A C T A P A L A E O N T O L O G I C A P O L O N I C A

Vol. 27 1982 No. 1—4

JANINA SZCZECHURA

MIDDLE MIOCENE FORAMINIFERAL BIOCHRONOLOGY AND ECOLOGY OF SE POLAND

SZCZECHURA, J.: Middle Miocene foraminiferal biochronology and ecology of SE Poland. Acta Palaeont. Polonica, 27, 1—4, 3—44, 1982. Issued January 1983.

Middle and Late Miocene (Late Badenian and Sarmatian) foraminifera of the epicontinental deposits of SE Poland (Roztocze area) have been examined. These deposits, referred to the Late Badenian are correlated with N13—N14 standard biostratigraphic zones, based on planktonic foraminifera. Sarmatian, therefore, especially its deeper water deposits, appears to represent younger zones. Changes in water depth appeared to control distribution of benthonic forms, whereas climatic changes and water depth controlled distribution of planktonic forms. The Middle/Late Badenian boundary probably represents an ecostratigraphic event. A correlation is suggested relating the Middle Miocene deposits of the Roztocze area with those of the Polish Fore-Carpathian Depression. *Bolboforma badenensis* sp. n., a planktonic form of uncertain taxonomic affinity is described.

Key words: Foraminifera, problematic planktonic form, Miocene, Poland, biochronology, ecology, taxonomy.

Janina Szczechura, Zakład Paleobiologii, Polska Akademia Nauk, Al. Żwirki i Wigury 93, 02-089 Warszawa, Poland. *Received: January, 1981.*

ACKNOWLEDGEMENTS

The samples from which the microfauna has been recovered were made available through courtesy of Dr. T. Musiał of the University of Warsaw's Institute of Geology and Dr. G. Jakubowski of the Polish Academy of Sciences' Museum of the Earth in Warsaw who also helped in sampling the profile at Trzęsiny. The nannoplankton of two samples from the Trzęsiny profile was identified by Professor E. Martini of the Geological-Paleontological Institute of the University of Frankfurt on the Main, the Federal Republic of Germany. Professor I. Premoli Silva of the University of Milan, Paleontological Institute, Italy; Dr. E. Łuczkowska and Dr. T. Śmigielska, both of the Academy of Mining and Metallurgy, Institute of Regional Geology and Coal Deposits, Dept. of Paleontology and

Stratigraphy, Cracow, Poland; Dr. F. Rögl of the Museum of Natural History, Dept. of Geology and Paleontology, Vienna, Austria; Dr. N. Ciaranfi of the University of Bari, Institute of Geology and Paleontology, Italy; Professor H. M. Bolli of the Swiss Federal Institute of Technology, Geology Dept., Zurich, Switzerland; Dr. W. A. Berggren of the Oceanographic Institution, Woods Hole, Massachusetts, USA and Dr. J. Małecki of the Academy of Mining and Metallurgy, Institute of Regional Geology and Coal Deposits, Dept. of Paleontology and Stratigraphy, Cracow, Poland — directly or indirectly contributed to determining the taxonomic position of some species. Valuable comparative material was kindly supplied by Dr. F. Rögl. Dr. W. A. Berggren has kindly read the manuscript and offered useful criticism.

SEM photographs were taken at the Electron Microscopy Laboratory of the Nencki Institute of Experimental Biology in Warsaw. Text-figures were prepared, after this writer's sketches, by Miss E. Gutkowska.

I wish to express my heartfelt gratitude to all the persons mentioned above.

INTRODUCTION

This paper contains an analysis of the age and environmental conditions of foraminifera from the Middle Miocene deposits of the Roztocze region (a southern prolongation of the Lublin Upland, SE Poland). Such an analysis turned out to be indispensable for understanding the results of my former preliminary studies on the ostracodes from those deposits, in particular for understanding the causes of the heterogeneity and variability of ostracode assemblages occurring in the sections studied. Since they are a more unequivocal stratigraphic and ecologic index than ostracodes, the foraminifera provide a more precise age determination of the sediments under study and the conditions of their depositions.

Except for the description of foraminifera from the peripheral area of Roztocze (Odrzywolska-Bieńkowa 1966, 1972), the microfauna of this region has not been studied to date. The age of deposits of this area which differ in fact from that determined on the basis of foraminifera, as well as sedimentary environmental conditions, have so far been determined mostly on the basis of macrofauna, in particular mollusks.

In evaluating the character and distribution of foraminifera of Roztocze, I have availed myself of a fairly detailed study of the foraminifera from the section in the environs of Trzęsiny which appear to be a representative one. The results obtained were compared with those of the foraminiferal studies conducted in other areas of Central Paratethys, in particular in the Polish part of the Fore-Carpathian Depression.

The section of the environs of Trzęsiny was sampled according to the description provided by Dr. T. Musiał who has earlier (*in*: Jakubowski and Musiał 1979*a*) described the lithological sequence and petrographic aspect of this section. The mollusks have been studied and described by Jakubowski (*in*: Jakubowski and Musiał 1979*a*). Professor E. Martini has conducted an analysis of nannoplankton from two samples coming from Trzęsiny.

The samples from other areas of Roztocze, used for the purposes of the present work, and which come from Dr. T. Musiał collections, were previously recorded in his publications (Musiał 1976, Jakubowski and Musiał 1979*a*, *b*) and, in addition, will be further discussed in Musiał's work (in preparation) summing up the geology of Roztocze. The material described is housed at the Polish Academy of Sciences' Institute of Paleobiology in Warsaw (abbrev. ZPAL).

GEOLOGICAL SETTING

The Roztocze region, a plateau in character is a prolongation of the Lublin Upland which, together with adjacent uplands, forms a northern margin of the Fore-Carpathian Depression (figs 1, 2). Roztocze is separa-

Fig. 1. Paleogeographic setting of the studied Roztocze area. Extent of the Middle Miocene sea in the Fore-Carpathian Depression is stippled; rectangled is the area enlarged in fig. 2.

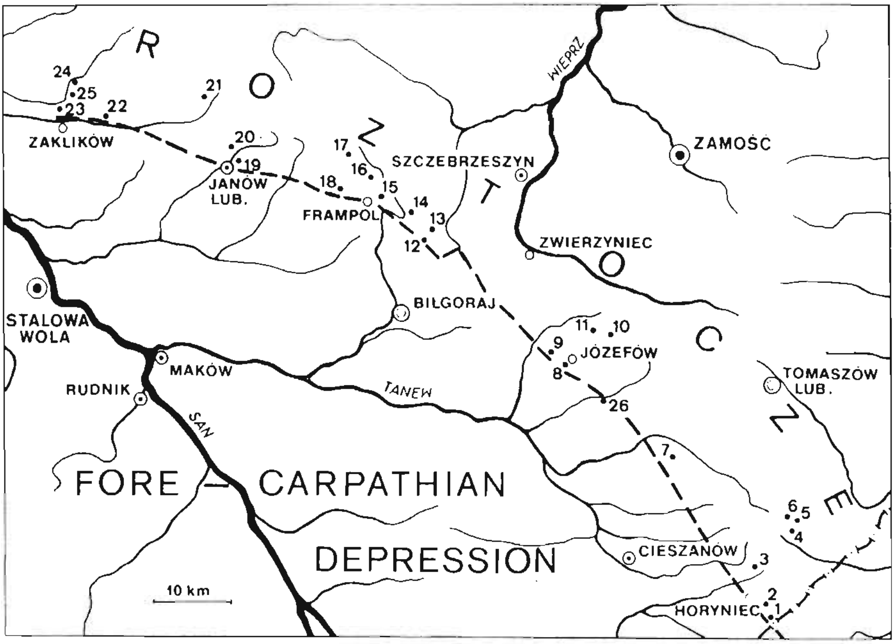


Fig. 2 Map showing contact of the Roztocze region and Fore-Carpathian Depression. Dashed line corresponds to a simplified boundary of the Fore-Carpathian Depression. Location of sampled outcrops is indicated by numbered dots: *1* Radruż, *2* Góra Brusno, *3* Miasteczko, *4* Monastyrz, *5* Długi Goraj, *6* Huta Lubycka, *7* Huta Różaniecka, *8* Józefów, *9* Tarnowola, *10* Górniki, *11* Szopowe, *12* Żelebsko, *13* Trzęsiny, *14* Wola Radzięcka, *15* Radzięcin-Poduchowne, *16* Frampol, *17* Goraj, *18* Kocudza, *19* Janów Lub., *20* Biała Ordynacka, *21* Wierzchowiska, *22* Łysaków, *23* Zdziechowice, *24* Hamernia.

ted from the Fore-Carpathian Depression by a distinct cuesta subsiding southward. In the Miocene, Roztocze constituted a marginal part of the Central Paratethys and, therefore, the deposits of this age represent here the nearshore sedimentary zones of the marine basin mentioned above. Variously consolidated sands, marls and various types of limestones, frequently intercalating each other, are rocks which most often occur in the Roztocze region. These deposits outcrop in profiles which are from a few to a dozen or so meters in thickness, sometimes more or less dislocated tectonically, situated at various absolute heights and, on the whole, comprising various sequences of lithologically varying deposits. Calcareous deposits predominate in principle nearer the NW periphery of Roztocze, while sandy deposits are more frequent further from it, in particular in the southern part of the Roztocze Upland. The distribution of facies in Roztocze and their detailed characteristics are presented, among others, in the following works: Brzezińska 1961; Areń 1962; Odrzywolska-Bieńkowa 1966, 1972; Bielecka 1967; Musiał 1976; Jakubowski and Musiał 1979*a*,*b*; Musiał (in preparation).

MATERIAL AND METHODS

I have made use of the material sampled in the profiles of Rawa Roztocze, that is, at Radruż, Brusno, Miasteczko, Monastyrz, Długi Goraj, Huta Różaniecka and Huta Lubycka; of Tomaszów Roztocze, that is, at Józefów, Tarnowola, Górniki, Szopowe, Żelebsko and Trzęsiny; of Goraj Roztocze, that is, at Wola Radzięcka, Radzięcin Poduchowne, Frampol, Goraj, Kocudza, Janów Lubelski, Biała Ordynacka and Wierzchowiska; of Urzędów Upland, that is, at Łysaków, Zdziechowice, Łychów and Węglin, as well as in the Hamernia region on the Sopot in the Fore-Carpathian Depression; in an outcrop of what is known as Krakowiec clays situated in the outskirts of Roztocze.

All the above mentioned Miocene localities represent a composite of the complete stratigraphic succession at Roztocze and contain nearly all the various taxa that occur in that section. It should be emphasized, however, that the outcrops were sampled rather at random which was conditioned by the availability of the samples for micropaleontological studies, that is, by the degree of their macerability. Samples from the Trzęsiny profile were subjected to an accurate micropaleontological analysis, while those from the remaining localities were analyzed as a control material.

The Trzęsiny section (fig. 3) is an 8 m-high outcrop at the base of which there occur fine-grained sands (samples 1a, 1b, 1c, 3, 6a and 6b) intercalated with compact sandstones grading upward into clayey sands (samples B and 7) and terminating in a detrital limestone with intercalations of clayey limestones (samples 10, 11 and 12).

In order to compare the faunal contents of these samples, a portion (0.25 kg) of each was weighed, macerated subsequently, if necessary, by means of glaubert salt ($NaSO_4$ $1OH_2O$) and, finally, washed on a screen with 0.0875 mm diameter mesh. The weight of the residue after washing called here a "residual sample", is given in table 2. The diagram obtained here provides evidence about the part of clayey material contained in an unwashed sample and is suitable for interpreting the rate of sedimentation in the profile under study and (with possible reservation) environmental changes.

Most samples contained a considerable number of individuals and, consequently, their residues were split before the specimens were picked, then identified and counted under a binocular microscope. All microfaunal individuals, both foraminifera and ostracodes, were picked in principle from 1 g of a dry residual sample.

In analyzing microfauna, the present writer concentrated mostly on foraminifera. *Bolboforma badenensis* sp. n., *incertae sedis*, and a frequent component of plankton in the samples from Roztocze likely to be index form of the Upper Badenian strata has, however, been taken into account in addition.

Due to the often poor state of preservation or dwarfed nature of the foraminiferal tests, not all individuals could be identified specifically. At the same time, it seemed superfluous to conduct a detailed taxonomic analysis of some foraminiferal groups for the purpose of the present paper, that is determining the age and deposition conditions of the samples under study. For this reason, in describing the foraminifera of Trzęsiny, I have, in some cases, confined myself only to generic or higher rank determination.

In analyzing the foraminifera from the Trzęsiny section (table 1), use was made of the contents of 1g portions separated from residual samples. The contents of 1g portion turned out, however, not to be representative of the rest of a residual sample. Therefore, the elements characteristic of the entire foraminiferal content of each sample, in particular those of essential importance to stratigraphy and a possible interpretation of the environment and which served as a control material were here included for the purposes of a final characterization of the foraminiferal assemblage of Trzęsiny.

Taxa (genera or systematic units of a higher rank) numbering more than five individuals are shown in table 1.

CHARACTERISTICS OF THE MICROFAUNA IN THE TRZĘSINY PROFILE

Stratigraphic significance

The dependence of the occurrence of both benthonic and planktonic foraminifera on the environmental conditions (pp. 13—19) requires caution in evaluating the significance of this group to stratigraphy and in an appropriate selection of its representatives for stratigraphical purposes.

Of the forms studied so far, of particular importance to the stratigraphy of the Miocene of Central Paratethys are decidedly Badenian elements occurring at Trzęsiny. They include such index forms at the bolivinids and uvigerinids, preferring in principle deeper water, as well as plankton (Papp, Cicha and Čtyroka 1978) whose distribution depends to a considerable extent on the environmental conditions (cf. the further remarks) and which also prefers a deeper-water habitat. Thus, their applicability to the stratigraphy of deposits occurring in the peripheral areas of the basin is rather limited.

In regard to stratigraphically important benthonic foraminifera, of those mentioned by Papp, Cicha and Čtyroka (1978), single specimens of *Uvigerina brunnensis* Karrer (pl. 7: 5—7) occur in the lower part of the Trzęsiny section, whereas *Bolivina dilatata* Reuss (pl. 7: 11) appears only in the upper strata. As indicated by the authors mentioned above, the two species are recorded from the entire Badenian, the former being, however, limited in its lower extent to the upper part of the Lower Badenian. According to Steninger (1977), *B. dilatata* is characteristic of the Upper Badenian, while *U. brunnensis* (named by this author *U. semiornata brunnensis*) is typical of the *Spiroplectammina* Zone, that is, Middle Badenian. Thus, there occurs an indubitable controversy concerning the stratigraphic extent of these two species.

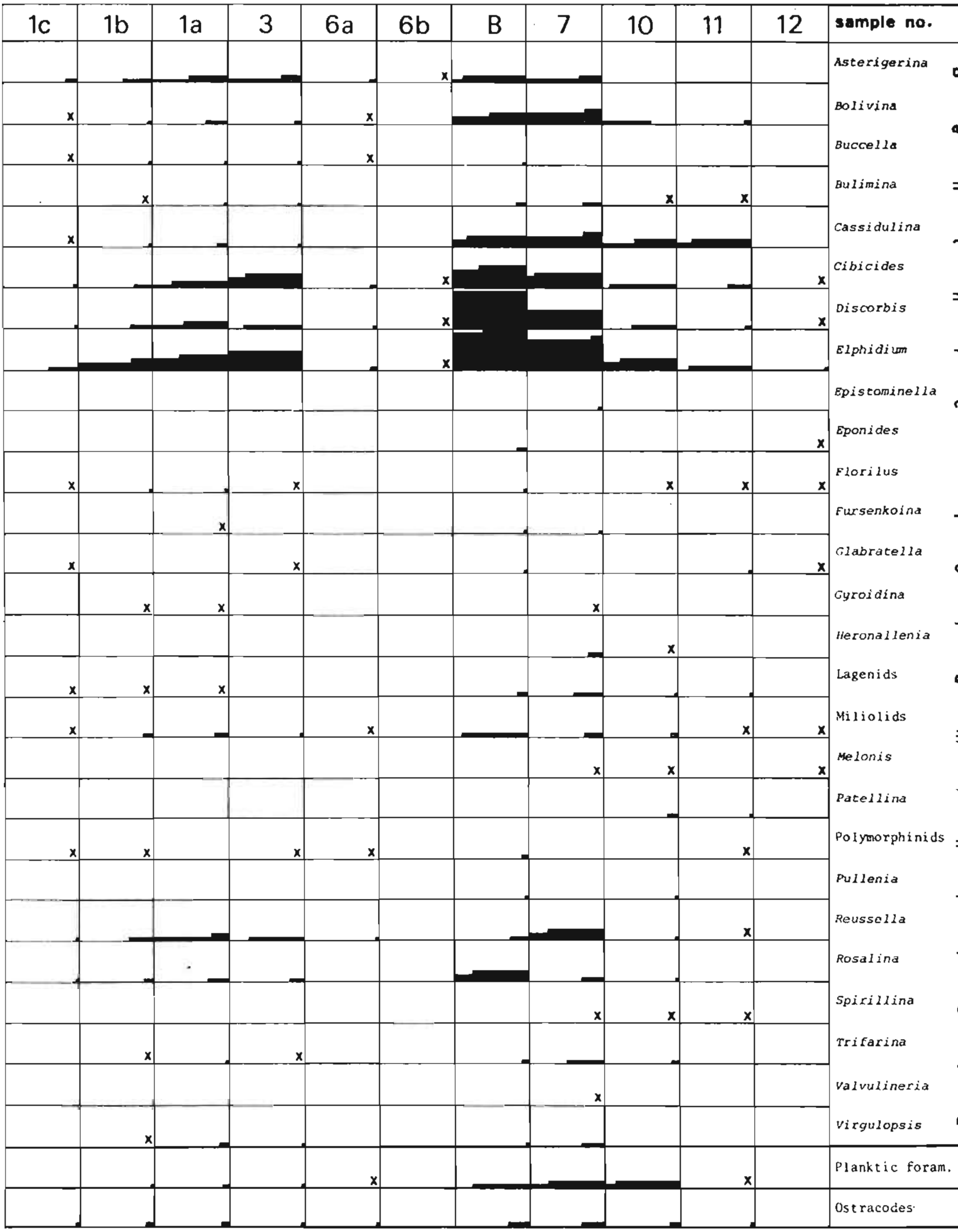
Planktonic forms of stratigraphic importance to the Badenian mentioned by Papp, Cicha and Čtyroka (1978), in the Trzęsiny section include *Globigerinoides*: *G. trilobus* Reuss (pl. 1: 1—3, 12) and *G. quadrilobatus* d'Orbigny (pl. 1: 5—9); globigerinids: *G. concinna* Reuss (pl. 2: 9, 10), *G. druryi* Akers (pl. 2: 1—3), *G. diplostoma* Reuss (pl. 2: 6), *G. praebulloides* Blow (pl. 2: 4, 4, 8) and *G. tarchanensis* Subb. and Chutz. (pl. 3: 1—4); *Globorotalia siakensis* Le Roy (pl. 6: 5, 7); *Orbulina suturalis* Brönn. (pl. 4: 1, 2); *Praeorbulina glomerosa* Blow (pl. 4: 6) and *Velapertina indigena* (Łuczkowska) (pl. 4: 9, 11, 12). As shown by the vertical range of the species mentioned from the Trzęsiny section (table 2), its lower part corresponds most probably to the upper part of Sandschaler Zone, while its upper part — to the *Bulimina* Zone *sensu* Papp, Cicha and Čtyroka (1978) that is, to the upper part of the Middle and to the Upper Badenian respectively. Somewhat perplexing is the presence of *P. glomerosa* which, according to the authors mentioned above, is limited to the Lower Badenian only. At Trzęsiny, this species (single specimens) accompanies *Velapertina indigena* which, in Central Paratethys, is considered a late-Badenian form. The upper limit of the stratigraphic range of this *Praeorbulina* should, therefore, by revised.

In regard to the vertical distribution of planktonic foraminifera mentioned by Papp, Cicha and Čtyroka (1978) as stratigraphically significant, of particular importance seems to be the disappearance of most species (except for *G. trilobus*) representing the *Globigerinoides* on the boundary of the Middle and Upper Badenian and the occurrence of *Velapertina indigena* within the two stages. At Trzęsiny, the vertical range of most *Globigerinoides* (except for *G. ? trilobus*) does not overlap that of the *Velapertina*. This may be explained by inadequate environmental conditions, in particular the water depth precluding the existence of these species. Their concurrence, although with a very small part of the *Globigerinoides*, has been recorded in other localities of the Roztocze region (e.g., Miasteczko, Józefów). It is not unlikely that in those localities there were favorable conditions for their concurrence or that the *Globigerinoides* occurred there on a secondary deposit. The coexistence of the *Globigerinoides* and *Velapertina* was, however, recorded by Kollmann and Rögl (1978) from the Middle and Upper Badenian of the Vienna Basin.

The boundary between the Middle and Upper Badenian (*sensu* Papp,

Table 1

Distribution of foraminifera (benthonic and planktonic forms) and ostracodes in Trzęsiny section



• – 10–20 specimens

x – 5–10 specimens

Table 2

Distribution of planktonic foraminifera and *Bolboforma badenensis* sp. n., a planktonic form of uncertain taxonomic affinity, in the Trzęsiny section. The curve on the left shows changes of sand: silt ratio. Suggested depths, for some samples, are based on the character of foraminiferal associations

sample no.	shelf (outer | inner); sand : silt ratio (in g): silty ↔ sandy (50, 100, 150, 200, 250)	Planktic foraminifera: Globigerinoides quadrilobatus	Globigerinoides sacculifer	Globigerinoides trilobus	Globorotalia cf. continuosa	Globorotalia siakensis	Globigerina cf. bollii	Globigerina concinna	Globigerina diplostoma	Globigerina druryi	Globigerina praebulloides	Globigerina tarchanensis	Velapertina indigena	Praeorbulina glomerosa	Orbulina suturalis	Inc. sedis: Bolboforma badenensis	ecostratigraphy
12	±30																Globigerina ecozone
11					I		I	I	I	I	I						Globigerina ecozone
10					I		I	I	I	I	I	I				I	Globigerina ecozone
7	±120			?	I	I	I	I	I	I	I	I	I	I	I	I	Globigerina ecozone
8							I		I	I	I	I					Globigerina ecozone
6b		shallowing															?
6a		shallowing															?
3	±50	I	I	I													Globigerinoides ecozone
1a		I	I	I				I	?	?	I	?					Globigerinoides ecozone
1b		I	I	I			I			?	I						Globigerinoides ecozone
1c																	Globigerinoides ecozone

Cicha and Čtyroka 1978), at Trzęsiny has been delimited by the upper limit of abundant occurrence of the *Globigerinoides*. It is possible, however, that the overlying, plankton-barren layer, may reflect a shallowing of the basin and correspond to an evaporite horizon, known from various areas of Paratethys (at the boundary between the Middle and Upper Badenian) and assigned by Krach and Ney (1978) to the Middle Badenian. Assuming, however, that the strata with evaporites represent the Upper Badenian (cf. p. 29) and the *Globigerinoides* ecozone (cf. p. 18) is extended, in its upper part, to the Middle-Upper Badenian boundary, this boundary at Trzęsiny should actually be traced between strata 3 and 6, that is, in the place where the *Globigerinoides* disappear.

If a change in environmental, especially climatic, conditions caused indeed a change in the character of planktonic foraminifera in the Late Badenian and, at the same time, their vertical range was controlled by the bathymetry of the basin, then the stratigraphic significance ascribed so far to this group of foraminifera was overestimated. The Miocene planktonic foraminifera of Paratethys seem to be primarily of ecostratigraphic importance useful for local (or regional) chronostratigraphy. Therefore, they cannot serve for strictly stratigraphic purposes. Extinguished in the Middle Badenian of Central Paratethys, the *Globigerinoides* survived outside this region under more favorable conditions.

The Middle-Upper Badenian boundary (*sensu* Papp, Cicha and Čtyroka 1978) adapted on the basis of the distribution of planktonic foraminifera, denotes perhaps a short-lived geologic event, suitable for regional correlation, but not sufficient to be acknowledged as a global stratigraphic marker. According to Berggren and Van Couvering (1974: 46), "... chronostratigraphic boundaries cannot be based upon climatic changes, for these may be local or regional or diachronous in different hemispheres, and often are not reflected in the rock record."

On the basis of planktonic foraminifera, Steninger (1977) separated, within the Badenian of Paratethys, its lower part with *Globigerinoides sicanus* De Stefani, *Praeorbulina glomerosa circularis* (Blow) and *Orbulina suturalis* Brönn., corresponding to nannoplanktonic zone NN5, as well as its upper part with *Velapertina indigena* and *Globigerina druryi* corresponding to nannoplanktonic zone NN6 and NN7. In such a system, the whole profile at Trzęsiny should be assigned to the Late Badenian. This is in conformity with the opinion of Professor E. Martini who, after studying the nannoplankton from the lower (stratum 1) and upper (stratum 7) part of this profile, identified the following species; sample 1a: *Braarudosphaera bigelowi*, *Coccolithus pelagicus*, *Cyclococcolithus rotula*, *Helicosphaera walbersdorfensis*, *Rhabdosphaera procera*, *Reticulofenestra* sp. (small), *Sphenolithus abies*, *Syracosphaera* cf. *hystrica*; sample 7: *Braarudosphaera bigelowi*, *Coccolithus pelagicus*, *Discolithina* sp., *Helicosphaera carteri*, *H. walbersdorfensis*, *Reticulofenestra pseudoumbilicata*, *R.* sp.

(small), *Rhabdosphaera procera* and *Sphanolithus abies*. According to Professor E. Martini samples from both these strata belong to Middle Miocene, representing NN6 to NN7.

Bolboforma badenensis sp. n., abundantly occurring in the clayey-sandy deposits of Trzęsiny (and in other localities of the Roztocze region) (pl. 6: 1—4), seems to be useful as an index form of Late Badenian deposits, *B. metzmacheri* (Clodius) and *B.* sp. aff. *rotunda* Daniels et Spiegler described earlier (Odrzywolska-Bieńkowa 1976) and which are characteristic of the Early Badenian of the southern part of the Holy Cross Mts., do not occur in the samples studied from Roztocze.

It should be mentioned that according to the latest data on the age of the Trzęsiny section based on studies of mollusks (bivalves and gastropods) (Jakubowski and Musiał 1979*a*) its lower part (strata 1—6) is assigned to the Lower Badenian (Opolian) and its uppermost part (strata 11—12), sampled by the present writer, to the Upper Badenian.

Like Steninger (1977), Papp, Seneš and Steininger (1978) compare the upper part of the Badenian with the lower part of the Serravallian, which is not younger than N13, whereas the presence of the representatives of the *Globorotalia continuosa* lineage at Trzęsiny and other localities of the Roztocze area allows us to extend it up to N14, that is, to the upper part of the Serravallian (cf. Cita and Blow 1969; Berggren and Amdurer 1973; Zachariasse 1975; Thunell 1979).

An interpretation of environmental conditions

The microfauna sampled in the Trzęsiny section is conspicuously variable both in the frequency of its particular elements, that is, foraminifera, ostracodes and *incertae sedis* plankton and in its taxonomic content, that is, diversity of the faunal groups mentioned above. Two optima (samples 3 and 7), probably corresponding to the best possible conditions of the development of microfauna can be distinguished on the whole in this profile (table 1). Above these optima, a distinct drop is observed in both the absolute abundance and diversity of microfauna.

These optima differ from each other in the fact that the upper one, as compared with the lower, contains an absolutely larger number of more differentiated foraminifera (including a decidedly larger number of planktonic foraminifera), more ostracodes and that the planktonic *incertae sedis*, identified as *Bolboforma badenensis* sp. n., occurs only in it. The sandy samples 6a and 6b contain few foraminifera which make up a relict of assemblages of lower strata.

The differentiation in microfauna, in particular the quantitative one, examined against the background of changes in the character of deposit, is indicative of an increase in the amount of microfauna occurring together with an increase in the clay content of deposits. A larger productivity (?) was connected with a slower rate of sedimentation, while the latter, as follows from the data presented below, was determined by bathymetric changes in the part of the basin comprising Trzęsiny. The higher rate of sedimentation was connected with shallowing and lower with deepening the basin. This thesis has been corroborated by a bathymetric model prepared by Dr. T. Musiał (fig. 3) according to R. Passega's method and on the basis of granulometric data.

The picture of environmental conditions, in particular those concerning changes in bathymetry and temperature, becomes more clear and precise due to an accurate analysis of the distribution of foraminifera (tables 1, 2). The character of the foraminiferal assemblage, in particular the presence of planktonic foraminifera in almost the whole profile, is

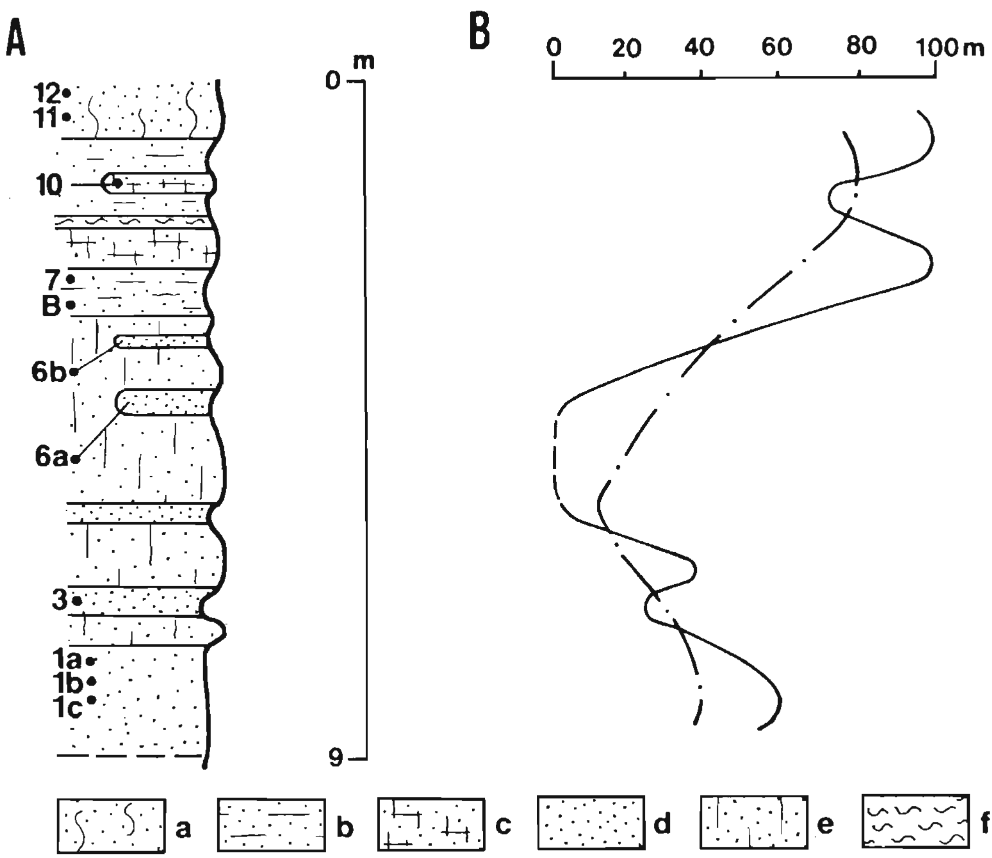


Fig. 3. *A* Geological section at Trzęsiny locality. Micropaleontological samples indicated by numbered dots. Types of facies, indicated by letters, are as follows: *a* biodetrital limestones, *b* clayey sands, *c* clayey limestones, *d* quartz sands, *e* sandstones, *f* coquinoid limestones. *B* Curves showing depth of sedimentation obtained by using change of grain-size analysis (study done by Dr. T. Musiał); solid line is a bathymetric curve after R. Passega method; dashed line is a median bathymetric curve.

indicative of an unvarying open-sea salinity. The control examination of the remains of the residual samples, that is, the amounts of residue larger than the separated 1 g turned out to be of particular significance in this respect.

The results of the analysis mentioned above, which was based on contemporary distribution of the species found at Trzęsiny, should be treated only considerably approximating the actual one since: (1) the distribution of the foraminifera depends on many other factors and not only on bathymetry and temperature; (2) there is evidence enough that the environmental preferences of these same taxa could change with the passage of time; (3) there are certain differences in determining the taxonomy of foraminifera and, finally, (4) an assemblage of fossil foraminifera may include forms from various bathymetric horizons and various climatic zones which is a result of the inclusion of elements nontypical of a given biotope, admixed, for example by submarine slides, currents and post-mortem displacements of other types. In interpreting environmental conditions a quantitative part of particular elements of the thanatocoenose under study seems to be also of considerable importance, that is, the trace occurrence of some elements testifies to conditions on the whole unfavorable to them and may, therefore, be neglected.

As mentioned above, samples from strata 3 and 7, that is, the ones containing a particularly abundant and diverse foraminiferal microfauna, are composed mainly of calcareous, benthonic and planktonic forms. Among the benthic forms, predominant are the elphidiids (mostly *Elphidium*, *Cribrononion* and *Protelphidium*), nonionids (*Astrononion*, *Florilus*), cibicidids (*Cibicides*), anomalinids (*Cibicidoides*, *Hanzawaia*, *Heterolepa*), discorbids (*Discorbis*, *Conorbina*, *Buccella*, *Rosalina*, *Discorbinella*) and asterigerinids, *Asterigerina*). The occurrence of *Ammonia beccarii* (Linné) is limited to the lower part of the profile only. Its lower part contains, in addition, only single specimens of *Uvigerina brunnensis* Karrer and *Fursenkoina schreibersiana* (Czjzek), as well as few, flat cassidulinids and bolivinids. The upper (but not the uppermost) part of the section contains, in addition to the decidedly more numerous than in the lower part, bolivinids, uvigerinids, rotund cassidulinas and fursenkoinas, also elements absent earlier (in the lower part of the profile) including *Pullenia quinqueloba* (Reuss) (pl. 11: 5, 6), *P. bulloides* (d'Orb.) (pl. 10: 1, 2), *Gyroidina soldanii* d'Orb. (pl. 10: 3, 4), *Heterolepa dutemplei* (d'Orb.) (pl. 12: 6, 9), *Sphaeroidina bulloides* d'Orb. (pl. 10: 7, 11) and *Cibicides ungerianus* (d'Orb.) (pl. 12: 8). Such a distribution of benthonic foraminifera fairly unequivocally indicates that the lower part of the profile represents the deposits of the upper part of the neritic zone of the basin, that is, the inner shelf, not more than 50 m deep, while the upper part of the profile, represented by samples B and 7, corresponds to an overdeeping of the basin to at least 100 to 120 m.

The species of benthonic foraminifera mentioned above, which occur in higher samples, prefer, in contemporary seas, the outer shelf or even the bathyal (cf. Berggren *et al.* 1976; Wiman 1978; Corliss 1979; Bremer *et al.* 1980; Boltovskoy 1980; Ingle *et al.* 1980, etc.).

As compared to strata 3 and 7, the samples from the top strata represent undoubtedly the deposits of a shallow, regressive sea and the character of an environment represented by them was bound to be, apart from the depth, different. Samples 11 and 12 contain a rich organogenic, calcareous detritus and, very rare in lower strata, arenaceous foraminifera [1], as well as numerous representatives of *Eponides repandus* (Fichtel and Moll) (pl. 14: 3, 4). Abundantly occurring tests of miliolids, elphidiids and discorbids are large and thick-shelled.

A small degree of the variability of foraminifera from the uppermost strata of the section, a lack of plankton, large-sized tests of foraminifera and considerable extent of reworked tests are indicative of shallow-water, pericoastal, turbulent (?), unstable and unfavorable, that is, stressed conditions (Lankford 1967; Feyling-Hanssen 1980).

The plankton present in these deposits seems to be of decisive significance for the interpretation of environmental conditions represented by the Trzęsiny section. The planktonic forms of the lower and upper part of the profile differ from each other. As mentioned above, the plankton is more numerously represented in the upper (but not uppermost) part of the profile in which a very rich planktonic fauna of uncertain affinities occurs in addition to planktonic foraminifera. The increase in the amount of planktonic foraminifera may be a proof of the deepening of the basin (Ingle 1967; Reiss *et al.* 1974; Boltovskoy and Wright 1976), but it may be also indicative of the cooling of its waters (Parker 1958; Reiss *et al.* 1971).

In the samples from the lower part of the section, there occur the globigerinids, but they are also accompanied there by numerous (and only unique in the higher part) *Globigerinoides* (cf. table 2). In contrast to small, thick-shelled *Globigerinoides*, without large, distinct, supplementary apertures, of one species only, that is, *Globigerinoides* ? *trilobus* (Reuss), occurring in the upper part of the section, its lower part contains at least four thin-walled species having large tests and numerous, well developed supplementary and large primary apertures (pl. 1: 10, 11).

Globigerinoides trilobus (pl. 1: 1—3, 12), predominant among the *Globigerinoides*, occurs at present mostly at depths to 50 m and prefers subtropical and tropical temperatures (24 to 30°C) (Emiliani 1969; Boltovskoy and Wright 1976; Bé 1977). *G. quadrilobatus* (d'Orbigny) (pl. 1: 5—9), occurring in the lower part of the Trzęsiny section, probably also preferred an appropriately high temperature which according to Douglas' and

---

[1] The tests of these foraminifera come from the control material, i.e. they have been selected from the residual samples.

Savin's (1978) oxygen isotopic calculations on specimens from Miocene deposits, was 20.2°C.

Globigerinoides sacculifer (Brady) (pl. 1: 10, 11) from the lower part of the Trzęsiny section also represents mainly a near-surface dwelling species which prefers subtropical and tropical waters at temperatures exceeding 20°C and is related at present to warm ocean currents (Bé and Tolderlund 1971). According to these authors (*l.c.*, p. 137) "*Globigerinoides sacculifer* is, next to *Globigerinoides ruber*, the most profilic and widespread species among the warm-water planktonic foraminifera ... *Globigerinoides sacculifer* occurs over a surface temperature range of 15° to 30°C, with peak abundance primarily between 24° and 30°C."

Samples from the higher (but not uppermost) part of this profile contain mostly globigerinas, including *G. praebulloides* Blow (or, according to some authors, *G. bulloides* d'Orbigny) (pl. 2: 4, 5, 8) which, being closely related to *G. bulloides*, is similar to the latter in its environmental requirements. Like most globigerinas, *G. bulloides* prefers subarctic and transitional, that is, colder and temperate (5—10°C) waters and, even living close to the coast, intermediate waters depths of 50 to 100 m (Ingle 1967; Boltovskoy and Wright 1976; Bé 1977). The *Globigerina* biofacies also includes exceptionally abundant small-sized forms similar to *Globigerina bollii* (pl. 5: 8—15) (kindly determined by its author Professor I. Premoli Silva), as well as few globigerinids resembling *G. quinqueloba* Natland (pl. 3: 5—11) and *Globorotalia continuosa* Blow (pl. 3: 1—7), that is, typical cold-water forms.

Sample 7 which seems to come from the deepest part of the basin (as compared with the depths represented by other samples) contains single representatives of *Globorotalia siakensis* Le Roy (pl. 5: 5—7), single orbulinids (*O. suturalis* Brönn.)[2], praeorbulinids (*P. glomerosa* Blow)[2] (pl. 4: 6) and relatively numerous velapertinids (*V. indigena* Łuczk.)[2] (pl. 4: 9, 11, 12).

Orbulina-like foraminifera, that is, except orbulinids and praeorbulinids, probably also velapertinids, are assigned by Douglas and Savin (1978) to shallow- and intermediate-water forms which live in the surface mixed layers and subsurface mixed layers, above the thermocline. On the other hand, globorotalias are assigned by these authors to intermediate- and deep-water forms. The deep-water nature of the *Globorotalia* is also indicated by Szczechura and Pożaryska (1976). According to Douglas and Savin (1978) the morphology and ornamentation of the tests of planktonic foraminifera pronouncedly depend on the depth of their habitat.

The Recent *Orbulina universa* (d'Orbigny), similar to *O. suturalis* Brönn., prefers depths ranging from 50 to 150 m and, in regard to its

---

[2]) The tests of these species come from the control material, that is, they were picked from the remains of the residual sample.

climatic requirements, is considered a fairly cosmopolitan form characteristic of warm-water regions of subtropical provinces (Bé 1977; Thunell 1979; Douglas and Savin 1978). It prefers a temperature of 15 to 24°C which is lower than that required by the *Globigerinoides* (cf. Bé 1977). The connection of the orbulinas with the Badenian deep-water deposits of the Vienna Basin is indicated by Van Couvering and Berggren (1977). The absence of *Orbulina*-like forms among shallow-water and at least subtropical foraminifera, representing *Globigerinoides* assemblage in the lower part of the Trzęsiny section seems to be indicative of the fact that not only an appropriately high temperature, but also a relatively deep water is indispensable for the existence of *Orbulina*-like forms. Although very rare, they occur in the upper part of the Trzęsiny section together with abundant globigerinids representing deeper-water environment. *Orbulina*-like form are common in the entire earlier, that is, tropical and deeper-water Badenian deposits in the Fore-Carpathian Depression and elsewhere in Central Paratethys. Noteworthy is also the fact that the tests of *O. suturalis* from Trzęsiny are relatively thick-shelled and small as compared with those of the same species from Korytnica (a well known Middle Badenian outcrop in the Holy Cross Mts., Poland), a locality (and geological level) in which there were more favorable environmental conditions (cf. pl. 4: 1, 2 and 4) (cf. Bé *et al.* 1973; Colombo and Cita 1980). Thus mostly climatic changes in the environment seem to be responsible for the reduction in number and the dwarf size of *Globigerinoides* in the upper part of the Trzęsiny section, while the appearance in this part of profile of *Orbulina*-like forms results perhaps mostly from bathymetric changes, ie. increase in depth. The insufficient overdeepening and insufficient temperature probably precluded any more extensive development of *Orbulina*-like forms in the deposits representing a maximum overdeepening of the basin in the area and during the period included by the Trzęsiny section. It is not unlikely that the *Velapertina* is a cold-water equivalent of the warm-water representatives of the *Orbulina* and *Praeorbulina*.

To sum up, it seems that the vertical range of the benthonic foraminifera in the Trzęsiny section was controlled mostly by the basin's depth, while that of the planktonic foraminifera depended primarily on the temperature and, less so, on the depth of the water (cf. also p. 26). Changes in the two parameters mentioned above during the formation of deposits in the profile under study are responsible for the vertical differentiation in the foraminifera occurring in it. Climatic changes, that is, a drop in temperature was the most likely obstacle to the development of the *Globigerinoides* the presence of which was limited to the lower part of the section (the *Globigerinoides* ecozone) and, on the other hand, stimulated development of globigerinids in its upper part (the *Globigerina* ecozone). The shallowing, then the overdeepening and once again, the shallowing, during the period of a moderate temperature of surface layers of the sea water masses in the *Globigerina* ecozone,[8] caused an additional differentiation of the foraminiferal benthos and plankton which would allow one to separate certain probable subecozone.

The changes of the depth of the sedimentation basin extending through the Roztocze area appear to reflect the seemingly synchronic changes of depth of the Fore-Carpathian Depression. These latter were stated, among others, by Urbaniak (1974) who connected them with the unstability (uplift and folding) of the Carpathians.

CORRELATION OF THE MIOCENE DEPOSITS OF THE ROZTOCZE

Badenian strata

Planktonic foraminifera have been adopted in the present paper as a basis for correlating Miocene deposits outcropping in the Roztocze region. They frequently occur in sandy-clayey-marly deposits or in limestones of some types, for example, algal-bioclastic ones.

Data obtained by studying foraminifera from an outcrop at Trzęsiny considered as typical for the whole of Roztocze, have been taken into account in stratigraphic consideration.

The assemblage of planktonic foraminifera, characterising the lower part of the section, that is, the *Globigerinoides* ecozone, occurs, besides, at Trzęsiny, only in sandy samples from Huta Lubycka. Single elements of this assemblage, *Globigerinoides*, accompany a plankton characteristic of the Late Badenian which occurs abundantly in clayey samples from Miasteczko and Józefów. However, in these localities, they probably occur on a secondary deposit. More or less abundant globigerinids, including *G. druryi*, sometimes accompanied by single and non typical *Globigerinoides ? trilobus* and few *Orbulina*-like forms, occur in the remaining plankton-bearing Miocene samples from Roztocze ie. Monastyrz, Długi Goraj, Góra Brusno, Tarnowola, Goraj, Janów Lubelski, Wola Radzięcka, Łysaków, Węglin and Żelebsko. *Velapertina indigena* was found at Miasteczko, Monastyrz, Góra Brusno, Tarnowola, Józefów and Węglin.

An accurate indication of strata containing this species will be taken into account by Musiał (in preparation).

The presence of *Globorotalia bykovae* (Aisenstat) (pl. 6: 8—10) was found in addition at Długi Goraj and Miasteczko.

Late Badenian sandy-clayey deposits rich in plankton have almost always been accompanied by more or less abundant *Bolboforma badenensis* sp. n., a planktonic form of uncertain taxonomic affinity.

---

[8] Sandy and devoid of plankton, stratum 6 (or lower ones?) are here perhaps a limiting zone.

Biofacies containing plankton and assigned to the *Globigerina* ecozone predominate in the Badenian deposits of Roztocze. They occur in both calcareous (or their sandy-clayey intercalations) and sandy-clayey deposits. The calcareous deposits of this ecozone occur mostly on the western periphery of the Roztocze region, while the sandy ones are better developed somewhat further from, or strictly speaking, east of this periphery. In the north-western part of Roztocze, the differentiation of both bio- and lithofacies is less distinct.

The distribution of planktonic foraminifera in the Badenian deposits over the entire area of Roztocze seems to confirm the existence of a dependence of the occurrence of their particular groups on climatic and bathymetric conditions. This dependence is shown on a simplified model (fig. 4),

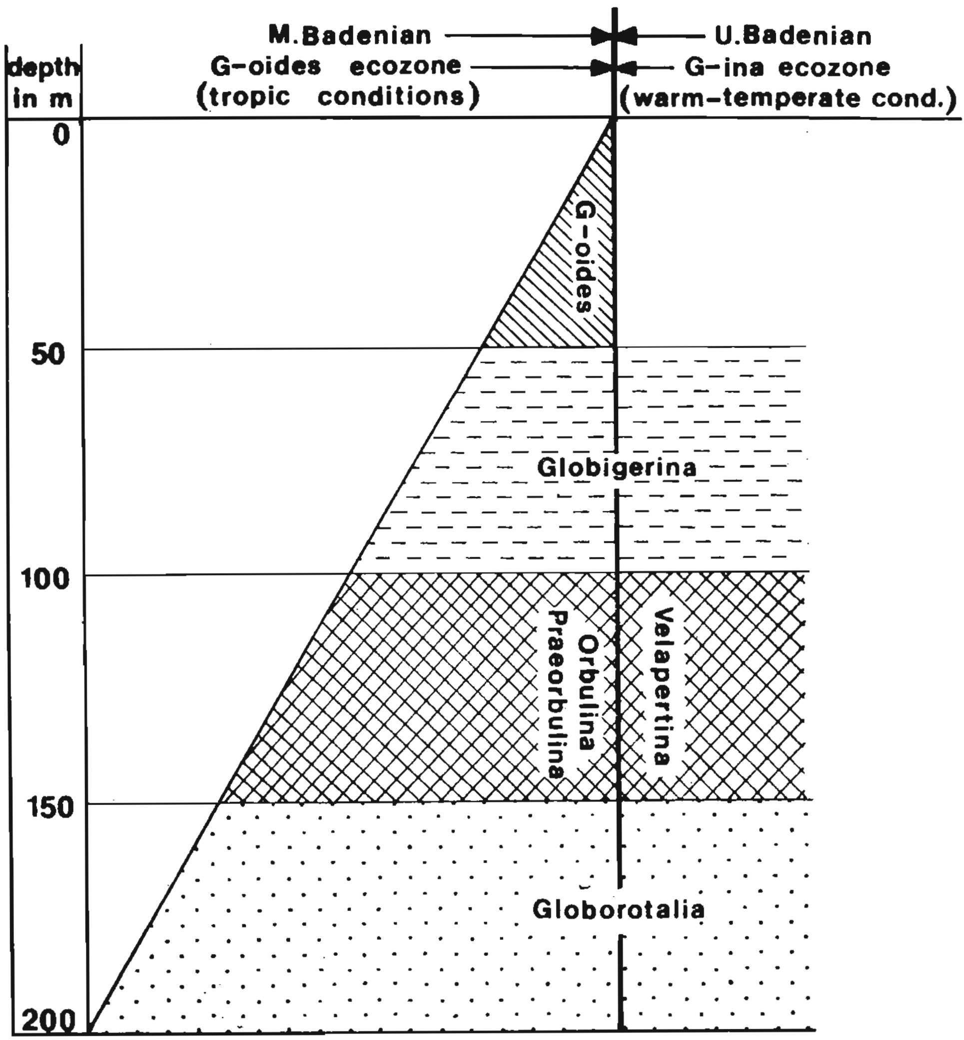


Fig. 4. Possible depth and temperature dependence of distribution of planktonic foraminifera in the Badenian of Roztocze area.

which takes into account the environmental parameters mentioned above and which control the distribution of particular genera occurring in this region. This model also presents the importance of this dependence for stratigraphic (that is, ecostratigraphic) interpreting the Late Badenian of Roztocze and other areas of Central Paratethys.

In Roztocze, Miocene deposits of various types are usually accompanied by various assemblages of benthonic foraminifera. There are, on the whole, various combinations of assemblages found in the Trzęsiny section or counterparts of such foraminiferal assemblages occurring in this locality. The diversity of assemblages results from the fact that deposits of various types represent various depths of the basin and various distance from the shore.

Microfaunal elements absent from the Trzęsiny section occur, sometimes abundantly, in few samples, in particular those coming from deposits which are probably younger than the Trzęsiny deposits. Here belong, for example: *Hoeglundina elegans* (d'Orbigny) (pl. 10: 5, 6, 10), recorded only in sandy-clayey samples from Monastyrz and Długi Goraj; *Bulimina elongata* d'Orbigny (pl. 7: 8, 9), particularly abundant at Goraj; *Burseolina* sp. (pl. 12: 3—5), occurring at Miasteczko and Góra Brusno; *Bolivinella subpectinata* (Cushman) (pl. 7: 2, 4), present at Poduchowne only; *Cancris auriculus* Fichtel and Moll (pl. 9: 11), particularly numerous at Zdziechowice and "*Anomalinoides dividens*" Łuczkowska [4] (pl. 13: 5—11) which is exceptionally abundantly represented at Tarnowola. The foraminifera mentioned above seem to form distinct "patches" (cf. Boltovskoy and Wright 1976: 125), that is, to be subject of a microdistribution which is rather independent either of the lithofacies, or age of deposits (the latter, of course, to a small extent only) and depending only on local environmental conditions.

Of more ubiquitous, benthonic species present at Trzęsiny, forms corresponding to greater depths accompany facies which are particularly abound in plankton, that is, sandy-clayey ones, in particular those situated east of Roztocze's periphery. For example, at Monastyrz and Długi Goraj, in addition to richly represented *Hoeglundina elegans* (d'Orbigny), *Uvigerina brunnensis* Karrer, *Bulimina elongata* d'Orbigny, *B. insignis* Łuczkowska (pl. 7: 13, 14) and *B.* cf. *aculeata* (d'Orbigny) (pl. 7: 1), the upper part of the section contains all other species, both planktonic (including *Bolboforma badenensis* sp. n.) and benthonic, which occur in the sample corresponding to the greatest overdeepening of the Trzęsiny section.

A similar foraminiferal assemblage rich in the *Bulimina*, *Bolivina*, *Uvigerina*, *Hoeglundina* and *Cassidulina* occurs at present in the neritic

---

[4] "*Anomalinoides* dividens" Łuczkowska has been considered by me to at most a variety of *Cibicides lobatulus* (Walker and Jacob). These taxons are compared on pl. 13. Specimens shown on pl. 13: 7 and 8 come from an Upper Badenian sample, with many globigerines (including *G. druryi*) and with *Velapertina indigena*.

zone, at depths of 45—100 m, in the Adriatic and Aegean sea where it descends to the bathyal zone (Chierici, Busi and Cita 1960). According to Bandy (1967: OB-13B): "*Hoeglundina elegans* ... is an important isobathyal species (i.e. species with rather consistent range in depth in different oceanic areas) common to the Mediterranean Sea, California, the Gulf of Mexico, and elsewhere. The upper bathymetric limits are about 100 meters and the most characteristic occurrence is at the edge of the shelf and in the bathyal and abyssal zones..." At least the middle part of the neritic zone is confirmed by the following species accompanying them: *Sphaeroidina bulloides*, *Pullenia bulloides*, *Cassidulina subglobosa*, *Gyroidina soldanii*, *Cibicides ungerianus*, *C. pseudoungerianus*, *Heterolepa dutemplei*, *Melonis soldanii*, etc. (cf. Berggren and Haq 1976; Berggren *et al.* 1976; Corlisss 1979; Wiman 1978).

Among them, the uvigerinids, *Hoeglundina elegans*, *Cassidulina subglobosa*, *Pullenia bulloides* and *Gyroidina soldanii* may be index species of not only deeper, but also colder waters (cf. Schnitker 1979; Corliss 1979) and, therefore, it is not unlikely that their presence in the Late Badenian deposits in Roztocze confirms, like that of the planktonic foraminifera, the climatic deterioration suggested by me.

According to Schnitker (1979), who studied Neogene foraminiferal associations in deep-sea drilling cores from the northern part of the Atlantic Ocean, the deep-water foraminifera are differentiated depending on the character of water masses which, in turn, depend on their temperature and oxygen content rather and not on their depth. Such associations as the *Hoeglundina-Uvigerina* are included by Schnitker (*l.c.*) to the foraminiferal associations depending on the character of water masses.

Badenian/Sarmatian strata

The most difficult problem is posed by samples in which "*Anomalinoides dividens*" Łuczkowska appears with decidedly Badenian forms. Such is the case of samples coming from Tarnowola, Frampol, Łysaków and Goraj, that is, mostly from the upper part of a complex of the algal-detrital limestones. The badenian age of these samples is corroborated by both the foraminiferal benthos and plankton, At the same time, "*A. dividens*" has generally been acknowledged as an index form of the lowest Sarmatian or of transitional strata between the Badenian and Sarmatian.

Noteworthy is the fact that single (and small) specimens representing other Sarmatian foraminifera, for example, *Elphidium reginum* (d'Orbigny) (pl. 15: 7—9), *E. echinum* Ser. (pl. 15: 2) and *E. josephinum* (d'Orbigny) (pl. 15: 1) also occur in the Badenian profile of Józefów and in an outcrop on the Sopot near Hamernia. The latter is located close to the periphery of Roztocze, in the area of the Fore-Carpathian Depression. A small part of the Sarmatian elements among the decidedly Badenian foraminifera seems to give evidence of their in situ occurrence. Purely Sarmatian foraminiferal assemblage seems to occur only in samples from the Biała Ordynacka and Wierzchowiska, where large elphidiids, characteristic of Sarmatian, for example, *Elphidium reginum* (d'Orbigny) (pl. 15: 7—9), *E. antoninum* (d'Orbigny) (pl. 15: 6), *E. hauerinum* (d'Orbigny) (pl. 15: 4), *E. josephinum* (d'Orbigny) (pl. 15: 1), *E. echinum* Ser. (pl. 15: 2) and *E. aculeatum meoticum* Goerke (pl. 14: 6, 7) predominate.

As is well known, the Sarmatian of Paratethys is represented by the fauna of a freshening and probably warm sea. It seems, therefore, that combinations of Badenian and Sarmatian element occurring in relatively deep-water deposits are the result of a higher degree of stability of the deep-water environment, that is, a slower response of its fauna content to changes in this environment. In the case of shallow-water faunas, their response to such changes is more rapid and causes a more distinct differentiation depending on local conditions.

The issue of the Badenian/Sarmatian boundary seems still to remain open to discussion, especially as the Sarmatian elements appear as early as in the unquestionably Upper Badenian. It seems that the true Sarmatian may be distinguished from the Badenian on the basis of the distinct predominance of Sarmatian forms occurring in the former and the presence of shallow-water elements (without plankton) characteristic of a warm and freshening sea; still, it is necessary to find its index microfossils.

A small (or none at all) part of the Sarmatian forms in decidedly Upper Badenian samples representing the N13-N14 Zone, which corresponds to the Upper Serravallian, indicates that the truly Sarmatian beds, without Badenian elements, can be correlated with the Tortonian. It seem to be valuable especially for deeper water deposits; sediments deposited in shallower part of the basin may represent an older stage.

The foraminiferal biofacies presented above constitutes extreme examples of biofacies occurring in the Miocene outcrops of Roztocze. It is difficult to mention all of them, since the distribution of biofacies changes not only horizontally, but also vertically so that various sediments of one and the same profile, making up one and the same stratigraphical horizon, frequently contain a different foraminiferal microfauna. A more detailed analysis of these changes would require additional and more accurate studies.

It is beyond any doubt that the distribution of biofacies discussed above indicates a lack of the homogeneity and stability of environmental conditions in the Late Badenian sedimentary basin including the area of Roztocze and gives evidence that the Late Badenian transgression in this area covered a rugged ground, with a variable morphology of the sea bottom.

It seems that the transgression, started in the upper part of the Middle Badenian (*sensu* Steininger *et al.* 1978), came from the south or rather south-east, since the most deep-water deposits occur in the south-eastern part of Roztocze (at Monastyrz, Długi Goraj), while the oldest, here studied, part of this profile appears at Huta Lubycka and at the base of the Trzęsiny section.

The Upper Badenian (*sensu* Steininger *et al.* 1978) prodominates in the central part of Roztocze, whereas it is overlaid by the Sarmatian in the north-western part of this region. It is not unlikely, therefore, that the absence of the Sarmatian from the south-eastern part of Roztocze is a secondary phenomenon resulting from geomorphological changes that occurred after the deposition of sediments of this age in this area. Thus, after the tectonic uplift of this area, Sarmatian deposits possibly occurring here and particularly exposed to erosion might have been completely destroyed.

Deposits of a somewhat shallower sea, but intercalated by those of a deeper and more open sea (at Miasteczko, Józefów, Żelebsko and Łysaków) were formed along the elevated, western periphery of Roztocze simultaneously with deep-water sediments of the south-eastern part of this region deposited further from this periphery. The lack of the Lower Badenian deposits in the Roztocze region, at least in the profiles here analyzed, suggests rather unequivocally that Roztocze constituted then an area already uplifted in relation to the Fore-Carpathian Depression (with a well developed Lower Badenian) which could not been reached by the Early Badenian transgression.

PREVIOUS ESTIMATES OF THE AGE OF THE MIOCENE DEPOSITS IN ROZTOCZE

The age of the Miocene deposits outcropped in Roztocze, suggested in the present paper as not older, in their lowermost part, than the upper part of the Middle Badenian (early Late Badenian), is only in part conformable to that given by various authors mentioned above.

In regard to micropaleontologic investigations of the Miocene deposits in Roztocze, particularly noteworthy is Odrzywolska-Bieńkowa's (1966) paper on boreholes of the north-eastern periphery of the Fore-Carpathian Depression (including those from the environs of Radruż and Brusno, Rawa Roztocze, mentioned above). That author (*l.c.*) determined the age of the deposits under study as Upper Tortonian (*recte* Upper Badenian) and Sarmatian, including the calcareous-detrital deposits whose age she estimated tentatively as Upper Tortonian (*recte* Upper Badenian). She subsequently (Odrzywolska-Bieńkowa 1972) determined the age of sediments occurring in the Dzwola borehole (near Frampol). On the basis of bethonic foraminifera, in particular *Cibicides crassiseptatus* Łuczkowska, considered index species, as well as *Bulimina insignis* Łuczkowska, she assigned part of the deposits studied to the Upper Badenian and, on the basis of mollusks and foraminifera, including *Elphidium reginum* (d'Orbigny), she found the occurrence of the Sarmatian.

It is beyond any doubt that the foraminiferal horizons, zones and assemblages distinguished (or only accepted after other authors) by that author in the Miocene deposits of Roztocze correspond, in the present paper, to the differentiation in the Badenian and Sarmatian biofacies. They correspond to definite foraminiferal associations not necessarily related with a given type of facies and age (in particular within the range of the Badenian various biofacies may represent the same stratigraphic horizon) but rather with environmental conditions.

As mentioned, among other things, by Odrzywolska-Bieńkowa (1972), the estimates of the age of the Miocene deposits in Roztocze, based on microfaunal studies are discordant with those based on macrofaunal studies. Areń (1962), Krach (1962), Bielecka (1967), Jakubowski and Musiał (1979*a*, *b*) not to mention earlier authors, even suspect the occurrence of the Lower Badenian in the outcrop examined in the present paper, for example, at Trzęsiny (Jakubowski and Musiał 1979*a*), Huta Lubycka (Jakubowski and Musiał 1979*b*) and in the area of Zaklików, that is near Węglin, Łychów, Zdziechowice etc. (Krach 1962; Bielecka 1967; Krach *et al.* 1974).

A fairly exceptional standpoint was taken in this respect by Brzezińska (1961) who, studying mollusks from numerous outcrops in Roztocze (including some studied by me), assigned all the deposits under study, including lithothamnian beds, to the super-gypsum strata of the Upper Tortonian (recte Upper Badenian) and Sarmatian, that is, in conformity with my opinion.

In the light of the above data, of importance seems to be the finding that a decidedly Upper Badenian, formerly unnoticed, microfauna occurs in the detrital lithothamnian limestones of Węglin. A sample, which I collected from an outcrop of lithothamnian limestones, that is, from beds assigned to the Lower Badenian ie. Moravian, contains, in addition to other foraminifera (Bielecka 1974: 52), *Velapertina indigena* and *Globigerina druryi*, both being index microfossils of the Late Badenian. Of the foraminifera mentioned by Bielecka (*l.c.*) from the lithothamnian limestones, the planktonic foraminifera are represented by *Globigerina bulloides* only.

It seems that macrofauna, in particular mollusks, are less important stratigraphically than the foraminifera, especially the planktonic ones. They are marked by relatively considerable longevity, their distribution is fairly controlled by environmental conditions and thus, their main role seems to consist in their suitability for environmental interpretation.

CORRELATION OF THE LATE BADENIAN DEPOSITS OF ROZTOCZE WITH THOSE OF THE FORE-CARPATHIAN DEPRESSION AND OTHER AREAS

The stratigraphy of the Late Badenian deposits in Roztocze has been based on the planktonic foraminifera and, strictly speaking, on a change in their character observed on the Middle/Upper Badenian boundary (*sensu* Papp, Cicha and Čtyroka 1978). This change was explained by climatic changes (drop of the temperature in the Upper Badenian). Similar stratigraphic (ecostratigraphic ?) criteria can be applied for distinguishing respective Badenian deposits in the Fore-Carpathian Depression.

The change in the character of planktonic foraminifera, found in the Late Badenian deposits of Roztocze, can be traced near the periphery of the Carpathian Mts. (for example, in the Kłaj borehole between Wieliczka and Bochnia, studied by Łuczkowska in 1978), near the northern boundary of the occurrence of the Miocene deposits of the Fore-Carpathian Depression (for example, in boreholes situated in the environs of Staszów-Grzybów and Tarnów-Chmielnik, examined by Łuczkowska in 1964 and 1967) and in Upper Silesia (Alexandrowicz 1963). In her paper on microfauna from the boreholes mentioned above, Łuczkowska (1964, 1967) expressively points to the differentiation in the planktonic foraminifera, that is, to the disappearance of the warm-water foraminifera below the strata containing chemical deposits.

The hypothesis of a climatic deterioration in the Late Badenian is also supported by the disappearance of the warm-water large foraminifera *Borelis*, *Amphistegina* and *Heterostegina* which occur in the Early Badenian deposits of the entire Paratethys.

The cooling of climate in the Late Badenian of Paratethys is also indicated by palynologic studies (Planderova *et al.* 1978), as well as studies on the Silicoflagellates (Dumitrică 1978) and other faunal groups such as mollusks, corals, etc. (cf. Jiřiček 1974).

Chemical deposits (gypsum and salt) are either separated by differentiated assemblages of planktonic foraminifera, that is, the warm-water and cold-water assemblages, or the cold-water one occurs somewhat earlier than the chemical deposits. Under such circumstances contrary to the views accepted so far (reviewed by Kwiatkowski 1972) according to which the gypsum deposits were formed in a hot and dry climate, the view seems to be correct that the cooling of climate was among the causes of their formation. Studying the conditions and causes of the formation of Miocene gypsum deposits in Poland, Kwiatkowski (1972) suggests that they were formed at a depth (on the average) of some dozen meters (that is, less than the depth of the formation of salts) and at a temperature of about 19°C, in a dry climate under the conditions of a turbulent, shifting sea. He also believes that the shallowing of the basin, as a result of tectonic movements and intensive evaporation, started the sedimentation of gypsum deposits. Kwiatkowski (*l.c.*) quotes various palinologists' contradictory opinions concerning climatic conditions, that is, temperature and humidity in the Miocene in Poland. In my opinion, these opinions result from not taking into account climatic changes which occurred during the formation of the Middle Miocene deposits in this country (and elsewhere in Central Paratethys). The palynologists' divergent conclusions on the Miocene climate were probably caused by their studies on floral remains coming from various horizons of the Miocene. Cooling gives favorable conditions for the precipitation of salts (cf. Książkiewicz 1968; Gradziński *et al.* 1976). The formation of certain evaporations, including hydrohalite is, as proved by Perthuisot (1980: 226), the result of cooling as an indirect factor.

Studying the genesis of the Messinian evaporations from the Mediterranean area, Rouchy (1980) drew attention to the complexity of factors cousing the formation of the salts, including the undoubted significance of climatic conditions. Making use of paleobotanical analyses, he related the precipitation of chemical deposits with climatic changes, that is, drop in humidity and temperature.

It seems that the Miocene chemical deposits were formed on the bottom of a relatively deep basin (in particular in its axial part) which is indicated by the character of microfauna from the underlying beds, separating and covering chemical deposits in Poland (see Alexandrowicz 1963; Łuczkowska 1964, 1967, 1978; Barwicz-Piskorz 1978).

The hitherto presented estimates of the relative age of chemical deposits in the Middle Miocene of Poland (as well as in the entire Paratethys) were faily variable (cf. Alexandrowicz 1963; Łuczkowska 1967; Krach and Ney 1978), but until recently were rather unanimously accepted as a basis for separating so-called "sub-gypsum" and "supra-gypsum" horizons, that is, for distinguishing the Lower and Upper Tortonian (recte Badenian).

According to the latest stratigraphic division, the Badenian of the Fore-Carpathian Depression in Poland (Krach and Ney 1978; Łuczkowska 1978) is divided into Lower (Lageniden Zone), Middle (Sandschaler Zone) and Upper (*Bulimina-Bolivina* Zone), that is, the Moravian, Wielician and Kosovian respectively. The chemical deposits are ascribed to the top of the Middle Badenian, that is, Wielician. In this biofacial division of the Badenian of Poland (conformable in fact with a newer stratigraphical division of the entire Central Paratethys), its older horizons, that is, lower and middle, are discernible mostly on the basis of the orbulinas, large foraminifera and lithothamnian beds (level). That latter have not been distinguished at all in the Upper Badenian. The Upper Badenian is characterized by the presence of definite planktonic foraminifera, that is, *Velapertina indigena* (Łuczkowska) and *Globigerina druryi* Akers. There are distinguished, moreover, numerous strata characteristic of various biofacies and expressing the lithological heterogeneity and faunal content of the Badenian deposits of Poland and other areas of Central Paratethys.

The foundations of the division of the Badenian in Poland, presented above, allowed its authors (Krach and Ney 1978) to assign the Middle Miocene deposits of Roztocze to the Lower and Upper Badenian, of which the Lower Badenian ones (together with those of the environs of Korytnica, also assigned to the Lower Badenian) to correlate with what is known as the Lower Badenian "Die nordliche Randzone" and the Upper Badenian ones of Roztocze to compare with synchronous deposits known as "Die Randzone".

As a result of my micropaleontological studies conducted in the Roztocze region (and based on surface samples only) these deposits do not represent the Lower, but mostly Upper and, sporadically, also top parts of the Middle Badenian (*sensu* Krach and Ney 1978; Papp, Cicha and Čtyroka 1978). The lithothamnian limestones occurring in Roztocze have been assigned by me to the Upper Badenian.

On the basis of the micropaleontological studies I conducted and which were mostly restricted to the Late Badenian deposits of the Roztocze area, it is difficult to take a firm standpoint concerning the stratigraphy of the lower deposits of the Badenian. On the other hand, the result of these studies enable me to present a comparative analysis of the stratigraphy (in particular its foundations) within the range of the Late Badenian, in particular in Poland.

The analysis of the distribution of planktonic foraminifera (next to the nannoplankton, the most important fossil index in stratigraphy) of the Badenian deposits of Roztocze indicates that the determination of the age of distinctly Upper Badenian strata (*sensu* Papp, Cicha and Čtyroka 1978; Łuczkowska 1978), representing the *Globigerina* ecozone (*sensu* Szczechura, present paper), and most likely to correspond to the "Super-gypsum beds" (or gypsum-bearing beds) of the Fore-Carpathian Depression can be accepted unreservedly, whereas the age of strata which represent the *Globigerinoides* ecozone (*sensu* Szczechura, present paper) (and those directly overlying it, e.g. in Trzęsiny), poses a certain problem, resulting, among other things, from the lack of unquestionable index forms unequivocally determining the age of these strata.

Globigerina druryi, a form in fact assigned to this species only tentatively, recorded, however (like *Velapertina*) from both the Upper and Middle Badenian of Paratethys (see Papp, Cicha and Čtyroka 1978) occurs in Roztocze in the biofacies containing the *Globigerinoides*. However, in this region there are no index forms of the earlier Badenian, in particular orbulinids and praeorbulinids which I noticed in such obviously Middle Badenian layers as those occurring at Korytnica. It is, however, not unlikely after all that they are facial forms (cf. p. 17) controlled by bathymetry. Thus, unfortunately, mostly negative data serve for determining the age of the zone with *Globigerinoides*.

The Late Middle Badenian age suggested for *Globigerinoides* ecozone, in Roztocze, is based, therefore, on the lack of index forms of earlier Badenian, and at the same time, the presence of *Globigerina ? druryi* together with abundant *Globigerinoides* being absent in Upper Badenian (*sensu* Papp, Cicha and Čtyroka 1978).

The standard section at Trzęsiny displays a gap in the distribution of planktonic foraminifera, which falls at the boundary between the *Globigerinoides* and *Globigerina* ecozones and thus determining the age of this barren part of the section poses a difficult problem.

In the Fore-Carpathian Depression, chemical deposits occur either on the boundary of analogous ecozones, or the *Globigerina* ecozone underlays in part the gypsum. Different parts of the two ecozones may, therefore, be contained in the barren part of the Trzęsiny section. Nevertheless, it is beyond any doubt that the chemical deposits, or other strata making up their age equivalent, should be assigned to the *Globigerina* ecozone, that is, the Upper rather and not Middle Badenian as it has hitherto been supposed.

Further studies are also necessary for explaining the real vertical ranges of some planktonic foraminifera, in particular those considered of stratigraphic importance to the Late Badenian, for example, *Velapertina indigena*, *Globigerina druryi* and *G. decoraperta*. It seems that in the Badenian of Paratethys they should be connected only with the *Globigerina* ecozone, that is, occur both above and below the chemical deposits, but only within the limits of the Upper Badenian. Their lower range, that is the Middle-Upper Badenian boundary, would be, therefore, conditioned by the disappearance of the *Globigerinoides* which, according to Papp, Cicha and Čtyroka (1978) are limited, to much extent, to the Middle and Lower Badenian.

The hitherto accepted distribution of index planktonic foraminifera mentioned above poses problems and causes inconsistencies in determining the age of deposits containing them. Thus, for example, a bed with radiolarians from the Polish part of the Fore-Carpathian Depression and containing *Velapertina indigena*, so far recorded from both the Middle and Upper Badenian of Paratethys, is assigned by Barwicz-Piskorz (1978) to the Middle Badenian.

Deposits which, in addition to the orbulinids and *Globigerinoides*, contain *Globigerina decoraperta* were studied by Gonera (1980) in the area of Rzeszów, *G. decoraperta* is typical mostly of the Middle Badenian (cf. Papp, Cicha and Čtyroka 1978), much the same as *Spiroplectamnina carinata* occurring in these deposits. Despite this fact, the deposits under study were assigned by that author to the Lower Badenian.

As a stage, the Badenian is considered by Papp, Seneš and Steininger (1978) as an age equivalent of the Langhian and early Serravallian, that is, as a section from the top part of Zone N8 up to Zones N11—N13. This view is in conformity with Berggren's and Van Couvering's following opinion (1974: 99): "... Badenian is probably not younger than the stratigraphical Langhian and early Serravallian (Zones N9—N13)". Later, these authors (Van Couvering and Berggren 1977), reduced the age of this stage placing it between Zones N8 and N12.

As indicated by recent studies (the present paper), the true Badenian also includes Zone N14 and, therefore, corresponds to the upper part of the Serravallian, while the overlying Sarmatian beds, which cannot be earlier than N14, correspond to the Tortonian.

Definite species of planktonic foraminifera and their character turned out to be of importance for determining the age of the Miocene deposits of Roztocze and correlating them with such deposits of adjacent areas.

The appearance of cold-water foraminifera (considered in the present paper as coincident with cooling of climate) in the Upper Badenian, that is upper part of the Middle Miocene of Paratethys, coincides to a considerable extent with climatic fluctuation which occurred more or less simultaneously in various other regions of the world.

Studying the foraminiferal microfauna from boreholes of eastern Canada, Gradstein and Srivastava (1980) point out an increasing cooling that took place during the post-Middle Miocene period. A brief period of the Late Miocene cooling (represented by an assemblage of temperate planktonic foraminifera and a reduced number of individuals of warm-water species) of waters of the Indian Ocean is indicated by Boltovskoy (1974). Describing the expansion of polar planktonic faunas in the later Miocene of southern California, Bandy (1968) ascribes it to the cold time interval. A distinct worldwide expansion of tropical planktonic faunas in the early Middle Miocene and, later, their equatorial contraction, as well as the appearance of cool-water species in the areas of Japan and New Zealand were pointed out by Stainforth *et al.* (1975, fig. 22). These authors emphasize (*l.c.*, p. 99): "Worldwide cooling toward the end of the early Middle Miocene (*Globorotalia fohsi lobata-robusta* Zone), caused marked equatorward restriction of tropical faunas." Studying the Tertiary foraminifera of Australia, McGowran (1979) finds that their distribution was controlled, among other things, by climate and proves that a distinct, major decline in istotopic temperatures took place at the turn of the Middle to late Miocene (*l.c.*: 255), that is, to quote him: "... after the larger foraminiferal excursion of Zone N14 i.e. close to Middle/Late Miocene boundary." This author also points out a concurrence of this drop in temperature with another found by Bizon and Müller (1977) on the basis of analyzing a calcareous plankton in the Mediterranean (falling in Zones N13—N15, with its maximum in Zone N15). On the basis of their research conducted by means of an oxygen and carbon isotope analysis and micropaleontological studies on samples from DSDP from the northeast Atlantic, Vergnaud Grazzini *et al.* (1979) stated the following (*l.c.*: 482): "In the late middle Miocene, temperatures decreased again and the high $\delta^{18}O$ values observed near Zone N15 may have resulted from the building up of Antarctic ice cap."

Differences resulting from the above comparison of the recordings of Miocene worldwide climatic changes (cooling), can be explained by erroneous dating or, and may be even more so, by time delay in the cooling as a function of latitude. The latter is indicated by an analysis of marine temperatures in various regions of the world obtained by means of isotopic data (Savin *et al.*, 1975). Studying the oceanic surface and bottom temperatures in various parts of the world over the Mesozoic and Cenozoic eras and making use of istotopic data obtained by studies on both planktonic and benthonic foraminifera, these authors unquestionably proved fluctuation in temperature which occurred in various epochs, including the Late Miocene and found the following (*l.c.*: 1499): "A temperature rise through early Miocene time was followed in middle Miocene time by sudden divergence of high- and low-latitude temperatures: high-latitude temperatures dropped dramatically, perhaps corresponding to the onset of major glaciation in Antarctica, but low-latitude temperatures remained constant or perhaps increased." These authors proved that the temperatures differed sympathetically up to the end of the early Miocene and, afterwards, differed distinctly. Referring to Gibson's (1967) studies, Berggren and Hollister (1974: 176) point out: "... southward displacement of the temperate faunal province along the coastal margin of the Atlantic Coastal Plain during early-middle Miocene time..."

The data on Late Miocene climatic changes and their symptoms, collected so far, are for the time being relatively scant, in particular in regard to the areas of Tethys and Paratethys which are here of particular importance. This may be the result either of a lack of complete sedimentation (or of plankton), or not paying a sufficient attention, if only, to short-term climatic shift which is primarily reflected in the character of planktonic foraminifera. Thus, further studies are indispensable for determining the range and character of the Miocene climatic changes and their usefulness for correlating deposits. In regard to the latter feature, of particular interest seems to be the relation of the Middle Miocene climatic crisis in Paratethys to the deterioration in climate observed in the Upper Miocene of the Mediterranean region (Berggren and Van Couvering 1974), especially if it corresponds to the evaporite-bearing Messinian facies.

TAXONOMY OF THE FORAMINIFERA RECORDED

In identifying the foraminifera, in particular benthonic ones, I have myself made use of a generally accepted taxonomy concerning the Miocene foraminifera of Paratethys. Its more penetrating analysis exceeded the range of the subject matter of the present paper. Nevertheless, the following general observations, concerning the taxonomy of the microfauna under study, seem to be of importance.

The benthonic foraminifera, in particular their deep-water forms, are relatively cosmopolitan and display a world-wide distribution and extensive stratigraphic range. Many Miocene, as well as Recent forms appeared in the early Tertiary or even in the Cretaceous. The benthonic foraminifera also display an environmental, ontogenetic and individual variability. Erecting various names for the same species but coming from various areas and from deposits differing in age was caused also by not taking into account the three types of their variability mentioned above.

The investigators of microfauna of a definite age, for example, the Neogene, frequently take no account on literature concerning the fauna of another age, in particular the Paleogene and especially that coming from more distant areas of its occurrence. Erecting new and new specific names is also caused by inaccurate descriptions and illustrations, which may be observed in particular in earlier elaborations. For example, *Heterolepa dutemplei*, occurring in the Badenian of Roztocze, which was originally described by d'Orbigny (1846) from the Miocene of Vienna Basin as *Rotalina dutemplei.* In my opinion, both the presence and morphology of this widely distributed species are controlled by environmental conditions, mostly bathymetry (?) (compare specimens presented on pl. 12: 6, 7, 9, 10 and pl. 16: 8—11). In the present paper, it is suggested that *H. dutemplei* is conspecific or closely related with at least *Rotalina haidingeri* d'Orbigny 1846, *Rotalia eoceana* Gümbel 1868, *Cibicides mexicana* Nuttall 1932 (cf. pl. 16: 6, 7), *Cibicides subhaidingeri* Parr 1950 and *Eponides spiratus* Łuczkowska, 1955, later renamed by that author *E. omnivagus* (Łuczkowska 1959). This latter is figured in the present paper, pl. 12: 7, 10, as *Heterolepa dutemplei.*

Hanzawaia bouana, described by d'Orbigny (1846) as *Truncatulina boueana*, constitutes another example. In all likelihood, this species is conspecific with *Truncatulina producta* Terquem 1882, *Truncatulina americana* Cushman 1918, *Anomalina bundensis bundensis* Van Bellen 1946 and *Cibicides boueana* (d'Orbigny) *crassa* Łuczkowska 1955, which was emended as a separate species and renamed *Cibicides crassiseptatus* Łuczkowska 1959 (cf. pl. 12: 11, 12 and pl. 16: 1—5). This latter is figured in the present paper, pl. 16: 4, 5, as *Hanzawaia boueana.* According to Brzobohatý *et al.* (1967), *Cibicides crassiseptatus* is a subspecies of *Hanzawaia boueana.*

In my opinion, *Rosalina globularis* erected by d'Orbigny (1826), should be identified with *Discorbis globularis* var. *bradyi* Cushman 1915, and *Discorbis douvillei* Cushman, 1928, whereas *Eponides repandus* described by Fichtel and Moll 1978, as *Nautilus repandus*, is surely conspecific with *Eponides probatus* described by Krashennikov 1958.

"*Anomalinoides dividens*", described by Łuczkowska (1967) and cited in the present paper under this name, makes up a separate problem of importance to both stratigraphy and taxonomy. In recent literature (Brestenská 1974), this species together with *Cibicides certus* Venglinski 1963, *C.* (*Anomalinoides*) *pokutica* Aisenstat 1954, *C.* (*A.*) *kaluschiensis* Aisenstat 1954, *C.* (*A.*) *postkarpaticus* Aisenstat 1954, *C.* (*A.*) *transkarpaticus* Aisenstat 1954, *C.* (*A.*) *predcarpaticus* Aisenstat 1955 and *C. menneri* Serova 1955, has been included in the synonymy of *Anomalinoides badenensis* (d'Orbigny), described by d'Orbigny (1846) from the Tertiary (Miocene) of the Vienna Basin as *Anomalina badenensis*. Krach *et al.* (1974) also identify *Anomalinoides dividens* Łuczkowska with *Cibicides badenensis* (d'Orbigny).

I believe that this species (or rather a group of species) is a phenotypic variety of *Cibicides lobatulus* (Walker and Jacob 1978) formed as a result of changes in environmental conditions, probably a decrease in salinity. Its comparison with "*Anomalinoides dividens*" is shown on pl. 13: 1—11; see also my paper in preparation.

A proper determination of the species discussed above and other ones mentioned in the present paper, requires further studies based on original material. It is indispensable to determine the interdependence between the morphology of their tests and the character of their environment, as well as to study their actual distribution in time and space, that is, their evolution and geographical variability.

SYSTEMATIC DESCRIPTION

Genus *Bolboforma* Daniels et Spiegler 1974

Bolboforma badenensis sp. n.

(pl. 6: 1—4)

Holotype: specimen ZPAL V.IX/3; pl. 6: 3.

Paratype: specimen ZPAL V.IX/2; pl. 6: 2.

Type horizon: Upper Badenian (Middle Miocene).

Type locality: Trzęsiny (Roztocze), sample no. 7.

Derivation of the name: *badenensis* — after Baden, Austria, the town which the Badenian stage name is derived.

Material — Hundreds of well preserved specimens.

Diagnosis. — The test somewhat flattened horizontally or regularly round, densely reticulated and spiny.

Description. — The test slightly flattened horizontally or round, bearing one, exceptionally two, round apertures, without neck. The entire test's surface more or less distinctly reticulated. Irregularly polygonal eyes of reticulation sharply rimmed; their contacting angles bear singular or branching spines. The test seems to be pierced by rather rare, tiny, irregularly spaced hollows.

Variation. — Insignificant variation concerns the size (100-180 μ), shape and ornamentation of the tests, which may be regularly round or somewhat flattened horizontally, and not always distinctly reticulate. It is possible that the lack of distinct reticulation of the test's surface is the result of the poor preservation of specimens. In some specimens two, instead one, closely situated apertures occur.

Remarks. — *Bolboforma badenensis* sp. n. is similar to *B. reticulata* Daniels et Spiegler (1974), occurring in the Middle and Upper Miocene of western Germany. It differs from the latter by being more densely reticulated and spiny.

Occurrence. — Late Badenian (Middle Miocene) of the Roztocze area (SE Poland) outcropping at: Trzęsiny, Tarnowola, Józefów, Monastyrz, Żelebsko, Łysaków, Miasteczko, Goraj, Góra Brusno and Hamernia (eastern periphery of Fore-Carpathian Depression).

REFERENCES

ALEXANDROWICZ, S. W. 1963 Stratygrafia osadów mioceńskich w Zagłębiu Górnośląskim. — *Prace IG*, **39**, 147 pp.

AREŃ, B. 1962. Miocen Roztocza Lubelskiego między Sanną i Tanwią. — *Ibidem*, **30**, 5—77.

— 1972. Pozycja stratygraficzna margli tereszpolskich w wierceniu Dzwola na Roztoczu. — *Kwart. Geol.*, **16**, 3, 676—683.

BANDY, O. L. 1967. Benthic foraminifera as environmental indices. *In*: AGI Short Course Lecture Notes, Paleoecology, OB-1—27. American Geological Institute, Washington.

— 1968. Cycles in Neogene paleoceanography and eustatic changes. — *Palaeogeogr. Palaeoclimat. Palaeoecol.*, **5**, 1, 63—75.

BARWICZ-PISKORZ, W. 1978. The Miocene Radiolaria from the Carpathian Foredeep. — *Acta Palaeont. Polonica*, **23**, 3, 223—248.

BÉ, A. W. H. 1977. An ecological, zoogeographic and taxonomic review of Recent planktonic foraminifera, *In*: A. T. S. Ramsay (ed.), Oceanic Micropaleontology, 1, 88 pp. Academic Press, London, New York, San Francisco.

—, HARRISON, S. M. and LOTT, L. 1973. *Orbulina universa* d'Orbigny in the Indian Ocean. — *Micropaleont.*, **19**, 2, 150—192.

— and TOLDERLUND, D. S. 1971. Distribution and ecology of living planktonic foraminifera in surface waters of the Atlantic and Indian Oceans. *In*: B. M. Funnel and W. R. Riedel (ed.), The Micropaleontology of Oceans, 105—149. Cambridge University Press.

BERGGREN, W. A. and AMDURER, M. 1973. Late Paleogene (Oligocene) and Neogene planktonic foraminiferal biostratigraphy of the Atlantic Ocean. — *Riv. Ital. Paleont.*, **79**, 3, 337—392.

—, BENSON, R. H., HAQ, B. U., RIEDEL, W. R., SANFILIPPO, A., SCHRADER, H. J. and TJALSMA, R. C. 1976. The El Cuevro section (Andalusia, Spain): Micropaleontological anatomy of an early Late Miocene lower bathyal deposit. — *Marine Microp.*, **1**, 3, 195—221.

— and COUVERING, J. A. Van. 1974. The Late Neogene. Biostratigraphy geochronology and paleoclimatology of the last 15 milion years in marine and continental sequences. — *Palaeogeogr. Palaeoclimat. Palaeoecol.*, **16**, 1/2, spec. issue, 216 pp.

— and HAQ, B. U. 1976. The Andalusian Stage (Late Miocene): biostratigraphy, biochronology and paleoecology. — *Ibidem*, **20**, 1/2, 67—129.

— and HOLLISTER, C. D. 1974. Paleogeography, paleobiogeography and the history of circulation in the Atlantic Ocean. *In*: W. W. Hay (ed.), Studies in paleo-oceanography, spec. publ., **20**, 126—186. Society of Economic Paleontologists and Mineralogists.

BIELECKA, M. 1967. Trzeciorzęd południowo-zachodniej części Wyżyny Lubelskiej. *In*: Z badań geologicznych regionu Świętokrzyskiego, 7. — *Biul. IG*, **206**, 115—188.

— 1974. Miocen okolic Zaklikowa, Zdziechowic i Węglina. *In*: W. Krach, E. Łuczkowska and R. Ney (ed.), Miocen przedgórza Karpat. Przewodnik wycieczki. VII Sympozjum na temat Paratetydy, 43—54. Kraków.

BOLTOVSKOY, E. 1974. Neogene planktonic foraminifera of the Indian Ocean Ocean (DSDP, Leg 26). — Initial Repts. Deep Sea Drilling, **26**, 675—741. Washington, U. S. Government Printing Office.

— 1980. Benthonic foraminifera of the bathyal zone from Oligocene through Quaternary. — *Rev. Esp. Microp.*, **12**, 2, 283—304.

— and WRIGHT, R. 1976. Recent foraminifera. W. Junk Publ., Hague, 515 pp.

BREMER, M. L., BRISKIN, M. and BERGGREN, W. A. 1980. Quantitative paleopaleobathymetry and paleoecology of the late Pliocene — early Pleistocene foraminifera of Le Castella (Calabria, Italy). — *J. For. Res.*, **10**, 1, 33 pp.

BRZEZIŃSKA, M. 1961. Miocen z pogranicza Roztocza zachodniego i Kotliny Sandomierskiej. — *In*: Z badań trzeciorzędu w Polsce, 4. — *Biul. IG*, **158**, 5—111.

BRZOBOHATÝ, R., CICHA, I., KHEIL, J., KNOBLOCH, E., ONDREJÍČKOVA, A., PLANDEROVÁ, E., ŘEHÁKOVÁ, Z., TEJKAL, J. and ZAPLETALOVÁ, I. 1967. Faunistische und floristische Charakteristik der Karpatischen Serie. *In*: J. Seneš (ed.), Chronostratigraphie und Neostratotypen, Miozän M_3, Karpatien, 286—312. VEDA, Bratislava.

CHIERICI, M. A., BUSI, M. T. et CITA, B. M. 1962. Contribution à une étude écologique des foraminifères dans la Mer Adriatique. — *Rev. Micropaleont.*, **5**, 2, 123—142.

CITA, M. B. and BLOW, W. H. 1969. The biostratigraphy of the Langhian, Serravallian and Tortonian stages in the type-sections of Italy. — *Riv. Ital. Paleont.*, **75**, 3, 549—603.

COLOMBO, M. R. and CITA, M. B. 1980. Changes in size and test porosity of *Orbulina universa* d'Orbigny in the Pleistocene record of Cape Bojador (DSDP Site 397 eastern North Atlantic). — *Marine Microp.*, **5**, 1, 13—29.

CORLISS, B. H. 1979. Taxonomy of Recent deep-sea benthonic foraminifera from the southeast Indian Ocean. — *Micropaleont.*, **25**, 1, 19 pp.

COUVERING, J. A. van and BERGGREN, W. A. 1977. Biostratigraphical Basis of the Neogene Time Scale. *In*: E. G. Kauffman and J. E. Hazel (ed.), Concepts and methods of biostratigraphy, 283—306. Dowdern, Hutchinson and Ross, Inc. Stroudsburg, Pennsylvania.

DANIELS, C. H. von and SPIEGLER, D. mit einem Beitrag von. ORTLAM, D. 1974. *Bolboforma* n.gen. (Protozoa?) — eine neue stratigraphisch wichtige Gattung aus dem Oligozän/Miozän Nordwestdeutschlands. — *Paläont. Z.*, **48**, 1/2, 57—76.

DOUGLAS, R. G. and SAVIN, S. M. 1978. Oxygen isotopic evidence for the depth stratification of Tertiary and Cretaceous planktic foraminifera. — *Marine Microp.*, **3**, 2, 175—196.

DUMITRICA, P. 1978*a*. Badenian Silicoflagellates from Central Paratethys. *In*: E. Brestenska (ed.), Chronostratigraphie und Neostratotypen, Miozän M_4, Badenian, 207—218, Veda, Bratislava.

— 1978*b*. Badenian Radiolaria from Central Paratethys. — *Ibidem*, 231—261.

EMILIANI, C. 1969. A new paleontology. — *Micropaleont.*, **15**, 3, 265—300.

FEYLING-HANSSEN, R. W. 1980. Microbiostratigraphy of young Cenozoic marine deposits of the Qivituq Peninsula, Baffin Island. — *Marine Microp.*, **5**, 2, 153—184.

GONERA, M. 1980. Osady mioceńskie w Zalesiu koło Rzeszowa. — *Kwart. Geol.* **24**, 2, 299—310.

GRADSTEIN, F. M. and SRIVASTAVA, S. P. 1980. Aspects of Cenozoic stratigraphy and paleoceanography of the Labrador Sea and Baffin Bay. — *Palaeogeogr., Palaeoclimat., Palaeoecol.*, **30**, 3/4, 261—295.

GRADZIŃSKI, R., KOSTECKA, A., RADOMSKI, A. and UNRUG, R. 1976. Sedymentologia, Ewaporaty, 347—379. Wydawnictwa Geologiczne, Warszawa.

HASEGAWA, S. 1979. Foraminifera of the Himi Group, Hokuriku Province, Central Japan. — *Tohoku Univ., Sci, Rep., 2nd ser. (Geol.)*, **49**, 2, 89—163.

INGLE, J. C., Jr. 1967. Variation of foraminiferan and radiolarian biofacies in time. *In*: AGI Short Course Lecture Notes, Paleoecology JI-B-1-18, AGI, Washington.

—, KELLER, G. Jr. and KOLPACK, R. L. 1980. Benthic foraminiferal biofacies, sediments and water masses of the southern Peru—Chile, Trench area, southeastern Pacific Ocean. — *Micropaleont.*, **26**, 2, 113—150.

JAKUBOWSKI, G. and MUSIAŁ, T. 1979*a*. Lithology and fauna of the Middle Miocene deposits of Trzęsiny (Roztocze Tomaszowskie, Region, South-eastern Poland). — *Prace Muz. Ziemi*, **32**, 37—70.

— and — 1979*b*. Midle Miocene sandy and carbonate deposits of Huta Lubycka and Huta Różaniecka (Roztocze Rawskie Region, South-eastern Poland) — *Ibidem*, **32**, 71—100.

JIŘÍČEK, R. 1974. Corrélation du Néogene supèrieur des régions de la Paratéthys et de la Tethys. *In*: Geol. Zbornik, Geologica Carpathica. — *Geol. zborn. Slov. akad. vied.*, **25**, 1, 145—166.

KOLLMAN, K. and RÖGL, F. 1978. 2 Faziostratotypus: Sassbachtal, Sterrisches Becken, Steiermark, Osterreich, (Boundary Stratotypus: Badenian-Sarmatien; M_{4a-d}—A_{5ab}). *In*: E. Brestenska (ed.), Chronostratigraphie und Neostratotypen, Miozän M_4, Badenian, 158—168, VEDA, Bratislava.

KRACH, W. 1962. Stratygrafia i fauna miocenu okolic Zaklikowa i Modliborzyc (Wyżyna Lubelska). — *Prace IG, 40 lat Instytutu Geologicznego*, **30**, 3, 417—439.

— and NEY, R. 1978. Vortiefe der West — und Ostkarpaten in Polen. *In*: E. Brestenska (ed.), Chronostratigraphie und Neostratotypen, Miozän M_4, Badenian, 96—100, VEDA, Bratislava.

—, RUTKOWSKI, J, and KUCIŃSKI, T. M. 1974. B. Die Sedimentationsräume und Schichtengruppen des Sarmats *s.str.* und *s. lato* in der Vortiefe der Karpaten und des Balkans (Übergangsgebiet zur euxinischen Entwicklung. 1. Der Sedimentationsraum und die Schichtengruppe des Sarmats *s.str.* in Polen. — *Ibidem*, 105—113.

KSIĄŻKIEWICZ, M. 1968. Geologia dynamiczna. C. Kopalne produkty sedymentacji, 355—416. Wydawnictwa Geologiczne, Warszawa.

KWIATKOWSKI, S. 1972. Sedymentacja gipsów mioceńskich południowej Polski. — *Prace Muz. Ziemi*, **19**, 5—93.

LANKFORD, R. R. 1967. The depauperate fauna concept relative to foraminifera. *In*: AGI Short Course Lecture Notes, Paleoecology, RL1B—RL2B, AGI, Washington.

ŁUCZKOWSKA, E. 1964. Stratygrafia mikropaleontologiczna w rejonie Tarnobrzeg—Chmielnik (The micropaleontological stratigraphy of the Miocene in the region Tarnobrzeg—Chmielnik). — *Prace Geol. PAN*, **20**, 7—72.

— 1967. Paleoekologia i stratygrafia mikropaleontologiczna miocenu okolic Grzybowa koło Staszowa (Paleoecology and micropaleontological stratigraphy of the Miocene in the vicinity of Grzybów near Staszów). — *Acta Geol. Polonica*, **17**, 1, 219—249.

— 1978. 1. Faziostratotypus Bohrung Kłaj-1, Karpatische Vortiefe in Polen. (Boundary Stratotypus; Unter-, Mittel-und Oberbaden; $M_{4ab-c-d}$; Moravien—Wielicien—Kosovien). *In*: E. Brestenska (ed.), Chronostratigraphie und Neostratotypen, Miozän M_4, Badenian, 155—158.

McGOWRAN, B. 1979. The Tertiary of Australia: Foraminiferal overview. — *Marine Micropaleont.*, **4**, 3, 235—264.

MUSIAŁ, T. 1976. Występowanie i własności piasków mioceńskich południowego Roztocza, oraz możliwości ich gospodarczego wykorzystania. — *Biul. IG*, **292**, 61—134.

ODRZYWOLSKA-BIEŃKOWA, E. 1966. Stratygrafia mikropaleontologiczna miocenu na północno-wschodniej krawędzi zapadliska przedkarpackiego. — *Kwart. Geol.*, **10**, 2, 432—441.

— 1972. Stratygrafia młodszego trzeciorzędu w wierceniu Dzwola na Roztoczu w świetle badań mikropaleontologicznych. — *Ibidem*, **3**, 16, 669—675.

— 1976. O niektórych gatunkach z rodzaju *Bolboforma* (Protozoa?) w miocenie Polski. — *Ibidem*, **20**, 3, 551—558.

PAPP, A., CICHA, I. and ČTYROKÁ, J. 1978. Foraminifera, 3.1. Allgemaine Charakteristic der Foraminiferenfauna im Badenian. *In*: E. Brestenska (ed.), Chronostratigraphie und Neostratotypen, Miozän M_4, Badenian, 263—325, VEDA, Bratislava.

—, SENES, J. and STEINIGER, F. 1978. Diskussion der Äquivalente des Badenian in Europa. — *Ibidem*, 55—59.

PARKER, F. L. 1958. Eastern Mediterranean Foraminifera. Swedish Deep-Sea Exp., Rept. 8, 4, 219—283.

PERTHUISOT, J. P. 1980. Sites et processus de la formation d'evaporites dans la nature actuelle (Sites and processes of evaporite formation in actual nature). — *Bull. Cent. Rech. Explor. — Prod. Elf-Aquitaine*, **4**, 1, 207—233.

REISS, Z., MERLING-REISS, P. and MOSHKOVITZ, S. 1971. Quaternary planctonic foraminiferida and nannoplankton from the Mediterranean Continental shelf and slope of Israel. — *Israel J. Earth-Sci.*, **20**, 4, 141—177.

—, HALICZ, E. and PARELIS, L. 1974. Planktonic Foraminiferida from Recent sediments in the Gulf of Elat. — *Ibidem*, **23**, 3, 69—105.

ROUCHY, J.-M. 1980. La genese des evaporites messiniennes de Mediterranee: un bilan Genesis of Mediterranean Messinian Evaporites: and evaluation. — *Bull. Cent. Rech. Explor. — Prod. Elf-Aquitaine*, **4**, 1, 511—545.

SAVIN, S. M., DOUGLAS, R. G. and STEHLI, F. G. 1975. Tertiary marine paleotemperatures. — *Bull. Geol. Soc. America*, **86**, 11, 1499—1522.

SCHNITKER, D. 1979. The deep waters of the western North Atlantic during the past 24,000 years, and the re-initiation of the Western Boundary Undercurrent. — *Marine Micropaleont.*, **4**, 3, 265—280.

STAINFORTH, R. M., LAMB, J. L., LUTERBACHER, H.-P., BEARD, J. H. and FORDS, R. M. 1975. Cenozoic planktonic foraminiferal zonation and characteristics of index forms. — *Univ. Kansas Paleont. Contr.*, **62**, 13—152.

STEININGER, F. F. 1977. Integrated Assemblage-Zone Biostratigraphy at Marine-Nonmarine Boundaries: Examples from the Neogene of Central Europen. *In*: E. G. Kauffmann and J. E. Hazel (eds.), Concepte and Methods of Biostratigraphy, 235—256, Dowden, Hurtchinson and Ross, Inc., Stroundsburg, Pennsylvania.

—, RÖGL, F. and MÜLLER, C. 1978. Geodynamic und palaogeographische Entwicklund des Badenien. *In*: E. Brestenska (ed.), Chronostratigraphie und Neostratotypen, Miozän M_4, Badenian, 110—127, VEDA, Bratislava.

SZCZECHURA, J. and POŻARYSKA, K. 1976. Paleocene provinces in Europe and their planktonic foraminiferes. — *Rev. Esp. Micropaleont.*, **8**, 1, 23—30.

THUNELL, R. C. 1979. Meditterranean Neogene planktonic foraminiferal biostratigraphy: Quantitative results from DSDP Sites 125, 132 and 372. — *Micropaleont.*, **25**, 4, 412—437.

URBANIAK, J. 1974. Stratygrafia miocenu przedgórza Karpat nad Dunajcem koło Tarnowa.. — *Prace Geol. PAN, Kom. Nauk. Geol., Kraków*, **86**, 7—89. Wydawnictwa Geologiczne, Warszawa.

VERGNAUD GRAZZINI, C., MÜLLER, C. LETOLIE, C. P. R., PEYPOUQUET, J. P. 1979. Stable isotopes and Tertiary paleontological paleoceanography in the Northeast Atlantic. — Initial Repts. Deep Sea Drilling, **158**, 475—487, Washington (U. S. Government Printing Office).

WIMAN, S. K. 1978. Mio-Pliocene foraminiferal biostratigraphy and stratochronology of central and northeastern Tunisia. — *Rev. Esp. Micropaleont.*, **10**, 1, 87—143.

ZACHARIASSE, W. J. 1975. Planktonic foraminiferal biostratigraphy of the Late Neogene of Crete (Greece). — *Bull. Utrecht Micropaleont.*, **11**, 5—171.

JANINA SZCZECHURA

BIOCHRONOLOGIA I EKOLOGIA OTWORNIC ZE ŚRODKOWEGO MIOCENU PŁD.-WSCH. POLSKI

Streszczenie

Otwornice z odsłonięć miocenu z płd.-wsch. Polski (Roztocze) wykorzystano dla celów stratygraficznych i interpretacji ich warunków środowiskowych. Stwierdzono, iż spośród dających się zauważyć zmian parametrów środowiska, zmiany klimatyczne i batymetryczne kontrolowały rozprzestrzenienie otwornic planktonicznych, natomiast głównie zmiany batymetryczne wpływały na rozprzestrzenienie otwornic bentonicznych.

Na podstawie otwornic planktonicznych zaliczono badane osady do środkowego i górnego badenu (*sensu* Papp, Cicha and Čtyroka 1978), wykluczając stwierdzony tam wcześniej dolny baden, a jednocześnie przypisano ekostratygraficzny charakter granicy pomiędzy środkowym i górnym badenem. Zmiany klimatyczne na granicy środkowego i górnego badenu, tj. ochłodzenie mogło spowodować powstanie osadów chemicznych, które zaliczane są tutaj do górnego badenu. Osady górnego badenu

Roztocza zaliczone są do standardowej biostratygraficznej zony planktonowej N13—N14 tj. do górnej części miocenu środkowego.

Otwornice bentoniczne umożliwiły stwierdzenie obecności na Roztoczu osadów sarmackich przy czym powstał problem wieku biofacji sarmackich. Pojawienie się elementów tych biofacji w osadach pełnomorskich (o normalnym zasoleniu), niewątpliwie badeńskich, pozwala przypuszczać, że w tym samym czasie mogły istnieć płytkowodne i wysłodzone zbiorniki, zawierające biofacje otwornicowe zdecydowanie sarmackie. "*Anomalinoides dividens*" Łuczkowska, uznawany dotąd jako forma charakteryzująca warstwy przejściowe pomiędzy badenem i sarmatem, potraktowany jest tutaj jako odmiana *Cibicides lobatulus* (Walker et Jacob), występująca już w niewątpliwym badenie.

Wnioski stratygraficzne i ekologiczne, wynikające z badania mioceńskiej mikrofauny Roztocza wydają się aktualne dla synchronicznych osadów całej Paratetydy Centralnej.

W pracy zawarto uwagi na temat taksonomii opracowanej mikrofauny, a nadto opisano *Bolboforma badenensis* sp.n., planktoniczną mikroskamieniałość o nieznanej przynależności systematycznej.

EXPLANATIONS TO THE PLATES 1—16

Plate 1

1—3, 12. *Globigerinoides trilobus* (Reuss); 1×100, ZPAL F. XXVII/1; 2×100, ZPAL F. XXVII/2; 3×100, ZPAL F. XXVII/3; 12×120, ZPAL F. XXVII/4.

4. *Globigerinoides* sp., ×75, ZPAL F. XXVII/5.

5—9. *Globigerinoides quadrilobatus* (d'Orb.); 5×125, ZPAL F. XXVII/6; 6×125, ZPAL F. XXVII/7; 7×100, ZPAL F. XXVII/8; 8×100, ZPAL F. XXVII/10.

10, 11. *Globigerinoides sacculifer* (Brady); 10×75, ZPAL F. XXVII/11; 11×75, ZPAL F. XXVII/12. All figured specimens are from the Trzęsiny loc., sample 1a, from the Badenian strata.

Plate 2

1—3. *Globigerina druryi* Akers; 1×100, ZPAL F. XXVII/13; 2×100, ZPAL F. XXVII//14; 3×100, ZPAL F. XXVII/15; Monastyrz loc.

4, 5, 8. *Globigerina praebulloides* Blow; 4×100, ZPAL F. XXVII/16; 5×100, ZPAL F. XXVII/17; 8×100, ZPAL F. XXVII/18; Trzęsiny loc., sample B.

6. *Globigerina diplostoma* Reuss; ×100; ZPAL F. XXVII/19; Trzęsiny loc., sample B.

7. *Globigerina* sp.; ×100; ZPAL F. XXVII/20; Trzęsiny loc., sample B.

9, 10. *Globigerina concinna* Reuss; 9×100, ZPAL F. XXVII/21; 10×100, ZPAL F. XXVII/22; Trzęsiny loc., sample B. All figured specimens are from the the Badenian strata.

Plate 3

1—4. *Globigerina tarchanensis* Subb. and Chutz.; 1×150, ZPAL F. XXVII/23; 2×150, ZPAL F. XXVII/24; 3×150, ZPAL F. XXVII/25; 4×150, ZPAL F. XXVII/26; 1—3 Józefów loc.; 4 Trzęsiny loc., sample 7.

5—11. *Globigerina* cf. *quinqueloba* Natland; 5×150, ZPAL F. XXVII/27; 6×150, ZPAL F. XXVII/165; 7×150, ZPAL F. XXVII/28; 8×150, ZPAL F. XXVII/29; 9×300, ZPAL F. XXVII/30; 10×300, ZPAL F. XXVII/31; 11×300, ZPAL F. XXVII/32; 5—8 Józefów loc.; 9—11 Zdziechowice loc. All figured specimens are from the Badenian strata.

Plate 4

1, 2, 4. *Orbulina suturalis* Brönn.; 1×100, ZPAL F. XXVII/33; 2×100, ZPAL F. XXVII/34; 4×75, ZPAL F. XXVII/35; 1, 2 Trzęsiny loc., sample 7; 4 Korytnica loc., Korytnica Clays.

3. *Globigerina* sp.; ×125, ZPAL F. XXVII/36, Miasteczko loc.

5, 8. *Globigerinoides ?trilobus* (Reuss); 5×100, ZPAL F. XXVII/37; 8×100, ZPAL F. XXVII/38; Trzęsiny loc., sample 7.

6. *Praeorbulina glomerosa* (Blow); ×125; ZPAL F. XXVII/39, Trzęsiny loc., sample 7.

7, 9—12. *Velapertina indigena* (Łuczkowska); 7×100, ZPAL F. XXVII/40; 9×100, ZPAL F. XXVII/41; 10×150, ZPAL F. XXVII/42; 11×125, ZPAL F. XXVII/43; 12×125, ZPAL F. XXVII/44; 7 Monastyrz loc.; 9, 11, 12 Trzęsiny loc., sample 7; 10 Józefów loc. All figured specimens are from the Badenian strata.

Plate 5

1—7. *Globorotalia* cf. *continuosa* Blow; 1×150, ZPAL F. XXVII/45; 2×150, ZPAL F. XXVII/46; 3×150, ZPAL F. XXVII/47; 4×150, ZPAL F. XXVII/48; 5×150, ZPAL F. XXVII/49; 6×150, ZPAL F. XXVII/50; 7×150, ZPAL F. XXVII/51; 1, 4, 5 Józefów loc.; 2, 3, 6, 7 Trzęsiny loc., sample 7.

8—15. *Globigerina* cf. *bollii* Cita and Premoli; 8×150, ZPAL F. XXVII/52; 9×150, ZPAL F. XXVII/53; 10×150, ZPAL F. XXVII/54; 11×150, ZPAL F. XXVII/55; 12×150, ZPAL F. XXVII/56; 13×150, ZPAL F. XXVII/57; 14×150, ZPAL F. XXVII/58; 15×150, ZPAL F. XXVII/59; 8, 10—15 Trzęsiny loc., sample 7. All figured specimens are from the Badenian strata.

Plate 6

1—4. *Bolboforma badenensis* sp. n.; 1×22.5, ZPAL V. IX/1; 2×150, ZPAL V. IX/2; 3×150, ZPAL V. IX/3, holotype; 4×150, ZPAL V. IX/4; Trzęsiny loc., sample 7.

5—7. *Globorotalia siakensis* Le Roy; 5×100, ZPAL F. XXVII/60; 6×150, ZPAL F. XXVII/61; 7×100, ZPAL F. XXVII/26; 5, 7 Trzęsiny loc., sample 7; 6 Miasteczko loc.

8—10. *Globorotalia bykovae* (Aisenstat); 8×150, ZPAL F. XXVII/63; 9×150, ZPAL F. XXVII/64; 10×150, ZPAL F. XXVII/65; Miasteczko loc.

11—13. *Globorotalia* cf. *continuosa* Blow; 11×125, ZPAL F. XXVII/66; 12×125, ZPAL F. XXVII/67; 13×125, ZPAL F. XXVII/68; Monastyrz loc. All figured specimens are from the Badenian strata.

Plate 7

1. *Bulimina* cf. *aculeata* d'Orb.; ×75; ZPAL F. XXVII/69, Monastyrz loc.
2, 4. *Bolivinella subpectinata* (Cush.): 2×50, ZPAL F. XXVII/70; 4×50, ZPAL F. XXVII/71; Poduchowne loc.
3. *Trifarina angulosa* (Williamson); ×125; ZPAL F. XXVII/72; Tarnowola loc.
5—7. *Uvigerina brunnensis* Karrer; 5×30, ZPAL F. XXVII/73; 6×30, ZPAL F. XXVII/74; 7×50, ZPAL F. XXVII/75; 5 Trzęsiny loc., sample B; 6, 7 Monastyrz locality.
8, 9. *Bulimina elongata* d'Orb.; 8×50, ZPAL F. XXVII/76; 9×50, ZPAL F. XXVII/77; Goraj loc.
10. *Bolivina* cf. *hyalina* Śmig. ×80, ZPAL F. XXVII/78; Józefów loc.
11. *Bolivina dilatata* Reuss; ×100, ZPAL F. XXVII/79; Trzęsiny loc., sample B.
12. *Fursenkoina schreibersiana* (Czjzek); ×40, ZPAL, F. XXVII/80; Trzęsiny loc., sample 7.
13, 14. *Bulimina insignis* Łuczk.; 13×60, ZPAL F. XXVII/80; 14×60, ZPAL F. XXVII/82; Monastyrz loc.
15. *Reussella incrassata* Łuczk.; ×100, ZPAL F. XXVII/83; Trzęsiny loc., sample 1a.
16. *Virgulopsis* sp.; ×150, ZPAL F. XXVII/84; Trzęsiny loc., sample 1a.
17. *Bolivina pseudoplicata* Heron Allen and Earland; ×150, ZPAL F. XXVII/85; Trzęsiny loc., sample 1a.
18. *Reussella spinulosa* (Reuss); ×70, ZPAL F. XXVII/86; Trzęsiny loc., sample 1a. All figured specimens are from the Badenian strata.

Plate 8

1, 2. *Discorbis* sp.; 1×100, ZPAL F. XXVII/87; 2×100, ZPAL F. XXVII/88; Trzęsiny loc., sample 1a.
3, 4. *Neoconorbina* sp.; 3×150, ZPAL F. XXVII/89; 4×150, ZPAL F. XXVII/90; Trzęsiny loc., sample 1a.
5—7. *Rosalina globularis* d'Orb.; 5×100, ZPAL F. XXVII/91; 6×100, ZPAL F. XXVII/92; 7×100, ZPAL F. XXVII/93; Trzęsiny loc., sample 1a.
8—11. *Glabratella imperatoria* (d'Orb.); 8×65, ZPAL F. XXVII/94; 9×50, ZPAL F. XXVII/95; 10×50, ZPAL F. XXVII/96; 11×70, ZPAL F. XXVII/97; Trzęsiny loc., sample 10.
12, 14. *Buccella cf. hannai* (Phleger and Parker); 12×100, ZPAL F. XXVII/98; 14× ×100, ZPAL F. XXVII/99; Trzęsiny loc., sample 1a.
13. *Discorbis discoides* (d'Orb.); ×75, ZPAL F. XXVII/100. All figured specimens are from the Badenian strata.

Plate 9

1, 4. *Asterigerina planorbis* d'Orb.; 1×75, ZPAL F. XXVII/101; 2×75, ZPAL F. XXVII/102; Trzęsiny loc., sample 1a.
2, 3, 8, 9. *Ammonia beccarii* (Linné); 2×100, ZPAL F. XXVII/103; 3×100, ZPAL F. XXVII/104; 8×50, ZPAL F. XXVII/105; 9×50, ZPAL F. XXVII/106; 2, 3 Trzęsiny loc., sample 1a; 8, 9 Hamernia loc.
5—7. *Asterigerina minuta* Śmig.; 5×150, ZPAL F. XXVII/107; 6×150, ZPAL F. XXVII/108; 7×150, ZPAL F. XXVII/109; Trzęsiny loc., sample 1a.

10, 12. *Neoconorbina* cf. *miocenica* Krash.; 10×65, ZPAL F. XXVII/110; 12×65, ZPAL F. XXVII/111; Zdziechowice loc.

11. *Cancris auriculus* (Fichtel and Moll); ×50, ZPAL F. XXVII/112; Zdziechowice loc. All figured specimens are from the Badenian strata.

Plate 10

1, 2. *Pullenia bulloides* (d'Orb.); 1×75, ZPAL F. XXVII/113; 2×75, ZPAL F. XXVII/ /114; Trzęsiny loc., sample 7.

3, 4. *Gyroidina soldanii* d'Orb.; 3×65, ZPAL F. XXVII/115; 4×60, ZPAL F. XXVII/ /116; Trzęsiny loc., sample 7.

5, 6, 10. *Hoeglundina elegans* (d'Orb.); 5×38, ZPAL F. XXVII/117; 6×38, ZPAL F. XXVII/118; 10×30, ZPAL F. XXVII/119; Monastyrz loc.

7, 11. *Sphaeroidina bulloides* d'Orb.; 7×50, ZPAL F. XXVII/120; 11×50, ZPAL F. XXVII/121; Trzęsiny loc., sample 7.

8, 16. *Heronallenia* cf. *kempii* (Heron-Allen and Earland); 8×125, ZPAL F. XXVII/ /122; 16×125, ZPAL F. XXVII/123; Trzęsiny loc., sample 7.

9. *Pyrgo bulloides* (d'Orb.); ×30, ZPAL F. XXVII/124; Trzęsiny loc., sample 11.

12. *Pyrgo cf. inornata* (d'Orb.); ×50, ZPAL F. XXVII/125; Trzęsiny loc., sample 11.

13. *Textularia* sp.; ×20, ZPAL F. XXVII/126; Trzęsiny loc., sample 11.

14. *Gaudryina* sp.; ×38, ZPAL F. XXVII/127; Trzęsiny loc., sample 11.

15. *Spiroplectammina acuta* Reuss; ×20, ZPAL F. XXVII/128; Trzęsiny loc., sample 11. All figured specimens are from the Badenian strata.

Plate 11

1. *Epistominella* sp.; ×200, ZPAL F. XXVII/129; Trzęsiny loc., sample B.

2. *Cassidulina punctata* Reuss; ×170, ZPAL F. XXVII/130; Trzęsiny loc., sample B.

3, 9. *Cassidulina* cf. *laevigata* d'Orb.; 3×150, ZPAL F. XXVII/131; 9×150, ZPAL F. XXVII/132; Trzęsiny loc., sample B.

4. *Cassidulina* sp.; ×130, ZPAL F. XXVII/133; Trzęsiny loc., sample B.

5, 6. *Pullenia quinqueloba* (Reuss); 5×100, ZPAL F. XXVII/134; 6×100, ZPAL F. XXVII/135; Trzęsiny loc., sample 7.

7, 8. *Cassidulina crassa* d'Orb.; 7×115, ZPAL F. XXVII/136; 8×115, 150, ZPAL F. XXVII/137; Trzęsiny loc., sample B.

10, 11. *Cassidulina subglobosa* Brady; 10×150, ZPAL F. XXVII/138; 11×100, ZPAL F. XXVII/139; Trzęsiny loc., sample 7. All figured specimens are from the Badenia strata.

Plate 12

1, 2. *Cibicides pseudoungerianus* (Cushman); 1×50, ZPAL F. XXVII/140; 2×50, ZPAL F. XXVII/141; Trzęsiny loc., sample 7.

3—5. *Burseolina* sp.; 3×65, ZPAL F. XXVII/142; 4×65, ZPAL F. XXVII/143; 5×65, ZPAL F. XXVII/144; Miasteczko loc.

6,7,9,10. *Heterolepa dutemplei* (d'Orb.); 6×35, ZPAL F. XXVII/145; 7×35, ZPAL F. XXVII/146; 9×35, ZPAL F. XXVII/147; 10×35, ZPAL F. XXVII/148; 6, 9 Trzęsiny loc., sample 7; 7, 10 Monastyrz loc.

8. *Cibicides ungerianus* (d'Orb.); ×50, ZPAL F. XXVII/149; Trzęsiny loc., sample 7.

11, 12. *Hanzawaia boueana* (d'Orb.); 11×90, ZPAL F. XXVII/150; 12×75, ZPAL F. XXVII/151; Trzęsiny loc., sample 7. All figured specimens are from the Badenian strata.

Plate 13

1—3. *Cibicides lobatulus* (Walker and Jacob); 1×70, ZPAL F. XXVII/152; 2×70, ZPAL F. XXVII/153; 3×40, ZPAL F. XXVII/154; 1, 2 Frampol loc.; 3 Trzęsiny loc., sample 1a.

4. Transition form between *Cibicides lobatulus* and "*Anomalinoides dividens*"; ×100, ZPAL F. XXVII/156; Frampol loc.

5—11. "*Anomalinoides dividens*" Łuczk.; 5×70, ZPAL F. XXVII/157; 6×70, ZPAL F. XXVII/158; 7×150, ZPAL F. XXVII/159; 8×125, ZPAL F. XXVII/160; 9×100, ZPAL F. XXVII/161; 10×100, ZPAL F. XXVII/162; 11×100, ZPAL F. XXVII/163; 5, 6 Frampol loc.; 7, 8 Tarnowola loc.; 9—11 Biała Ordynacka loc.
Specimens (numbered) 1—8 are from Badenian strata, wheres those numbered 9—11 are from Sarmatian beds

Plate 14

1. *Astrononion perfossum* (Clodius); ×75, ZPAL F. XXVII/164; Trzęsiny loc., sample 1a.

2. *Melonis soldanii* (d'Orb.); ×75, ZPAL F. XXVII/166; Trzęsiny loc., sample 7.

3, 4. *Eponides repandus* (Ficht. and Moll); 3×38, ZPAL F. XXVII/167; 4×38, ZPAL F. XXVII/168; Trzęsiny loc., sample 11.

5. *Elphidium* cf. *earlandi* Cush.; ×100, ZPAL F. XXVII/169; Trzęsiny loc., sample B.

6, 7. *Elpihidium aculeatum meoticum* Goerke; 6×75, ZPAL F. XXVII/170; 7×75, ZPAL F. XXVII/171; Biała Ordynacka loc.

8. *Elphidium aculeatum* (d'Orb.); ×50, ZPAL F. XXVII/172; Trzęsiny loc., sample 1a.

9. *Elphidium crispum* (Linnée); ×30, ZPAL F. XXVII/173; Trzęsiny loc., sample 1a.

10. *Elphidium* cf. *flexuosum* (d'Orb.); ×65, ZPAL F. XXVII/174; Trzęsiny loc., sample 1a.

11. *Florilus boueanus* (d'Orb.); ×65, ZPAL F. XXVII/175; Trzęsiny loc., sample 1a.
Specimens numbered 6, 7 are from the Sarmatian strata, whereas the rest are from the Badenian beds.

Plate 15

1. *Elphidium josephinum* (d'Orb.); ×100, ZPAL F. XXVII/176; Hamernia loc.

2. *Elphidium echinum* Serova; ×50, ZPAL F. XXVII/177; Hamernia loc.

3. *Protelphidium subgranosum* (Egger); ×50, ZPAL F. XXVII/178; Trzęsiny loc., sample 1a.

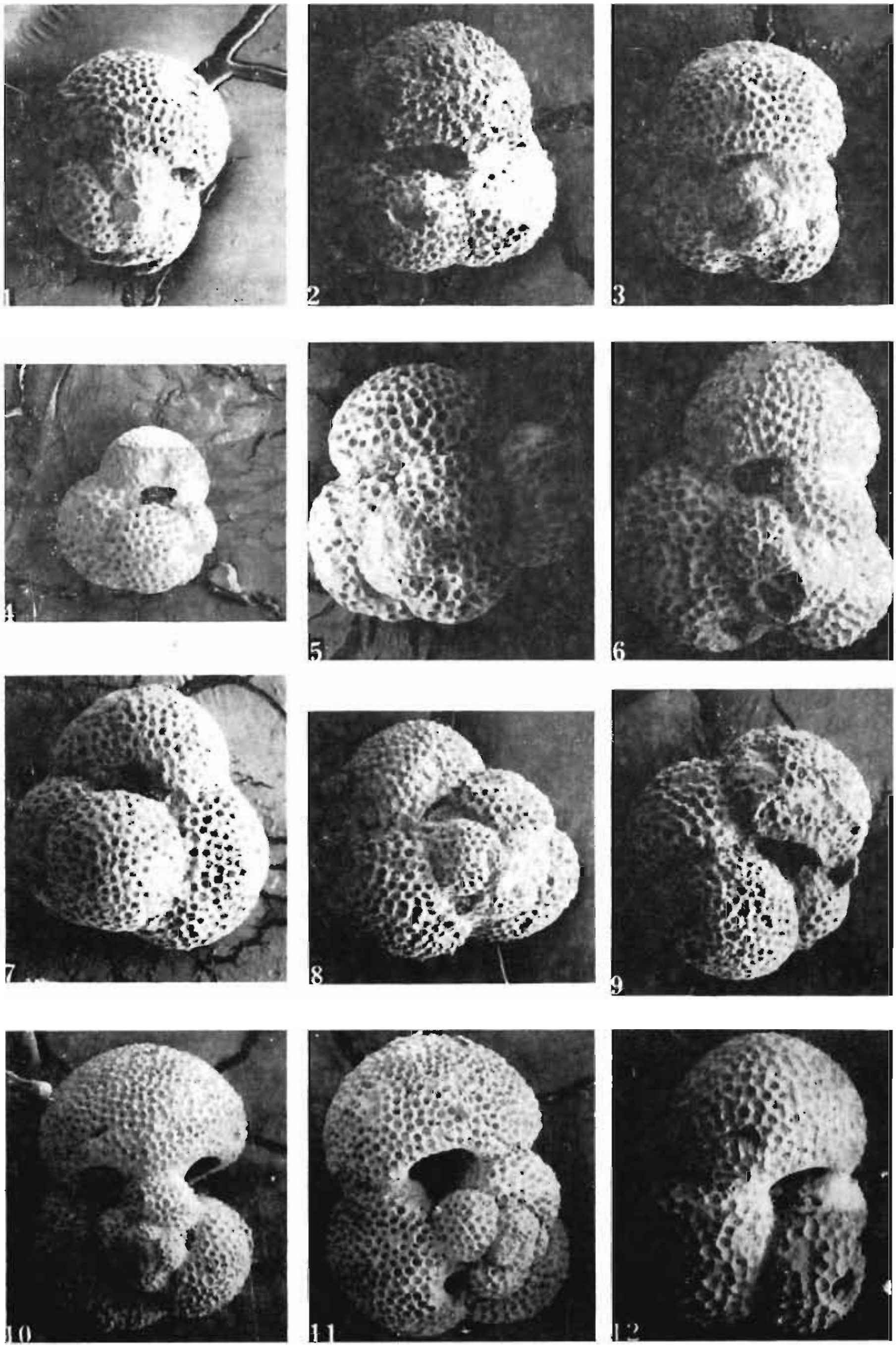
4. *Elphidium hauerinum* (d'Orb.); ×75, ZPAL F. XXVII/178; Biała Ordynacka loc.

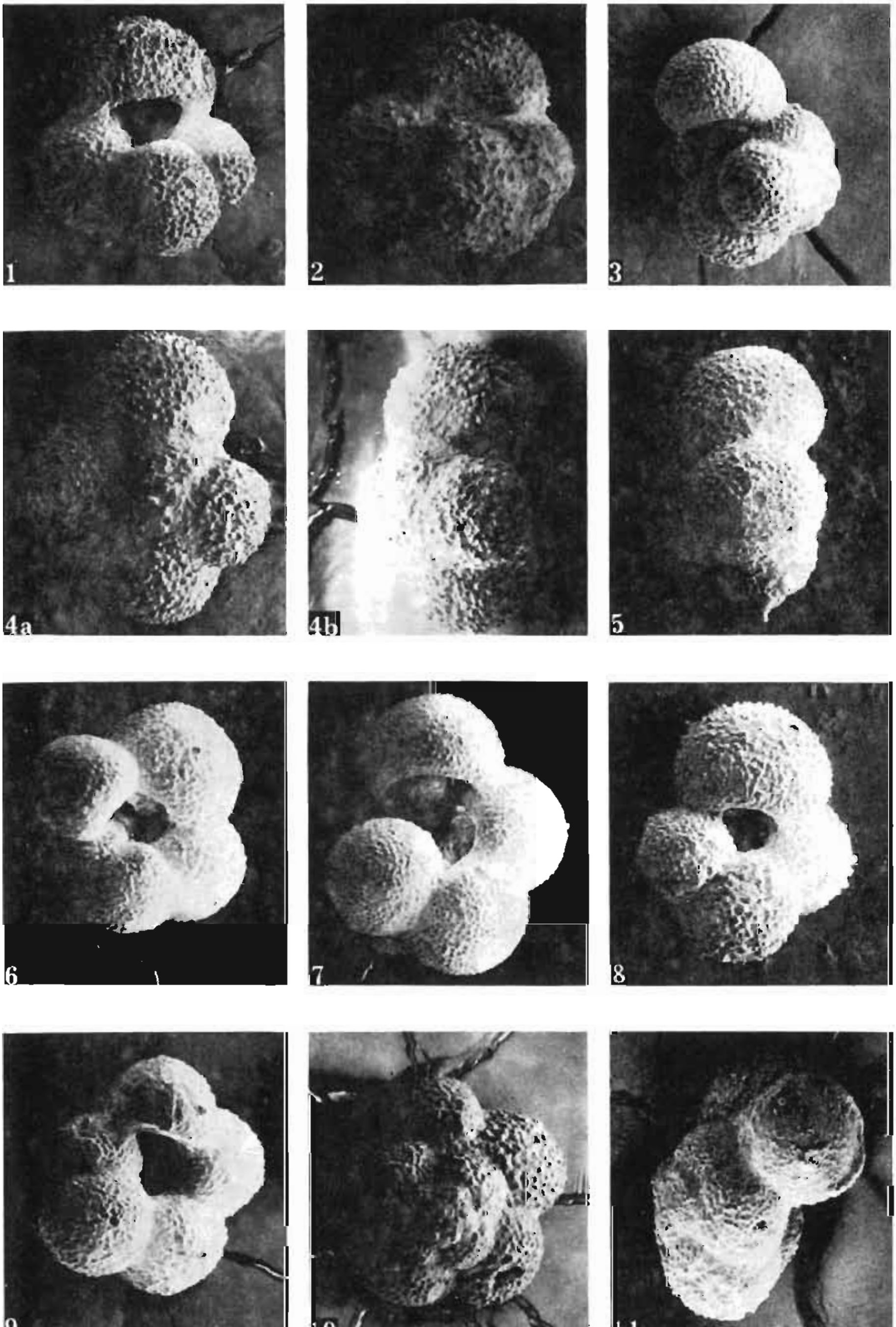
5. *Protelphidium granosum* (d'Orb.); ×75, ZPAL F. XXVII/179; Zdziechowice loc.

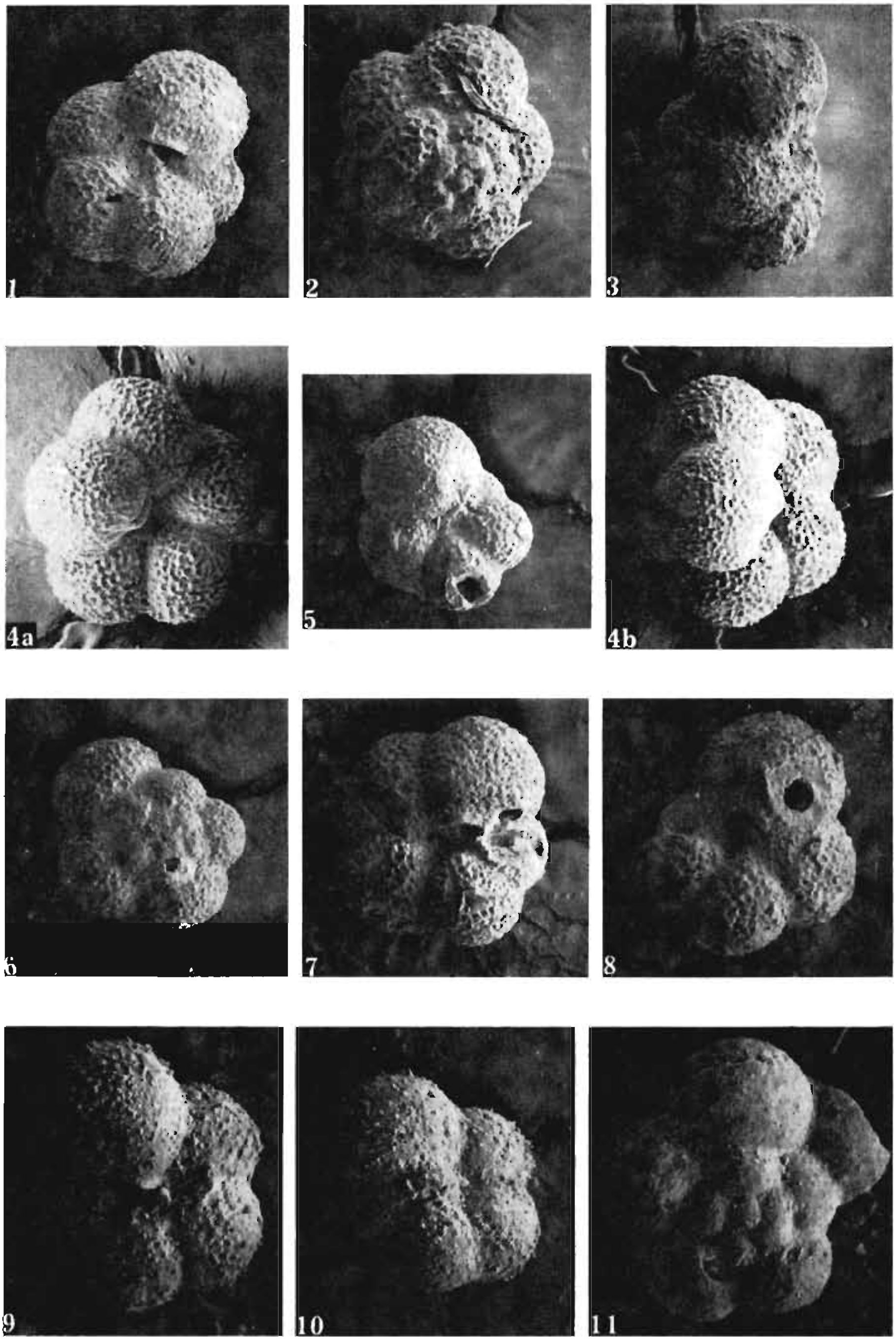
6. *Elphidium antoninum* (d'Orb.); ×100, ZPAL F. XXVII/180; Biała Ordynacka loc.
7—9. *Elphidium reginum* (d'Orb.); 7×50, ZPAL F. XXVII/181; 8×50, ZPAL F. XXVII//182; 9×50, ZPAL F. XXVII/183; 7—9 Biała Ordynacka loc.
Specimens numbered 4, 6—11 are from the Sarmatian strata, whereas the rest are from the Badenian beds.

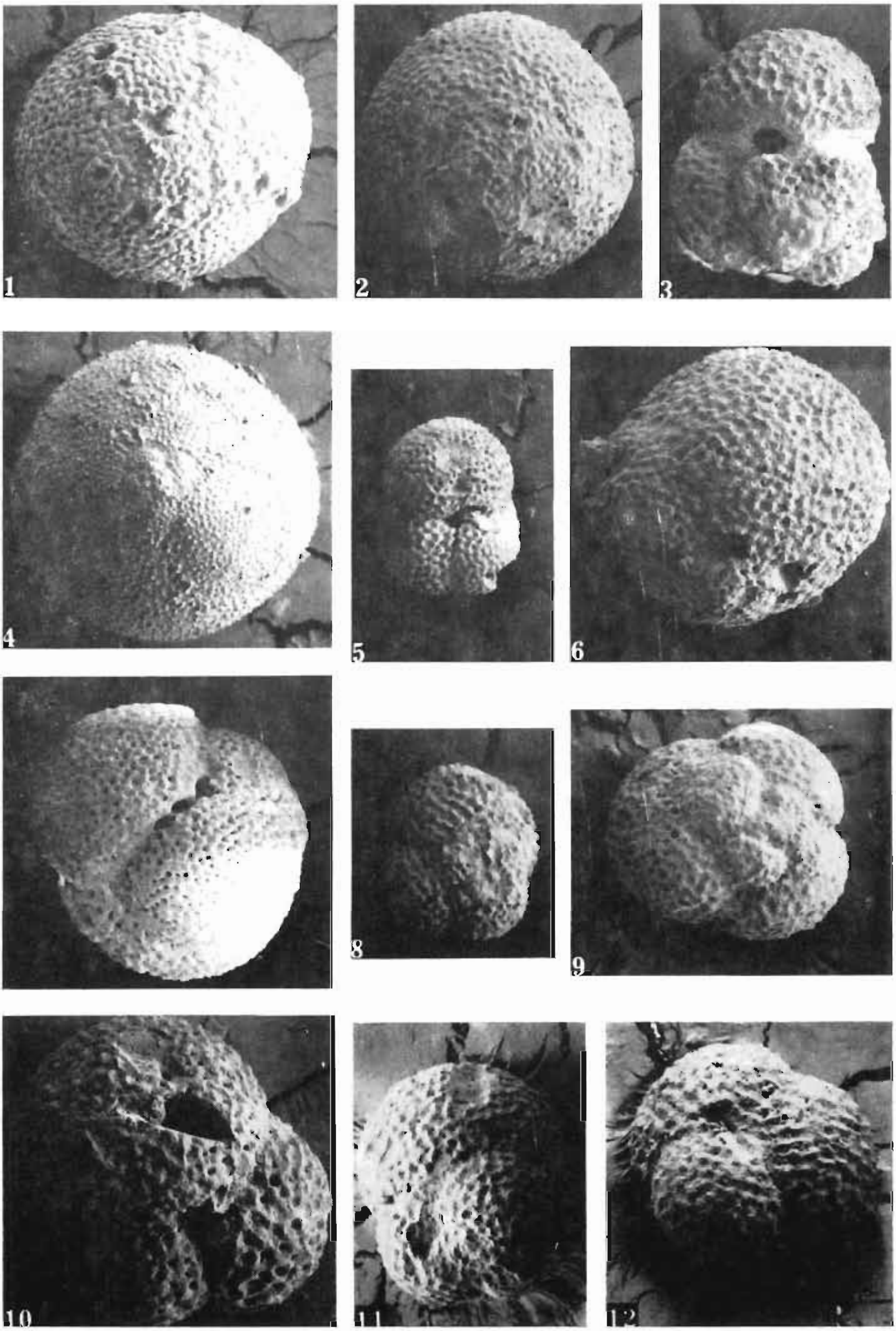
Plate 16

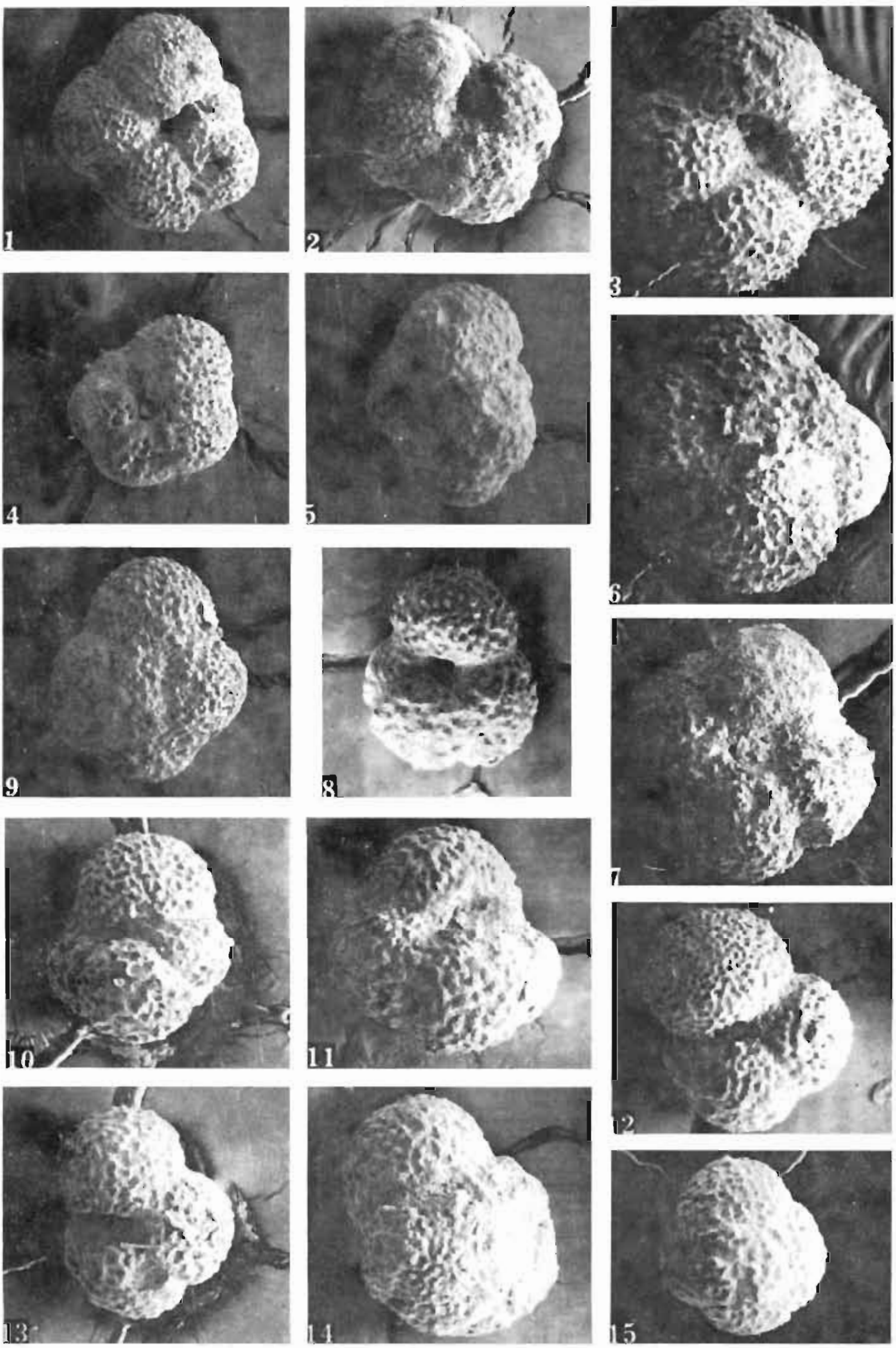
1—3. *Hanzawaia bundensis bundensis* (van Bellen); 1×150, ZPAL F. XXVII/184; 2×150, ZPAL F. XXVII/185; 3×150, ZPAL F. XXVII/186; 3×150, ZPAL F. XXVII/187; Pamiętowo boring, depth 257 m (Polish Lowlands).
4, 5. *Hanzawaia boueana* (d'Orb.); 4×150, ZPAL F. XXVII/188; 5×150, ZPAL F. XXVII/189; Długi Goraj loc.
6, 7. *Cibicides mexicana* Nuttall; 6×75, ZPAL F. XXVII/190; 7×75, ZPAL F. XXVII/191; Aragon loc. (Mexico).
8, 9. *Heterolepa dutemplei* (d'Orb.); 8×140, ZPAL F. XXVII/192; 9×100, ZPAL F. XXVII/193; Baden loc. (Austria).
10, 11. *Heterolepa dutemplei* (d'Orb.); 10×60, ZPAL F. XXVII/194; 11×75, ZPAL F. XXVII/195; Staropatica loc. (Bulgaria).
Specimens numbered 1—3 are from the Middle Paleocene; 4, 5 from the Upper Badenian; 6, 7 from the Lower Eocene (Aragon Fm.); 8—11 from the Middle Badenian.

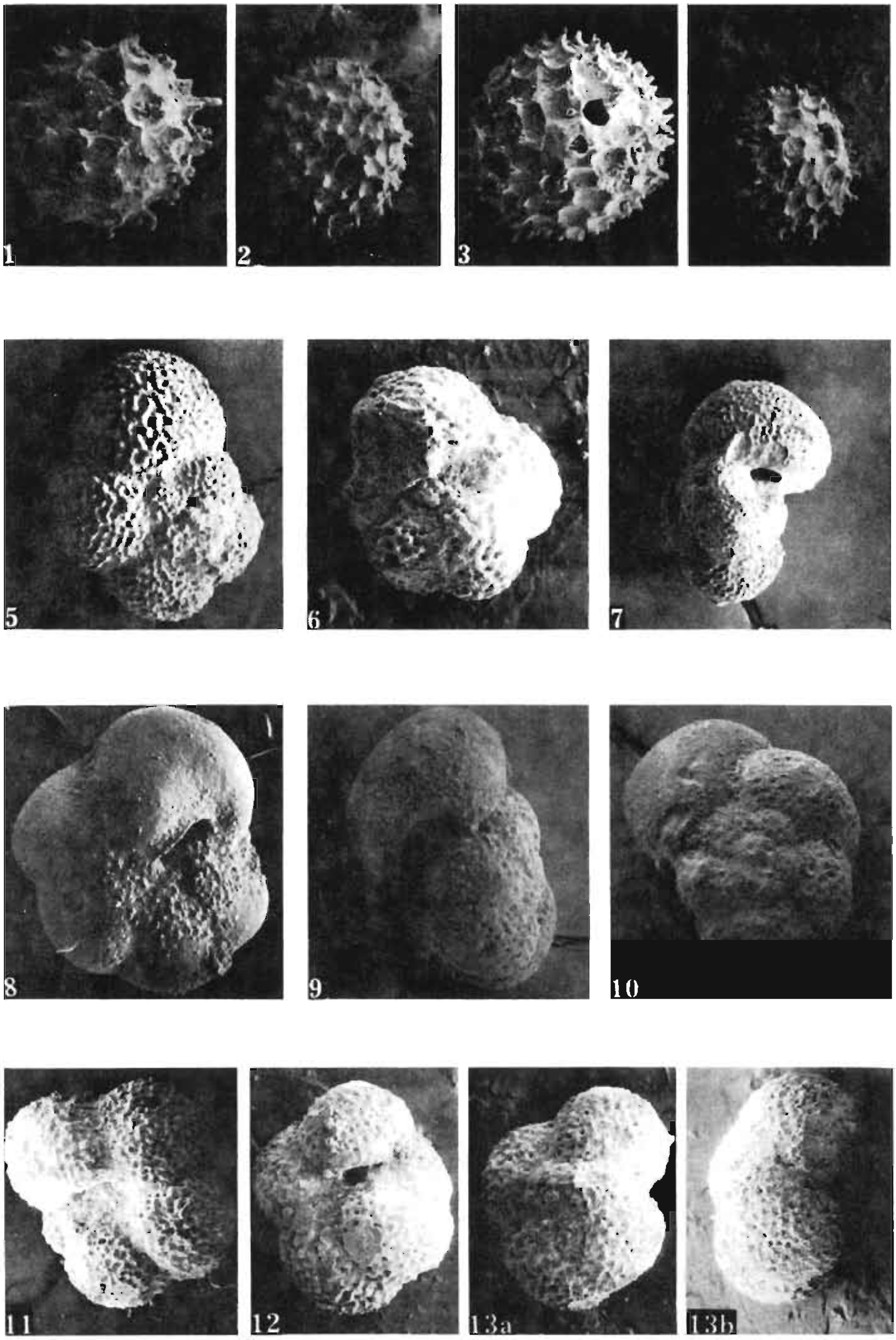

1
2
3
4
5
6
7
8
9
10
11
12

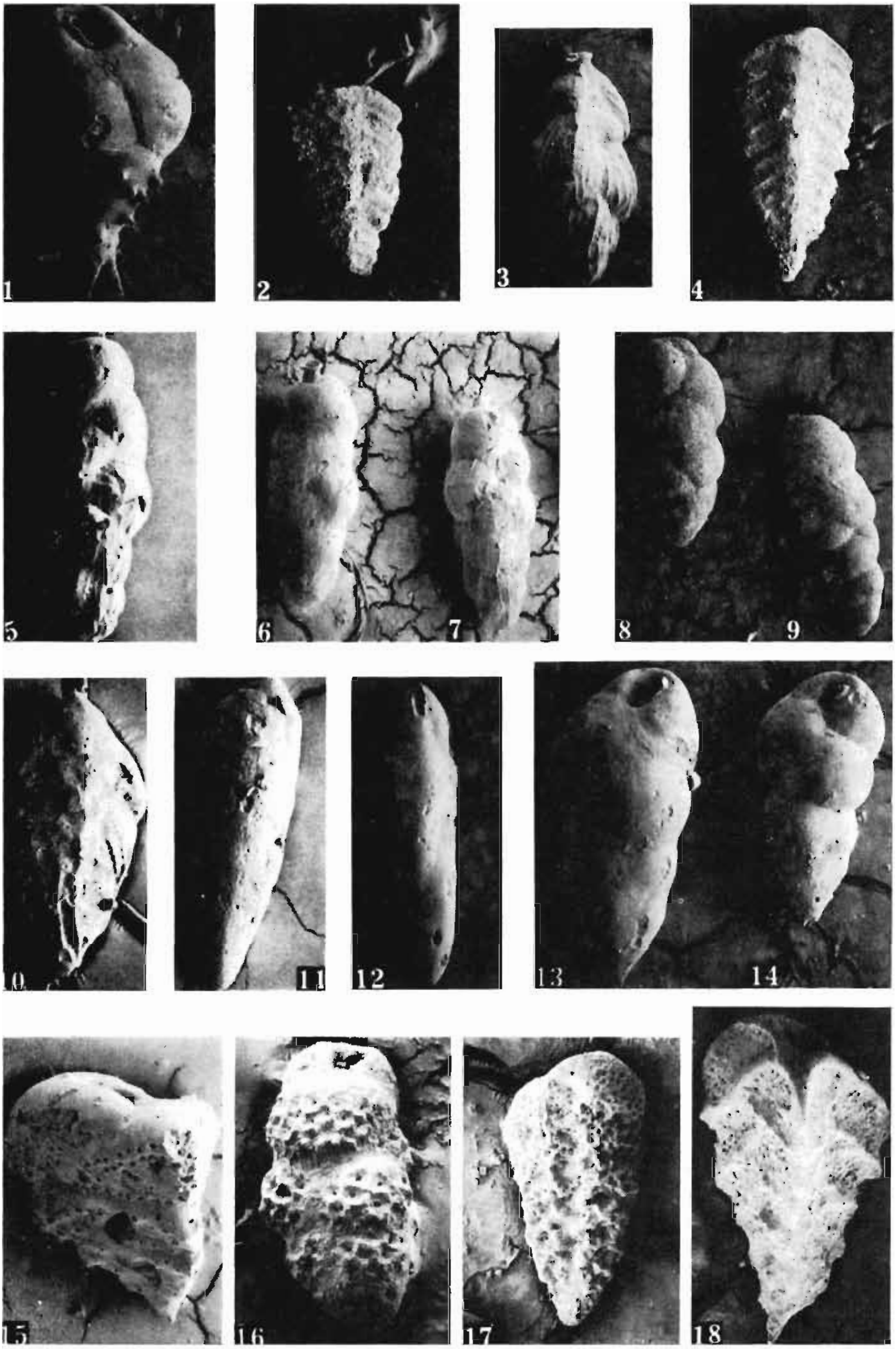

1
2
3
4a
4b
5
6
7
8
9
10
11

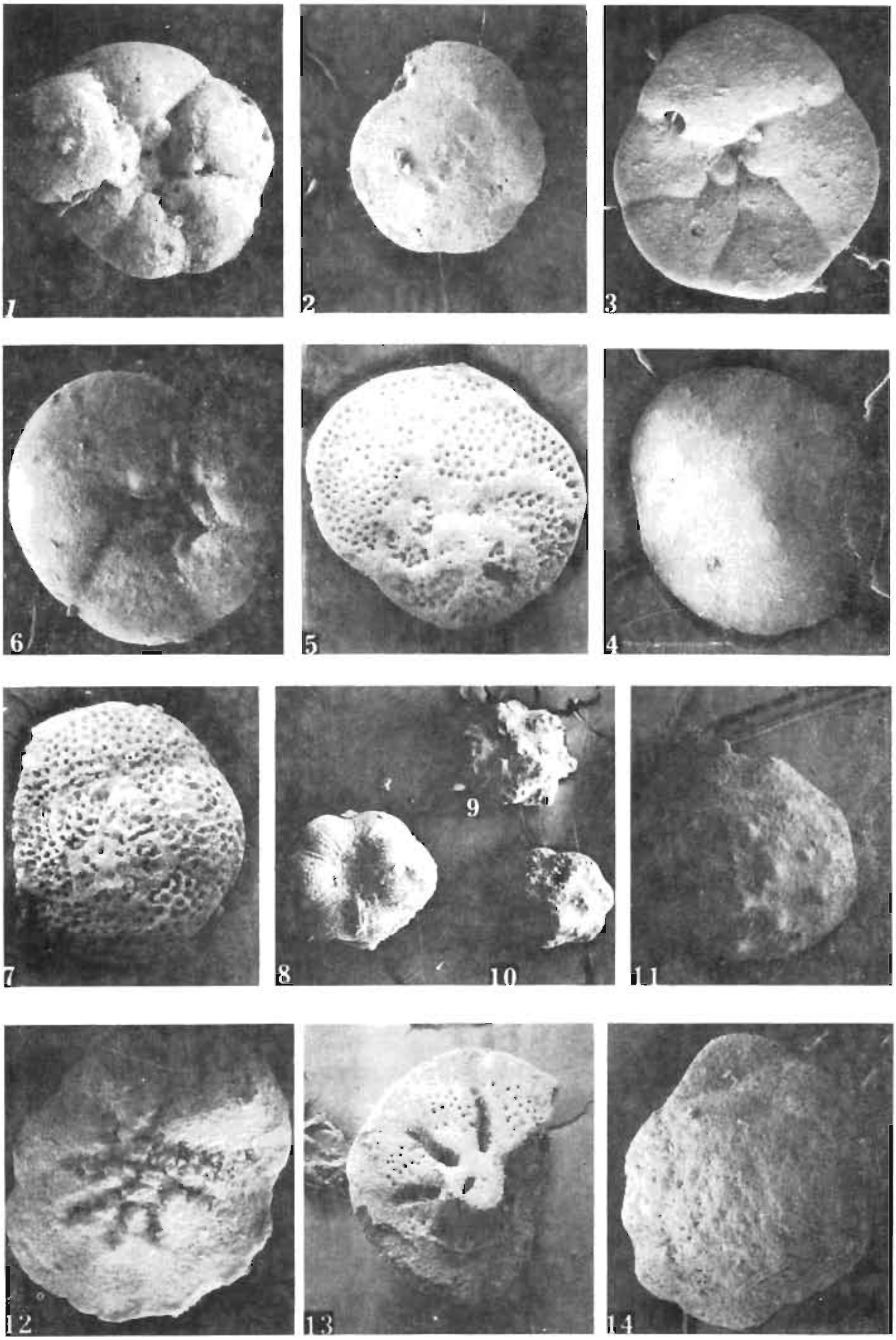

1
2
3
4a
5
4b
6
7
8
9
10
11

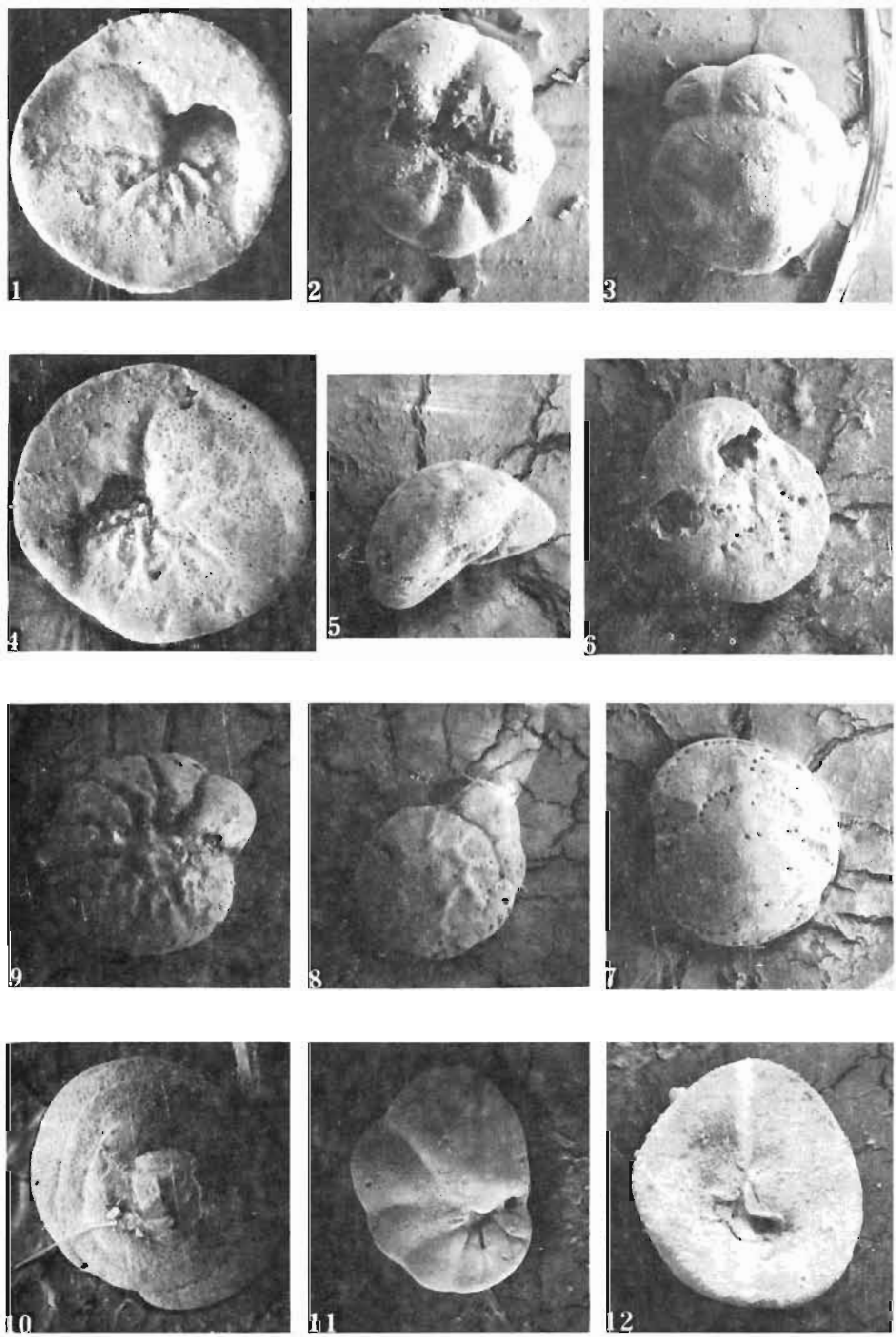


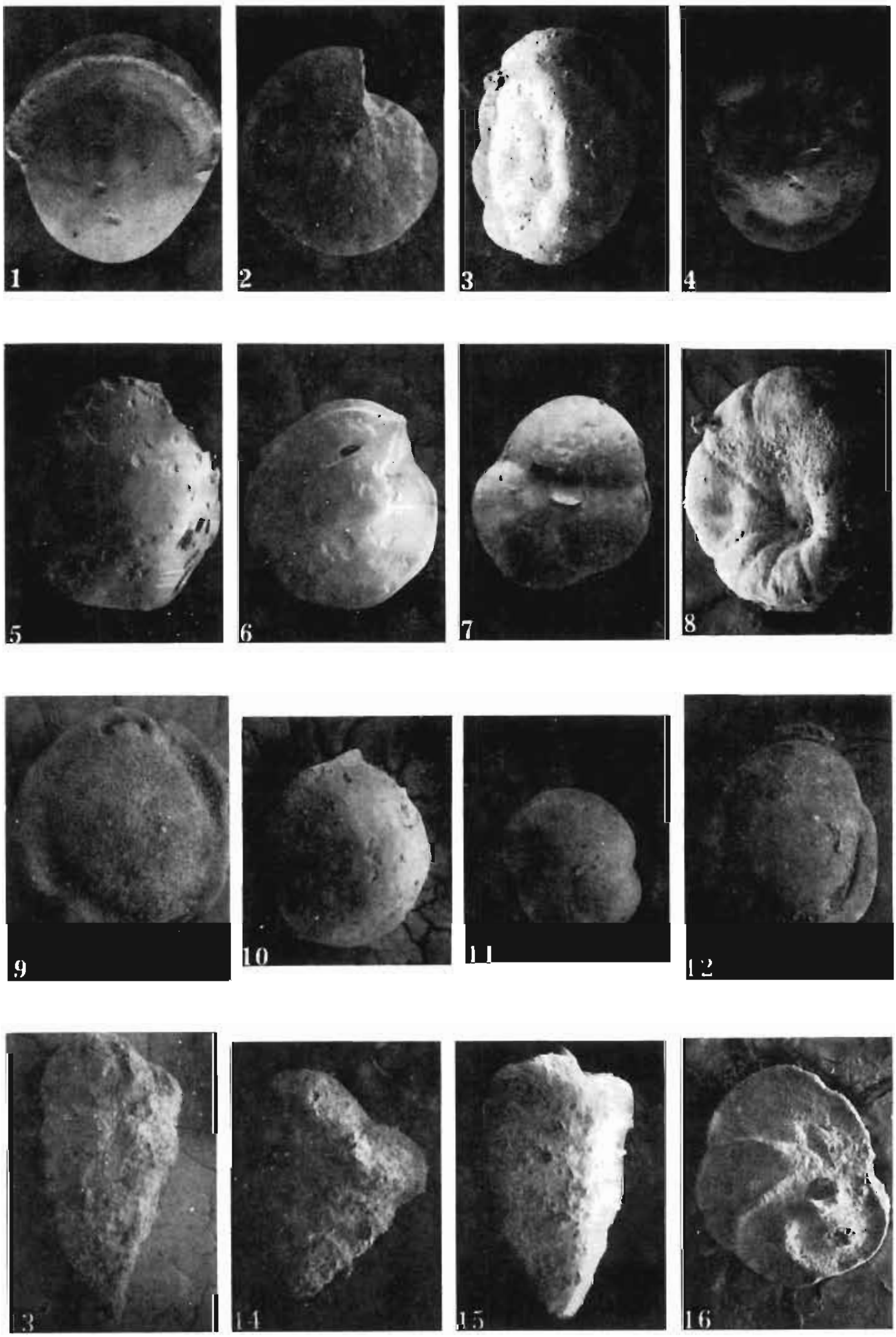

1
2
3
4
5
6
9
8
7
10
11
12
13
14
15

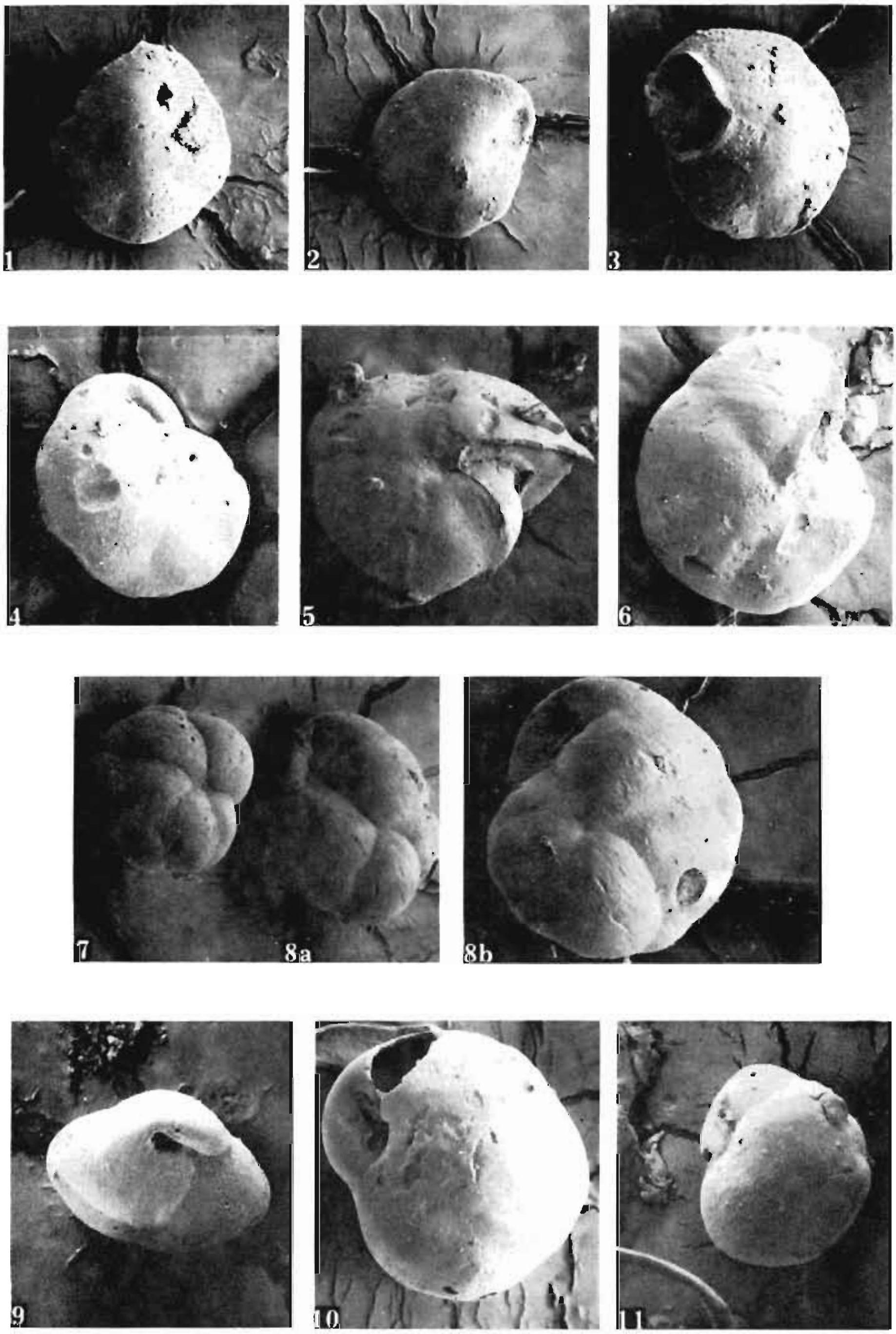

1
2
3
5
6
7
8
9
10
11
12
13a
13b

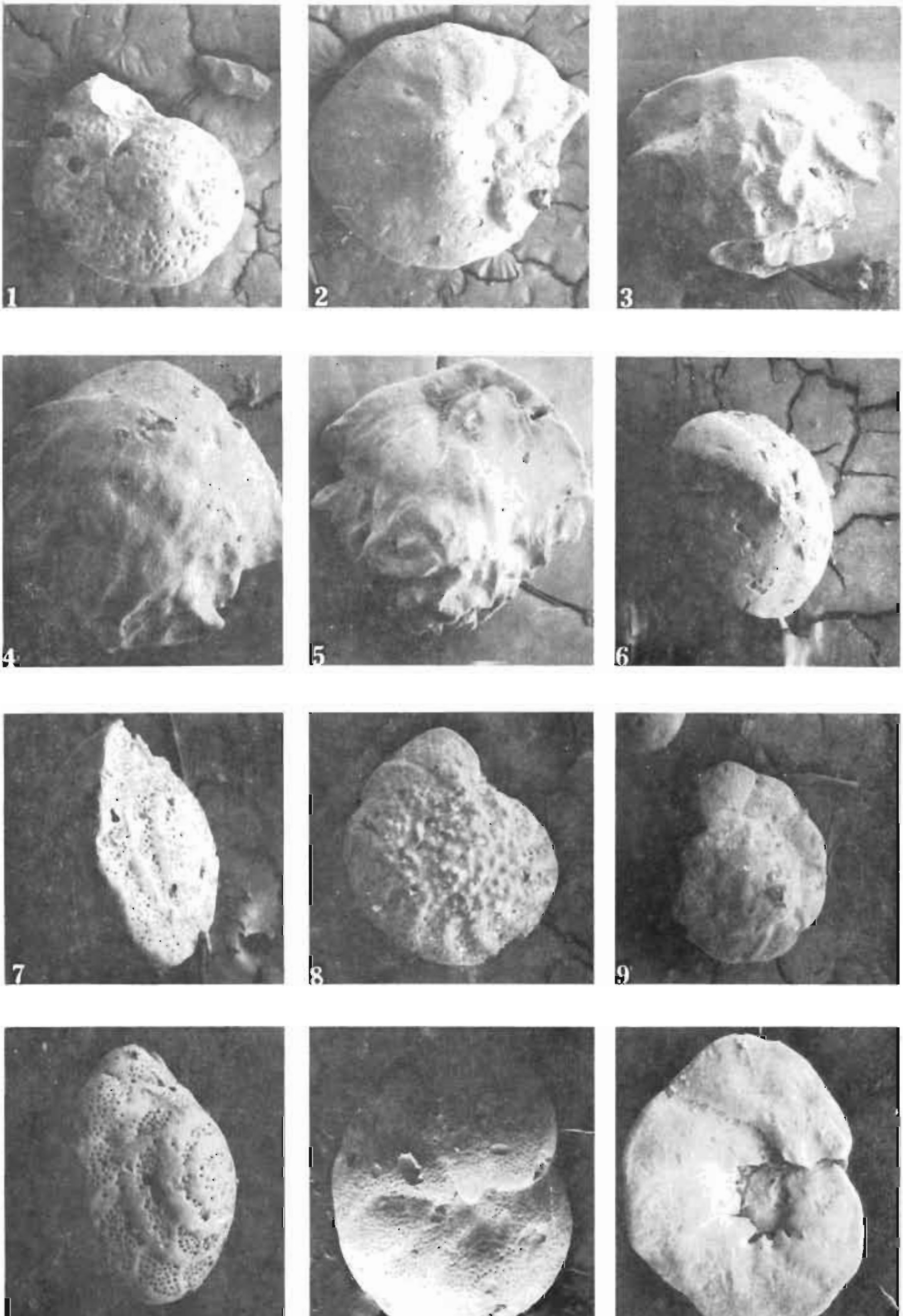

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18

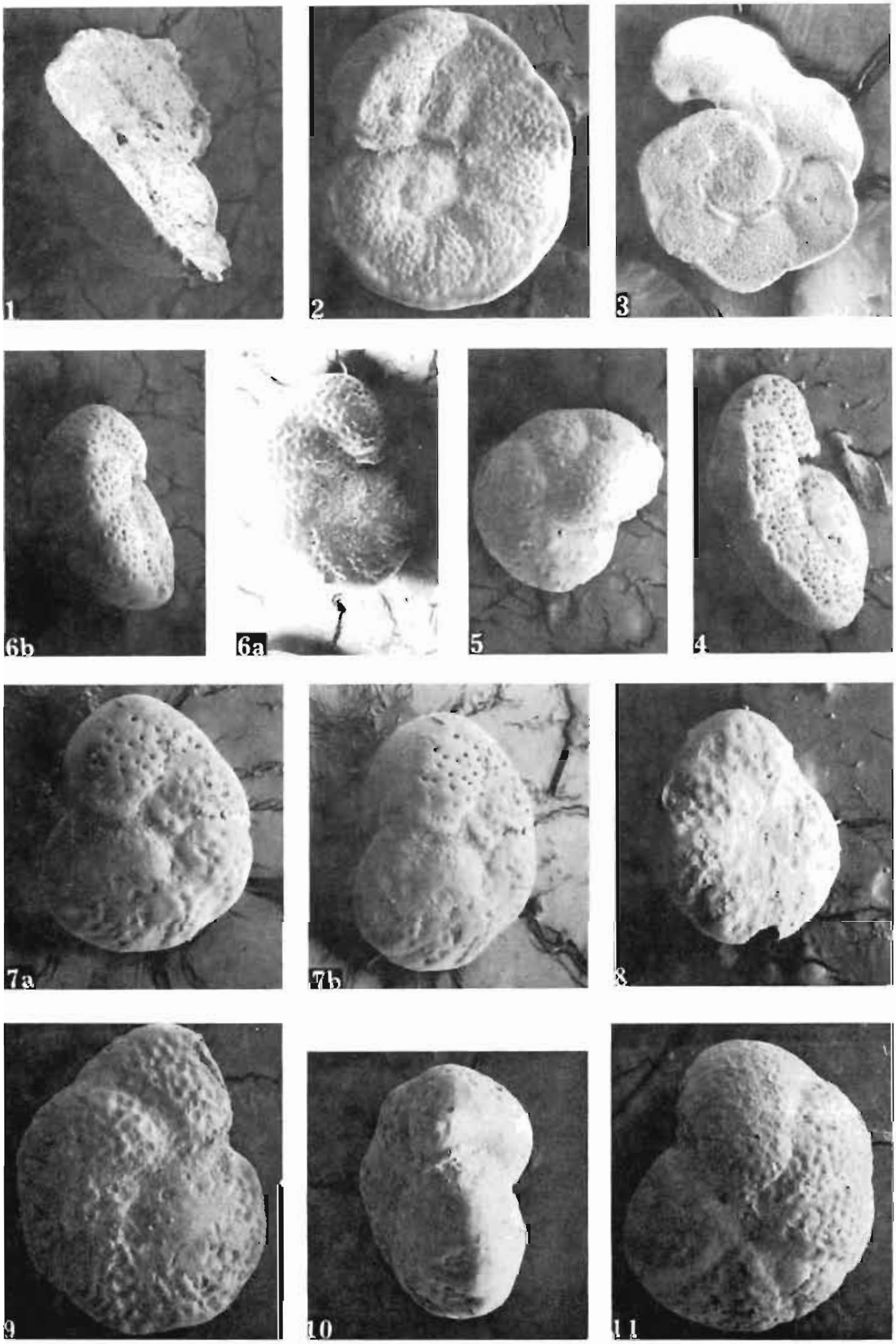

1
2
3
6
5
4
7
9
8
10
11
12
13
14

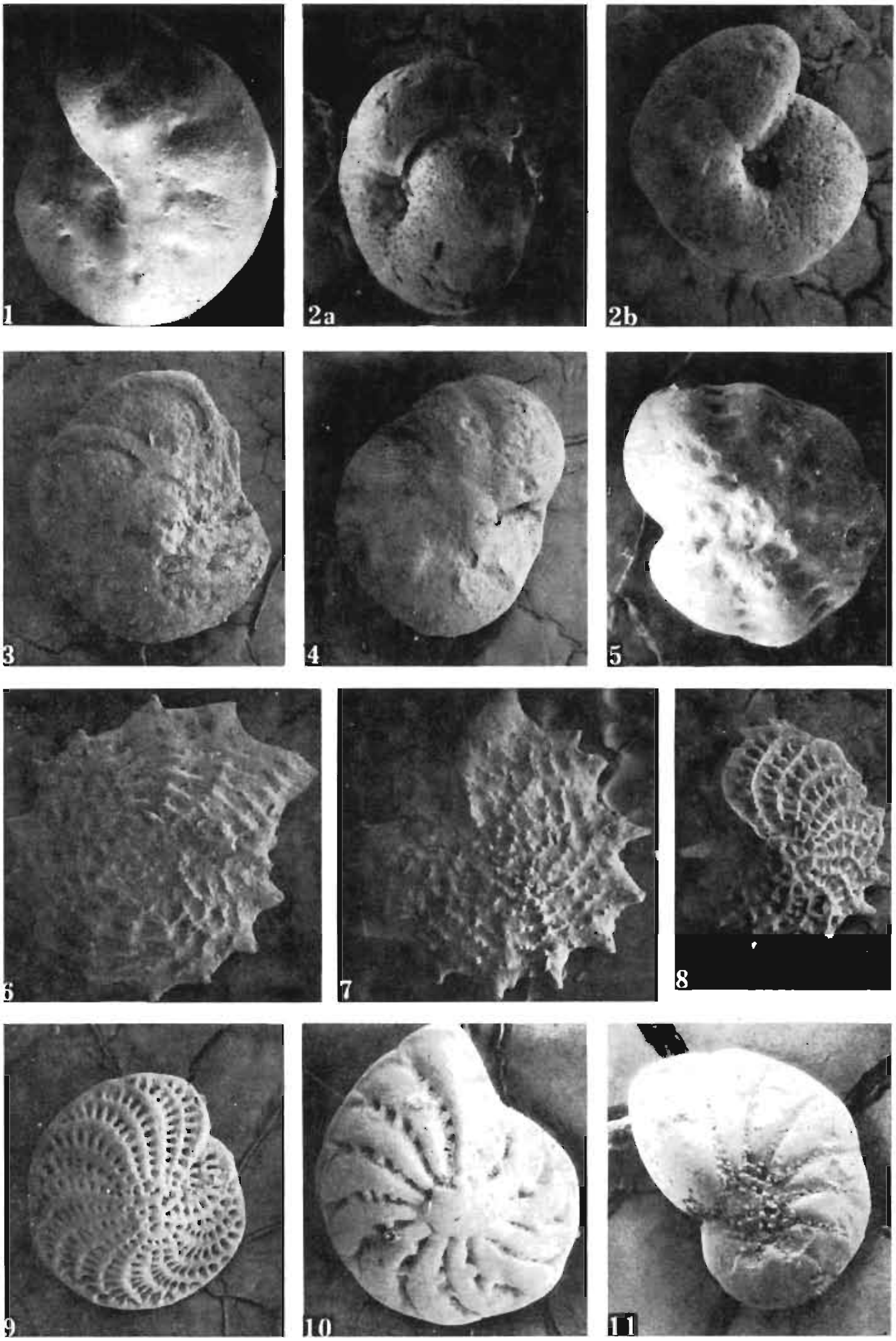

1
2
3
4
5
6
9
8
7
10
11
12

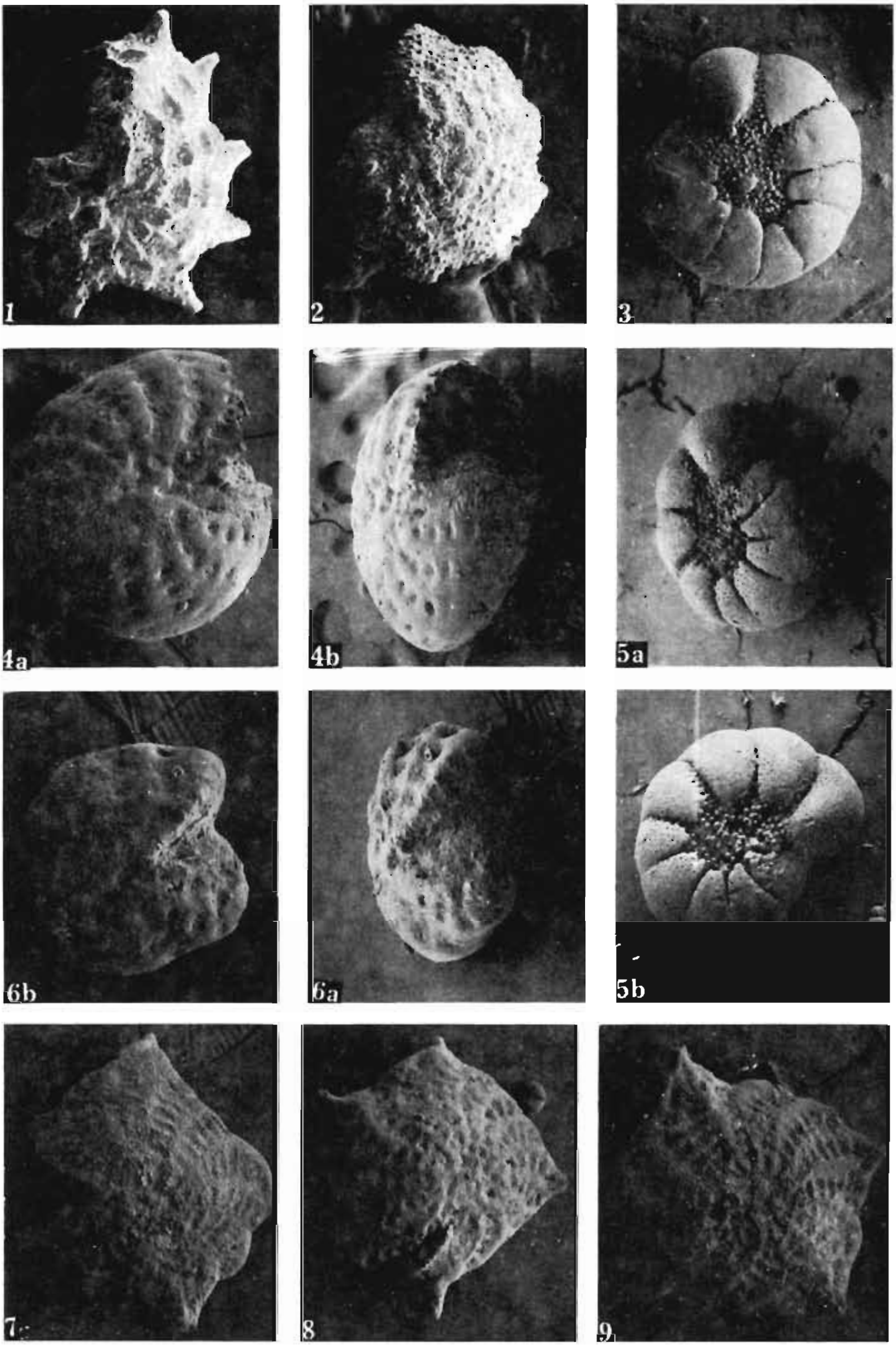

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

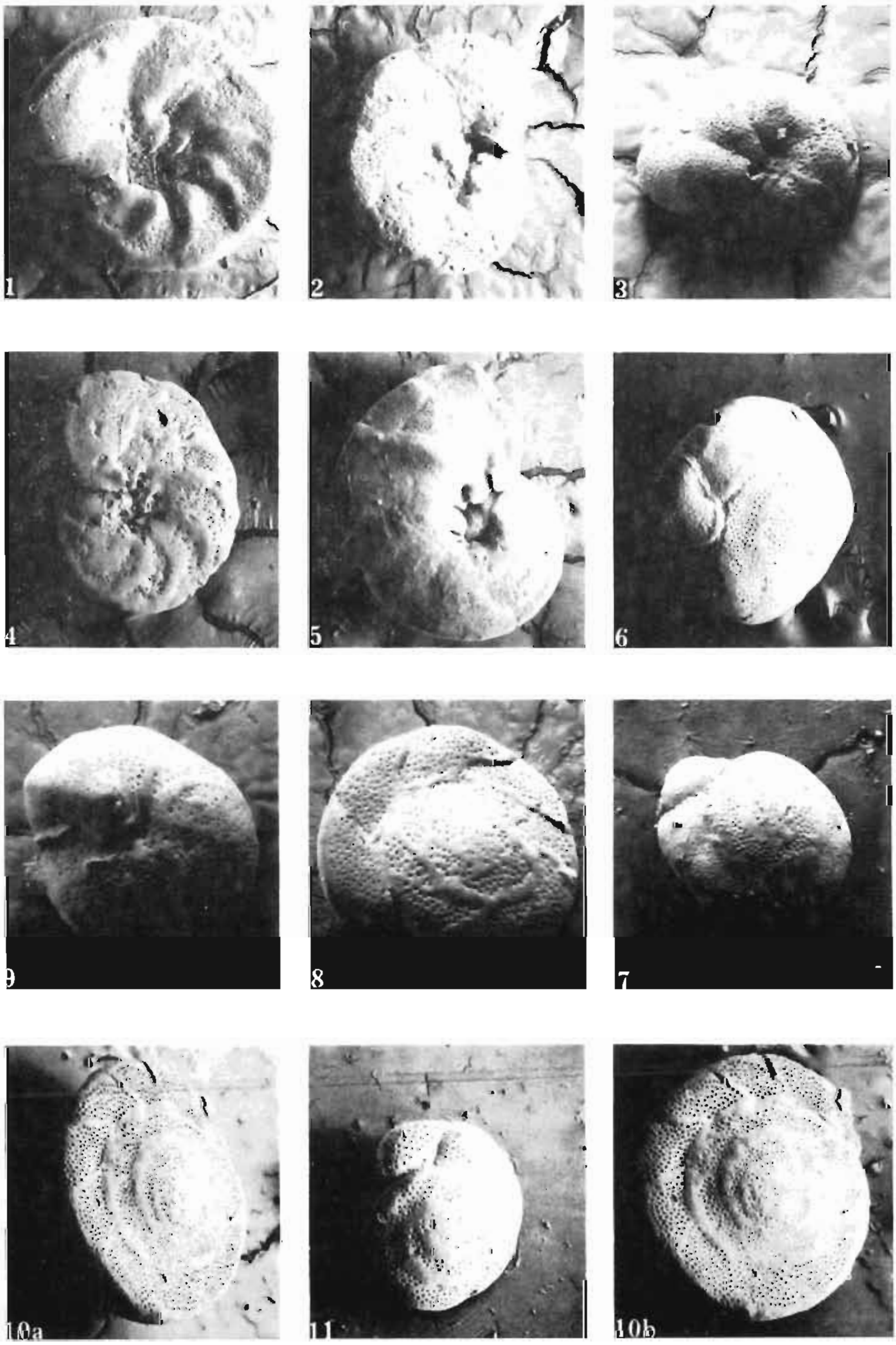

1
2
3
4
5
6
7
8a
8b
9
10
11


1
2
3
4
5
6
7
8
9
10
11
12


1
2
3
6b
6a
5
4
7a
7b
8
9
10
11


1
2a
2b
3
4
5
6
7
8
9
10
11


1
2
3
4a
4b
5a
6b
6a
5b
7
8
9


1
2
3
4
5
6
9
8
7
10a
11
10b