — clayey siliceous shales, black, locally silicified; C — thin-bedded cherts with shales; D — brown marls with shales; E — medium-bedded sandstones with shales; F — thin-bedded sandstones with shales; G — shales with thin cherts and sandstones.

The calculations (Table 2) have not proved the heterogeneity of the profile discussed. However, the maximal value of v_k corresponds to the detected boundary between levels with marks C and D but it is located in an interval keeping the null hypothesis on the significance level 0,05.

At the moment one could draw a precocious conclusion that the method is useless. But in reality our presumption of the authenticity of model, in which the point t represents the assemblage of specimens from several levels, was wrong (probably the random variable Ξ_t has not a normal distribution in this case).

The second profile of the Menilite Beds put under such examinations was sampled at Rogi. The 11 levels with fish belonging in entirely to the neritic-sublittoral assemblage were found here. All the levels occur in shales; the intercalations of cherts are rarely met in the profile. The input material and the results of calculations are shown in Table 3.

In the first stage the heterogeneity of the profile was confirmed and the profile was divided into parts 1—5 and 6—11 along the boundary 5/6, for which the value of $v_k = 21{,}626$ is larger than the critical value of $\chi^2_{0{,}05;6} = 12{,}592$.

In the second stage the heterogeneity of the upper section on the boundary 4/5 was detected and the homogeneity of the lower section was confirmed.

The lack of boundaries in the section 1—4 was stated in the third stage. It follows, that the whole profile is divided by two boundaries into three homogeneous sections.

The comparison of neighbouring sections had not showed the presence of false boundaries. Although the fish assemblage in the profile is qualitatively homogeneous, the changes in quantity of some genera have proved to be statistically significant.

The assemblage II differs from the assemblage I by a larger proportion of *Capros*, *Clupea* and *Palaeogadus* and from the assemblage III by genera *Capros*, *Clupea* and *Glossanodon*. The differences between assemblage I and

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time distribution in calculations. Since the percentage proportion of *Eomyctophum* in lower complexes is proved, we must be very carefull in conclusions concerning the influence of the *Eomyctophum* sceletons appearance in upper levels of complex C for the appearance of the boundary discussed.

Tabela 2

Partition of the Jamna profile into homogeneous sections (on the basis of fish present in lithological complexes)
Podział profilu Jamnej na odcinki jednorodne (na podstawie ryb występujących w kompleksach litologicznych)

t	Complex	Number of individuals collected															Partition into homogeneous sections		
																	Stage I		
		Clupea	Glossanodon	Palaeogadus	Lepidopus	Syngnathus	Hipposyngnathus	Serranus	Trachinus	Eomyctophum	Scopeloides	Palimphyes	Vinciguerria	Centriscus	Capros	Ammodytes	v_k	m	$\chi^2_{m;0,05}$
1	G	3	7	1	0	0	0	0	0	0	0	0	0	0	0	0	3,757	15	24,996
2	F	2	8	2	3	0	0	0	0	0	0	0	0	0	0	0	8,016		
3	E	7	41	0	13	2	17	2	62	0	0	0	0	0	0	0	14,231		
4	D	2	18	5	3	0	0	1	0	0	0	0	0	0	0	0	22,847		
5	C	2	0	0	12	0	0	0	0	12	17	1	13	2	1	0	13,367		
6	B	10	0	0	2	0	0	0	0	0	0	0	14	13	1	1	5,124		
7	A	0	0	0	1	0	0	0	0	0	1	0	2	0	0	0			

Tabela 3

Partition of the Rogi profile into homogeneous sections
Podział profilu Rogów na odcinki jednorodne

t	Level	Number of individuals collected						Partition into homogeneous sections									
		Clupea	Glossanodon	Palaeogadus	Capros	Properca	Serranus	Stage I			Stage II			Stage III			Distinguished sections
								v_k	m	$\chi^2_{m;0,05}$	v_k	m	$\chi^2_{m;0,05}$	v_k	m	$\chi^2_{m;0,05}$	
1	1	8	1	7	0	0	10	0,955	6	12,592	1,582	6	12,592	3,238	6	12,592	A
2	2	11	2	4	0	1	14	2,034			3,293			8,706			
3	3	4	1	2	1	0	0	2,730			3,880			4,363			
4	4	10	0	1	0	0	6	2,815			15,432						
5	5	37	3	17	11	1	10	21,626									B
6	6	5	0	38	0	0	100	17,945			10,945	6	12,592				C
7	7	3	0	0	0	0	1	10,301			6,424						
8	8	3	0	0	0	0	0	5,923			7,432						
9	9	17	1	7	8	1	15	16,976			3,906						
10	10	0	1	1	0	0	6	10,022			3,967						
11	11	0	0	0	0	1	5										

III concern a larger proportion of *Glossanodon* and *Clupea* and a smaller proportion of *Serranus* in the first case.

It should be noted, that without the use of the described method the detection of these boundaries would be impossible.

II. COMPARISON OF STRATIGRAPHICAL PROFILES

The differentiation of fish assemblage in a vertical profile within a specific ecologic assemblage is most probably responsible for the lack of resemblance between individual fish localities at Jamna and Rogi as was shown in a previous paper (Jerzmańska, Kotlarczyk, Krawczyk, 1973). The division of Rogi profile into three sections rises a question whether the Jamna section I shows a resemblance with any of 3 sections distinguished in Rogi.

The problem can be also solved by means of the Rodionow's method.

The linearly arranged class of sets Ξ^{T_h} will be a statistical model of our geological object (Ξ^{T}) divided into h profiles forming linearly arranged sets Ξ^{T_s} of the random variable Ξ_t, $t \in T_s$. The homogeneous subsets $\Xi^{A_{s_r}}$ separated in a range of set Ξ^{T_s} represent a determined stratigraphic order of different assemblages of ichtiofauna. The two neighbouring profiles represented by sets Ξ^{T_s} and $\Xi^{T_{s+1}}$ can be correlated if they have even one pair of subsets $\Xi^{A_{s_r}}$ and $\Xi^{A_{(s+1)_l}}$ for which the null hypothesis

$$H_0\colon \quad \Theta_{s_r} - \Theta_{(s+1)_l} = \{0, 0, \ldots, 0\}\,, \tag{19}$$

where:

$$\Theta_{s_r} = M(\Xi_t | t \in A_{s_r})\,,$$

$$\Theta_{(s+1)_l} = M(\Xi_t | t \in A_{(s+1)_l})\,,$$

will be accepted.

The acceptation of the alternative hypothesis means, that both correlated profiles have no common homogeneous element. The criterion for checking the null hypothesis is analogical as the previous one:

$$v(A_{s_r}, A_{(s+1)_l}) = \frac{n_{s_r} + n_{(s+1)_l} - 1}{n_{s_r} n_{(s+1)_l} (n_{s_r} + n_{(s+1)_l})} \times$$

$$\times \sum_{j=1}^{m} \frac{\Big[n_{(s+1)_l} \sum\limits_{t \in A s_r} x_{tj} - n_{n s_r} \sum\limits_{t \in A(s+1)_l} x_{tj}\Big]^2}{\sum\limits_{t \in A s_r \cup A(s+1)_1} x_{tj}^2 - \dfrac{1}{n_{s_r} + n_{(s+1)_l}} \Big(\sum\limits_{t \in A s_r \cup A(s+1)_1} x_{tj}\Big)^2}\,. \tag{20}$$

Thus all homogeneous elements of the set Ξ^{T_s} with every element of the set $\Xi^{T_{s+1}}$ are compared in pairs. In this case we are looking for a minimal value, which indicate the homogeneity.

Thus, if:

$$\min_{r,l} v(A_{s_r}, A_{(s+1)_l}) \leqslant \chi^2_{q,m} \tag{21}$$

the null hypothesis (19) do not deny the sample data and the profiles can be correlated because they have at least one common element.

During further procedure such corresponding homogeneous subsets A_{s_r} and $A_{(s+1)_l}$ are joined in one subset and sequential comparisons of pairs of subset (according to formula (20)) are carried out. It is not necessary to carry out the calculations for every pair, because the first correlated element in two stratigraphic profiles precludes further comparisons of subsets occurring above the correlated subset in one profile with subsets occurring below the correlated subset in the second one. The detection of a new minimal value of the index v_k (smaller than the critical value of χ^2) leads to another connection of suitable homogeneous subsets. As a result, all possible homogeneous elements common for both profiles will be correlated and the other subsets will represent sediments wedging out between the sampled profiles.

The calculations executed for our arrangement are shown in Table 4. Although from the rational point of view no one section of the bathypelagic Jamna assemblage can be compared with any section from the neritic Rogi assemblage, in order to show and check the method the comparison of all homogeneous sections was executed (i.e. 15 different pairs). The calculated values of v_k for neighbouring homogeneous sections in every profile: Jamna I—II, Jamna II—III, Rogi I—II and Rogi II—III were utilized in Table 4.

As it was expected all comparisons of sections Jamna II and III with sections of Rogi have proved, that the null hypothesis of their homogeneity should be rejected (Fig. 2).

The interesting result is the rejection of the null hypothesis for all pairs during comparing the Jamna I with three sections of Rogi. It indicates a still larger differentiation of the neritic assemblage than it was proved before (Jerzmańska, Kotlarczyk, Krawczyk, 1973).

The only pair, for which the index v_k is less than the permissible critical value (indicating its statistical homogeneity) is the pair Rogi I — Rogi III. It was confirmed, that the differences of content of *Glossanodon*, *Clupea* or *Serranus* are not decisive. Although both sections are separated by the section Rogi II they can be considered as representing the same type of biocoenosis.

According to the procedure, the sections Rogi I and III should be joined and new indexes calculated for pairs formed by other sections and the new joint set. Because in our case, the homogeneous sections described represent different parts of the same geological section, such a connection would have no substantial meaning. In this first stage we must end the calculations concerning the connection of homogeneous sections.

It is difficult to decide presently, whether the impossibility of correlation of the Rogi and Jamna localities results from comparing sections of the profile of Menilite Beds of various age (within a neritical biocoenosis) or from a horizontal differentiation of the biocoenos's. The problem could be

Tabela 4

Comparison of the different homogeneous sections in the investigated profiles by means of Rodionow's method
Porównanie różnych odcinków jednorodnych badanych profili za pomocą metody Rodionowa

v_k	Rogi III	Rogi II	Rogi I	Jamna III	Jamna II	Równe
Jamna I	19,449 /18,307/	54,877 /18,307/	33,719 /18,307/	29,338 /22,362/	38,344 /23,685/	27,624 /16,919/
Jamna II	25,443 /21,026/	21,983 /21,026/	27,922 /21,026/	26,163 /16,919/		
Jamna III	27,768 /19,675/	72,877 /19,675/	47,158 /19,675/			
Rogi I	4,568 /12,592/	15,438 /12,592/				
Rogi II	15,210 /12,592/					

Kotów	Krępak	v_k
7,633 /15,507/	8,578 /15,507/	Jamna II
13,351 /15,507/	40,961 /15,507/	Jamna III

5,488 /12,592/	13,380 /12,592/	4,667 /12,592/	Równe
Rogi III	Rogi II	Rogi I	v_k

In brackets - critical values of $\chi^2_{m;0,05}$.

solved definitively by finding a further part of the profile at Rogi, up to the boundary with bathypelagic assemblage.

There are following examples of correlation possibility of homogeneous fish assemblages in two profiles. The material, which we can show here is modest, but nevertheless it can be used as an illustration of the Rodionow's method.

In a direct nearness of the Rogi profile, at Równe locality, an exposure was found, in which 74 fishes belonging to the neritic assemblage were collected from four levels.

The homogeneity of the assemblage was proved by values v_k lower than a critical value of χ^2 (Table 5). The comparison of homogeneous pairs of Równe assemblage with assemblages of Rogi I, II and III has indicated a possibility of parallelization in sections Równe — Rogi I and Równe — Rogi III. Because in case of the first pair, the quantity v_k is minimal, one should parallelize this assemblages as most similar ones (Fig. 2).

Tabela 5

Partition of the Równe profile into homogeneous sections
Podział profilu Równego na odcinki jednorodne

t	Level	Number of individuals collected					Partition into homogeneous sections		
							Stage I		
		Clupea	Glossanodon	Palaeogadus	Properca	Serranus	v_k	m	$\chi^2_{m;0,05}$
1	0	3	0	4	3	4	4,258	5	11,070
2	1	30	9	5	1	2	7,269		
3	2	0	3	2	0	4	4,140		
4	3	0	0	0	0	4			

Another example concerns the bathypelagic assemblage. A fish collection from one level at Krępak locality (about 8 km from Jamna) was chosen for comparison with collections from two sections of the Jamna profile (first stage — homogeneity test — was not carried out because of comparing of only one level). From such comparison we note, that the level (No. 3) from Krępak displays affinity with the assemblage Jamna II while it differs significantly (Table 4, Fig. 2) from the assemblage Jamna III (different proportions of *Eomyctophum*, *Scopeloides* and *Lepidopus*, like in the pair Jamna II — Jamna III).

Tabela 6

Comparison of the different homogeneous sections in the investigated profiles by means of χ^2 test
Porównanie różnych odcinków jednorodnych badanych profili za pomocą testuχ^2

$P/\chi^2 \leqslant \chi^2_{cal.}/$	Rogi III	Rogi II	Rogi I	Jamna III	Jamna II	Równe
Jamna I	⁎	⁎	⁎	⁎	⁎	⁎
Jamna II	⁎	⁎	⁎	⁎		
Jamna III	⁎	⁎	⁎			
Rogi I	⁎	0,003				
Rogi II	⁎					

Kotów	Krępak	$P/\chi^2 \leqslant \chi^2_{cal.}/$
0,001	0,556	Jamna II
0,157	⁎	Jamna III

⁎	0,001	0,030	Równe
Rogi III	Rogi II	Rogi I	$P/\chi^2 \leqslant \chi^2_{cal.}/$

⁎ - $P/\chi^2 \leqslant \chi^2_{cal.}/ < 0,0005$

$\chi^2_{cal.}$ - calculated value of χ^2

In a previous paper the authors (Jerzmańska, Kotlarczyk, Krawczyk, 1973) assuming the stability of the biocoenosis in time, carried out a comparison of fish genera belonging to the same ecological assemblage (the fish collections were founded in several localities). In these comparisons the χ^2 test was used (formula for empirical distributions) as well as the Spearman's rank correlation. The results, with some exceptions (Równe — Winnica, Równe — Leszczawa, Winnica — Leszczawa) rejecting a possibility of correlations between localities, led to a conclusion on time differentiation of the biocoenosis, discussed in the introduction. Now, after finding a suitable method for determining the variation it is worthwhile to carry out a comparison of distinguished homogeneous sections by means of methods used before in order to check the correctness of argumentation. First of all the impossibility of comparison of the assemblage Jamna I with distinguished assemblages at Rogi was checked. The test χ^2 and even the less sensitive rank correlation have confirmed the conclusions of a lack of correlation of the assemblages (Table 6, 7) which were drawn on a base of Rodionow's method.

The comparison of homogeneous sections at Rogi has also given results conformable with Rodionow's method, but with the restriction that the test χ^2 rejected a close similarity of sections I and III even on a significance level 0,005. The χ^2 test led also to the rejection of the hypothesis of similarity of Równe assemblage with sections I and III from Rogi on the significance level of 0,05. The hypothesis of similarity of Rogi I and Równe is accepted after lowering of the significance level to 0,025. However, the rank correlation has shown a significant correlation 0,92 for this pair.

In other cases the correlation was not shown also by this test.

The test χ^2 and the rank correlation have confirmed a very substantial affinity of Krępak with a section Jamna II shown by Rodionow's method.

In addition, the tests of correlation of some other collections with those described from Jamna and Rogi were carried out. The correlated collections contained specimens from several levels of one exposure and belonging to a determined ecologic assemblage. The high affinity of the localities Winnica and Rogi I ($P = 0{,}123$) was proved by the test χ^2 as well as for the pair Kotów and Jamna III ($P = 0{,}157$, see Table 6). Moreover the substantial affinity between Jamna III and Skopów as well as between Leszczawa and Rogi I was confirmed by the rank correlation method.

CONCLUSIONS

1. The variation in time of ichthyofauna biocoenosis of Menilite Beds predicted by the present authors in another paper (Jerzmańska, Kotlarczyk, Krawczyk, 1973) was confirmed by means of a new statistical method, described by Rodionow. The variation concerns not only the sequence

Tabela 7

Comparison of the different homogeneous sections in the investigated profiles by means of rank correlation
Porównanie różnych odcinków jednorodnych badanych profili za pomocą korelacji rangowej

r_s	Rogi III	Rogi II	Rogi I	Jamna III	Jamna II	Równe
Jamna I	- 0,349 /0,653/	- 0,282 /0,653/	- 0,157 /0,653/	- 0,554 /0,566/	- 0,524 /0,544/	- 0,113 /0,693/
Jamna II	- 0,683 /0,591/	- 0,570 /0,591/	- 0,639 /0,591/	+ 0,128 /0,693/		
Jamna III	- 0,595 /0,620/	- 0,438 /0,620/	- 0,512 /0,620/			
Rogi I	+ 0,691 /0,877/	+ 0,666 /0,877/				
Rogi II	+ 0,579 /0,877/					

Kotów	Krępak	r_s
- 0,075 /0,741/	+ 0,926 /0,741/	Jamna II
+ 0,565 /0,741/	+ 0,196 /0,741/	Jamna III

+ 0,435 /0,877/	+ 0,371 /0,877/	+ 0,928 /0,877/	Rów-ne
Rogi III	Rogi II	Rogi I	r_s

In brackets - critical values for the significance level of 0,05.

of various bathymetrically determined ecologic assemblages (which was detected before) but first of all a differentiation within the assemblages.

2. The statistical model of ichthyofauna of Menilite Beds is a multidimensional random variable Ξ_t (genus spectrum of ichthyofauna) given on a set T of points t (of thin fish levels), linearly arranged in subsets T_s (profiles of localities), along the time axis.

3. The application of the Rodionow's method made possible the detection of statistically homogeneous sections (A_s) on account of a complex of attributes within the profiles of the Menilite Beds at Jamna, Rogi, Równe, Krępak and Kotów (the sections include from one to several fish levels) as well as parallelization between profiles. The Jamna profile was divided into three homogeneous sections: I — neritic-sublittoral, II and III — bathypelagic, and the Rogi profile was divided into three sections: I, II and III, all belonging to the neritic assemblage. The profiles: Równe — neritic and Kotów — bathypelagic were not divided and they represent homogeneous sections; Krępak containing only one level is homogeneous by definition.

The lack of possibility of parallelization of the section Jamna I with any section in Rogi was confirmed. The parallelization was successfull between sections Krępak and Jamna II, Kotów and Jamna II and Jamna III as well as Równe and Rogi I (on account of small frequency of Kotów's sample the geological reasons indicate the parallelization with Jamna III as more meaningful).

4. In order to confirm the utility of methods used in a previous paper (test χ^2 and rank correlation) the homogeneity and correlation tests for assemblages from the different localities were carried out on the homogeneous sections determined at Jamna and Rogi. The division into such sections made possible in a few cases the correlation between localities by means of the χ^2 test, for instance, for the pair Winnica — Rogi I. On the other hand, the correlation established by Rodionow's method for pairs Krępak — Jamna II and Kotów — Jamna III as well as the lack of parallelization of Jamna I with Rogi I, II and III were confirmed. However, the parallelization on the level of 0,05 of Rogi I and Rogi III (accepted at the level of 0,001) and of Rogi I and Równe (accepted at the level of 0,025) was not confirmed.

It is interesting, that the rank correlation (a less sensitive method) has also confirmed the lack of correlation of Jamna I with anyone of sections from Rogi. In other words the high correlation index (about 0,9) in a preliminary comparison of two fish collections indicates their homogeneity. This method can be treated as a first stage in statistical examinations of ichthyofauna.

The test χ^2, sensitive for frequency of particular classes (fish genera), used in order to prove a homogeneity of two fish collections sampled in different exposures from several levels do not take under consideration the dispersion of fish genera in particular levels and therefore this method is not a good measure of the homogeneity. Its value will increase in case of examination of collection from a decreasing number of levels. The confirmation of homogeneity of the pair Krępak (one level) — Jamna II (three levels) in a contrary to the pair Rogi III (six levels) — Równe (four levels) parallelized by Rodionow's method can illustrate the above conclusion.

5. In a result of used statistical methods the following trends of ecological changes (not stratigraphic) of Menilite Beds ichtiofauna were stated:

a. The deep-water assemblage of ichthyofauna beginning with a complex of predominant genera *Vinciguerria*, *Centriscus* and *Scopeloides*, changes by disappearance of *Centriscus* and numerous appearance of *Eomyctophum*.

b. The shallow-water assemblage begins with a complex of genera (as known from Jamna): *Glossanodon*, *Palaeogadus* and *Serranus*, in which appears a single level enriched additionally in genera *Syngnathus*, *Hipposyngnathus* and *Trachinus*. The shallow-water, qualitatively monotonous assemblage at Rogi indicates a small quantitative differentiation of some genera. This leads to the distinction within the above assemblage a quantitatively different section (one level).

c. The wide-distribution genera *Clupea* and *Lepidopus* participate with various intensity in all mentioned ecological assemblages and complexes and they influence on the determination of homogeneous complexes in the assemblages.

d. The horizontal extension of distinguished complexes (subassemblages) was not properly recognized because of the lack of detailed methodically sampled material. Such procedure is time consuming. The first results obtained seem to indicate a spatial constancy of the recognized subassemblages: Rogi I — Równe, Rogi I — Winnica, Jamna II — Krępak, Jamna III — Kotów.

6. The distinction of the section Rogi II without the distinction of the level E1 with three separate genera from Jamna is a result of action of the used method, which eliminate the random events and underlines the substantial quantitative changes in a fixed and long lasting set of attributes.

7. The explanation of causes of variation of ichthyofauna is not simple. The appearance of various ecological assemblages results from changes of basin bathymetry, while the appearance of the level E1 can correspond with maximal shallowing of the basin, or it can be interpreted as a result of migrations of fishes as well as action of currents. The appearance of the genus *Capros*, known to inhabit the zone of continental slope (Bougis, 1959), can be interpreted by migration of individuals belonging to this genus into the shallower zone of Rogi from a deeper part of the geosyncline. Similarly, the appearance of this genus in bathypelagic assemblage Jamna II—III can be interpreted by migration of *Capros* from shallower part of the geosyncline into its bathial part.

The general difference between Jamna I and each of the sections of Rogi can be interpreted as follow:

1. assuming the lateral variation of coeval biocoenosis in various parts of the basin,
2. assuming a different age of the both ichthyofaunas and variation of the biocoenosis in time.

In case of this second possibility we can not decide now, which of the ichthyofaunas (Jamna I and Rogi) is younger. In the case of isochronous ecologic changes within the whole basin the Rogi ichthyofauna would be undoubtedly younger. Instead, if changes of depth in sampled parts of the basin are assumed at different time, the neritic assemblage could appear there in various periods. In such a case the Rogi ichthyofauna could be even older than Jamna I and correspond in age (not ecologically) to Jamna II.

The change of genera content of the bathypelagic assemblage in time is probably a result of migration of particular genera in the Thetys Ocean clockwise along its shores. The elimination of genus *Centriscus* (which moved east to Caucasus) and the appearance of the genus *Eomyctophum* in highest levels of the bathypelagic horizon could be interpreted in this way.

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STRESZCZENIE

Autorzy przyjęli jako model ichtiofauny karpackiej wielowymiarową, przestrzenno-czasową zmienną losową, reprezentowaną przez rodzaje ryb. Model ten badano za pomocą metody D. A. Rodionowa (1965, 1968, 1972) statystycznego rozdzielania uporządkowanych obiektów geologicznych na podstawie zespołu cech. Za pomocą kryterium (15) i (18) dokonano podziału na odcinki jednorodne ze względu na zespół ichtiofauny trzech szczegółowo opróbowanych profili: Jamna (tab. 1, 1a), Rogi (tab. 3) i Równe (tab. 5). Metoda Rodionowa potwierdziła rozpoznane wcześniej paleontologicznie istnienie różnych zespołów ekologicznych w tych profilach, a ponadto wprowadziła dodatkowy podział na zespoły jednorodne w obrębie tych pozornie jednorodnych zespołów. W dalszym etapie porównano wydzielone w ten sposób odcinki ze sobą oraz z kilkoma innymi odsłonięciami (zawierającymi tylko po jednej warstewce z ichtiofauną) za pomocą kryterium (20) (tab. 4), testu χ^2 (tab. 6) i współczynnika korelacji rangowej Spearmana (tab. 7). Na podstawie otrzymanych wyników przeprowadzono paralelizację między jednorodnymi odcinkami poszczególnych stanowisk, a co za tym idzie — korelację profili tych stanowisk (fig. 2), czego nie udało się dokonać przy porównywaniu sumarycznych zespołów. Równocześnie brak możliwości skorelowania odcinków jednorodnych między niektórymi stanowiskami świadczy o istnieniu zmienności czasowej w rozwoju każdego zespołu ekologicznego. Sformułowano wnioski dotyczące kierunku zmian ekologicznych ichtiofauny w warstwach menilitowych. Podjęto próbę wyjaśnienia przyczyn wykrytej i opisanej zmienności ichtiofauny.

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