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VIRŠUTINĖS KREIDOS BIOSTRATIGRAFINIS SUSKIRSTYMAS PLANKTONINIŲ FORAMINIFERŲ DUOMENIMIS (LIETUVA)

Daktaro disertacijos santrauka
Fiziniai mokslai, geologija (05 P)

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The dissertation will be defended at the public meeting of the Council of Scientific Field of Geology in the the Legislative Hall of Institute of Geology and Geography at 15 a.m. on February 15, 2011.

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A copy of the doctoral dissertation is available for review at the Libraries of Vilnius University and Institute of Geology and Geography.

Introduction

Planktic foraminifera is a group of marine, single-celled protists that shield their cytoplasm within a secreted calcareous ($CaCO_3$) skeleton. The preservation and accumulation of foraminifera tests within marine sediments yields a long and valuable fossil record. Fossilized tests of foraminifera are used to determine faunal succession on a refined scale, each biostratigraphic unit (biozone) being a geological stratum that is defined on the basis of its characteristic fossil taxa (Loeblich and Tappan; 1988; McGowran, 2008).

Also calcareous fossil foraminifera are formed from elements found in the ancient seas they lived in. Thus they are very useful in paleoclimatology and paleoceanography. They can be used to reconstruct paleoclimate by examining the stable isotope ratios of oxygen, and the history of the carbon cycle and oceanic productivity by examining the stable isotope ratios of carbon. Geographic patterns seen in the fossil records of planktic foraminifera are also used to reconstruct ancient ocean currents. Because certain types of foraminifera are found only in certain environments, they can be used to figure out the kind of environment under which ancient marine sediments were deposited (McGowran, 2008).

Planktic foraminifera are thought to be one of the most suitable groups for local, regional and intercontinental stratigraphic correlations, because of their wide geographic occurrence, abundance and relatively fast rate of evolution (Loeblich and Tappan; 1988).

Upper Cretaceous sedimentary rocks are found in boreholes along the southern and the southwestern parts of Lithuania. Marine terrigenous and carbonatic sediments characterize this section (Grigelis, 1994).

The marine basin invaded Lithuania in Late Albian and lasted throughout Late Cretaceous. It was a part of a widespread European marine transgression developed from the southwest. The sea level changes had an important significance to the distribution and evolution of planktic foraminifera (Grigelis, 1994).

Relevance of study. Planktic foraminifera were studied poorly in Lithuania. There are a few species of Upper Cretaceous mentioned in publications. The beginning of the research of Late Cretaceous planktic foraminifera started in 1957 by S. Abramavičiūtė – Garunkštienė and later were continued by A. Grigelis starting from 1961's but he worked more with benthic foraminifera (Григялис, Любимова, Рыгина, 1961; Григялис, 1962; 1963; Григялис, Гарункштене, 1966; 1970; Григялис, Акимец, Липник, 1974; Григялис, 1976). He distinguished biozones in the Upper Cretaceous of Lithuania on the basis of benthic foraminifera (Григялис, 1962; 1963).

The good taxonomical analysis of planktic foraminifera will let to make biostratigraphical zonation of Upper Cretaceous rocks of Lithuania. Taxonomical and biostratigraphical information of Upper Cretaceous planktic foraminifera from Lithuania generally would be important because this territory was a shallow marginal part of the Tethys ocean.

Object of study. The Upper Cretaceous planktic foraminifera fossils are abundant in the territory of Lithuania. At the beginning of the transgression in Albian time the marine basin in Lithuanian territory was shallow (up to 50 m deep) and progressively the depth increased up to 200-500 m. Newly formed deep-water niches allowed to spread new planktic foraminifera species in this epicontinental basin (Grigelis and Leszczynski, 1998).

Study area. The Upper Cretaceous sedimentary rocks composed of terrigenous and carbonatic sediments are distributed in the southern and southwestern Lithuania. The continental regime prevailed until the middle Albian and ended when new tectonic submergences began in the Polish - Lithuanian Depression. A widespread marine transgression developed from the southwest and the sea had to occupy the area as far as the present Lithuania – Latvia border (whole northeastern part of Lithuania was eroded by glaciers in Quaternary). As a result an epicontinental comparatively shallow marine basin was formed and maritime regime lasted uninterruptedly during the whole Late Cretaceous (Grigelis, 1994).

The subject of study. The main subject of the present study is to establish Upper Cretaceous (Cenomanian - Maastrichtian) biostratigraphic zones and to reconstruct paleogeographic conditions on a basis of planktic foraminifera in Lithuania. Also it is important to document the assemblages of planktic foraminifera.

The objective of the thesis are:

- to evaluate the taxonomic variety of planktic foraminifera;
- to correlate Upper Cretaceous benthic and planktic foraminifera zones in Lithuania;
- to compare and identify the taxonomical differences between foraminiferal assemblages from the open basin and from the shallower marginal part (Lithuania) of the Tethys.

Thesis statements:

- planktic foraminifera was quite abundant and widespread in Late Cretaceous shallow basin in recent Lithuania territory.
- the taxonomical composition of planktic foraminifera is characteristic for shallow basins or littoral foraminiferal assemblages. The changes in species variety are related to ever changing conditions in the studied basin.
- the planktic foraminiferal faunal composition reflects basin development cycles (transgression, regressions).
- zones and zonal complexes in Lithuania correlate with other boreal realm regions zones and zonal complexes.

Significance of the research. Most of planktic foraminifera species found in Upper Cretaceous sedimentary rocks of Lithuania were described for the first time.

Planktic foraminifera of the Upper Cretaceous rock units from Lithuania have been investigated in order to establish a biostratigraphic subdivision of this time interval. Total abundance and diversity of planktic foraminifera vary from rare to high and preservation is poor to moderate due to lithologic variation. Planktic foraminiferal zonation from bottom to top of the studied succession consists of zones defined by *Praeglobotruncana stephani*, *Whiteinella archaeocretacea*, *Helvetoglobotruncana helvetica*, *Marginotruncana coronata*, *Dicarinella primitiva*, *Dicarinella concavata*, *Dicarinella asymetrica, Globotruncana linneiana, Rugotruncana subcircumnodifer* and *Abathomphalus mayaroensis*. Planktic foraminiferal zonation have been corelated with the benthic foraminifera zonation established by A. Grigelis (1963) in the same successions. Hence an integrated zonation scheme composed of planktic foraminifera and benthic foraminifera was created. That has allowed a detailed stratigraphy of these successions to be erected.

Extent and structure of the dissertation. The PhD thesis consists of introduction, three chapters, conclusions, a list of references and a list of publications on the thesis subject.

The collection of prof. A. Grigelis (32 boreholes) and 407 rock samples from other 17 boreholes were used for the research. Rock samples were prepared using disaggregation techniques (e.g., the ‘Solvent Method' described by Brasier (Armstrong and Brasier, 1980). The result was 380 samples for fauna separation. 37 species of planktic foraminifera were identified and described from these samples. Descriptions and SEM photos are presented in the appendix (1-7) of this paper.

10 planktic foraminifera zones were distinguished in Upper Cretaceous after elaborating of foraminifera fossils. 13 crosscections with distribution of species and benthic/planktic zones correlation were done as well.

Approbation of the dissertation. The result of this study was presented in the international conference “7th Micropalaeontological Workshop MIKRO-2009” (Św. Katarzyna, Poland, 28-30 September 2009). The poster „Planktonic foraminiferal assemblages and biostratigraphy of Upper Cretaceous in Lithuania“ was presented there.

Preliminary results were presented in LMA young scientists conference „Bioateitis: gyvybės ir geomokslų perspektyvos"(Academy of Science, 5 December 2008) as well. Oral report “Viršutinės kreidos biostratigrafinis suskirstymas remiantis planktoniniais foraminiferais” was presented there.

Participation in “SYNTHESYS” (2007 06 24 - 2007 07 21) program was important for the studies. “SYNTHESYS” project title „Taxonomic investigation of Upper Cretaceous (Cenomanian - Coniacian) planktonic foraminifera (Tethys Realm)”. It was hosted by The Museum national d'Histoire naturelle (MNHN) in Paris. The possibility to access to the collections of MNHN, various facilities and consultation of experts let to describe species from Lithuania more precisely. As a result of good taxonomical analysis better biostratigraphical zonation of Upper Cretaceous rocks of Lithuania was made. Taxonomical and biostratigraphical information of Upper Cretaceous planktic foraminifera from Lithuania was interesting because little was known about this was shallow marginal part of the Tethys.

During the training in “SYNTESYS” program collections of Upper Cretaceous planktic foraminifera of five great scientists were studied. Scanning electron microscope (SEM) photos of Lithuanian planktic foraminifera fossils were made there as well.

Two publications about this study were presented. One was published in *Geologija* (Venckutė–Aleksienė, 2005). Another is approved for publication in journal *Geologija*.

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1. Review of earlier research

Lithuania. The firts publications about Cretaceous system in Lithuania were done in the second half of XIX century. C. Grewingk (1872) dated sedimentary rocks as Senonian age on a basis of fossils. A. Giedroyc (1895) discovered new outcrops in Nemunas and Merkys rivers valleys and made a map of Cretaceous distribution (Гедроиц, 1895). Another significant contribution in to understanding of Cretaceous time deposits was studies of M. Kaveckis (1931), J. Dalinkevičius (1934) and J. Kisnėrius (1957). J. Dalinkevičius presented the first biostratigraphical subdivision of Cretaceous in Lithuania (Dalinkevičius, 1934; 1935).

Micropalaentological studies of Upper Cretaceous was started by G. Jūrėnaitė. Later studies allowed to distinguish Upper Cretaceous stages (Paškevičius, 1994). J. Dalinkevičius (1947; 1952) after new abundant boreholes data was available made geological maps where he distinguished Lower Cretaceous and subdivided Upper Cretaceous in to Cenomanian, Turonian, Coniacian, Santonian, Campanian and Maastrichtian stages. Later more studies were done by A. Vienožinskienė (1963) on Cretaceous spores and polen, as well macrofossils as shark teeth Mertinienė (1976; 1978) (Веножинскене, 1963; Мертинене, Григялис, Веножинскене, 1976; Мертинене, 1978).

Cretaceous planktic foraminifera are studied poorly in Lithuania. According publications 21 species were found and only a few boreholes (Meilės sala-275, Drucminai-63) of Southeastern Lithuania were investigated (Григялис, Кузнецова, Горбачик, 1988; Grigelis, 1994). The most studied are Late Cretaceous benthic foraminifers. The first discovery of foraminifera from the Cretaceous of Lithuania was made by S. Abramavičiūtė - Garunkštienė (Garunkštienė 1957, Гарункштене, 1960), who reported several bentic and planktic species *Anomalina cenomanica* Brotzen, *A. berthelini* Keller, *Cibicides jarzaevae* Vassilenko, *Globigerina cretacea* d'Orb., *Arenobulimina presli* Reuss, *A. sabulosa* (Chapman), *Gaudryina* sp., *Cristellaria* sp. The author points out that the Cenomanian foraminifers are not rich and numerous in Lithuania. In later publication S. Garunkštienė (1960') lists these typical Cenomanian foraminifers: *Guembelitria cenomana* (Kell.), *Rotalipora appenninica* (Renz), *Anomalina cenomanica* Brotzen, *A. baltica* Brotzen, *A. globosa* Brotzen, *Cibicides jarzaevae* Vassilenko. Species like *Bolivinita eouvigeriniformis* Kell., *Anomalina berthelini* Kell. were found sporadicly.

A. Grigelis (1962; 1963; 1971; Григялис, Киснерюс 1982) divided Cretaceous sediments in peribaltic on the basis of foraminiferal research data. The biostatigraphic scheme, sedimentation and palaeogeographic schemes of Upper Cretaceous foraminifera were presented as well (Grigelis, 1994). Biostratigraphical zones have been determined of Cenomanian – Coniacian strata in Lithuania on a basis of benthic foraminifera (Grigelis, 1994, 1996).

All over the world. D’Orbigny (1802-1857) was the first to present classification of foraminifera. He recorded those of the various geologic series in France in the early 19^{th} century, but elsewhere interest soon turned toward the taxonomic description and illustration of the morphological detail of the abundant and exquisite tiny shells (Vénec-Peyré, 2004). English biologist, comparative anatomist and paleontologist Sir Richard Owen (1804-1892) was the first to figure out that part of foraminifera are planktic (Owen, 1867). It was thought that foraminifera are exclusively sea-floor dwellers before. S. R. J. Owen described several species that belongs to genus Globigerina, Orbulina, Pulvinulina (Ggloborotalia). The discovery that planktic foraminifera exist was ignored for some time and only after *Challenger expedition* (1872-1876) most of researchers agreed that planktic foraminifera exists as evidence were routinely gathered in the surface waters during expedition (Be, 1977).

J. A. Cushman (1927) introduced the genus Globotruncana into which until the early 1940's all trochospiral, single and double keeled Cretaceous planktic species were placed (Caron, 1985).

It was only in the twenties and thirties of 20^{th} century that the planktic foraminifera began to be studied in detail. Another significant contribution was of W. Schott (1935). He made the first quantitative study of planktic foraminifera in waters as well as in the surface sediments of the equatorial Atlantic (*Meteor Expedition* 1925-1927). He was able to determine the regional variations in abundance of individual species of planktic foraminifera, the ranges of their depth habitats, and the similarities and differences in the distribution patterns of life and death assemblages (Be, 1977). Hans E. Thalmann was the first to point out in 1934 the stratigraphic significance of the genus Globotruncana and its species (Thalmann, 1934).

Many more scientists followed: Plummer (1931, United States), Brotzen (1934, 1936, 1942, 1945, 1948, Sweeden), Marie (1938, 1941, France), Ten Dam (1946, 1947, 1948a, b, c Netherlands), William Mitchell (1948, United Kingdom), Bartenstein (1948, 1962, 1965 Germany), Berggren (1962, Sweeden), McGugan (1957, United Kingdom), Loeblich and Tappan, (1961, 1964, United States), Eicher (1965, 1966, 1967, United States), Goel (1965, France) and Magniez Jannin (1975, France), Gawor–Biedowa

(1972, Poland), Klaus (1960 Switzerland) and Caron (1966, 1981, Switzerland), Neagu (1965, 1970, 1972 a, b, Romania), Douglas and Rankin (1969, United States), Norlig (1973, Sweeden), Peryt (1980, Poland).

One of the most significant works on planktic foraminifera is the *"Atlas de Foraminiferes planctoniques du Cretace Moyen (Mer boreale et Tethys)"* Robaszynski and Caron (1979 a, b). This atlas was a basis of the species recognition in my studies.

2. Methodology

2.1. Preparation of samples

Rock samples were prepared using disaggregation techniques - the 'Solvent Method' described by Brasier (Armstrong and Brasier, 1980).

To extract tests from sediments few steps may be involved. In the case of consolidated sediments, the sample must be disaggregated, washed and the foraminiferal tests separated from the sediments.

At the beginning it is necessary to disaggregate sample, if it consists of consolidated sediments. The rock should be crushed to small fragments by hitting it whit a hammer. Weakly cemented sediments can be disaggregated by soaking it in water. Boiling the water sometimes aids this process. Boiling also serves to clean the specimens partially.

The foraminifera may be removed from the partially disaggregated material by a variety of different methods: Soda, Crystallization, Hydrogen peroxide, Gasoline.

Soda method (Armstrong and Brasier, 1980) was used for this study. 100 g the rock sample was placed in non-aluminium container (1l) and adding 800ml distilled water mixed with spoonful of Na_2CO_3. This mixture then is boiled one to three hours.

The sample is placed in a 5 l beaker after being boiled and agitated with watter. The mixture is poured away approximately after 5 second of keeping it still and leaving only sediments.

The washed sample is placed in a porcelain plate and left to dry in the air or in an oven.

Dried sample should be sieved using 1,0 mm and 0,16 mm aperture diameter sieves leaving only the fraction that is in between these two sieves.

Binocular must be used to separate tests from the sediment, mounting it on slides and making taxonomical determination. The sample is spread in a single layer on an extraction tray then under the microscope specimens are picked up using a brush o a needle.

2.2. Biostratigraphy

Biostratigraphic units (biozones) are bodies of strata that are defined or characterized on the basis of their contained fossils. Biostratigraphic units exist only where the particular diagnostic feature or attribute on which they are based has been identified (International Stratigraphic Guide, 1994).

Biostratigraphic units are distinct from other kinds of stratigraphic units in that the organisms whose fossil remains establish them show evolutionary changes through geologic time that are not repeated in the stratigraphic record. Five main formal types of biozone can be designated: *assemblage zone, range zone, interval zone, lineage zone, abundance zone* (International Stratigraphic Guide, 1994).

Procedures for establishing Biostratigraphic Units (International Stratigraphic Guide, 1994). It is recommended that the definition or characterization of a biostratigraphic unit include the designation of one or more specific reference sections that demonstrate the stratigraphic context of the taxon or taxa diagnostic of the unit.

Procedures for extending Biostratigraphic Units - Biostratigraphic Correlation (International Stratigraphic Guide, 1994). Biostratigraphic units are extended away from the areas where they were defined or from their reference sections by biostratigraphic correlation, which is the establishment of correspondence in biostratigraphic character and position between geographically separated sections or outcrops based on their fossil content. Biostratigraphic correlation is not necessarily time-correlation.

It may approximate time correlation, or it may be the identification of the same biofacies, which may be diachronous.

Naming Biostratigraphic Units (International Stratigraphic Guide, 1994). The formal name of a biostratigraphic unit should be formed from the names of one, or no more than two, appropriate fossils combined with the appropriate term for the kind of unit in question. The function of a name is to provide a unique designation for the biozone.

The printing of fossil names for stratigraphic units should be guided by the rules laid down in the International Code of Zoological Nomenclature or the International Code of Botanical Nomenclature. The initial letter of the unit-term (Biozone, Zone, Assemblage Zone) should be capitalized as well as that of the generic names; the initial letter of the specific epithets should be in lowercase; taxonomic names of genera and species should be in italics, for example *Exus albus* Range Zone (Lietuvos stratigrafijos vadovas, 2002).

2.3. Foraminifera classification

Traditionally, classification of foraminifera has been based primarily on characters of the shell or test. Wall composition and structure, chamber shape and arrangement, the shape and position of any apertures, surface ornamentation, and other morphologic features of the shell are all used to define taxonomic groups of foraminifera. New research is adding molecular data on relationships among species that may greatly affect how these organisms are classified.

The following classification is used in this work (Sen Gupta, 2002; Brands, 1989-2005 [interactive]):

Biota

DOMAIN **EUKARYOTA** Whittaker and Margulis, 1978

KINGDOM **PROTOCTISTA** Hogg, 1860

PHYLUM **GRANULORETICULOSA** Lee, 1990

CLASS **FORAMINIFERA** Eichwald, 1830

ORDER **ALLOGROMIDA**

ORDER **ASTRORHIZIDA**

ORDER **TEXTULARIDA**

ORDER **ROBERTINIDA**

ORDER **CARTERINIDA**

ORDER **SPIRILLINIDA**

ORDER **MILIOLIDA**

ORDER **LAGENIDA**

ORDER **ROTALIIDA**

ORDER **GLOBIGERINIDA**

Globigerinida is the only one planktic order of Foraminifera. They produce hyaline calcareous tests and are known as fossils from the Jurassic period onwards. The group has included more than 100 genera and over 400 species, of which about 30 species are extant (Sen Gupta, 2002).

Planktic foraminifera classification based on their chamber arrangement. They are grouped into order Globigerinina and in the four superfamilies:

1. Superfamily Planomalinacea
2. Superfamily Rotaliporacea
3. Superfamily Globotruncanacea
4. Superfamily Heterohelicacea

The planispiral forms are included in the Planomalinacea with generic distinctions based largely on apertural features and chamber shape (Sen Gupta, 2002).

By far the most dominant group of Cretaceous planktic foraminifera are those with a trochospiral chamber arrangement. Most of them are placed in the Superfamily Globotruncanacea. All genera included here are thought to have been derived from Hedbergella, the oldest and most primitive of the genera (Plankton Stratigraphy Vol. 1., 1989).

3. Material of study

Samples were collected from the following 17 boreholes (Varnupiai - 445; Baltašiškė – 267; Paversekis – 59; Salapieraugis – 451; Punios šilas – 315; Neravai – 453; Sūkuriai – 1; Viešvilė – 11; Žigaičiai – 7; Žalgiriai – 1; Simnas – 3; Rokai – 2; Pašiliškiai – 17; Punia – 4; Garliava – 9; Kybartai – 14) (***Fig. 1.***). Samples for micropalaeontological analysis are spaced approximately every 1 m. The result was 380 samples for fauna separation.

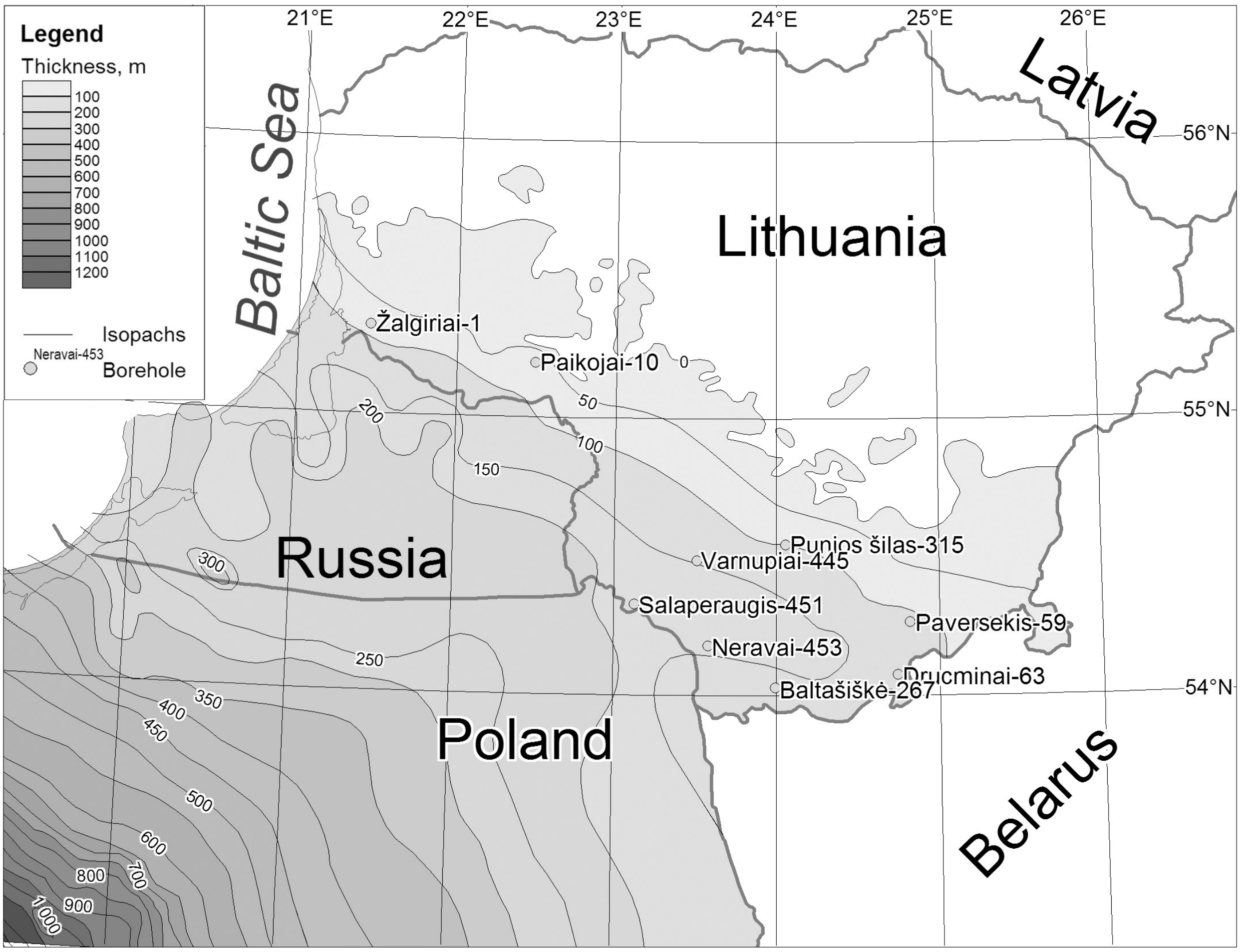

Fig. 1.Thickness map of Cretaceous (after Grigelis, Leszczynski, 1998) and studied boreholes.

4. Results

4.1. Foraminifera

The studied foraminiferal assemblages represent the earliest planktonic foraminiferal association found in Cenomanian stage. Planktonic foraminifera are quite poor and hedbergellids are dominant species at the beginning of Cenomanian. The diversity and quantity of planktonic foraminifera started to grow from middle Cenomanian. Then started to predominate genus *Whiteinella*. Also frequent are *Globigerinelloides ultramicra, G. caseyi, G. bentonensis, Heterohelix globulosa, H. moremani.*

Diversity and richness of the planktonic foraminiferal assemblages increase gradually in the overlying sediments, i.c. in the Turonian strata. These assemblages are characterized by the occurrence of one - keeled species *Helvetoglobotruncana helvetica, Praeglobotruncana gibba* and two – keeled species: *Dicarinella hagni, D. algeriana.* Samples from the Lower Turonian include *Whiteinella baltica* and *W. archaeocretacea.* Still are found long ranging species *Hedbergella delrioensis, H. simplex, H. planispira, Whiteinella brittonensis*. *Hedbergella hoelzli* is very rare in the Turonian samples. The amount of *Heterohelix globulosa* and *H. moremani* is very variable. Sometime these species represent up to 70-80% all specimens in the sample.

The Coniacian planktonic foraminiferal assemblage is rather similar to Upper Turonian. Main Turonian foraminifera genera persist in Coniacian foraminiferal associations. Principal difference between these assemblages is increased number of *Marginotruncana sp*. Coniacian planktonic foraminiferal association is represented by *Dicarinella hagni*, *D. algeriana*, *D. imbricata*, *D. asymetrica, Marginotruncana coronata*, *M. renzi*, *M. marginata*, *M. schneegansi*, *Archaeoglobigerina cretace*a.

The boundary between the Turonian and Coniacian is poorly defined because the planktonic foraminiferal assemblages of the Turonian and Coniacian strata are represented by long ranging species.

37 planktic formaminifera species were identified in studied Upper Cretaceous strata. Scanning electron microscope images of studied Upper Cretaceous planktonic

foraminifera are presented in the appendix (1-7) of this paper.

4.2. Foraminiferal zonation

It has been possible to distinguish 10 foraminiferal zones for Upper Cretaceous on the basis of the studied planktic foraminifera. These zones are of three types:

1. **Assemblage zone (AZ)**

The body of strata characterized by an assemblage of three or more fossil taxa that, taken together, distinguishes it in biostratigraphic character from adjacent strata. The boundaries of an assemblage zone are drawn at biohorizons marking the limits of occurrence of the specified assemblage that is characteristic of the unit. Not all members of the assemblage need to occur in order for a section to be assigned to an assemblage zone, and the total range of any of its constituents may extend beyond the boundaries of the zone. The name of an assemblage zone is derived from the name of one of the prominent and diagnostic constituents of the fossil assemblage (International Stratigraphic Guide, 1994).

2. **Interval zone (IZ)**

Interval zones defined as the stratigraphic section comprised between the lowest occurrence of two specified taxa ("lowest-occurrence zone") are also useful, preferably in surface work. The boundaries of an interval zone are defined by the occurrence of the biohorizons selected for its definition. The names given to interval zones may be derived from the names of the boundary horizons, the name of the basal boundary preceding that of the upper boundary (International Stratigraphic Guide, 1994).

3. **Range zone (RZ)**

The body of strata representing the known range of stratigraphic and geographic occurrence of specimens of a particular taxon. It is the sum of the documented occurrences in all individual sections and localities from which the particular taxon has been identified. The boundaries of a taxon-range zone are biohorizons marking the outermost limits of known occurrence in every local section of specimens whose range is to be represented by the zone. The boundaries of a taxon-range zone in any one section are the horizons of lowest stratigraphic occurrence and highest stratigraphic occurrence of the specified taxon in that section. The taxon-range zone is named from the taxon whose range it expresses(International Stratigraphic Guide, 1994).

The assemblage characteristic for each zone, comprises the following groups of species:

1. Species occurring in a given zone only;
2. Species appearing in a given zone and passing higher;
3. Species occurring in a given zone and lower;
4. Transit species, occurring both in a given zone and adjacent zones.

In addition, some species may occur in a part of a given zone only. For establishing the boundaries of zones only the first two categories of species were taken into account.

The species composition of assemblages is different in boreal zones compared with warm water zones of Tethys. Therefore, some zones characteristic of lower latitude is impossible to recognize. It was selected species for the zonal index, which are of wide geographic distribution and can be easily identified.

Biostartigraphic zones remarks.

13 crosscections with distribution of species and benthic/planktic zones correlation were done as well. One scheme of boreholes correlation and distribution of foraminiferal species is presented in appendix 8.

Following 10 planktic foraminifera zones were distinguished in Upper Cretaceous after elaborating of foraminifera fossils.

***Praeglobotruncana stephani* Zone** – rage zone (RZ)

Age: Lower – Middle Cenomanian.

Boundaries: interval, with widespread two taxon: *P. delrioensis* and *P. stephani* till the first *Whiteinella archaeocretacea* occurence.

Zonal species: *Hedbergella delrioensis, H. simplex, H. planispira*, *H. portsdownensis*, *Praeglobotruncana delrioensis*, *P. stephani*, *Whiteinella brittonensis*, *W. paradubia*, *Globigerinelloides bentonensis*, *G. caseyi*, *G. ultramicrus*. Genus Rotalipora is absent.

Correlation: *Praeglobotruncana stephani* Zone correlate with following zones: *Rotalipora globotruncanoides, R. reicheli, R. cushmani* in general zonation of Upper Cretaceous. Because of the lack of the zonal markers (Genus Rotalipora) in the Lower – Middle Cenomanian of Lithuania I attempted to find an acceptable substitute for the higher latitudes.

The *Praeglobotruncana stephani* Zone is correlated with the *Gavelinella cenomanica* Zone.

***Whiteinella archaeocretacea* Zone** – interval zone (IZ):

Age: Upper Cenomanian – Lower Turonian.

Boundaries: interval, with widespread taxon: *Whiteinella archaeocretacea* till the first *Helvetoglobotruncana helvetica* occurence.

Zonal species: *Hedbergella delrioensis*, *H. simplex*, *H. planispira*, *H. portsdownensis*, *Praeglobotruncana delrioensis*, *P. stephani*, *P. gibba*, *Whiteinella archaeocretacea*, *W. brittonensis*, *W. paradubia*, *W. baltica, W. aprica*, *Globigerinelloides ultramicrus*, *Dicarinella hagni*, *D. algeriana*, *Heterohelix moremani*.

Correlation: *Whiteinella archaeocretacea* Zone correlate with *Whiteinella archaeocretacea* Zone in general zonation of Upper Cretaceous. Also this zonal complex correlate with *Lingulogavelinella globosa* Zone.

***Helvetoglobotruncana helvetica* Zone** – range zone (RZ):

Age: Lower – Middle Turonian.

Boundaries: interval, with widespread taxon: *Helvetoglobotruncana helvetica.*

Zonal species: *Helvetoglobotruncana helvetica, Whiteinella baltica*, *W. archaeocretacea*, *W. brittonensis*, *W. aprica*, *Dicarinella hagni*, *D. algeriana*, *Heterohelix globulosa*, *Praeglobotruncana stephani*, *P. gibba*, *Hedbergella delrioensis*, *H. simplex*, *H. planispira*, *H. portsdownensis, H. hoelzli.*

Correlation: *Helvetoglobotruncana helvetica* Zone correlate with *Helvetoglobotruncana helvetica* Zone in general zonation of Upper Cretaceous.

The *Helvetoglobotruncana helvetica* Zone is correlated with the *Gavelinella vesca* Zone and *Gavelinella ammonoides* Zone.

***Marginotruncana coronata* Zone** – interval zone (IZ):

Age: Upper Turonian.

Boundaries: interval, with widespread taxon: *Marginotruncana coronata* till the first *Dicarinella primitiva* occurence.

Zonal species: *Marginotruncana coronata*, *M. marginata*, *Hedbergella delrioensis*, *H. simplex*, *H. planispira*, *H. hoelzl*, *Praeglobotruncana. Gibba, Whiteinella baltica*, *W. brittonensis, W. paradubia*, *W. archaeocretacea*, *W. aprica*, *W. inornata*, *Dicarinella imbricata*, *D. hagni*, *D. algeriana*, *Globigerinelloides ultramicra, Heterohelix moremani*, *H. globulosa*, *Archaeoglobigerina bosquensis*.

Correlation: *Marginotruncana coronata* Zone correlate with *Marginotruncana coronata* Zone in general zonation of Upper Cretaceous.

The *Marginotruncana coronata* Zone is correlated with the G*avelinella moniliformis* Zone.

***Dicarinella primitiva* Zone** – interval zone (IZ):

Age: Lower Coniacian.

Boundaries: interval, with widespread taxon: *Dicarinella primitiva* till the first *Dicarinella concavata* occurence.

Zonal species: *Dicarinella primitiva, D. imbricata, D. hagni*, *Hedbergella delrioensis*, *H. planispira*, *Whiteinella baltica*, *W. brittonensis*, *W. archaeocretacea*, *W. aprica, W. inornata*, *Marginotruncana coronata*, *M. marginata*, *M. renzi*, *M. schneegansi*, *Heterohelix globulosa, Globigerinelloides ultramicrus, Archaeoglobigerina cretacea*, *A. bosquensis*.

Correlation: *Dicarinella primitiva* Zone correlate with *Dicarinella primitiva* Zone in general zonation of Upper Cretaceous.

The *Dicarinella primitiva* Zone is correlated with the G*avelinella kelleri* Zone.

***Dicarinella concavata* Zone** – interval zone (IZ):

Age: Upper Coniacian.

Boundaries: interval, with widespread taxon: *Dicarinella concavata* till the first *Dicarinella asymetrica* occurence.

Zonal species: *Dicarinella concavata, D. primitiva, D. imbricata, Hedbergella delrioensis*, *Whiteinella baltica*, *W. brittonensis*, *W. archaeocretacea*, *W. aprica, W.*

inornata, *Marginotruncana coronata*, *M. marginata*, *M. renzi*, *M. schneegansi*, *Heterohelix globulosa, Globigerinelloides ultramicrus, Archaeoglobigerina cretacea*, *A. bosquensis.*

Correlation: *Dicarinella concavata* Zone correlate with *Dicarinella concavata* Zone in general zonation of Upper Cretaceous.

The *Dicarinella concavata* Zone is correlated with the *Gavelinella costulata* Zone.

***Dicarinella asymetrica* Zone** – interval zone (IZ):

Age: Santonian.

Boundaries: interval, with widespread taxon: *Dicarinella asymetrica* till the first *Globotruncana linneiana* occurence.

Zonal species: *Dicarinella asymetrica*, *D. concavata, D. imbricata, Hedbergella delrioensis*, *Whiteinella inornata*, *Marginotruncana coronata*, *M. marginata*, *M. renzi*, *M. schneegansi*, *Heterohelix globulosa, Globigerinelloides ultramicrus, G. bollii*, *Archaeoglobigerina cretacea*, *A. bosquensis, A. blowi*.

Correlation: *Dicarinella asymetrica* Zone correlate with *Dicarinella asymetrica* Zone in general zonation of Upper Cretaceous.

The *Dicarinella asymetrica* Zone is correlated with the *Gavelinella stelligera* Zone.

***Globotruncana linneiana* Zone** – interval zone (IZ):

Age: Campanian.

Boundaries: interval, with widespread taxon: *Globotruncana linneiana* till the first *Rugotruncana subcircumnodifer* occurence.

Zonal species: *Globotruncana linneina*, *G. arca*, *Dicarinella asymetrica*, *Marginotruncana coronata*, *Heterohelix globulosa, Globigerinelloides ultramicrus, G. bollii*, *Archaeoglobigerina cretacea*, *A. bosquensis*, *A. blowi*.

Correlation: *Globotruncana linneiana* Zone correlate with *Globotruncana ventricosa* Zone in general zonation of Upper Cretaceous.

The *Globotruncana linneiana* Zone is correlated with the *Brotzenella insignis*

Zone and *Brotzenella monterelensis* Zone.

Rugotruncana subcircumnodifer Zone – interval zone (IZ):

Age: Lower Maastrichtian.

Boundaries: interval, with widespread taxon: *Rugotruncana subcircumnodifer* till the first *Abathomphalus mayaroensis* occurence.

Zonal species: *Rugotruncana subcircumnodifer*, *Globotruncana linneina*, *G. arca*, *Heterohelix globulosa, Globigerinelloides ultramicrus, Archaeoglobigerina cretacea*, *A. bosquensis*, *A. blowi*.

Correlation: *Rugotruncana subcircumnodifer* Zone correlate with *Globotruncanella havanensis* Zone and *Globotruncana aegyptiaca* Zone in general zonation of Upper Cretaceous.

The *Rugotruncana subcircumnodifer* Zone is correlated with the *Brotzenella complanata Zone.*

***Abathomphalus mayaroensis* Zone** – interval zone (IZ):

Age: Upper Maastrichtian.

Boundaries: interval, with widespread taxon *Abathomphalus mayaroensis*.

Zonal species: *Abathomphalus mayaroensis , Rugotruncana subcircumnodifer*, *Globotruncana linneina*, *G. arca*, *Heterohelix globulosa, Globigerinelloides ultramicrus, Archaeoglobigerina bosquensis*, *A. blowi*.

Correlation: *Abathomphalus mayaroensis* Zone correlate with *Abathomphalus mayaroensis* Zone in general zonation of Upper Cretaceous.

The *Abathamphalus mayaroensis* Zone is correlated with the *Hanzawaia ekblomi Zone.*

5. Conclusions

37 planktic formaminifera species were identified in Upper Cretaceous. These species together represent an assemblage of planktic foraminifera characteristic only for Upper Cretaceous. Dominant species in that assemblage were dwellers of shallow waters but minority of species belongs to deep water dwellers. These deep water dwellers become dominant from Turonian age. It was a time of maximum sea transgression of Late Cretaceous sea. Species that preferred cold waters (g. Whiteinella) indicate that currents from polar regions were reaching this shallow basin.

Total abundance and diversity of planktic foraminifera vary from rare to high and preservation is poor to moderate due to lithologic variation as well rapidly changing conditions in Upper Cretaceous basin.

The earliest planktonic foraminiferal association from Cenomanian age is poor, monospecific and is represented by simple morphotypes, as genus *Hedbergella*. Hedbergellids are widely distributed in space and time. These species predominate in high latitudes and in upwelling areas, displaying an opportunistic life strategy (Gasinski, 1997; Alve 2003). Benthic forams are dominant in samples from that age.

The composition of association is changing rapidly starting from Middle Cenomanian to Middle Turonian. Planktic foraminifera become abundant. Significant increase in variety of taxons is easily noticed. Double keeled k-strategists species (g. *Dicarinella*, g. *Marginotruncna)* become dominant. Beside previously mentioned species one keeled genus *Helvetoglobotruncana* become widespread and numerous as well. The change of fauna was related with advancing transgression in to Lithuanian territory.

Foraminifers were still abundant but taxonomic variety started to decline during the Campanian age. Only 5 genus were identified in the assembly of that time. The decline of foraminiferal fauna diversity started at the end of Campanian. This was influenced by cooling climate, cold sea currents and sea regression which started from the middle of Maastrichtian. Again opportunistic species (g. *Heterohelix*, g. *Globigerinelloides*) become dominant during that age.

Biostratigraphical succession was pieced together after variety and stratigraphic position of planktic foraminifera were estimated. 10 planktic foraminifera zones were distinguished on a basis of that succession in the Upper Cretaceous sedimentary rocks (***Fig.2***). Majority of these zones are of a local significance nevertheless it is possible to correlate zonal complexes with other Tethys region zones or zonal complexes.

Conclusions about palaeogeographical conditions can be made that the Late Cretaceous sea basin was shallow and warm but time after time cold waters from polar regions could reach it.

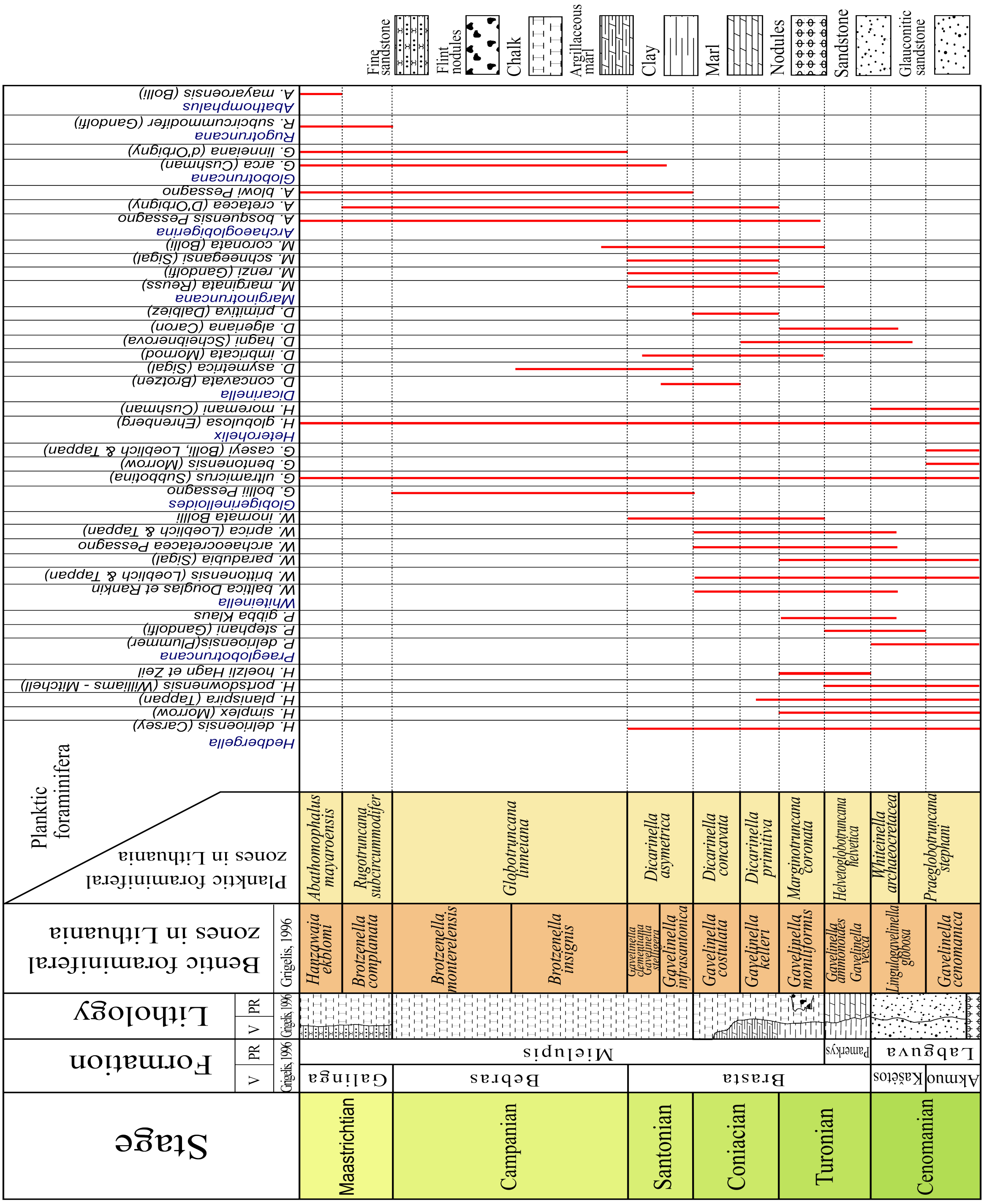

Fig. 2. Geological column, stratigraphy and vertical distribution of foraminifera.

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VIRŠUTINĖS KREIDOS BIOSTRATIGRAFINIS SUSKIRSTYMAS PLANKTONINIŲ FORAMINIFERŲ DUOMENIMIS (LIETUVA)

SANTRAUKA

Viršutinės kreidos nuosėdinės uolienos randamos Pietų ir Pietvakarių Lietuvoje, kur vėlyvajame albyje iš Lenkijos transgresavus negiliam epikontinentiniam jūriniam baseinui į Lietuvos – Lenkijos įdubą, ėmė klostytis terigeninės ir karbonatinės nuosėdos. Tiriant šias nuosėdines uolienas, randamos gerai išlikusios fosilinės bentosinių bei planktoninių foraminiferų bendrijos.

Duomenys apie viršutinės kreidos planktoninių foraminiferų įvairovę ir biostratigrafinį jų pasiskirstymą būtų svarbūs ne tik vietiniu, bet ir tarptautiniu požiūriu. Nes tiriamasis baseinas buvo didelio Tetijos vandenyno priekrantinė dalis. Tad išskirtas biozonas galima koreliuoti su gretimų regionų planktoninių foraminiferų zonomis.

Pagrindinis darbo tikslas - *viršutinės kreidos biozonų išskyrimas bei paleogeografinių sąlygų atkūrimas planktoninių foraminiferų duomenimis*.

Siekiant užsibrėžto tikslo, buvo iškelta keletas pagrindinių uždavinių: ištirti vėlyvosios kreidos planktoninių foraminiferų faunos įvairovę; sukoreliuoti viršutinės kreidos bentosinių ir planktoninių foraminiferų zonas; aptarti planktoninių foraminiferų bendrijų įvairovę Tetijos vandenyno šiaurinėje dalyje.

Medžiaga tyrimui buvo surinkta iš 17 Lietuvos gręžinių. Viso paimti 407 kerno ėminiai. Uolienų mėginiai, naudojant specialius uolienų apdorojimo metodus, išpreparuoti. Paruošti 380 mėginiai, iš kurių ir buvo atrinkta fauna tyrimui. Be to darbo metu buvo tirta prof. A. Grigelio kreidos foraminiferų kolekcija, surinkta iš 32 Lietuvos gręžinių.

Darbo metu nustatytos ir aprašytos 37 planktoninių foraminiferų rūšys. Ištirtų planktoninių foraminiferų bendrijų sudėtyje vyrauja negilių jūrinių baseinų ar priekrančių planktoniniai foraminiferai. Taip pat rastos kelios rūšys būdingos giliavandenių planktoninių foraminiferų bendrijoms *(Helvetoglobotruncana helvetica, Globotruncana linneiana, Rugotruncana subcircumnodifer, Abathomphalus mayaroensis*). Pirmoji jų, *Helvetoglobotruncana helvetica,* atsiranda turonio amžiuje, kai baseino transgresija vėlyvojoje kreidoje buvo pasiekusi maksimumą. Be to rastos

šaltamėgės rūšys (g. *Whiteinella*). Pastarosios byloja apie šaltų srovių prietaką. Tokia tirtos bendrijos sudėtis leidžia manyti, kad Lietuvos teritorijoje vėlyvosios kreidos metu egzistavęs jūrinis baseinas buvo negilus, šiltas, su šaltų srovių prietaka.

Tirtajame viršutinės kreidos pjūvyje planktoninių foraminiferų bendrijos rūšinė sudėtis kito. Keitėsi ir tirtos faunos skaitlingumas, tai rodo, kad sąlygos baseine buvo nepastovios ir nuolat kintančios.

Pirmosios planktoninių foraminiferų asociacijos, rastos apatiniame cenomanyje skurdžios. Rūšinė įvairovė maža, faunos skaitlingumas nedidelis. Šioje bendrijoje vyrauja oportunistinės, lengvai prisitaikančios prie besikeičiančių aplinkos sąlygų rūšys (g. *Hedbergella*). Tirtuose cenomanio amžiaus mėginiuose dominuoja bentosinės foraminiferų rūšys.

Planktoninių foraminiferų pradeda gausėti nuo cenomanio vidurio, ir iki konjakio vidurio planktoninių foraminiferų bendrijos sudėtis pakinta. Bendrijos sudėtyje ženkliai išauga naujų taksonų skaičius (padidėja rūšinė įvairovė). Taip pat padidėja planktoninių foraminiferų skaitlingumas. Bendrijos sudėtyje pradeda dominuoti dvikilės, K-strateginės rūšys (g. *Dicarinella*, g. *Marginotruncna)* ir vienakilė rūšis g. *Helvetoglobotruncana*. Tokį spartų planktoninių foraminiferų rūšių atsiradimą įtakojo Lietuvos teritorijoje esančio baseino pagilėjimas.

Kampanio planktoninių foraminiferų fauna gausi, tačiau rūšinė įvairovė ima mažėti (šio laikotarpio bendrijoje fiksuojamos tik 5 gentys).

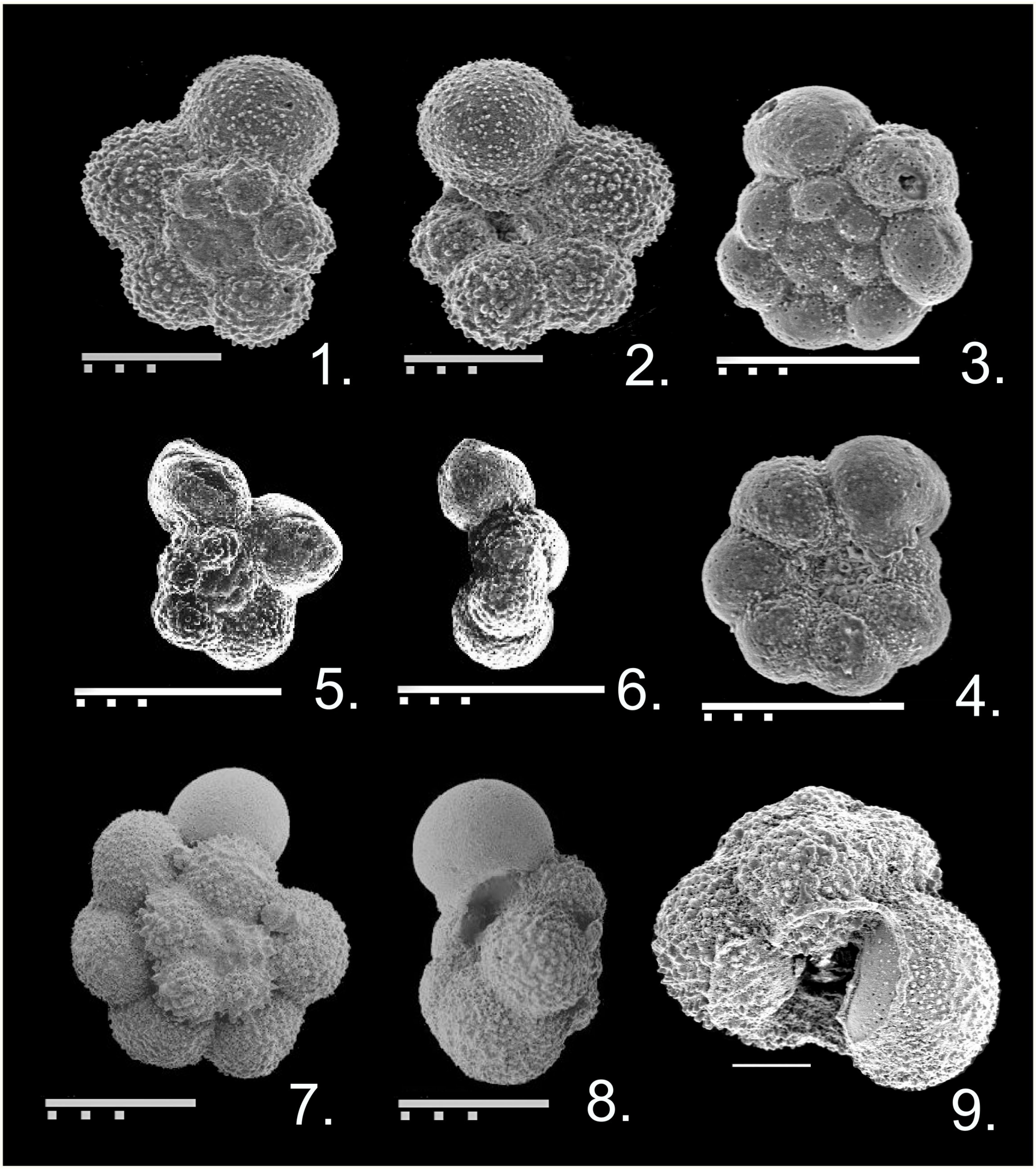
Kampanio pabaigoje planktoninių foraminiferų ima mažėti. Tam įtakos turėjo vėstantis klimatas, šaltų srovių prietaka, o nuo mastrichčio vidurio prasidėjo ir baseino regresija. Mastrichčio metu ima dominuoti oportunistinės rūšys (g. *Heterohelix*, g. *Globigerinelloides*).

Pagal fosilijų taksonominę sudėtį nuosėdinių uolienų pjūviai skirstomi į biostratigrafinius padalinius - biozonas.

Tiriant planktoninių foraminiferų seką viršutiniame kreidos pjūvyje išskirtos 10 planktoninių foraminiferų zonų: *Praeglobotruncana stephani*, *Whiteinella archaeocretacea*, *Helvetoglobotruncana helvetica*, *Marginotruncana coronata*, *Dicarinella primitiva*, *Dicarinella concavata*, *Dicarinella asymetrica, Globotruncana* *linneiana, Rugotruncana subcircumnodifer* ir *Abathomphalus mayaroensis*. Sudaryta 13 schemų, vaizduojančių planktoninių foraminiferų biostratigrafinį paplitimą bei planktoninių ir bentosinių zoninių foraminiferų koreliaciją tirtuose gręžiniuose.

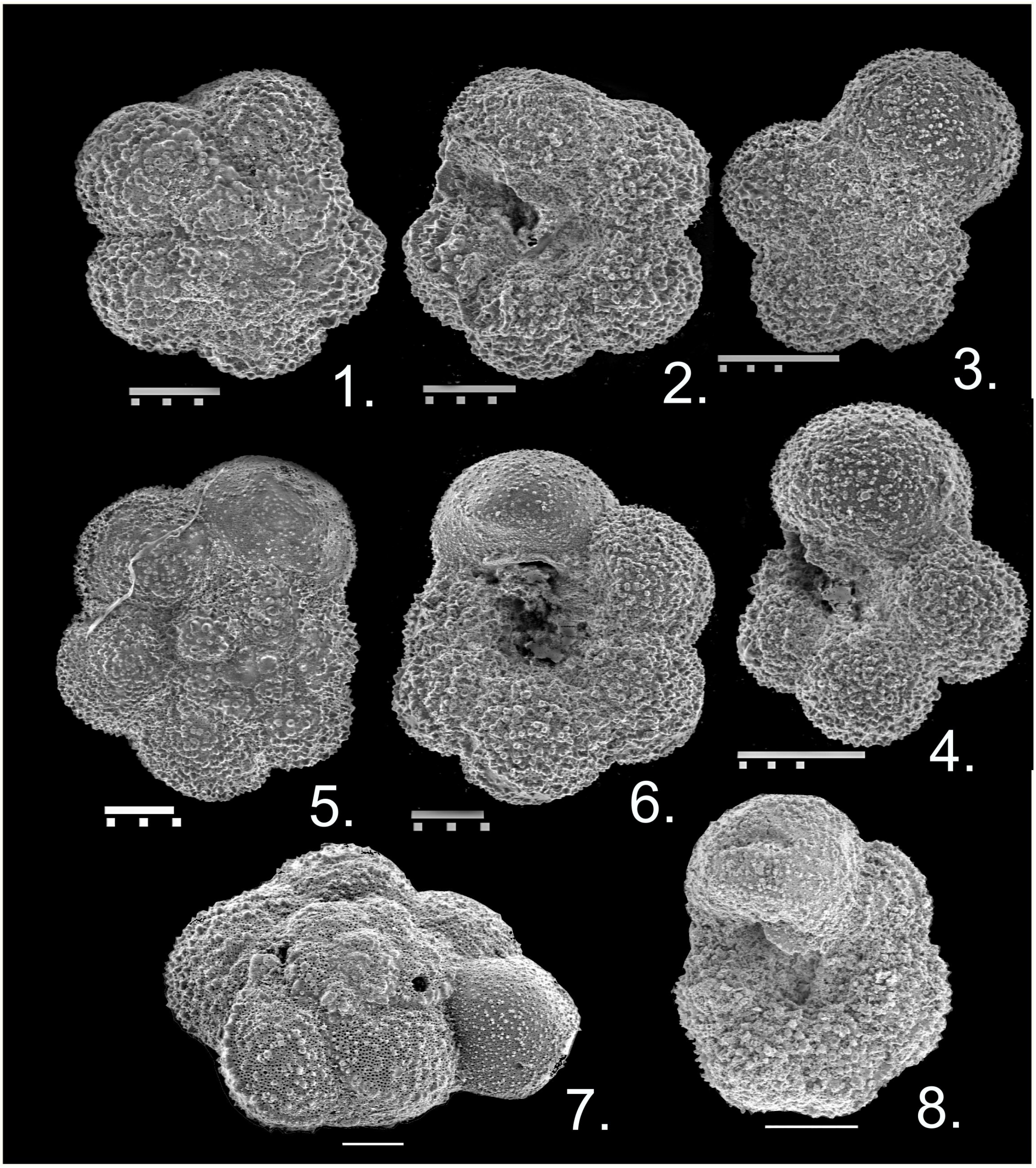
Pagrindiniai darbo rezultatai atspindėti suvestiniame viršutinės kreidos pjūvyje, kuriame taip pat pavaizduotas ir tirtų planktoninių foraminiferų biostratigrafinis paplitimas.

Appendix 1. *Scanning electron microscope images of studied Upper Cretaceous planktonic foraminifera.*



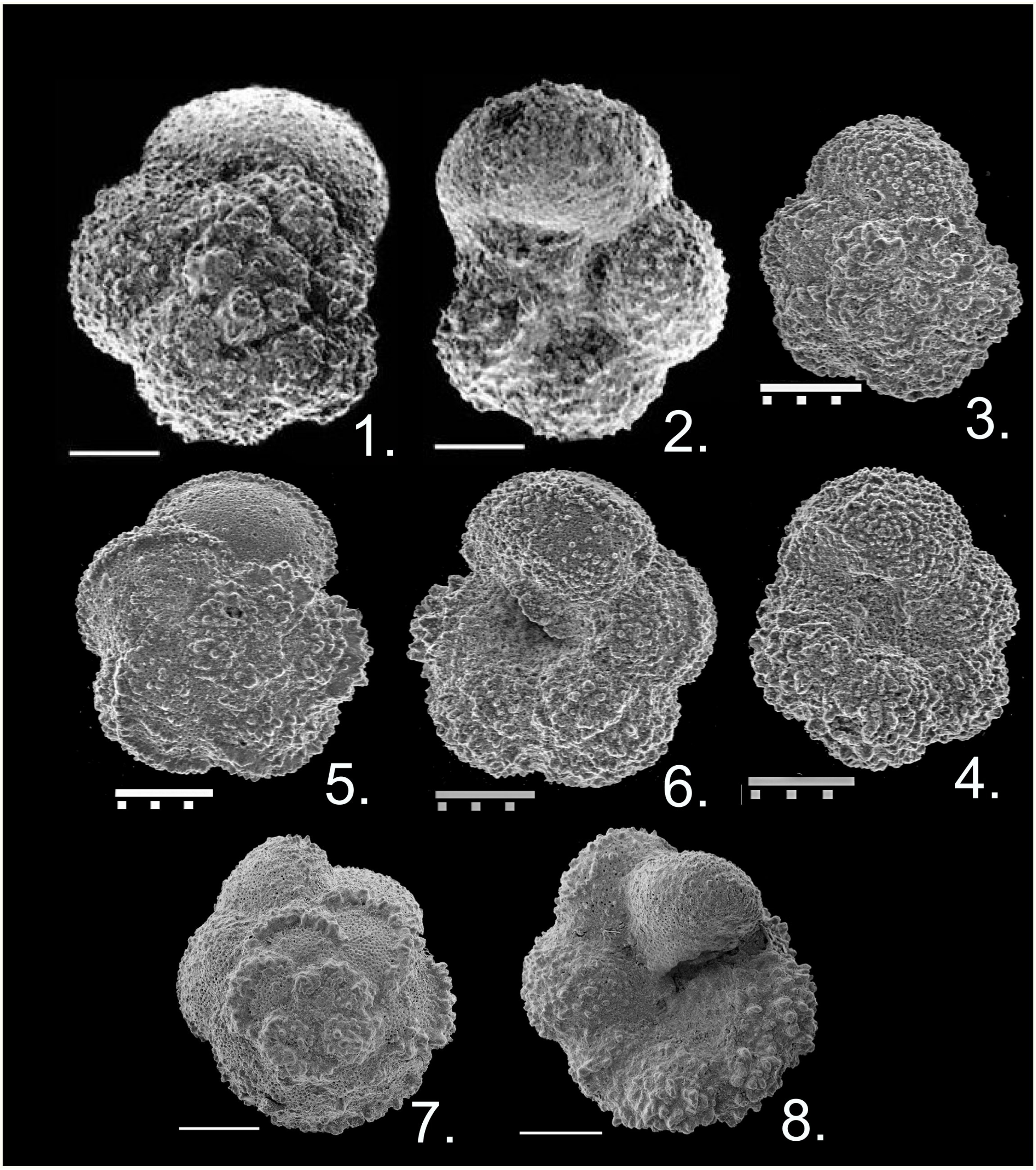
1, 2 - *Hedbergella delrioensis* (Carsey), Rokai - 2, 60,5 m; **3, 4** - *Hedbergella planispira* (Tappan), Žigaičiai - 7, 96,0 m; **5, 6** - *Hedbergella simplex* (Morrow), Rokai - 2, 60,5 m; **7, 8** - *Hedbergella portsdownensis* (Williams – Mitchell), Punios šilas - 315, 104,0 m; **9** - *Whiteinella paradubia* (Sigali), Viešvilė - 11, 96 m. Scale bar 100 µm.

***Appendix** 2. Scanning electron microscope images of studied Upper Cretaceous planktonic foraminifera.*



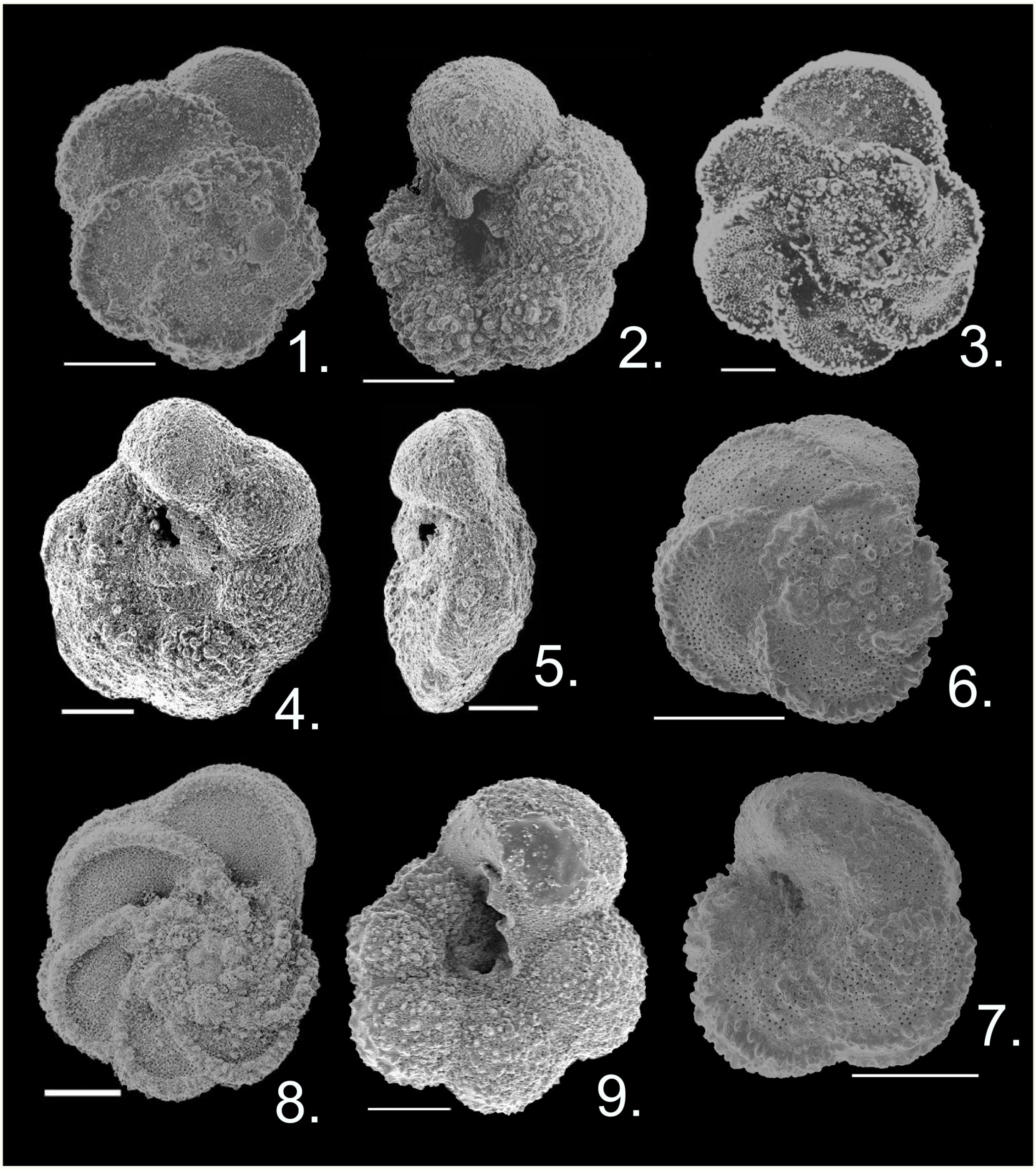
1, 2 - *Whiteinella brittonensis* Loeblich et Tappan, Rokai-2, 55,0 m; **3, 4** - *Whiteinella baltica* Douglas et Rankin, Žalgiriai-1, 68,5 m; **5, 6** - *Whiteinella archaeocretacea* Pessagno, Žalgiriai-1, 68,5 m; **7, 8** - Whiteinella aprica (Loeblich et Tappan), Varnupiai-445, 192,0 m. Scale bar 100 µm.

***Appendix** 3. Scanning electron microscope images of studied Upper Cretaceous planktonic foraminifera.*



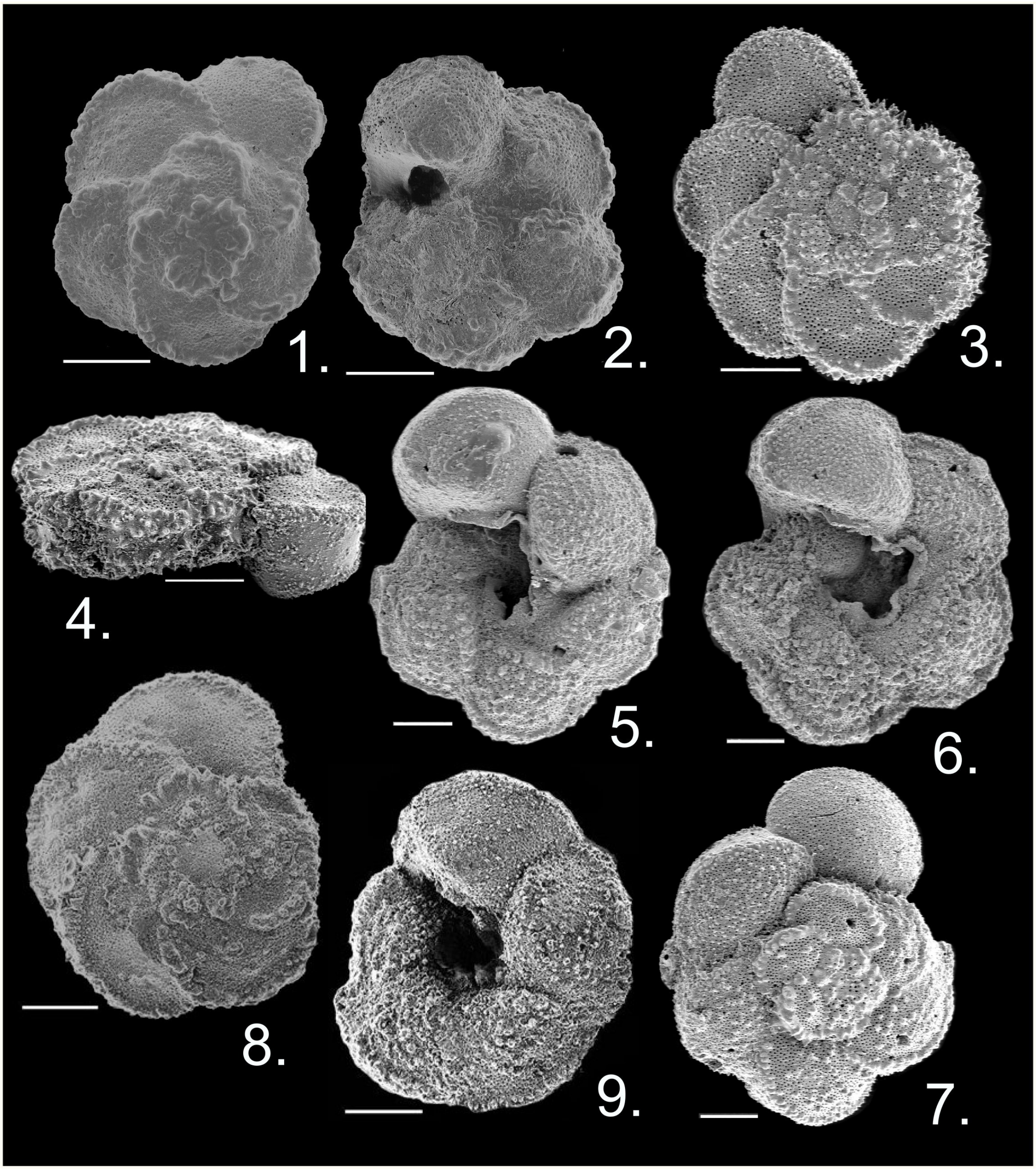
1, 2 - *Whiteinella inornata* Bolli, Punios šilas-315, 95,0 m; **3, 4** - *Praeglobotruncana delrioensis* (Plummer), Rokai-2, 60,5 m; **5, 6** - *Praeglobotruncana stephani* (Gandolfi), Rokai-2, 60,5 m; **7, 8** - *Praeglobotruncana gibba* Klaus, Žalgiriai-1, 72,0 m. Scale bar 100 µm.

Appendix 4. *Scanning electron microscope images of studied Upper Cretaceous planktonic foraminifera.*



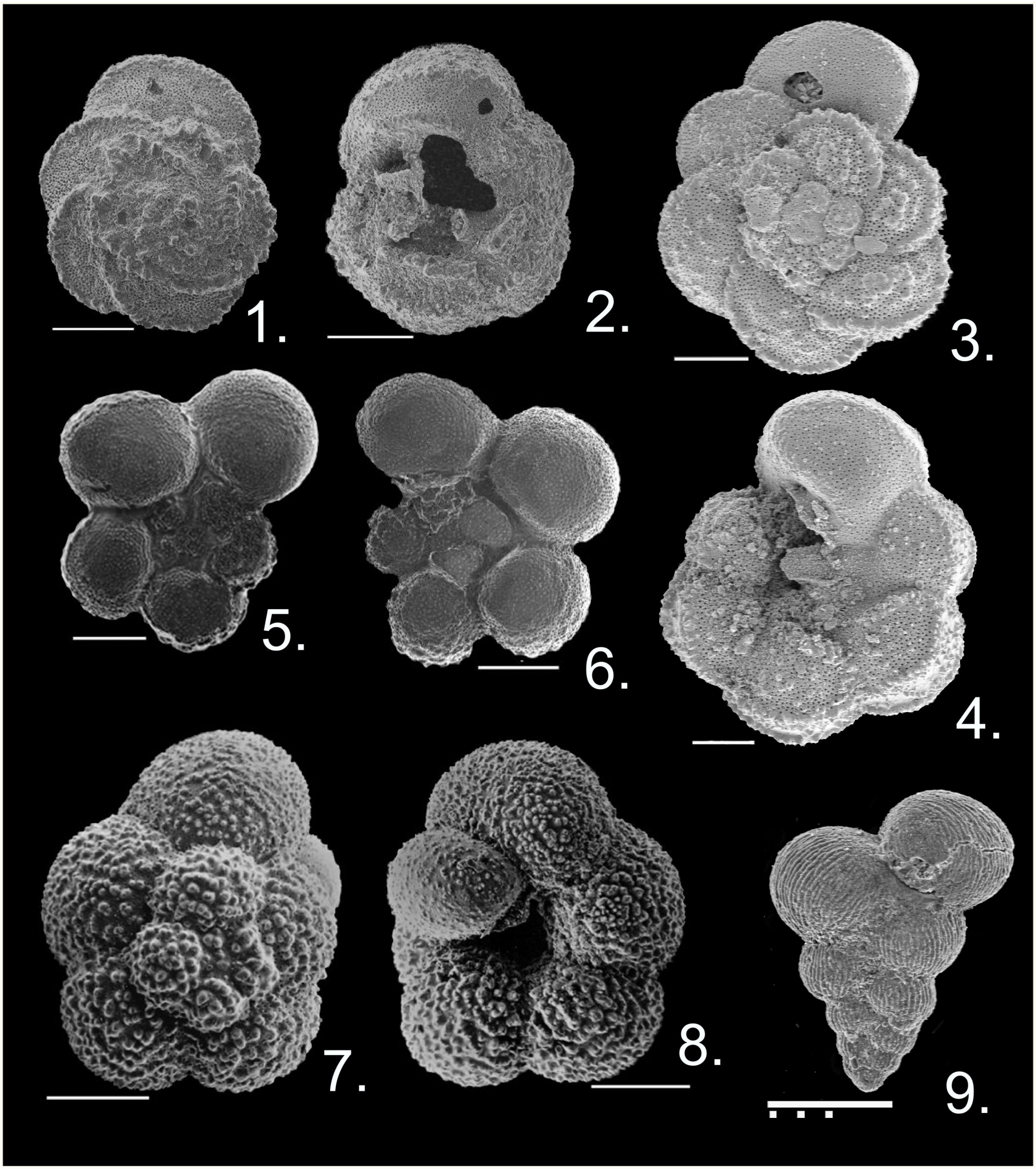
1, 2 - *Helvetoglobotruncana helvetica* (Bolli), Varnupiai-445, 185,0 m; **3, 4, 5** - *Dicarinella hagni* (Scheibnerova),Varnupiai-445, 185,0 m; **6, 7** - *Dicarinella algeriana* (Caron), Varnupiai-445, 185,0 m; **8, 9** - *Dicarinella concavata* (Brotzen), Punios šilas-315, 60,0 m. Scale bar 100 μm.

Appendix 5. *Scanning electron microscope images of studied Upper Cretaceous planktonic foraminifera.*



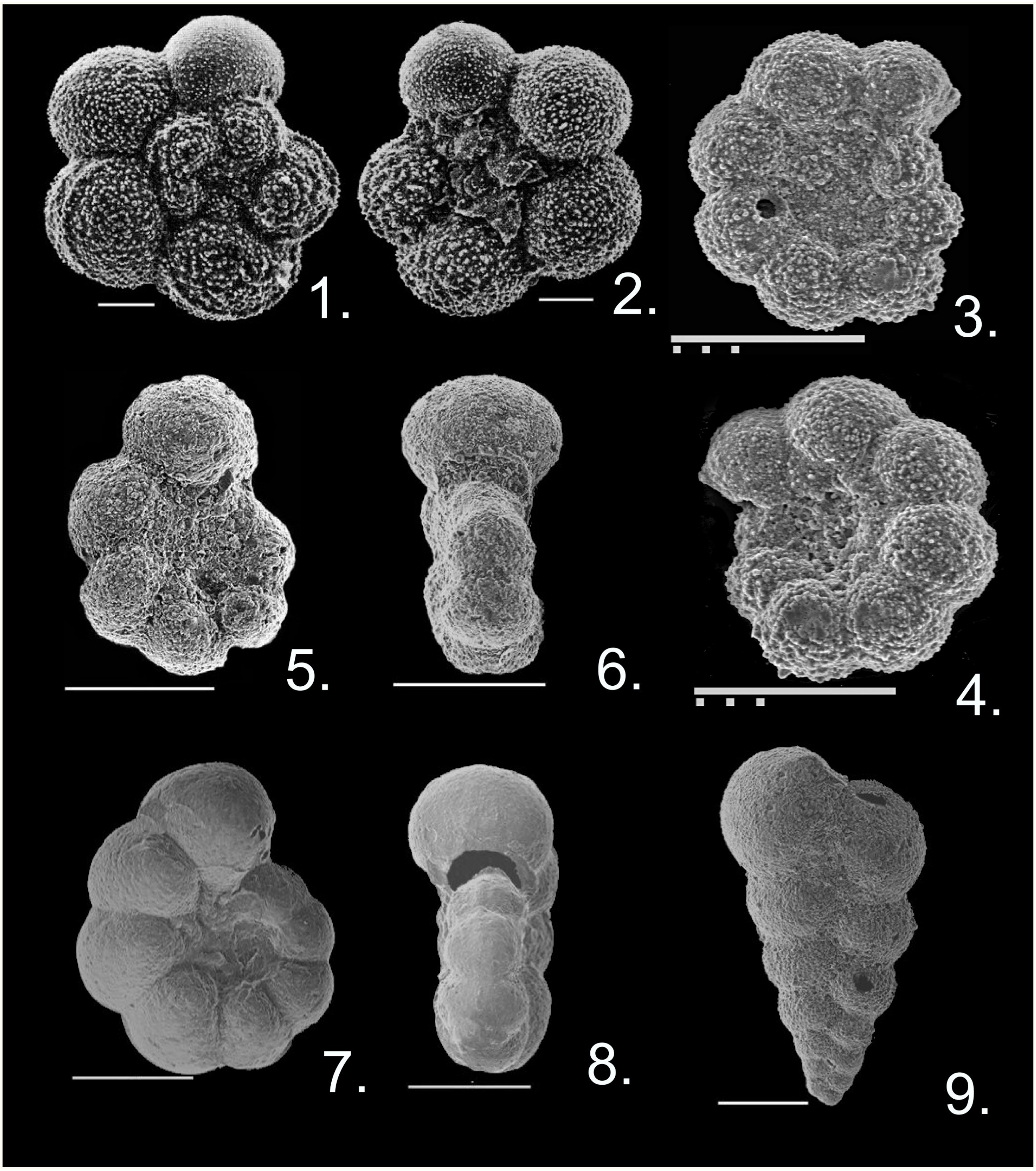
1, 2 - *Dicarinella imbricata* (Mornod), Neravai-453, 260,0 m; **3, 4, 5** - *Marginotruncana coronata* (Bolli), Neravai-453, 260,0 m; **6, 7** - *Marginotruncana marginata* (Reuss), Neravai-453, 260,0 m; **8, 9** - *Marginotruncana renzi* (Gandolfi), Neravai-453, 260,0 m. Scale bar 100 µm.

Appendix 6. *Scanning electron microscope images of studied Upper Cretaceous planktonic foraminifera.*

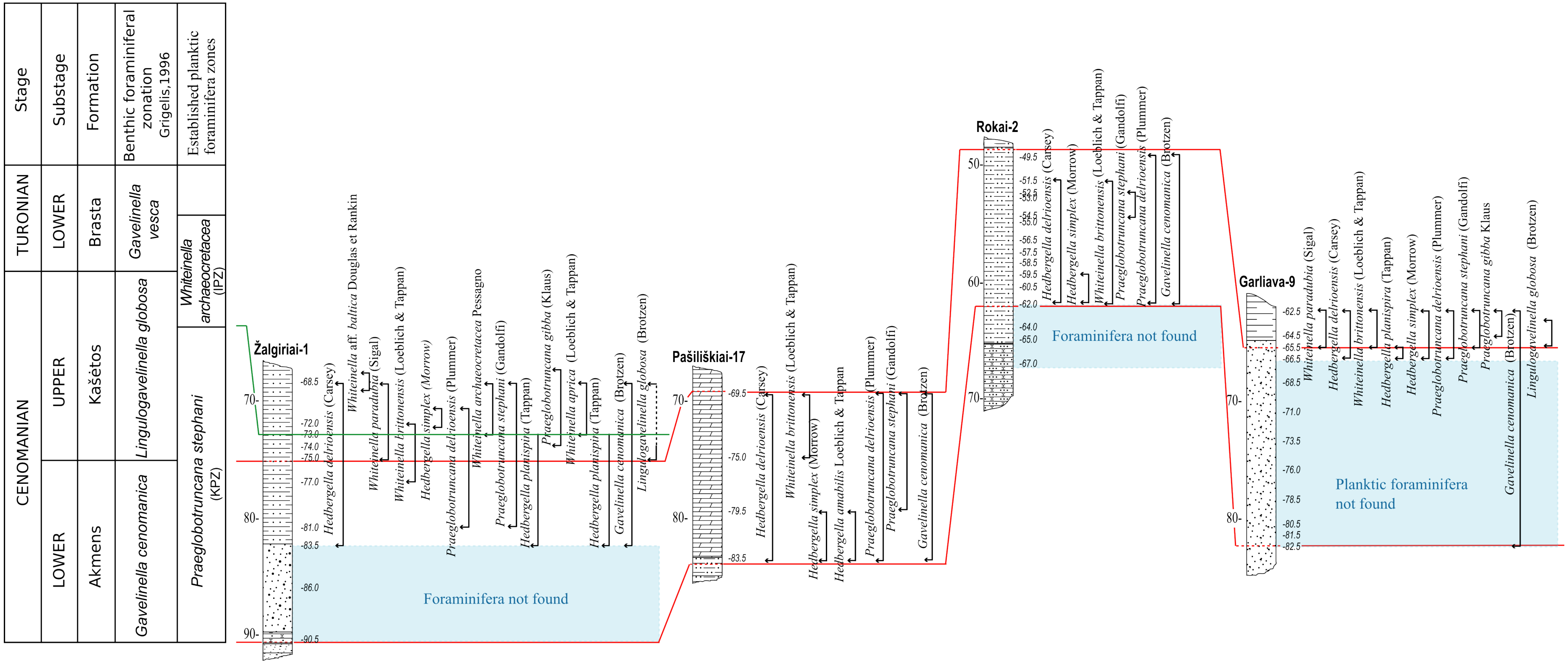


1, 2 - *Globotruncana arca* (Cushman), Baltašiškė-267,107,0 m; **3, 4,** - *Globotruncana linneina* (D'Orbigny), Baltašiškė-267, 107,0 m; **5, 6,** - *Archaeoglobigerina blowi* Pessagno, Baltašiškė-267, 99,0 m; **7, 8** - *Archaeoglobigerina bosquensis* Pessagno, Baltašiškė-267, 99,0 m; **9** - *Heterohelix globulosa,* Pessagno, Baltašiškė-267, 99,0 m. Scale bare 100 µm.

***Appendix** 7. Scanning electron microscope images of studied Upper Cretaceous planktonic foraminifera.*



1, 2 - *Archaeoglobigerina cretacea* (D'Orbigny), Baltašiškė-267,107,0 m; **3, 4,** - *Globigerinelloides ultramicrus* (Subbotina), Neravai-453, 210,0 m; **5**, **6,** - *Globigerinelloides bentonensis* (Morrow), Viešvilė-11, 89,0 m; **7**, **8** - *Globigerinelloides caseyi* (Bolli), Viešvilė-11, 89,0 m; **9** - *Heterohelix moremani* (Cushman), Punios šilas-315, 99,0 m. Scale bare 100 µm.



Appendix 8. *Dsitribution and correlation of Cenomanian planktic and benthic foraminifera in studied boreholes.*