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ANALYSIS OF FORAMINIFERAL ASSEMBLAGES FROM THE WESTERN CARPATHIAN LOWER MIOCENE USING SPECIAL STATISTICAL METHODS

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Abstract: Benthonic foraminiferal assemblages from the Karpatian of the Czecho-Slovak part of the Central Paratethys have been analysed by BC and BFA. These less known multivariate statistical methods were found to be suitable for present/absence type of data. Blocks of BC were interpreted paleoecologically on the basis of grouped taxons. Analysis of spatial distribution of these blocks and factors enabled a paleogeographical reconstruction of the sedimentary basin and to express the supposition of a connection between the eastern part of the Ipeľ Basin, Bánovce depression, northern part of Vienna Basin and central part of the Carpathian Foredeep.

Key words: Western Carpathians, Karpatian, foraminifera, block clustering analysis, paleogeography.

Introduction

About 40 % of the articles published the 1980s in micropaleontological journals *Micropaleontology and Journal of Foraminiferal Research* used multivariate statistical methods. Among them cluster analysis, Q-mode of factor analysis and principal component analysis were predominant.

So far these methods have rarely been used for the analysis of foraminiferal data from the Central Paratethys. Brzobohatý et al. (1981) and Rupp (1987) dealing with foraminiferal assemblages from Middle Miocene of Vienna Basin, are two notable exceptions.

The aim of this paper is to demonstrate the use of less known statistical methods for the analysis of homogeneous, by non-quantitative methods indistinguishable, Karpatian foraminiferal assemblages.

Characteristics of the analysed area

Analysed foraminiferal assemblages originate from the Karpatian (Late Burdigalian) of the Czecho-Slovak part of the Central Paratethys. The assemblages of calcareous nannoplankton from studied boreholes belong to the NN 4 Zone. Samples from "schlier" (schlier - calcareous claystones with silty laminae and silstone intracalations with mica and plant debris on the bedding surfaces) were analysed. The "schlier"is locally defined as Sečianky Mb. (Southern Slovakian Basin, Vass et al. 1983), Bánovce Mb. (Blatné and Bánovce depressions, Seneš 1971) and Lakšár Mb. (Vienna Basin, Špička & Zapletalová 1964). The conditions of sedimentation of this litotype have not been satisfactorily explained.

The assemblages of benthic foraminifers were analysed by several authors (Kantorová 1964, 1970; Cicha et al. 1967; Brestenská 1970). The attempts to distinguish type foraminiferal assemblages in the analysed area (Špička & Zapletalová 1963; Brzobohatý 1988) have shown that the assemblages occur only in a limited area. Differences among the assemblages in a larger area are not evident.

According to our experience the foraminiferal assemblages are diversified. Cibicidoids, lagenids (mainly *Lenticulina*) and *Florilus communis* often predominate. The assemblages indicate stable marine conditions characterized by paleodepth up to 500 m (NW of Vienna Basin, Bánovce Basin), exceptionally over 500 m (SE of Ipeľ Basin). Shallow-water assemblages occur locally in the marginal parts of basins, or in the lowermost Karpatian. In some places (e.g. NW of Ipeľ Basin) hyposaline foraminiferal assemblages were found.

Egerian (Chattian) foraminiferal assemblages from Lučenec Mb. (Seneš in Andrusov 1965), similarly represented by "schlier", were used for comparison with Karpatian assemblages. Calcareous nannoplankton from Egerian samples belongs to the NP 25 Zone. The benthic foraminiferal assemblages are in many respects similar to the Karpatian ones. Assemblages defined by non-quantitative methods (Danihelová 1954; Horváth 1983) occur in limited area. The assemblages indicate stable marine conditions characterized by a maximum paleodepth of about 200 m.

Material and methods

When preparing the data for analysis such sources of quantitatively or semiquantitatively analysed foraminiferal assemblages from the Czecho-Slovak part of the Central Paratethys

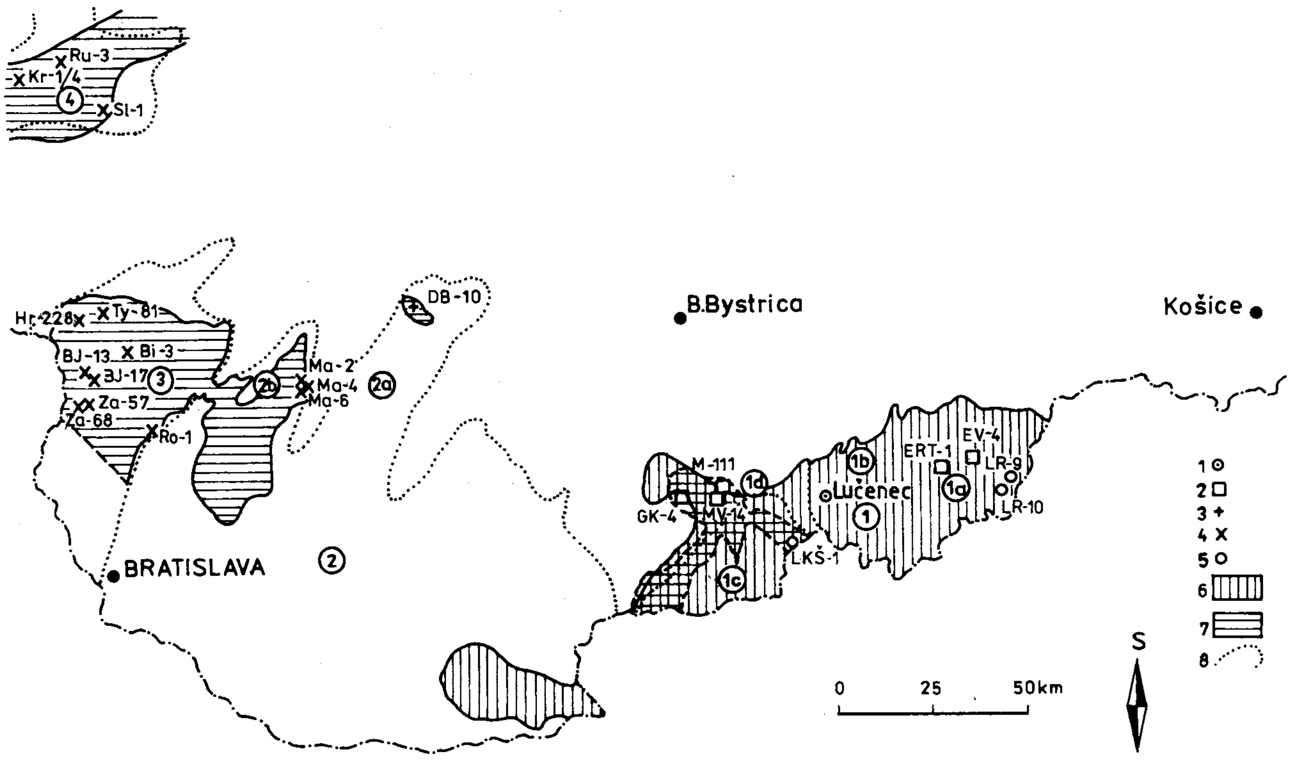

Fig. 1. Localization of statistically analysed boreholes. *Legend:* 1 - cities; 2 - 5: borehole micropaleontologically analysed by: 2 - Kantorová, 3 - Brestenská, 4 - micropaleontologists from the Moravian Oil Company Hodonín, 5 - author (empty signs refer to Karpatian samples, filled signs to Egerian ones); 6 - area of present-day Egerian sediments (Vass et al. 1989); 7 - area of present-day Karpatian sediments (Gašparík 1972); 8 - borderline of regional geological unit: 1 - Southern Slovakian Basin, 1a - Rimava Basin, 1b - Lučenec Basin, 1c - Ipeľ Basin, 2 - Danube Basin, 2a - Bánovce depression, 2b - Blatno depression, 3 - Vienna Basin, 4 - Carpathian Foredeep.

were chosen in which foraminiferal samples were preserved. This was necessary for unifying the taxonomical conceptions of various authors (mainly concerning the *Lenticulina* species). Species were not distinguished for badly differentiated taxons (e.g. *Nodosaria*, *Dentalina*, some agglutinated species). Species with supposed analogical paleoecological requirements have not been joined avoid influence on the results of statistical analysis.

A total of 215 samples from 25 boreholes (Fig. 1) and 112 taxons (Appendix 1) were chosen for multivariate analysis. 10 taxons were excluded from the analysis because they occurred only in one sample.

The basic input matrix consisted of 215 rows and 102 columns. The matrix rows correspond to samples, columns to taxons. During the first step of analysis we have reduced the entire amount of information to the level of binary variables. The initial analysis of the data in their semiquantitative form brought results that were inconsistent and difficult to interpret. The explanation follows from the fact that when the data are considered as nominal within the computation (i.e. different values from different categories) lot of natural connections are lost. The Boolean type of data reflects their character better, the logical value of presence is much more important than the quantity of presence.

The analysis of the data was based on the methods of block clustering (BC) and Boolean factor analysis (BFA). These methods were computed by means of BMDP programmes P3M and P8M. We give only a brief description of those methods which are fully described in BMDP Statistical Software Manual (Dixon 1989).

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         X(69)     X(103)    X(107)    X(111)    X(26)
          X(87)     X(35)     X(58)     X(29)     X(47)
           X(91)     X(78)     X(83)     X(10)     X(40)
            X(85)     X(105)    X(92)     X(20)     X(37)
             X(63)     X(109)    X(113)    X(9)      X(41)
              X(64)     X(38)     X(62)     X(4)      X(39)
               X(100)    X(43)     X(33)     X(46)     X(61
                X(102)    X(42)     X(67)     X(82)     X(55)
                 X(68)     X(45)     X(95)     X(11)     X(65
                  X(14)     X(52)     X(34)     X(21)     X(5
        +....+....+....+....+....+....+....+....+....+....+..
KVT 05  .      GG  G   DG1GGGDG1     G             GGGG
KVT 06  +      GG 2G   DGDGGGDGG    21             GGGG
KVT 03  .      GG  G    G2GGG 1G   2 G           22GGGG  2
KVT 04  .      GG 2G   2G GGG GG2    G             GGGG
KLA 02  .  2     FFF2  F2 1  2 2 FF1F1FFF
KLA 03  .    2  2FFF   F  F  2 2 FFFFFFFF
KLA 04  +  2     FFF2  F  F      FFFFFFFF                   2
ER8 02  .      DDFF1 2 F1D1DDD   1FF1F1F1            2
KVI 06  .      DD      DDDD111          22
ERQ 01  .     2DD  2   DD1D1DD   2    2             2      2
ERQ 02  .     2DD  2   DD1D1DD   2   222     2    2 2
ER8 01  +      DD   22 D1DDD1D     2   2             2     2
ER8 05  .      DD 2  2 D1D1DD1   2 2   2             2      2
ER8 06  .      D1   2  DDD1DD1   2     2          2         2
ER8 07  .     2DD    2 DDDDDDD   2     2     2              2
ER8 09  .      D1   2  DDDD1D1       2                      2
ER8 10  +      DD      1DDDDDD        2      2              2
ER8 11  .      D12 2   D1DDDDD               2    2         2
ER8 12  .      DD      D1D1DD1     2         2              2
ER8 13  .     2DD   2  DDDDDDD     2         2              2
KVM 02  .   2   22 2  1EE      E    E   BBEB2  2      2 E  1
KVM 09  +   2    2    11E      12   E2  BBEB    2       E  E
KVU 01  .             BE1    2 E    E2  B1EB            E  E
KVI 01  .2          2 2BE22    1   21   2 E      2  22  E  12
KVL 03  .              BE 2     22  1     E         2
KVR 03  .   2          11      E    12    E             E  E
KVT 02  +      1       BB2    2E    E     E   2     2 2 E  E
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Fig. 2. Part of the output of BC. Letters denote blocks, rows correspond to samples and columns to taxa expressed by its number ordered as in Appendix 1.

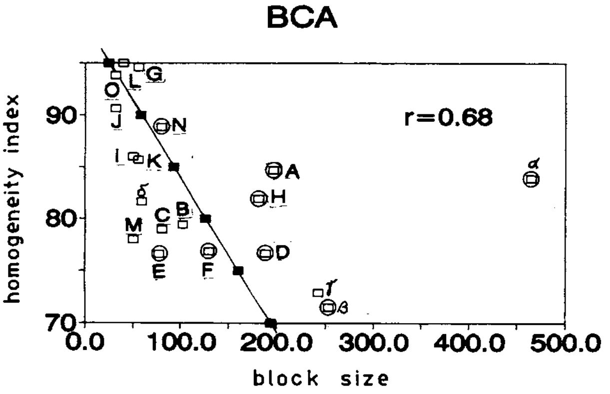
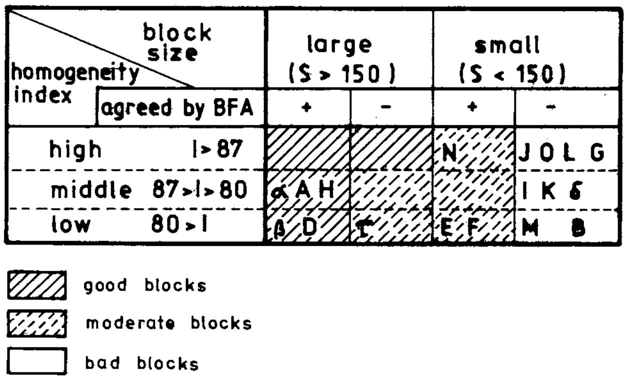


Fig. 3. Relation between block size and homogeneity index. Regression curve and correlation coefficient is given. Blocks which are in agreement with some factor what regards sharing some taxa, are circled.



homogeneity index / block size		large (S > 150)		small (S < 150)	
	agreed by BFA	+	-	+	-
high	I > 87	▨	▨	░ N	J O L G
middle	87 > I > 80	▨ α A H	░	░	I K δ
low	80 > I	▨ β D	░ γ	░ E F	M B

▨ good blocks
░ moderate blocks
☐ bad blocks

Fig. 4. Classification of blocks according to block size, homogenity index and agreement with Boolean factor analysis.

The BC method constructs block clusters by means of selection and reordering of rows and columns. Each column in a block is characterized by the value corresponding to the presence or absence of the taxon. Data in block, values of which differ from the characteristic block column values are called singletons. Some rows or columns belong to more blocks and the overlapping of blocks is possible. That means a taxon or group of taxa may be common to different blocks. The algorithm looks for a system of at most 19 blocks that minimizes the number of singletons. This method results in an easily readable table, part of which is presented in Fig. 2. For better comparison of the compactness of the blocks we have introduced the homogeneity index (I). This index is computed as the ratio of the true real and the theoretical count. The theoretical count of members in a block is computed for non-overlapping blocks as a product of number of rows and a number of columns. The real count of members is then the theoretical count diminished by the number of singletons. As the number of singletons increases, I decreases. In case of overlapping blocks the common part belongs to the block with identical characteristic block value. It may belong to more than one block. These situations should be distinguished when computing the theoretical block count.

The goal of BFA is similar to that of classical factor analysis: to express a greater number of variables by a considerably less number of factors (Davis 1973; Hartigan 1976). Both the input data matrix and the resulting factor loadings and factor scores are binary (boolean) data. The interpretation of factor loadings and factor scores is also similar. Firstly, the factor loadings form groups of taxa corresponding to the factors (Appendix 1). Secondly, the factor scores for a given sample give us information about which factors are active and which non-active in this sample.

The computational algorithm of BFA differs substantially from classical factor analysis. In BFA the factor loadings and factor scores are computed iteratively. The algorithm seeks a minimal number of discrepancies between the input data matrix and estimated data matrix. (The estimate is the result of a Boolean product of the loadings and the scores). The algorithm starts from an initial number of factors (which can be changed by the user) and continues with a higher number of factors. It stops when the number of discrepancies does not diminish.

From the above description it is obvious that BC method is more of local character because it provides information on groups of taxa connected to a limited number of samples. On the other hand, BFA is of global character since it forms groups of taxa for all the samples together.

BFA was used to solve paleoecological problems and as a complementary method for BC. Some preliminary computational screening led to the estimate of 22 factors as the optimal number.

The results for 20 factors differed only slightly and are not discussed in the sequel. Due to the prevalence of zeros in the data matrix (corresponding to the absence of a taxon in the sample) over units, it was useful to penalize the positive discrepancies (i.e. those corresponding to the observed value one and the estimated value zero). With twice as high cost for positive discrepancies we have successfully balanced the number of positive and negative discrepancies.

BC and BFA have not been commonly used in paleontology. The Braun-Blanquet method, using similar ideas to BC, was developed in plant sociology and was applied to analysis of foraminiferal assemblages (e.g. Hiltermann & Tüxen 1974; Barbin & Keller-Grünig 1991).

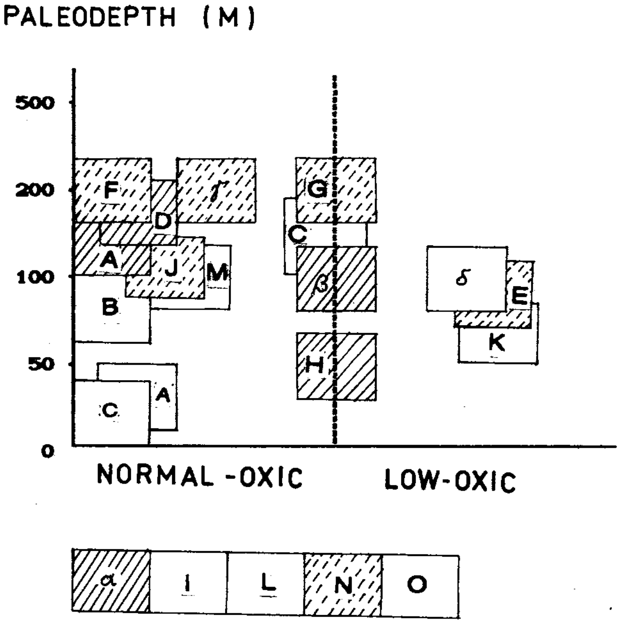


Fig. 5. Interpretation of paleoecological requirement of taxa grouped in the blocks. Blocks at the bottom did not find paleoecological interpretation. Hatching see Fig. 4.

Interpretations

The interpretations are based mainly on the results of BC which were compared to the results of BFA. We stress those results of BC which were approved by BFA.

The output of BC was resumed from the point of view of taxa in the table (Appendix 1).

The blocks were evaluated from two standpoints:

1 - from the statistical standpoint of the size of blocks, their index of homogeneity and the presence of joint subgroups of taxa (at least 3) both in BC and in BFA are appreciated. The size and the homogeneity index are negatively correlated ($r = -0.67$). On the base of Fig. 3 the blocks were classified into three groups (Fig. 4):

a - good blocks α, β, A, D, H

b - moderate blocks γ, F, E, N

c - poor blocks δ, J, L, O, I, K, M, C, B, G;

2 - the paleoecological standpoint follows from the paleoecological interpretability of blocks. From this point of view the blocks were classified into five groups:

a - large blocks containing taxa characteristic of different paleoenvironments (blocks α, A, C, G). The occurrence of these paleoenvironments is supposed for areas corresponding to these blocks;

b - blocks containing taxa which require stable marine conditions (blocks β, D, F, H). They do not permit accurate estimation of paleodepth, only an "average" paleodepths for areas corresponding to these blocks can be stated. Similar groups of taxa are commonly found by multivariate statistical methods (Rupp 1987). Experiences with multivariate statistical analysis of Recent foraminiferal assemblages from stable marine environments (Burke 1981; Culver & Buzas 1981) showed that depth interpretation cannot go further into detail than differentiating between e.g. shelf, upper slope, lower slope;

c - blocks containing taxa typical for paleoenvironments with long-term influence of some environmental stress factors (blocks δ, E, K). Interpretation of the taxa involved points to low-oxic conditions. Species composition of stress-resistant foraminiferal assemblages are so typical that they can be detected by common multivariate methods (e.g. van der Zwaan 1983; Hasegawa et al. 1990; Vismara-Shilling & Coutbourn 1991);

d - blocks containing the most frequent taxa from analysed foraminiferal assemblages: *Florilus communis, Heterolepa dutemplei, Lenticulina cultrata, Valvulineria* sp. (blocks γ, N). They are dispersed all over the area. Block B containing the most frequent agglutinated species is a special case of this group of blocks;

e - small blocks paleoecologically non-interpretable (blocks I, J, L, D). They are unimportant from the statistical standpoint, too.

The blocks have been paleoecologically interpreted on the basis of actuoecology (Pfleger 1957; Murray 1973, 1991; Boltovskoy & Wright 1976; Reiss & Hottinger 1984) of the foraminiferal taxa grouped in blocks. The shift of paleoecological requirements of taxa was taken into account (van der Zwaan 1983; Kurihara & Kennett 1988). The shift has been also observed in the analysed territory mainly in shallow-water biotops (Šutovská 1991).

The depth and O_2 content are probably the limiting paleoenvironmental factors (from factors determinable in the fossil record) for grouping taxa in the blocks. That is why the "average" paleoecological requirements of taxa associated in blocks were interpreted from a paleodepth/O_2 content diagram (Fig. 5). Description of blocks is given in Appendix 2.

Spatial distribution of blocks and factors

In the sequel, the spread of blocks over the samples is considered. Spatial distribution of blocks permits us to distinguish seven areas in the Karpatian and two in the Egerian. The areas are described by frequencies of samples in presented blocks in the form of bar graphs (Figs. 6 - 8). Using the paleoecological characteristics of blocks, the paleoenvironment in the areas has been interpreted:

The Eastern part of the Ipeľ Basin, Bánovce Basin and the northern part of the Vienna Basin are characterized by blocks containing taxa typical of the deepest areas of the Karpatian (paleodepth more than 200 m) with stable marine conditions. Marginal shallow-water biotops are deduced for the Bánovce Basin on the basis of the occurrence of shallow-water taxa (e.g. *Ammonia beccarii, Elphidium* sp.) in block α typical for this area. Vienna Basin was shallower in southern direction (in agreement with Jiříček 1978), Ipeľ Basin in NE direction. Low-oxic condition are considered for the southern part of Vienna Basin and for the shallow-water Blatno depression. Varied biotops with predominated shallow-water elements have been interpreted for analysed part of the foredeep near Zlín and Kroměříž (the deepest part of the Carpathian Foredeep in the Karpatian, Buday at al. 1965).

Shallower and low-oxic conditions in the eastern part and deeper-water and well-aerated environment in the western part were stated for the Egerian of the Rimava Basin (the control area), which is in agreement with the results obtained by classical paleoecological analysis of a large number of samples. The results showed deepening of the basin in a SW direction.

Spatial distribution of the blocks was compared to the distribution of factors. The results reflect the fact that BFA is of global character opposite to the local character of BC. The areas stated by BC were described by frequency of samples in which the factor is present, by means of a bar graph (Figs. 7, 8). This frequency was taken as input of index of similarity in clustering of seven areas (Fig. 9). Analysing these graphs, the areas were classified into two group:

The first group of the areas include the eastern part of the Ipeľ Basin, the Bánovce depression, the northern part of the Vienna Basin and the Carpathian Foredeep. The areas are clustered. Relatively high similarity supports the hypothesis about communication of these areas during the Karpatian. Paleoenvironmental resemblance as a cause of similarity of areas is slightly probable because some ecological conditions were interpreted for the Carpathian Foredeep and other for the rest. Similarity of the Ipeľ and Bánovce Basins draw attention because it is based on rare factors 18 a 19 (not found anywhere else). Hypothesis about connection of these areas through the present-day neovolcanites was expressed in earlier researches (Buday et al. 1965). The communication of the Carpathian Foredeep, the northen part of Vienna Basin and Bánovce depression is considered by Jiříček 1978: northern part of Vienna Basin and Bánovce depression formed Brezová depression in Lower Miocene.

While the first group is compact, the second group corresponds to a "collective group" of shallow-water areas (NW of the Ipeľ Basin, the southern part of the Vienna Basin and the Blatno depression). There are not only different from the first group areas but also among themselves. It can be explained by paleoecological variability of these areas.

A sketch of these paleogeographical ideas is given in Fig. 9.

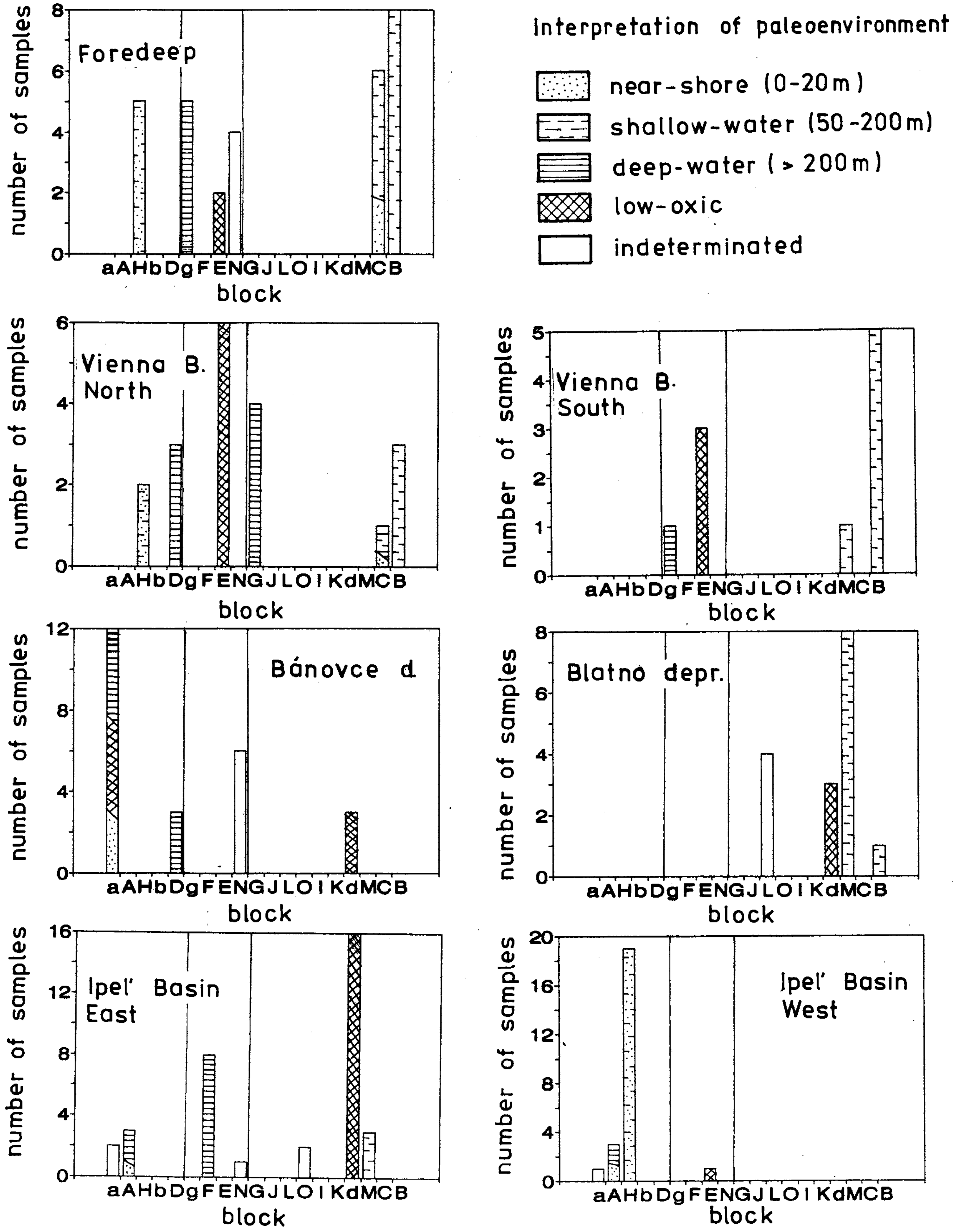


Fig. 6. The bar graphs for Karpatian area represent frequency of samples from given area in blocks ordered from good ones to bad ones. List of taxons for each block see Appendix 2. Paleoecological interpretation is designated by five types of hatching.

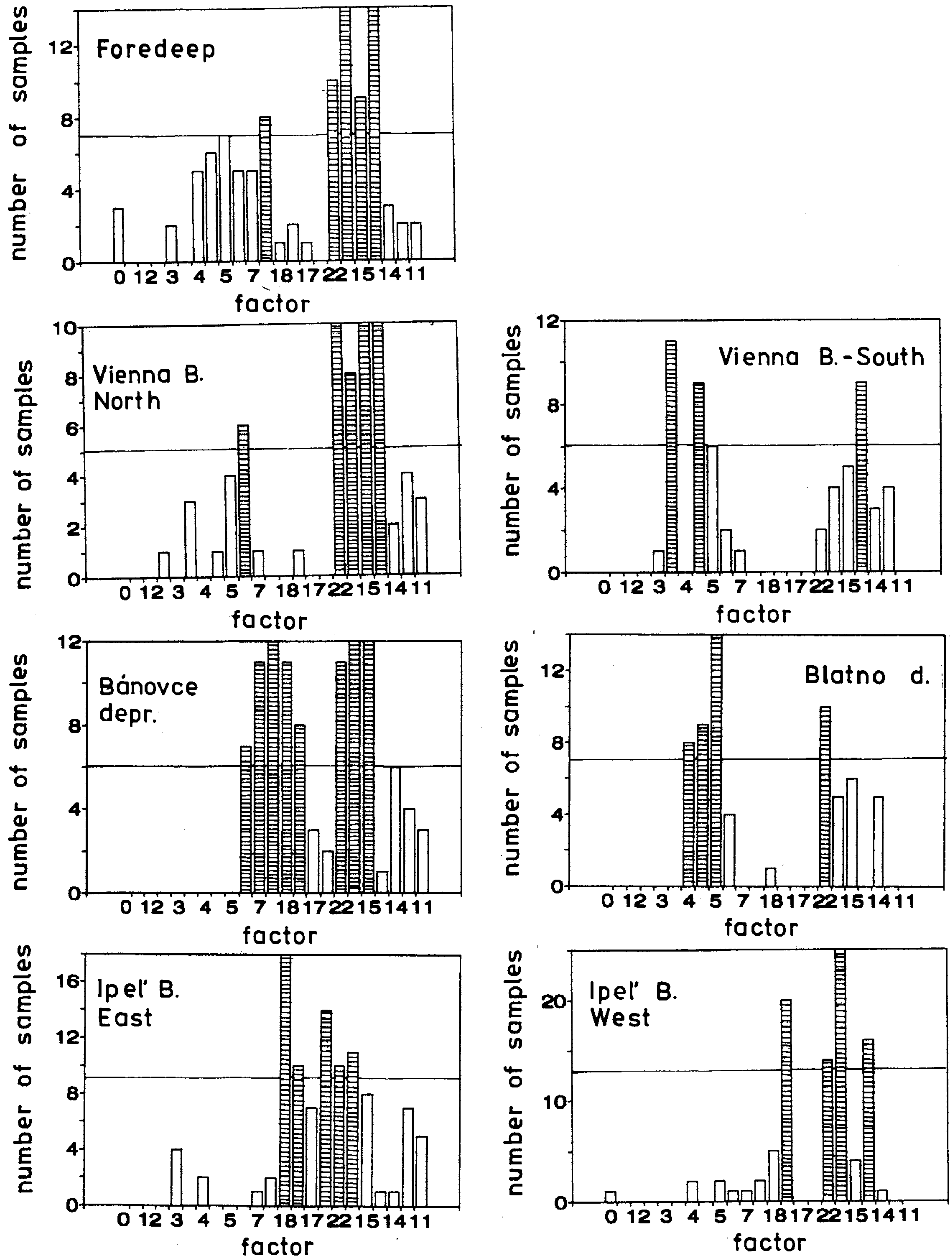


Fig. 7. The bar graphs for Karpatian area represent frequency of samples from given area in which the factor is present. Frequency higher than 50 % is pointed up by hatching.

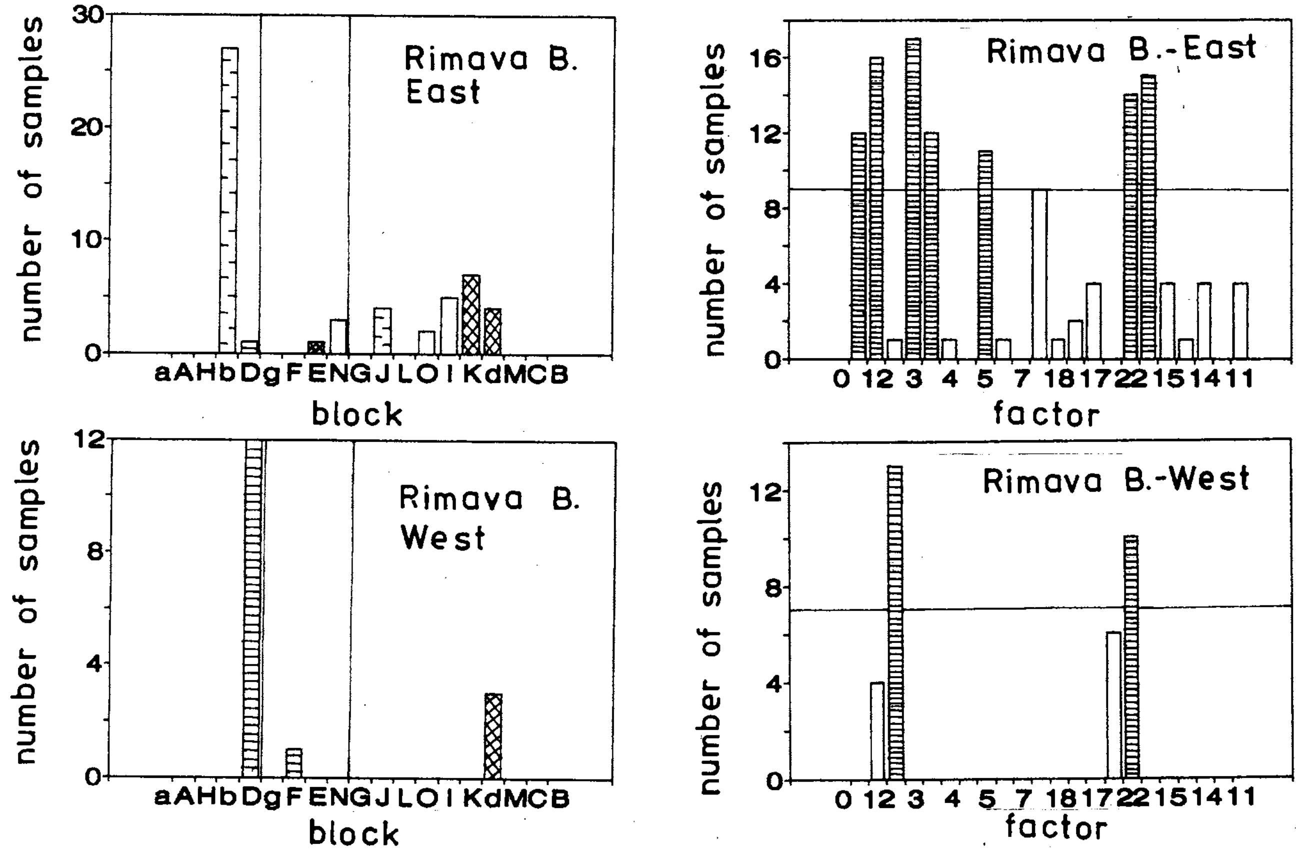


Fig. 8. The bar graphs for Egerian areas with the same explanation as in Figs. 6 and 7.

Conclusion

1 - A large amount of binary paleontological data without apriori differentiation was analysed by less known statistical methods, BC and BFA. Both of them were found suitable for such type of data. Nevertheless the BC method was preferred as simpler, more transparent and not demanding choice of parameters. Comparing the results of two different methods is a good way of verifying them.

2 - The taxons, which are grouped into blocks co-exist in many samples. Therefore, from the paleoecological point of view, these taxa characterize long-term stable paleoenvironment or an "average" environment averaging the oscillations of similar types of environment.

3 - On the base of spatial distribution of blocks and factors, paleogeographical sketch of the Czecho-Slovak part of the Karpatian Basin is given. The deepest parts of the basin, probably connected with each other, lay on the line: SE part of the Ipeľ Basin, Bánovce depression, northern part of the Vienna Basin and the Carpathian Foredeep. Remaining areas (NW part of Ipeľ Basin, Blatno depression, southern part of the Vienna Basin) represented shallow-water paleoecologically diversified parts of basin.

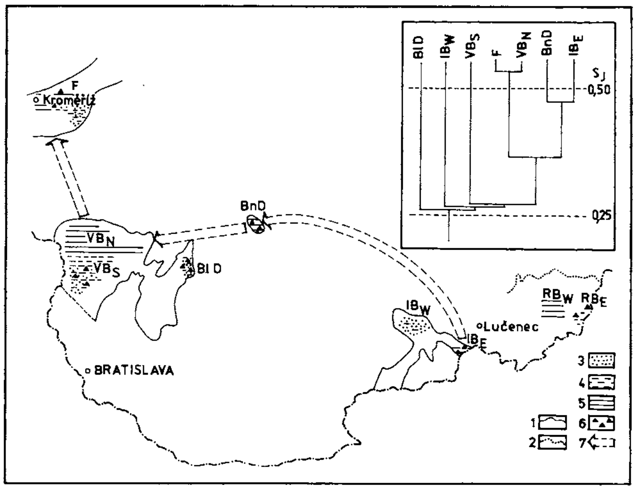


Fig. 9. A sketch of paleogeographic interpretation of analysed area determined by results of multivariate analysis.

Legend: 1 - borderline of present-day area of Karpatian sediments (Gašparík 1972); 2 - borderline of present-day area of Egerian sediments (Vass et al. 1989); 3 - paleodepth up to 50 m; 4 - paleodepth 50 - 200 m; 5 - paleodepth more than 200 m; 6 - low-oxic environment; 7 - marine connection supposed for at present isolated basins.

Dendrogram result from cluster analysis of areas: RB_W - western part of Rimava Basin, RB_E - eastern part of Rimava Basin, IB_W - western part of Ipeľ Basin, IB_E - eastern part of Ipeľ Basin, BnD - Bánovce depression, BlD - Blatno depression, VB_S - southern part of Vienna Basin, VB_N - northen part of Vienna Basin, F - Carpathian Foredeep, S_J - Jaccard's similarity index of benthonic foraminiferal assemblages.

APPENDIX 1

Species	Blocks BC																			Factors																			
	α	b	γ	δ	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	1				5					10					15					20
Uvigerinaparkeri breviformis Papp & Turn.							o																		x														
Elphidium crispum (L.)							o																																
Cribrononion hiltermanni Hagn					o		o												o	x														x		x			
Ammonia beccarii (L.)	o				o		o					o												x							x					x	x		
Stilostomella consobrina (Orb.)	o	o		o			o															x	x															x	
Stilostomella elegans (Orb.)	o	o	o		o												o					x					x			x						x			
Florilus commune (Orb.)																					x			x							x				x	x	x		x
Pullenia bulloides (Orb.)	o		o				o	o												x			x		x	x	x		x							x			
Bulimina pupoides (Orb.)			o				o			o					o						x								x		x			x					
Spiroplectammina carinata (Orb.)	o		o							o			o														x									x		x	
Gyroidina soldanii Orb.	o		o							o	o		o													x				x									
Lagena div.sp.	o		o		o																				x											x			
Uvigerina semiomata Orb.	o	o																																					
Cibicidoides pseudoungerianus (Cush.)	o		o			o						o			o																								
Heterolepa dutemplei (Orb.)	o		o			o		o	o	o							o		o			x		x		x	x												
Lenticulina cultrata (Monfort)	o		o					o	o		o																												
Marginulina div.sp.			o					o												x							x		x							x			
Lenticulina inomata (Orb.)								o		o	o															x	x		x						x				
Amphicoryna div.sp.								o												x							x								x				
Sphaeroidina bulloides Orb.								o					o														x			x									
Cibicidoides ungerianus (Orb.)	o	o						o										o									x			x				x	x				
Bolivina hebes Macfad.	o										o							o	o	x													x						
Valvulineria div.sp.	o			o					o		o					o		o															x		x		x		
Eponides div.sp.	o													o				o							x										x				
Hoeglundina elegans (Orb.)										o								o								x			x										
Stilostomella adolphina (Orb.)										o										x						x													
Dentalina div.sp.	o					o																				x									x				
Bulimina elongata Orb.	o								o	o																					x				x				
Fursekoina schreibersiana (Czj.)	o									o	o														x						x								
Frondicularia div.sp.	o				o					o																x										x			
Melonis pompiloides (F. & M.)	o				o					o																x									x	x			
Signoilopsis celatus (Orb.)	o					o				o															x						x		x						
Cribrostomoides div.sp.						o																						x											
Semivulvulina pectinata Rss.						o			o															x															
Haplophragmoides div.sp.						o								o		o	o						x					x											
Bathysiphon div.sp.														o		o	o			x	x																		
Plectofrondicularia div.sp.														o													x								x				
Baggina div.sp.														o																									
Cyclammina div.sp.													o	o		o							x																
Gaudrina div.sp.																o												x											
Quinqueloculina akneriana Orb.																o																x							
Lenticulina arcuatostriata (Hantk.)																o															x								
Lenticulina orbicularis (Orb.)											o					o																							
Lenticulina clericii (Fornasini)											o																												
Lenticulina macrodisca (Rss.)											o																x												
Lenticulina melvili (Cush. & Renz)			o								o																											x	
Islandiella sp.			o																																				
Bolivina dilatata Rss.	o		o						o															x	x														
Bulimina acuelata Orb.	o		o																						x														
Bolivina fastigia Cush.	o		o										o		o																			x					

Species	Blocks BC																			Factors																			
	α	b	γ	δ	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	1				5					10					15					20
Caucasina sp.	o			o					o			o			o									x						x				x					
Hanzawaia boueana (Orb.)	o			o	o							o													x		x									x	x		
Cibicidoides sp.	o				o							o																								x	x		
Cassidulina div.sp.	o											o													x				x		x						x		
Cibicides lobatulus (Walk. & Jac.)		o			o							o									x														x				
Cibicidoides bullatus (Franz.)		o		o																	x						x												
Triloculina consobrina Orb.													o																						x				
Uvigerina hantkeni Cush. & Edw.													o																	x									
Siphonina reticulata Czjz.													o																x										
Neoeponides schreibersii (Orb.)														o					o	x																			
Bolivina antigua Orb.															o				o				x																
Anomalina div.sp.		o																		x												x							
Heterolepa praecincta (Franz.)		o														o						x					x			x									
Bolivina liebusi Czjz.		o																		x										x									
Hyperammina div.sp.																																							
Ammodiscus incertus (Orb.)																																							
Reophax div.sp.																																							
Ammoscalaria div.sp.																							x																
Textularia gramen Orb.																										x													
Textularia pala Czjz.																											x									x			
Martinotiella communis (Orb.)																												x											
Shenkiella div.sp.																																							
Spiroloculina div.sp.																													x										
Pyrgo div.sp.																																	x						
Spirosigmoilina tenuis Czjz.																																							
Nodosaria div.sp.																																							
Lenticulina calcar (L.)																										x										x			
Planularia div.sp.																										x	x		x						x				
Guttulina communis Orb.																											x								x				
Globulina gibba Orb.																															x								
Guttulina problema Orb.																											x												
Bolivina beyrichii Hantk.																											x			x									
Reussella div.sp.																					x								x		x			x					
Uvigerina acuelata Orb.																										x													
Uvigerina boniensis Papp & Turn.																																							
Uvigerina graciliformis Papp & Turn.																																							
Uvigerina pygmoides Papp & Turn.																														x									
Uvigerina semiornata Orb.																																							
Discorbis div.sp.																																							
Rosalina div.sp.																				x		x					x							x					
Asterigerinata planorbis (Orb.)																																							
Elphidium fichtelianum (Orb.)																																							
Elphidium flexuosum (Orb.)																																							
Planulina div.sp.																											x												
Chilostomella ovoides Rss.																																							
Almeana div.sp.																					x						x			x									
Textularia abreviata Orb.																																							
Bolivina scalprata Cush.	o																																x						
Elphidium macellum (L.)	o																																						
Bolivina oligoceanica Hantk		o																																	x				

APPENDIX 2

α	_Ammonia beccarii_ (L.)	S: 15 x 31
	Stilostomella consobrina (Orb.)	I: 83.9
	Stilostomella elegans (Orb.)	SF: factor 7
	*_Pullenia bulloides_ (Orb.),	
	Spiroplectammina carinata (Orb.)	SD: Bánovce depression
	*_Gyroidina soldanii_ Orb.	Ipel Basin (rare)
	Lagena div. sp.	TD: Karpatian
	Uvigerina semiornata Orb.,,	
	Cibicidoides pseudoungerianus (Cush.),	
	Heterolepa dutemplei (Orb.),	
	Lenticulina cultrata (Monfort),	
	Cibicidoides ungerianus (Orb.),	
	Bolivina hebes Macfad,	
	Valvulineria div. sp.,	
	*_Eponides_ div. sp.,	
	Dentalina div. sp.,	
	Bulimina elongata Orb.,	
	*_Fursekoina schreibersiana_ (Czj.),	
	Frondicularia div. sp.,	
	Melonis pompiloides (F. & M.),	
	*_Signoilopsis celatus_ (Orb.),	
	Cibicidoides sp,	
	*_Cassidulina_ div. sp.,	
	*_Bolivina dilatata_ Rss,	
	*_Bulimina acuelata_ Orb.,	
	Bolivina fastigia Cush,	
	Caucasina sp,	
	*_Hanzawaia boueana_ (Orb.),	
	*_Bolivina scalprata_ Cush,	
	*_Elphidium macellum_ (L.),	
β	_Stilostomella consobrina_ (Orb.)	S: 27 x 9
	*_Stilostomella elegans_ (Orb.)	I: 72.8
	Uvigerina semiornata Orb.	SF: factor 12
	*_Cibicidoides ungerianus_ (Orb.),,	
	Cibicides lobatulus (Walk. & Jac.)	SD: eastern part of
	Cibicidoides bullatus (Franz.)	Rimava Basin
	*_Anomalina_ div. sp.	TD: Egerian
	*_Heterolepa praecincta_ (Franz.),	
	*_Bolivina liebusi_ Czj,	
γ	_Stilostomella elegans_ (Orb.)	S: 23 x 11
	Pullenia bulloides (Orb.)	I: 71.5
	Bulimina pupoides (Orb.),	
	Spiroplectammina carinata (Orb.)	SD: disperzed
	Gyroidina soldanii Orb.	TD: Karpatian
	Lagena div. sp.	Egerian
	Cibicidoides pseudoungerianus (Cush.),	
	Heterolepa dutemplei (Orb.),	
	Lenticulina cultrata (Monfort),	
	Marginulina div. sp.,	
δ	_Stilostomella consobrina_ (Orb.)	S: 6 x 10
	Valvulineria div. sp.	I: 81.7
	Lenticulina melvili (Cush. & Renz),	
	Islandiella sp.	SD: Rataje (Foredeep)
	Bolivina dilatata Rss.	TD: Karpatian
	Bulimina acuelata Orb.,	
	Bolivina fastigia Cush,	
	Caucasina sp,	
	Hanzawaia boueana (Orb.),	
	Cibicidoides bullatus (Franz.),	
A	*_Cribrononion hiltermanni_ Hagn	S: 14 x 14
	*_Ammonia beccarii_ (L.)	I: 84.7
	*_Stilostomella elegans_ (Orb.)	SF: factor 18
	*_Lagena_ div. sp.,	
	*_Frondicularia_ div. sp.	SD: Ipeľ Basin (mainly eastern
	*_Melonis pompiloides_ (F. & M.)	part),
	*_Hanzawaia boueana_ (Orb.)	TD: Karpatian
	*_Cibicidoides_ sp,	
	Cibicides lobatulus (W. & J.),	
B	_Cibicidoides pseudoungerianus_ (Cushm.)	S: 17 x 6
	Heterolepa dutemplei (Orb.)	I: 79.4
	Signoilopsis celatus (Orb.),	
	Cribrostomoides div. sp.	SD: disperzed
	Semivulvulina pectinata Rss.	TD: Karpatian
	Haplophragmoides div. sp.,,	
C	_Uvigerina breviformis_ Papp & Turn.	S: 9 x 9
	Elphidium crispum (L.)	I: 79.0
	Cribrononion hiltermanni Hagn,	
	Ammonia beccarii (L.)	SD: Foredeep
	Stilostomella consobrina (Orb.)	TD: Karpatian
	Pullenia bulloides (Orb.),	
	Bulimina pupoides (Orb.),	
D	***_Pullenia bulloides_ (Orb.)	S: 21 x 9
	*_Heterolepa dutemplei_ (Orb.)	I: 76.7
	Lenticulina cultrata (Monfort)	SF: factor 9
	**_Marginulina_ div. sp.,	
	***_Lenticulina inornata_ (Orb.)	SD: western part of Rimava

	**_Amphicoryna_ div. sp.	Basin
	Sphaeroidina bulloides Orb.	TD: Egerian
	*_Cibicidoides ungerianus_ (Orb.),	
E	*_Heterolepa dutemplei_ (Orb.)	S: 11 x 18
	Lenticulina cultrata (Monfort)	I: 76.6
	Valvulineria div. sp.	SF: factor 6
	Bulimina elongata Orb.,	
	*_Semivulvulina pectinata_ Rss.	SD: Vienna Basin
	*_Bolivina dilatata_ Rss.	TD: Karpatian
	*_Caucasina_ sp,	
F	* *_Pullenia bulloides_ (Orb.)	S: 11 x 7
	* _Bulimina pupoides_ (Orb.)	I: 76.9
	Spiroplectammina carinata (Orb.)	SF: factor 8
	*_Heterolepa dutemplei_ (Orb.),	
	* *_Lenticulina inornata_ (Orb.)	SD: Ipeľ Basin
	* *_Hoeglundina elegans_ (Orb.)	TD: Karpatian
	*_Stilostomella adolphina_ (Orb.),	
	Dentalina div. sp.,	
	* _Bulimina elongata_ Orb.,	
	* _Fursekoina schreibersiana_ (Czj.),	
	*_Frondicularia_ div. sp.,	
	*_Melonis pompiloides_ (F. & M.),	
	* _Sigmoilopsis celatus_ (Orb.),	
G	_Cibicidoides ungerianus_ (Orb.)	S: 4 x 14
	Gyroidina soldanii Orb.	I: 94.6
	Lenticulina cultrata (Monfort),	
	Lenticulina inornata (Orb.)	SD: Vienna Basin
	Bolivina hebes Macfad.	TD: Karpatian
	Valvulineria div. sp.,	
	Fursekoina schreibersiana Czjz.,	
	Lenticulina orbicularis (Orb.),	
	Lenticulina clericii (Fornasini),	
	Lenticulina macrodisca (Rss.),	
	Lenticulina melvili (Cush. & Renz),	
H	*_Ammonia beccarii_ (L.)	S: 26 x 7
	Cibicidoides pseudoungerianus (Cushm.)	I: 81.9
	Caucasina sp.	SF: factor 19
	Hanzawaia boueana (Orb.),	
	*_Cibicidoides_ sp.	SD: Ipeľ Basin
	*_Cassidulina_ div. sp.	western part
	*_Cibicides lobatulus_ (Walk. & Jac.)	TD: Karpatian
I	_Spiroplectammina carinata_ (Orb.)	S: 5 x 10
	Gyroidina soldanii Orb.	I: 86.0
	Sphaeroidina bulloides Orb.,	
	Cyclammina div. sp.	SD: Rimava Basin
	Bolivina fastigia Cushm.	TD: Kiscelian
	Triloculina consobrina Orb.,	
	Uvigerina hantkeni Cush. & Edw,	
	Siphonina reticulata Czjz,	
J	_Eponides_ div. sp.	S: 4 x 8
	Haplophragmoides div. sp.	I: 90.6
	Bathysiphon div. sp.,	
	Plectofrondicularia div. sp.	SD: eastern part
	Baggina div. sp.	of Rimava Basin
	Cyclammina div. sp.	TD: Egerian
	Neoeponides schreibersii (Orb.),	
K	_Bulimina pupoides_ (Orb.)	S: 7 x 8
	Cibicidoides pseudoungerianus (Cushm.)	I: 85.7
	Bolivina fastigia Cushm,	
	Caucasina sp.	SD: Rimava Basin
	Bolivina antigua Orb.	TD: Egerian
L	_Valvulineria_ div. sp.	S: 4 x 10
	Haplophragmoides div. sp.	I: 95.0
	Baggina div. sp.,	
	Cyclammina div. sp.	SD: Blatno depression
	Gaudrina div. sp.	TD: Karpatian
	Quinqueloculina akneriana Orb.,	
	Lenticulina arcuatostriata (Hantk.),	
	Lenticulina orbicularis (Orb.),	
M	_Stilostomella elegans_ (Orb.)	S: 10 x 5
	Heterolepa dutemplei (Orb.)	I: 78.0
	Haplophragmoides div. sp.	SD: Blatno depression
	Bathysiphon div. sp.	TD: Karpatian
N	*_Cibicidoides ungerianus_ (Orb.)	S: 16 x 5
	Bolivina hebes Macfad.	I: 88.8
	*_Valvulineria_ div. sp.	SF: factor 7
	*_Eponides_ div. sp.	SD: disperzed
	Hoeglundina elegans (Orb.)	TD: Karpatian
O	_Cribrononion hiltermanni_ Hagn	S: 4 x 8
	Heterolepa dutemplei (Orb.)	I: 93.8
	Bolivina hebes Macfad,	
	Siphonina reticulata Czjz.	SD: Southern Slovakia
	Neoeponides schreibersii (Orb.)	TD: Egerian Karpatian

Appendix 1: List of analysed taxons. Presence in some block of BC is signed by circle, presence in some factor of BFA by cross.

Appendix 2: Characteristics of blocks of BC: list of taxons included in a block, taxons markers with asterisks are jointly present in some factor, its rank number is given under SF, S- size of block (No. rows x No. columns), I- homogeneity index, SD - spatial distribution of samples grouped in a block, TD - distribution of blocks in time.

References:

Andrusov D., 1965: Geology of the Czechoslovak Carpathians - III. *VEDA*, Bratislava, 1 - 392 (in Slovak).

Barbin V. & Keller-Grünig A., 1991: Benthic foraminiferal assemblages from the Brendola section (Priabonian stage stratotype area, Northen Italy): Distribution, paleoenvironment and paleoecology. *Mar. Micropaleontol.* (Amsterdam), 17, 37 - 258.

Boltovskoy E. & Wright R., 1976: *Recent Foraminifera.* Hague, 1 - 515.

Brestenská E., 1964: Micropaleontological study of the boreholes DB-10 and DB-11 from the Bánovská Basin. Manuscript, Geofond, Bratislava (in Slovak).

Brzobohatý R., 1988: Paleobathymetry of the Neogene of the East Slovak Plain, from the point of view of microfauna. Manuscript, Geofond, Bratislava (in Czech).

Brzobohatý R., Holzknecht M., Jiříček R. & Matyáš V., 1981: Towards a paleobethymetry of the Middle Badenian sediments on the Elbe elevation. *Zem. Plyn. Nafta* (Hodonín), 26, 4, 719 - 739 (in Czech).

Buday T., Cicha I. & Seneš J., 1965: Miozän der Westkarpaten. *GÚDŠ*, Bratislava, 1 - 296.

Burke S. C., 1981: Recent benthic foraminifera of the Ontong Java Plateau. *J. foram. Res.* (Washington), 11, 1, 1 - 19.

Cicha I., Seneš J. & Tejkal J., 1967: Chronostratigraphie und Neostratotypen Miozän der Zentralen Paratethys. M3 Karpatien. *VEDA*, Bratislava, 1 - 312.

Culver S. J. & Buzas M. A., 1981: Recent benthic foraminiferal provinces on the Atlantic continental margin of North America. *J. foram. Res.* (Washington), 11, 3, 217 - 240.

Danihelová R., 1954: A preliminary report on the microfauna of the Yugoslav Oligocene. *Geol. Práce, Zpr.* (Bratislava), 88 - 89 (in Slovak).

Davis J. C., 1973: Statistics and data analysis in geology. *John Wiley*, New York.

Dixon W. J., 1989: BMDP statistical software. *Univ. Calif. Press.*, Berkeley.

Gašparík J., 1972: Paleogeographical map of Slovakia Neogene, *GÚDŠ*, Bratislava.

Hasegawa S., Sprovieri R. & Poluzzi A., 1990: 29. quantitative analysis of benthic foraminiferal assemblages from Plio-Pleistocene sequences in the Tyrrhenian sea, ODP leg 107. In: Kastens K. A. & Mascle J. (Eds.): *Proceedings of the Ocean Drilling Program. Scientific Results*, 107, Washington, 461 - 478.

Hartigan J. A., 1976: Modal blocks in dentition of west coast mammals. *Syst. Zoology* (Lawrence, Kansas), 25, 2, 149 - 160.

Hiltermann H. & Tüxen J. J., 1974: Biosociology of recent benthonic Foraminifera after the Brau-Blanquet method. *Rev. Esp. micropaleont.* (Madrid), 4, 1, 75 - 84.

Horváth M., 1983: Foraminiferal-paleoecological study of the environment on the Upper Kiscellian - Eggenburgian boundary. *Öslénzt. viták* (Budapest), 29, 203 - 217 (in Hungarian).

Jiříček R., 1978: Paleogeography of the Lower Miocene in the Western Carpathians. *Zem. Plyn Nafta* (Hodonín), 23, 1, 21 - 38 (in Czech).

Kantorová V., 1964: Microfauna of the marginal of a marginal facies of the Karpatian and the end of the Aquitainian. Manuscript, Geofond, Bratislava (in Slovak).

Kantorová, V., 1970: Foraminifers and their accompanying fossils from the basement of the Torthonian volcanites of the Krupinská vrchovina Mts. from the borehole GK-4 near Bzovík. Manuskript, Geofond, Bratislava (in Slovak).

Kurihara K. & Kennett J., 1988: Bathymetric migration of deepsea benthic foraminifera in the SW Pacific during the Neogene. *J. foram. Res.* (Washington), 18, 1, 75 - 83.

Murray J. W., 1973: Distribution and ecology of living benthic foraminiferds. *Heinemann Educ. Books Ltd.*, London, 1 - 274.

Murray J. W., 1990: Ecology and paleoecology of benthic Foraminifera. Longman scientific and technical, London, 1 - 396.

Phleger F. B., 1965: Ecology and distribution of recent foraminiferds. *John Hopkins Press*, Baltimore, 1 - 258.

Reiss Z. & Hottinger Z., 1984: The Gulf of Aqaba - ecological micropaleontology. *Ecol. Studies*, 50. *Springer Verlag*, Berlin-Heideberg-New York-Tokyo, 1 - 354.

Rupp Ch., 1987: Paläoökologie der Foraminiferen in der Sandschalerzone (Badenian, Miozän) des Wiener Beckens. *Beitz. Paläont. Österr.* (Wien), 12, 1 - 94.

Seneš J. et al., 1971: Korrelation des Miozäns der zentralen Paratethys. *Geol. Zbor. Geol. carpath.* (Bratislava), 22, 1, 3 - 9.

Špička V. & Zapletalová I., 1963: Sketch of the whole-basin correlation of the Karpatian in the Czechoslovak parts of the Vienna Basin. *Zprávy o geol. výskumu v r. 1962* (Praha), 34 - 48 (in Czech).

Špička V. & Zapletalová I., 1964: Correlation sketch of the Karpatian in the Czechoslovak parts of the Vienna Basin. *Sbor. geol. věd, Ř. G* (Praha), 8, 125 - 160 (in Czech).

Šutovská K., 1991: Shallow-water assemblages of Neogene foraminifers of the western part of the Western Carpathians. *Acta geol. geograph. Univ. Comen., Geol.* (Bratislava), 46, 119 - 131.

Vass D. & Elečko M. et al., 1989: Geology of the Rimava Basin. *GÚDŠ*, Bratislava, 1 - 160 (in Slovak).

Vass D. et al., 1983: Explanations of the geological map of the Ipeľ Basin and Krupina Plateau 1 : 50 000. *GÚDŠ*, Bratislava, 1 - 126 (in Slovak).

Vismara-Schilling A. & Coulbourn W. T., 1991: Benthic foraminiferal thanatofacies associated with Late Pleistocene to Holocene anoxic events in the Eastern Mediterranean sea. *J. foram. Res.* (Washington), 21, 2, 103 - 125.

Van der Zwaan G. J., 1983: Quantitative analyses and time reconstruction of benthic foraminiferal communities. *Utrecht micropaleont. Bull.* (Utrecht), 40 - 59.