"BABEŞ-BOLYAI" UNIVERSITY CLUJ-NAPOCA
FACULTY OF BIOLOGY AND GEOLOGY
DEPARTMENT OF GEOLOGY

THE RELATIONSHIP BETWEEN THE FOSSIL FORAMINIFERA ASSEMBLAGES AND THE DEPOSITIONAL ENVIRONMENTS IN THE HIDA FORMATION (NORTH-WESTERN TRANSYLVANIAN BASIN)

PHD THESIS

SUMMARY

PhD Student
Claudia Mariana Beldean

Scientific Coordinator
Prof. Dr. Sorin Filipescu

Cluj-Napoca

2010

TABLE OF CONTENTS

Key words: foraminifera, Hida Formation, Lower Miocene, Transylvanian Basin

INTRODUCTION

The main goal of this paper is the characterization of the Hida Formation, of Lower Miocene age, in terms of micropaleontologic and subordinately, sedimentologic data. The micropaleontologic analyses performed have implied the investigation of fossil foraminifera assemblages from the morphologic, taxonomic, biostratigraphic and paleoecologic point of view. The results have been correlated to the sedimentological data, in order to reconstruct the depositional environment, so that we achieve a clear overview of the sedimentary basin evolution.

The objectives of the current study were the following:

- ✓ detailed study of the Hida formation deposits from micropaleontologic and sedimentologic perspective;
- ✓ performance of qualitative and quantitative analyses which enable, by integration of results, the achievement of an evolution model of the foraminifera assemblages;
- ✓ identification of benthic foraminifera assemblages according to the modification of environment conditions such as: the oxygen concentration at the water/sediment interface, modification of the relative sea level, contribution of organic matter in the basin;
- ✓ biostratigraphy of the deposits by means of planktonic foraminifera assemblages and the framing of biozones within the regional stratigraphic context.
- ✓ elaboration of a synthetic model with the succession of the Lower Miocene paleoenvironment in the North-Western part of the Transylvanian Depression under the influence of the tectonic and paleogeographic context.

I would like to thank to Professor Dr. Sorin Filipescu for the help provided in the elaboration of this PhD thesis. During the almost four years of research, he offered me moral and logistic support, leading to the achievement of the proposed objectives. I thank him for the fact that he accompanied me to the field and for his patience in our debates.

I would like to thank also to the referents: Scientific Researchers I Dr. Popescu Gheorghe, Dr. Michael Kaminski and Professor Dr. Bucur Ioan, for the patience of reading and evaluating this paper.

I thank Dr. Fred Rögl for his help in determining the foraminifers, for the fact that he provided me with the foraminifera collection of the Natural History Museum in Vienna and for the constructive conversations.

I thank Scientific Researchers I Dr. Gheorghe Popescu and Dr. Michael Kaminski for the debates and suggestions referring to the taxonomic identification of the foraminifers.

Many thanks to Dr. Carlo Aroldi, Lecturer Dr. Săsăran Emanoil, and Reader Dr. Carmen Chira who accompanied me on field trips and helped me understand important issues related to the geology of the study region. I thank Dr. Ramona Bălc for the nannoplancton analyses.

I thank to the management of Romgaz SA Mediaş company for the providing me a part of the seismic profiles of the studied region, as well as to Dr. Csaba Krézsek for the indications offered in understanding the tectonic evolution of the Transylvanian Depression. I also thank to Assist. Dr. Lucian Barbu-Tudoran for his support in performing photographs with the electronic microscope.

I am grateful to all my colleagues and friends within the Geology Department whom I have spent with such quality time.

I thank my husband Paul Beldean, both for his understanding and support and for him accompanying me on field.

Last but not least, I thank my mother and her husband, whose moral and financial support have enabled me to elaborate this paper.

This research project was partially financed by CNCSIS Romania through the grant TD no. 473/2007

CHAPTER 1

Geologic evolution of the Transylvanian Depression

The formation of Transylvanian Depression has started in Upper Cretaceous, together with the end of the orogenic stages that led to the suture of continental blocks Tisza and Dacia (Csontos et al., 1992). The depression begins its evolution in a regional compression regime with E-W orientation (Ciulavu, 1999), with the possibility of a minor extensional phase during the Lower Badenian (Krézsek & Filipescu, 2005), representing a back-arc basin of the Carpathic subduction (Horvath et al., 2006).

The post-tectonic sedimentary fill of the Transylvanian Depression has locally a thickness of more than 5000 m (Vancea, 1960; Ciupagea et al., 1970) and it was divided into four major stratigraphic megasequences (Krézsek & Bally, 2006): Upper Cretaceous (rift, gravitational collapse), Palaeogene (sag), Lower Miocene (flexural), Middle Miocene – Upper Miocene (the backarc sequence influenced by the gravitational tectonics).

CHAPTER 2

Lower Miocene in the Transylvanian Depression

During Lower Miocene, the Transylvanian Depression has evolved in a flexural basin, located in the central-northern part of Transylvania (Krézsek & Bally, 2006). The sedimentary succession is represented by a large variety of deposits: from the nearshore deposits to the deep marine turbiditic deposits (Rusu, 1969, Popescu et al., 1995, Filipescu, 2001).

The Lower Miocene outcrops in the West and North-West of the Transylvanian Depression, and is characterized by several formations: the Coruş Formation (Hauer & Stache, 1863), the Chechiş Formation (Hofman, 1879) and the Hida Formation (Koch, 1900). The upper part of the Vima Formation develops in the same region (Lăzărescu, 1957, Rusu, 1969) with lateral equivalent facieses, respectively the Buzaş (Dumitrescu, 1957), Valea Almaşului (Răileanu & Saulea, 1956), Cuzăplac (Moisescu, 1972) and Cubleş (Moisescu, 1972) Formations.

The micropaleontologic studies performed on the Lower Miocene deposits in the North-West of the Transylvanian Depression are diverse, and various groups of organisms (molluscs, ostracodes, foraminifera) were analyzed. The analyses performed upon the foraminifera assemblages include especially taxonomic observations and more seldom paleoenvironment or paleoecological interpretations. The biozonations of lower Miocene deposits in the North-West of the Transylvanian Depression is difficult to achieve due to the absence of index fossils and to the presence of assemblages specific to some restrictive environment. These peculiarities render the impossibility of correlating the biozonations in the Transylvanian Depression with those from the Central Paratethys or the Mediterranean area. However, during the last decades, a series of reference biostratigraphic studies were performed.

CHAPTER 3

Materials and methods

In order to achieve results as complete and reliable as possible, we have integrated several approaches of the proposed topic. This study pursued the following work stages: sampling and processing of samples according to standard micropaleontologic methods, followed by the qualitative and quantitative interpretation of foraminifera assemblages (relative abundance, diversity – Shannon-Wiener, equitability, Fisher α). We insisted on the highlight of assemblages' type significance ("flysch type" assemblages, slope assemblages, abyssal assemblages) and of the agglutinated foraminifera morphogroups for the paleoambiental, biostratigraphic and paleogeographic characterization of the studied succession. Based on the planktonic/benthic ratio we have estimated the paleodepth, and based on the calcareous benthic foraminifera morphotypes we have calculated the dissolved oxygen index (BFOI).

CHAPTER 4

Results and discussions

During the 2006-2008 period, we have performed several field campaigns, and have consequently identified 44 outcrops (fig. 4), of which 253 samples were collected.

As a result of sedimentologic observations and of the sample processing we have identified a wide variety of foraminifera assemblages (over 250 taxa), so that we have succeeded in achieving a general vision over the distribution and evolution of depositional environment in the Hida Formation.

4.1. The relationship between sedimentary environment and the foraminifera assemblages

Based on the identified foraminifera assemblages and the sedimentologic observations, we have characterized the depositional environment from the area providing relevant data.

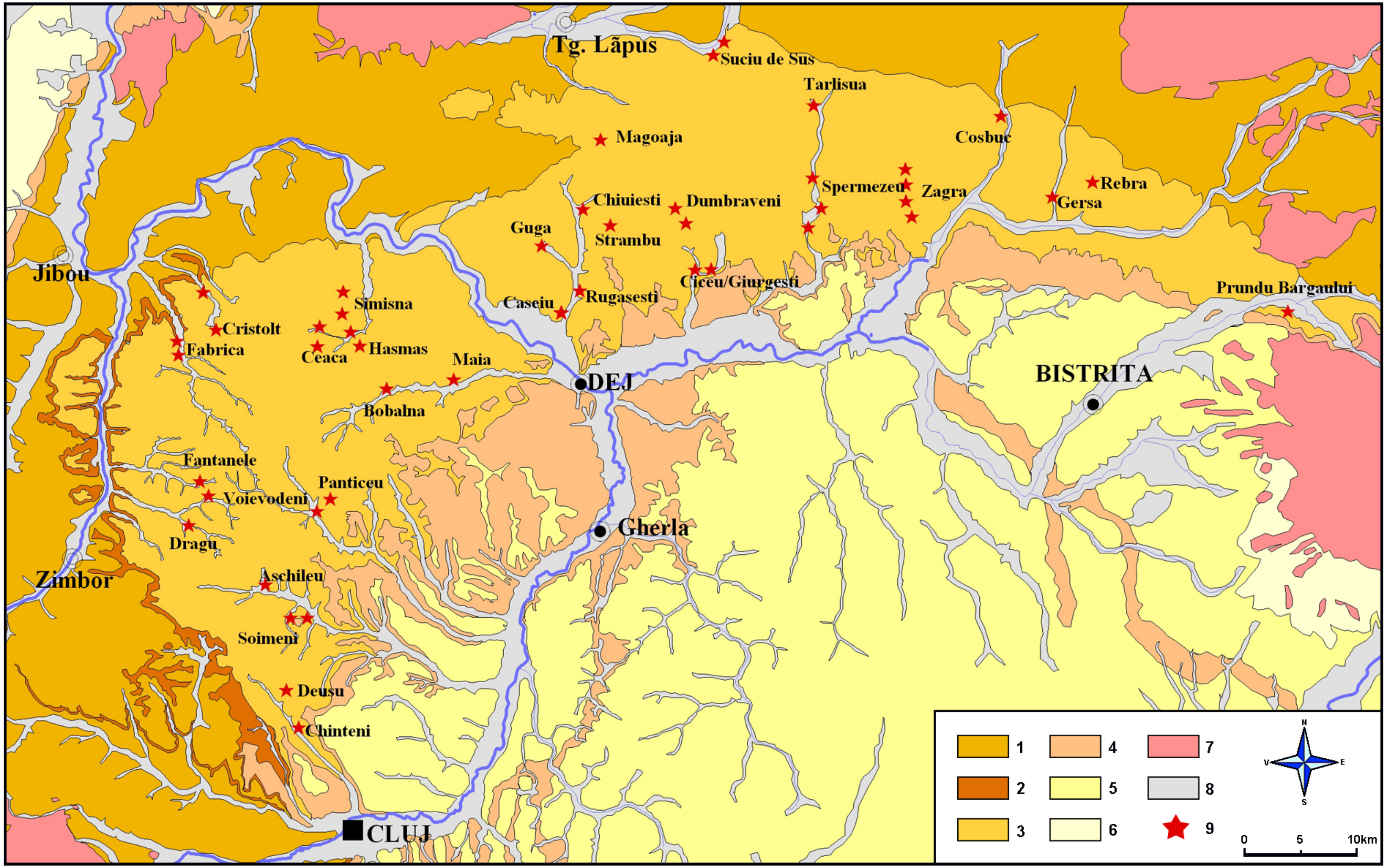

Fig. 4. Location of identified outcrops: 1 - Palaeogene, 2 – Lower Miocene shallow marine formations , 3 - Lower Miocene: Hida Formation, 4 - Badenian, 5 - Sarmatian, 6 - Pannonian, 7 - metamorphites, 8 - Quaternary, 9 – sampling points.

4.1.1. Suciu de Sus

Turbiditic deposits with progradant cycles (of the shallowing and coarsening-upward type) represent the sedimentary succession from Suciu de Sus, located in the lower part of the Hida Formation.

The Bouma Ta-b and Ta-c sequences are organized in alternant levels of individual widths of the sandstones layers up to 2 m, thus observing their lateral continuity. The depositional environment in this region may be considered one of transition from distal to middle fan, where the sedimentary contribution and the density of turbiditic current progressively increase in time.

The identified foraminifera assemblages are typical to the deep marine environment; both agglutinated and calcareous benthic, and planktonic foraminifera are present (Filipescu & Beldean, 2008) (fig. 7). Analyzing figure 7, one may notice the predominance of the benthic foraminifera, especially of the agglutinated ones, with abundance values exceeding 50%.

The abundance of planktonic foraminifera is low, these are weakly preserved, but there have been identified also a few forms representative for the Lower Miocene, such as: *Globorotalia peripheroronda, Globigerinoides primordius, Catapsydrax martini, Globigerina woodi, Globoquadrina langhiana, Globigerina lentiana.*

A relatively high diversity may be observed within the first part of the succession (samples 1-3) due to the presence of a large number of calcareous benthic foraminifera, after which the diversity ranges within constant values (H'~ 2.2 – 2.9; Fischer α ~10 - 8) up to the level of the last sample, when it decreases significantly. This decrease is seen also at the level of the equitability due to the predominance of a single species of agglutinated foraminifera (*Budashevaella wilsoni*).

The dissolved oxygen index (BFOI) ranges between 6 and 40, which indicates an oxygenated environment, with oxygen values between 1.5 – 3.0 ml/l.

After the analysis of agglutinated foraminifera morphogroups (fig. 8), can be observe the absence of the M2c morphogroup which is specific to the marginal marine environments. The other morphogroups are present in variable proportions, with the dominance of tubular opportunist forms, included in the M1 morphogroup, which sometimes reach values of 90%. According to Jones & Charnock (1985), this morphogroup present in proportion of more than 70 % indicates lower bathial to abyssal zones, where the marine currents constantly bring organic matter.

In the studied section, the high abundance of the M3a morphogroup is due largely to the *Ammodiscus incertus*.

While the lower part of the studied succesion was dominated by morphogroups specific to deep marine environments – bathial – towards the upper part, these are observed to be replaced by forms typical to outer shelf environment; the assemblages are formed of species of the M2b morphogroup. The transition from the bathial environment to the shelf environment is suggested by the increase of the percentage participation of the calcareous benthic foraminifera.

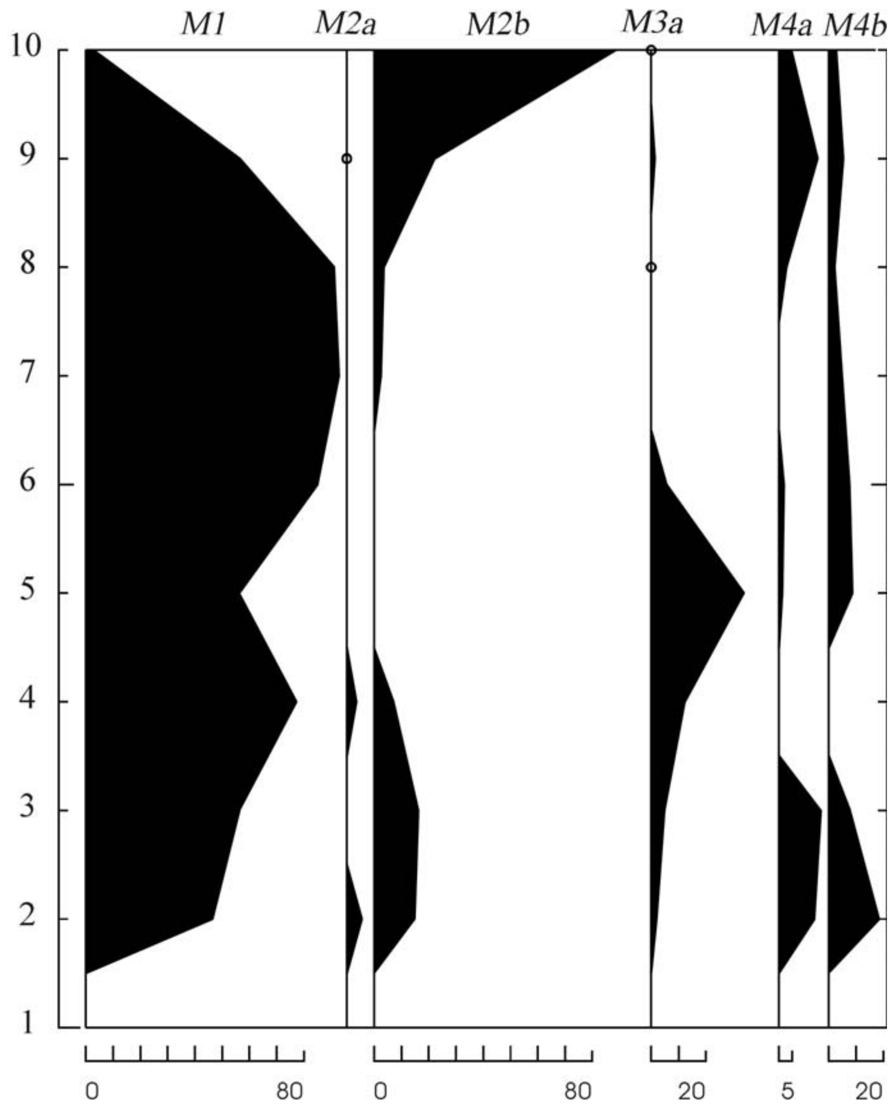

Fig. 8. The proportion between the main agglutinated foraminifera morphogroups from Suciu de Sus

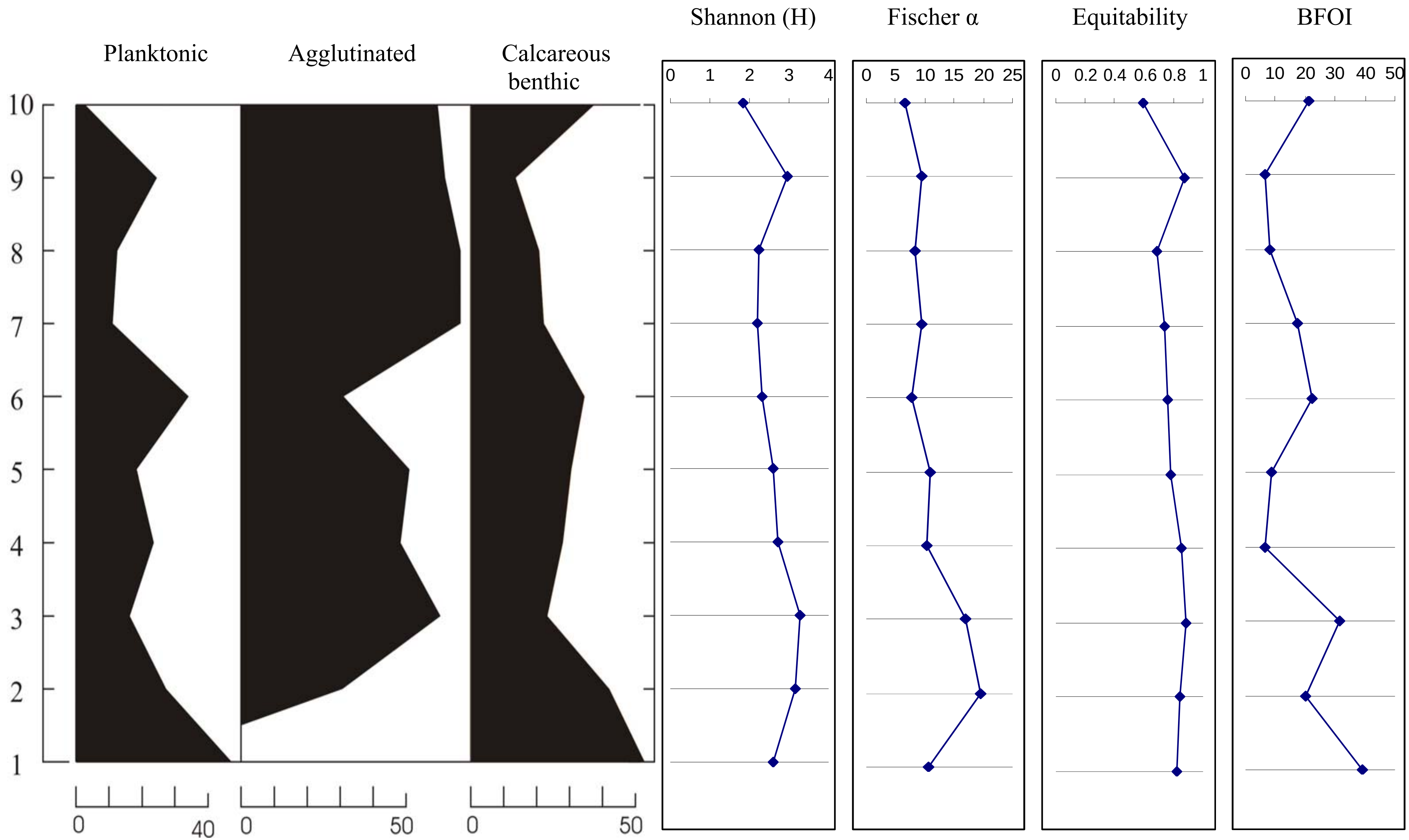

Fig. 7. The planktonic/benthic ratio (agglutinated and calcareous) and paleoecologic indices of foraminifera from Suciu de Sus

4.1.6. Spermezeu

Close to the Spermezeu village (Spermezeu 3), we have identified a succession beginning with sediments specific to distal turbidites, which, in the upper part become middle turbidites with massif sandstones banks, being a progradant succession (shallowing upward and coarsening up) (fig. 23). In the upper part of the opening, the vegetal material is present in considerable amounts, which indicates the active transport from the continent associated with a regressive trend. From these deposits, we collected 25 samples in order to perform micropaleontologic analyses.

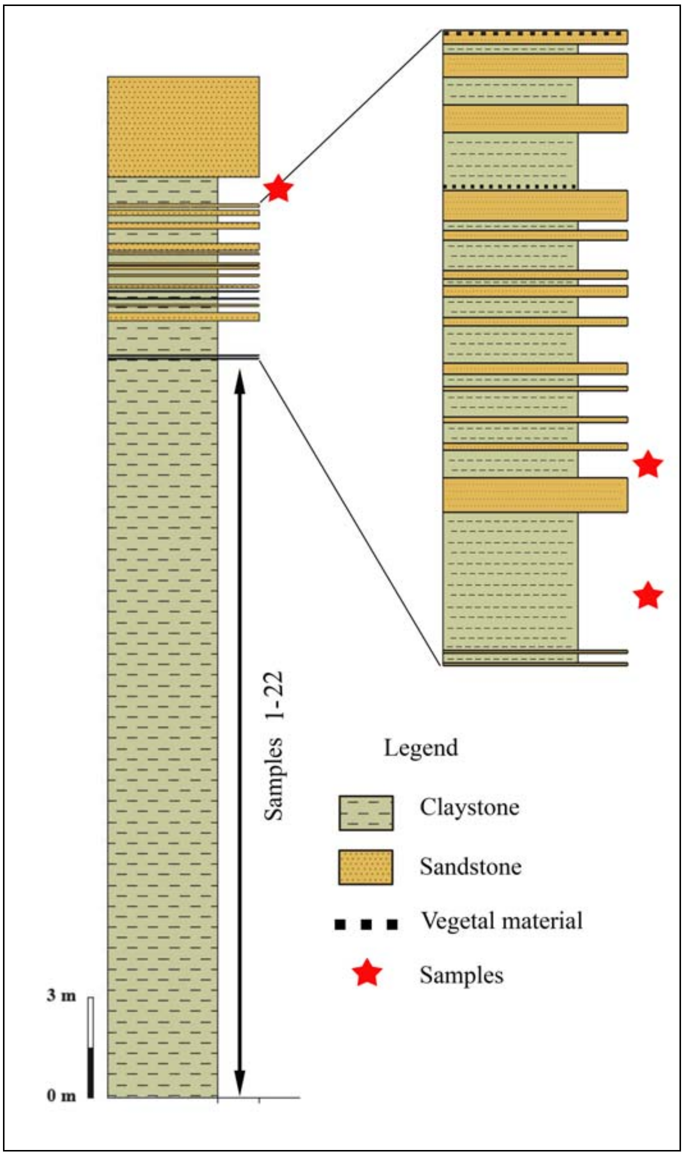

Fig. 23. Lithologic log of the Spermezeu 3 succession

One may notice the existence of both agglutinated benthic foraminifera and of calcareous and planktonic ones (fig. 24). In the lower part of the succession, calcareous benthic foraminifera prevail (> 50%), these correspond to a shallow marine environment (100-200 m in depth). Above this interval, one may observe the increase of planktonic foraminifera abundance up to 70%, which proves the transgressive trend (estimated depths up to 600 m). The dominant planktonic species are *Globigerina ottnangiensis, Globigerina praebulloides, Globorotalia obesa* and *Globigerinoides altiapertura*. At the same time, the abundance of calcareous benthic foraminifera decreases. Even if within the entire analyzed succession, the dissolved oxygen index has positive values, indicating an oxic environment, it seams that the prevailing role in colonizing the substratum belonged to the organic matter contribution (Beldean et al., 2010a).

In the upper part of the opening, the weight of planktonic foraminifera decreases significantly, as the agglutinated benthic foraminifera (tubular shapes) and the calcareous ones (*Siphonina reticulata, Globobulimina ovula*, *Valvulineria fabiani, Cibicidoides* sp.) having a larger participation. Parts of the identified calcareous benthic foraminifera are specific to the shelf environment, being identified taxa representatives for the Chechiş Formation (*Ammonia beccari, Sigmoilina* sp.). The trend to change the assemblages, which become characteristic to less deep environments, is confirmed by the progradant character of the sedimentation.

The diversity indices present minor fluctuations along the succession and range within the limits of high diversity. The lower diversity and equitability at the sample 24 level is due to the low abundance of the agglutinated foraminifera. The diversity values (Shannon H ~ 1.5-3.5; Fischer α ~ 5-30) range within the limits determined by Murray (1991) for the continental slope environments.

In the Spermezeu 3 succession, the agglutinated foraminifera have a relatively constant abundance, with minor fluctuations between 10 and 20%. Major changes in the foraminifera assemblages occur at the top of the opening, where the agglutinated forms reach an abundance of up to 50%. Except the M3b morphogroup, all the other morphogroups are present in variable proportions (fig. 26).

One may notice a negative correlation between the M1 and M4b morphogroups, due to different feeding strategies (suspension feeding vs. active deposit feeding) and oxygenation. The M4b morphogroup presents a higher abundance in a relatively high marine level, probably being more tolerant to the changes of the dissolved oxygen quantity in the environment, while the M1 morphogroup dominates the assemblages when the marine level is decreasing (Cetean, 2009).

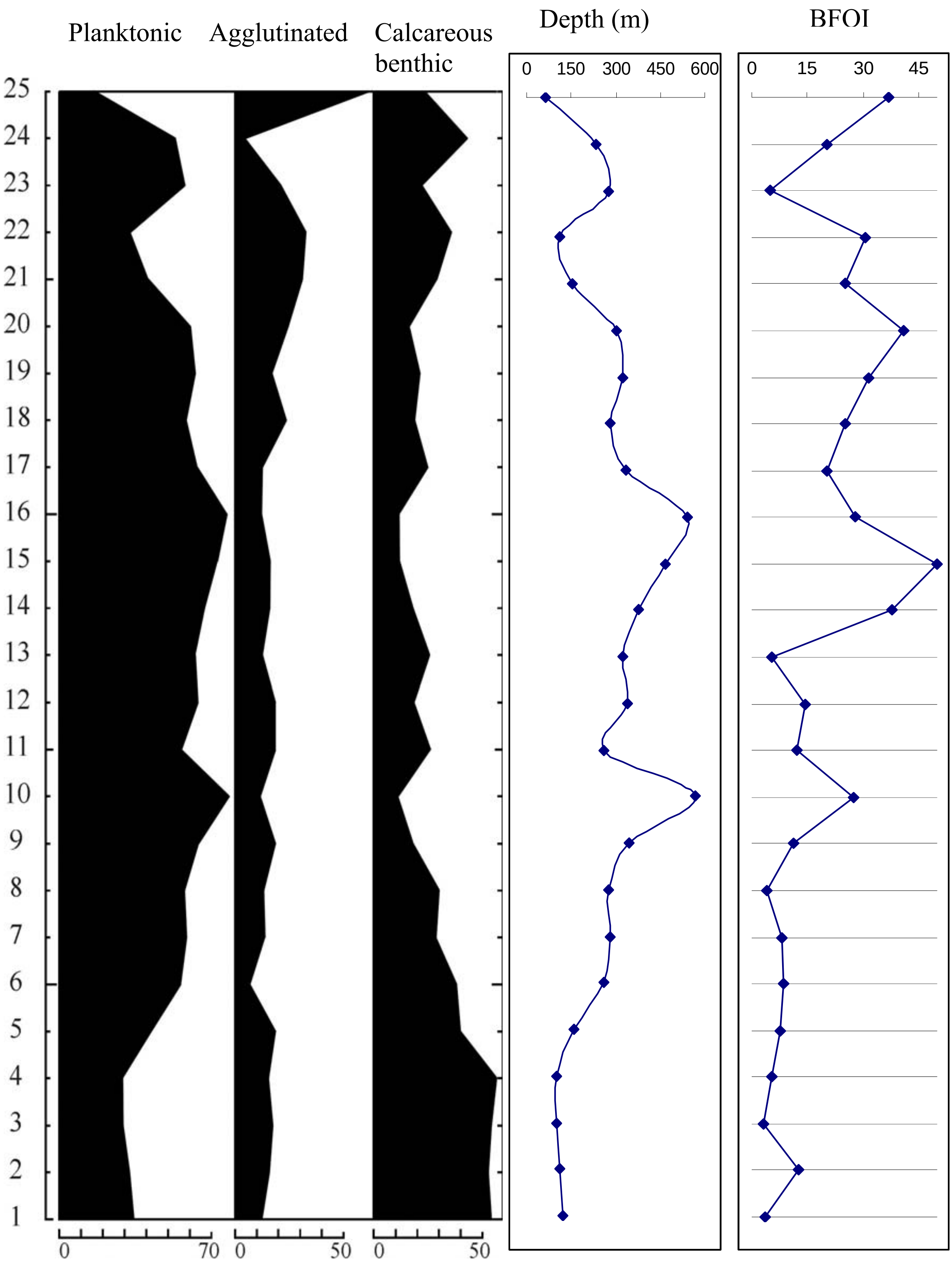

Fig. 24. The planktonic/benthic ratio (agglutinated and calcareous), water depth and dissolved oxygen index

One is to mention the sporadic presence of the M2c morphogroup (*Spiroplectammina*) probably correlated with a relative decrease of the relative sea level, in the upper part of the succession this morphogroup reach maximum values. At the top the abundance of M2b, M2c and M3a morphogroups increases and the abundance of the other morphogroups is reduced.

Based both on the planktonic/benthic ratio and on the morphogroups distribution may ascertain the transition from deep marine environment (bathial) to shelf environment.

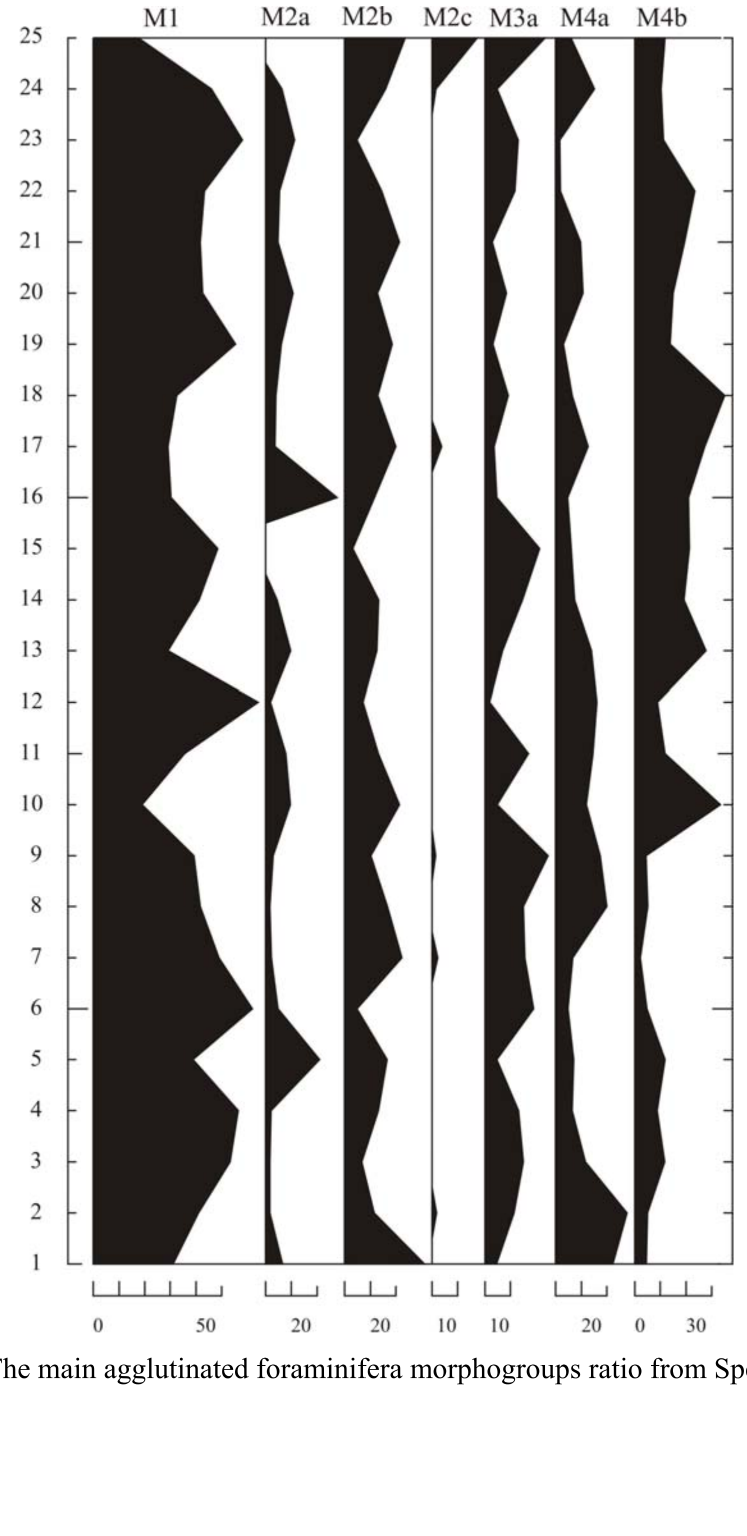

Fig. 26. The main agglutinated foraminifera morphogroups ratio from Spermezeu 3

On the territory of Chiuieşti village, the deposits are composed of fine clays corresponding to the Bouma Tc-Te divisions formed in the distal area of the turbiditic system.

The identified foraminifera assemblages are diverse, both with planktonic species and calcareous benthic and agglutinant. On the entire succession, both the values of diversity and the ones of equitability are high. The diversity is justified by the low values of the P/B ration and by the presence of various morphogroups (Beldean & Filipescu, 2008).

After analysing the identified foraminifera assemblages, it can be notice that the planktonic/benthic ratio (fig. 30) presents minor fluctuations, with the dominance of benthic foraminifera in the lower part of the succession, which subsequently are replaced by the planktonic one.

One notices the correlation between the foraminifera assemblages, water depth and dissolved oxygen quantity (fig. 30). Towards the top of the succession, there is a gradual transition from shallow environments, well oxygenated dominated by benthic foraminifera, especially calcareous (*Cibicidoides pachyderma, Neoeponides campester*), to deep marine environment, suboxic (0.3 – 1.5 ml/l oxygen) where the foraminifera assemblages are dominated by planktonic species. The benthic calcareous foraminifera present in the upper part of the section are representative for deep marine environments, weakly oxygenated: *Praeglobobulimina ovata, Globobulimina ovula, Uvigerina popescui, Stilostomella* sp.

The planktonic foraminifera are well preserved; the prevalent species are typical for Paratethys: *Globigerina praebulloides, Globigerina officinalis, Globigerina gnaucki, Globigerina steiningeri* and *Globigerina lentiana.* The peculiarity of planktonic foraminifera assemblages from this area is the relatively high dimension of individuals, which suggests the stability of the environment. As compared to other planktonic foraminifera assemblages identified in the Hida Formation (ex. Dragu, Cristolţ, Fântâlele), in Chiuieşti, the taxa belonging to the genus *Tenuilella* and *Tenuitellinata* are absent.

The agglutinated foraminifera (fig. 31) are present in relatively large proportions, which indicate the existence of favourable and stable environment conditions enabling the development of some large-sized tests (ex. very large tests of *Bathysiphon taurinense*).

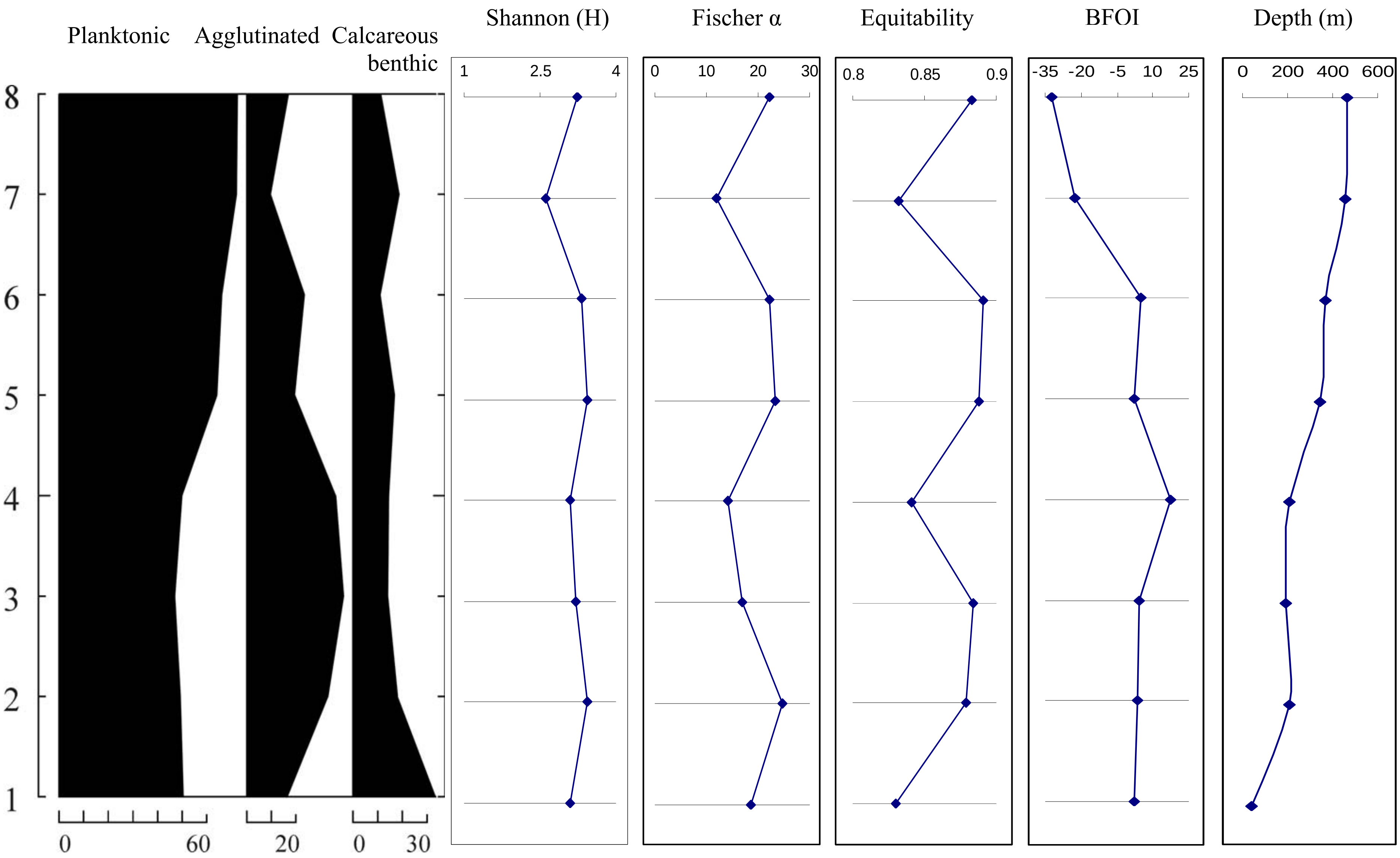

Fig. 30. The planktonic/benthic ratio (agglutinated and calcareous) and paleoecologic indices of foraminifera from Chiuieşti

The assemblage is composed of tubular forms (*Bathysiphon filiformis, Nothia latissima, Nothia excelsa, Psammosiphonella cylindrica, Hyperammina rugosa*), elongate tapered forms (*Reophax duplex*, *Karrerulina conversa, Karrerulina apicularis, Karreriella badenensis*) and coiling forms (*Cyclammina* sp., *Reticulophragmium acutidorsatum, Reticulophragmium rotundidorsatum, Trochammina kibleri, Miliammina* sp.).

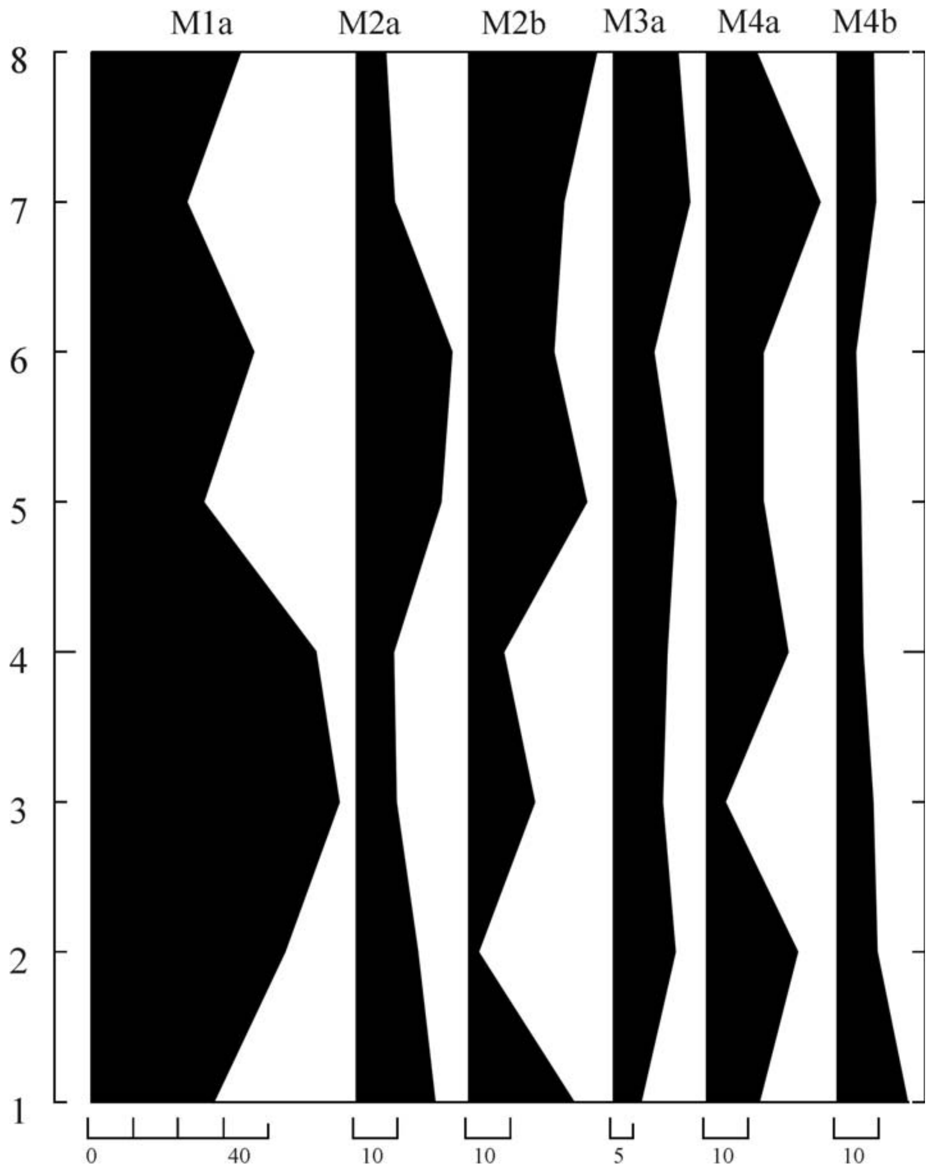

Fig. 31. The ratio between the main foraminifera agglutinated morphogroups from Chiuiești

The morphogroups distribution, the calcareous benthic foraminifera as well as the depth of water, indicates the transition from outer shelf environments to bathial environment, process probably associated to a transgressive episode.

4.1.10. Şimişna Valley

On the Şimişa Valley, close to the Ceaca village (Ceaca 1) we have identified clay deposits, characteristic to Bouma Td-Te divisions. Towards the upper part of the outcrop, sandstones replace clays.

Analyzing the planktonic/benthic ratio, one notices the prevalence of planktonic foraminifera (fig. 52); in the first sample, these reach an abundance of 80%, which corresponds to a high relative sea level. In the other samples, the abundance of planktonic foraminifera maintains its high values (50-60%). Both calcareous benthic foraminifera and the agglutinated ones present minor fluctuations in their abundance (between 10-20%).

The agglutinated foraminifera are diversified, even if they have a low abundance, being identified almost all the morphogroups (fig. 53), but the existence of higher proportions of M1 morphogroup (*Bathysiphon* sp., *Rhabdammina linearis, Psammosiphonella cylindrica*), M3a (*Ammodiscus* sp.) and M4a (*Cyclammina* sp., *Haplophragmoides* sp.) could be noticed. Among the representatives of the other morphogroups we have identified *Praesphaerammina subgaleata, Psammosphaera* sp. (M2a), *Budashevaella wilsoni, Cribrostomoides subglobosus* (M2b), (M3a), *Gaudrinopsis* sp., *Textularia* sp. (M4b).

The foraminifera assemblages (the planktonic/benthic ratio, distribution of agglutinated foraminifera morphogroups), as well as the sedimentologic features indicate a deep marine environment (bathial).

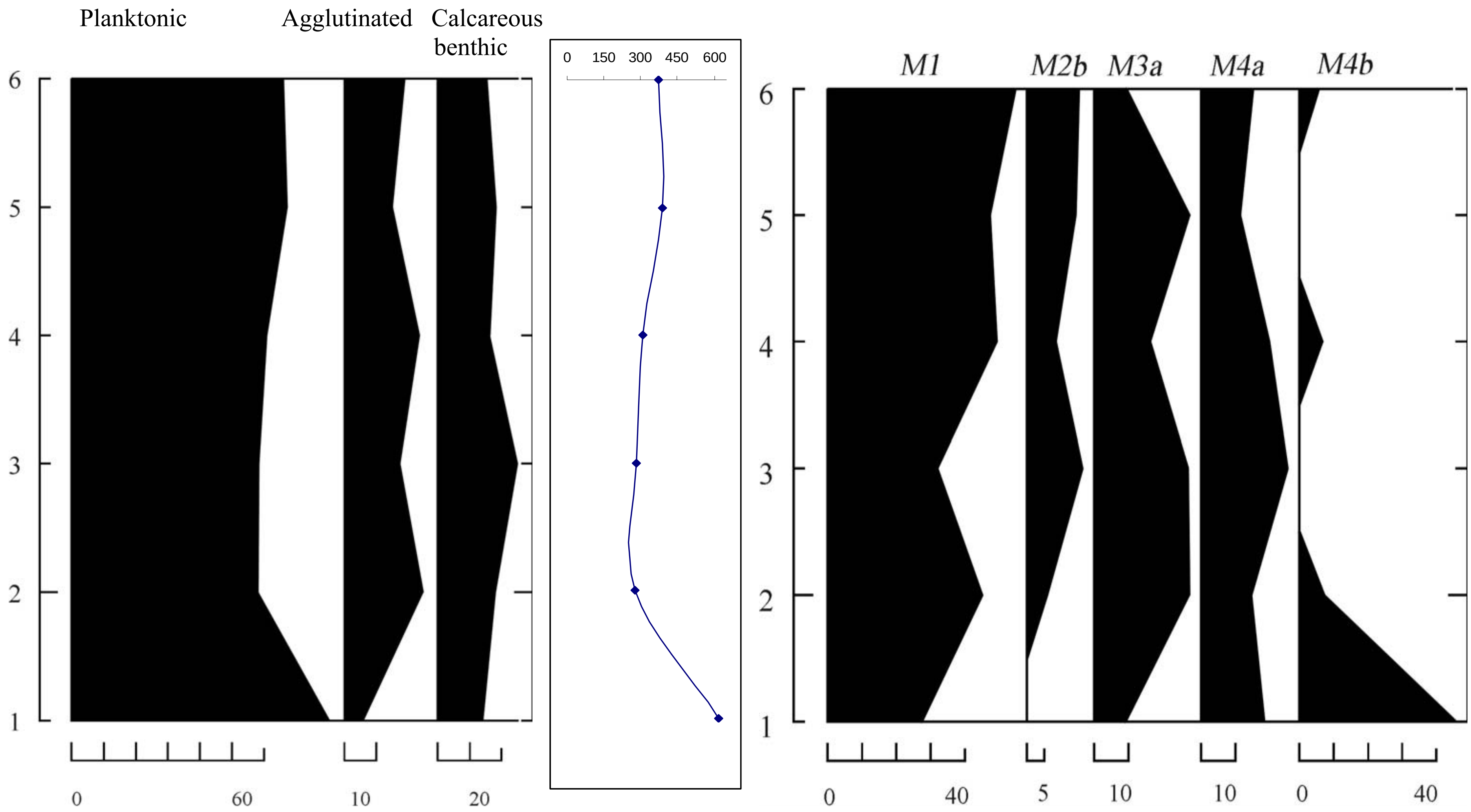

Fig. 52-53. The planktonic/benthic ratio, the depth and proportion of the main agglutinated foraminifera morphogroups from Ceaca 1

4.1.11. Cristolț

The deposits identified at Cristolț 2 are composed of centimetric and decimetric intercalations of sandstones and clays with a coarsening and thickening upward trend specific to middle turbidites (Tb-Td). From the clays intercalations we have collected three samples, the abundance of the main foraminifera groups is represented in figure 59. A gradual decrease of the planktonic foraminifera abundance is observed from the first to the third samples, correlated to the abundance of benthic forms.

Among the planktonic foraminifera there are found: *Globigerina bulloides, Globigerina praebuloides, G. diplostoma, G. concinna, G. ottnangiensis, G. dubia, Globigerinella obesa, Globigerina woodi, Paragloborotalia continuosa, Tenuitella clemenciae, Tenuitellinata juvenilis, Tenuitellinata pseudoedita.* The agglutinated foraminifera dominating the assemblage are represented by rounded planspiral and streptospiral forms (*Budashevaella laevigata, B. multicamerata, Haplophragmoides* sp., *Cyclamina cancellata*) together with some coarsely agglutinated tubular taxa (*Hyperammina rugosa*). The calcareous benthic foraminifera have a lower abundance; *Cibicidoides pseudoungerianus, Amphicoryna armata* and *Praeglobobulimina ovata* are the species with the largest number of individuals.

Both based on the sedimentologic and based on the succession of foraminifera assemblages, the regressive trend of the succession can be noticed.

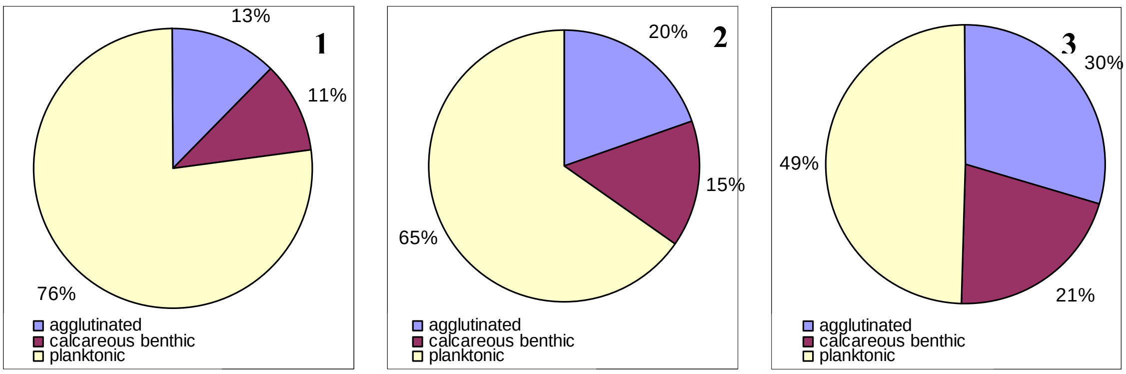

Fig. 59. The relative abundance of the main groups of foraminifera from Cristolț 2

4.1.15. Dragu

Near Dragu village, we have identified centimetres intercalations of clays, sandy-claystone, sands and sandstones corresponding to the middle part of the turbiditic fan (fig. 68).

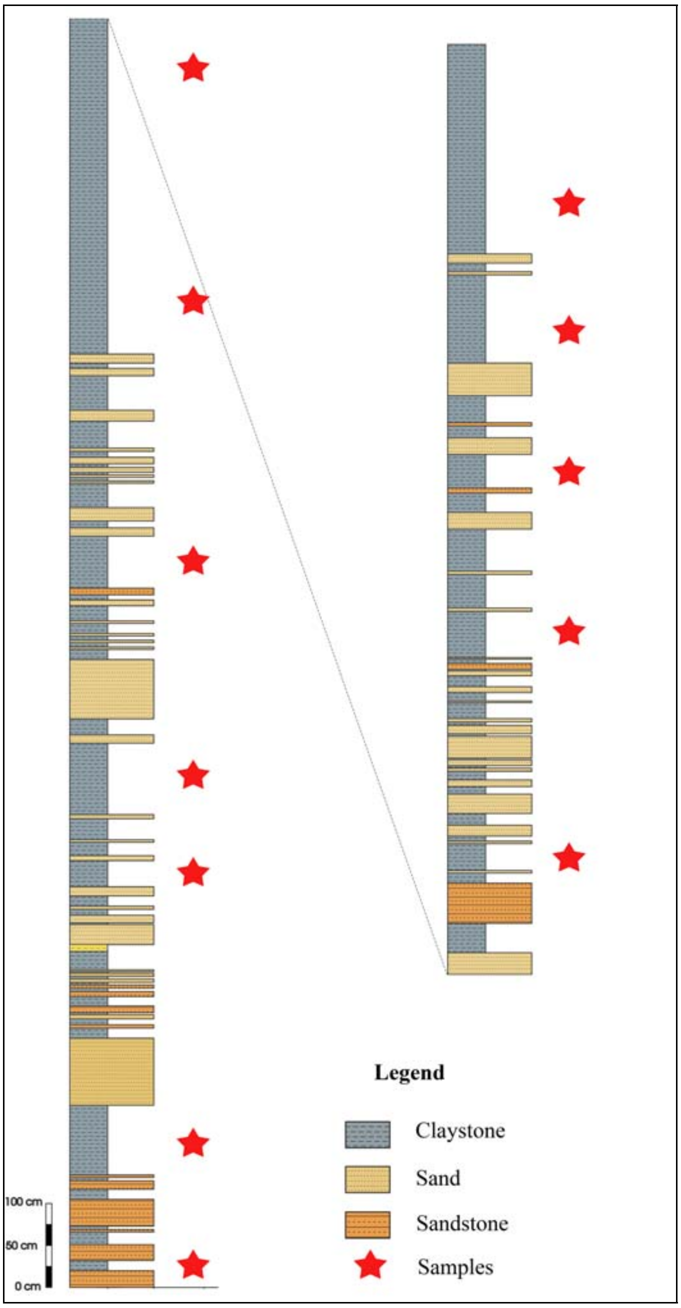

Fig. 68. The lithologic log of the Dragu succession

Analyzing the planktonic/benthic ratio (fig. 69) one could notice the net prevalence of the planktonic foraminifera; these have an abundance of more than 70% in almost all the succession. Similar to Cristolț, the small-sized planktonic foraminifera prevail:

Globigerina bollii, Globigerina bulloides, Globigerina praebulloides, Paragloborotalia semivera, Paragloborotalia continuosa, Paragloborotalia pseudocontinuosa, Globigerina altiapertura, *Tenuitellinata juvenilis, Tenuitellinata pseudoedita, Tenuitellinata angustiumbilicata, Tenuitellinata uvula, Tenuitella clemenciae.* The abundance of agglutinated foraminifera is generally low (10-20%) up to the level of the last sample, when their percentage participation reaches over 30%. The calcareous benthic foraminifera are represented by various species of the *Lenticulina, Nodosaria, Marginulina, Cibicidoides* genera, but with low abundance (exceptionally they reach 20% of the foraminifera total).

The water depth for the Dragu succession presents fluctuations between 200 m and 800 m, but with a general regressive trend especially in the upper part of the succession. Even if the relative marine level is high, the oxygen content has high values (1.5 – 6 ml/l), being an oxic to highly oxygenated environment.

The foraminifera diversity is relatively high (Shannon H 3 – 3.6; Fischer α 10 – 25), with minor fluctuations within the limit of these values. The same form characterizes the equitability values, which sometimes reach the upper limit.

The agglutinated foraminifera morphogroups distribution (fig. 71) is discontinuous, probably due to the low abundance and high diversity. Also, the sedimentary input and the disturbance of the substratum are factors determining the distribution of agglutinated foraminifera assemblages. The successive recolonization as a result of turbiditic flows might be the cause of small scale discontinuous distribution of the agglutinated foraminifera morphogroups.

In the Dragu succession, there are present all the morphogroups described by Kaminski & Gradstein (2005). One must notice the presence of the M3b morphogroup (*Ammolagena clavata*), as it occurs with very low frequency in the deposits of the Hida Formation, being present only in Cristolț and Șimișna.

The tubular taxa (the M1 morphogroup - *Bathysiphon* sp., *Rhyzammina indivisa, Rhizammina* sp) are abundant on the entire analyzed succession, representing sometimes up to 70% of the assemblage, with a lower percentage in the upper part when they reach 25%. Nagy et al., (1997) has interpreted the variations of this morphogroup as paleobathimetric indicator; this is abundant in the continental slope area where there is a high flow of organic matter. Similar to other sedimentary successions in the Hida Formation, one observes the reverse proportionality between the M1 and M4a morphogroup.

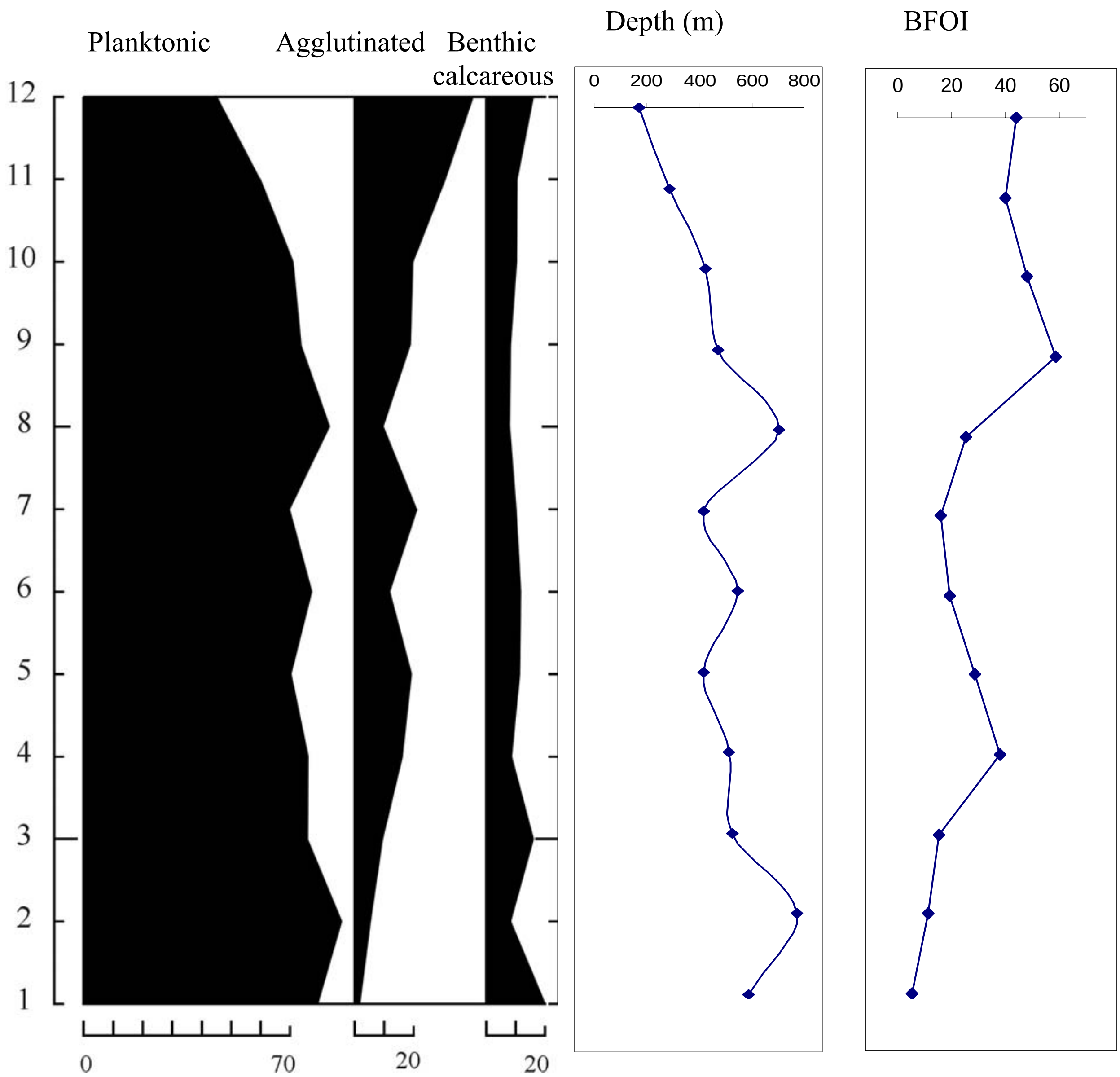

Fig. 69. The planktonic/benthic ratio (agglutinated and calcareous), depth and the dissolved oxygen index from Dragu

The planktonic/benthic ratio, the foraminifera agglutinated morphogroups distribution and the diversity values indices indicate a regressive trend in Dragu deposits and fluctuations of the oxygen content and organic matter.

All the samples collected from this outcrop, was analyzed to the calcareous nannoplankton point of view. Based on the identified assemblages, there was determined the Zone NN1 in samples 1-11, and in the last sample (12), the existence of the NN2 Zone was signalled.

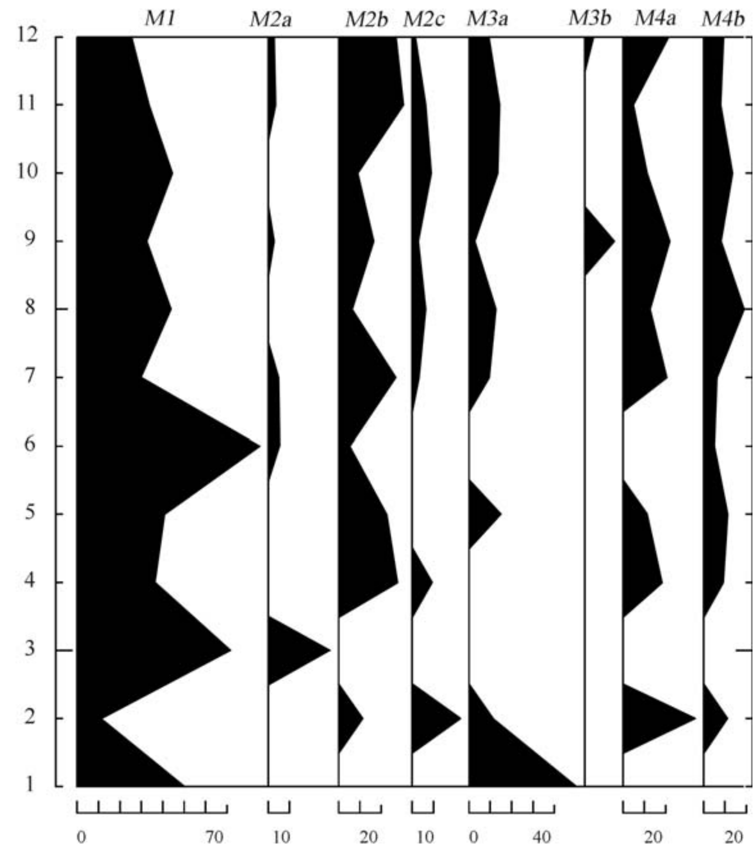

Fig. 71. The ratio between the main agglutinated foraminifera morphogroups from Dragu

4.2. Relationship between the agglutinated foraminifera assemblages and the depositional environments

In a series of studies (Kaminski, 2005; Kaminski et *al*., 1988; Kuhnt & Kaminski, 1990; Rai & Singh, 2001; Mendesa et *al*., 2004) benthic foraminifera were used for bathymetry interpretations.

For the characterization of the agglutinated foraminifera identified in the Hida Formation, we will use the types of assemblages separated by Kaminski & Gradstein (2005). Four types of deep marine assemblages were separated: assemblages (AA), "flysch type" assemblages (FTA) (lower bathial-abyssal), "scaglia type" assemblages (medium-low bathial) and slope assemblages (SMA) (upper-medium bathial) (fig. 81).

The "flysch type" and slope assemblages prevail in the Hida Formation; we have not identified proper abyssal assemblages, only "flysch type" assemblages with abyssal influences. Due to the tectonic evolution of the Transylvanian Basin, during the Lower Miocene there were no "scaglia type" assemblages.

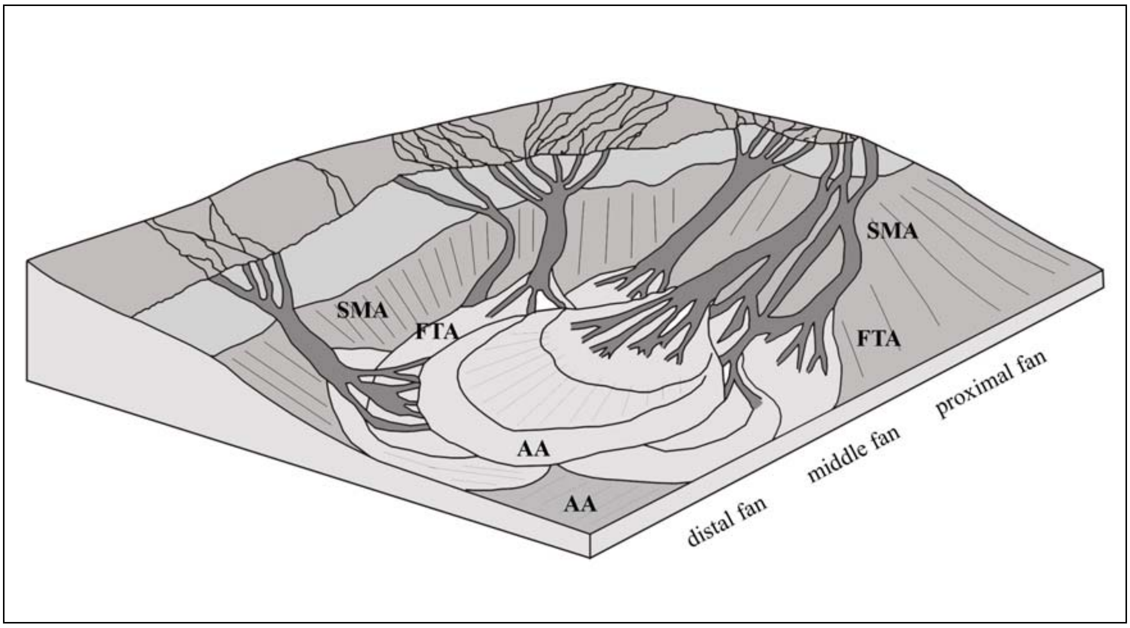

Fig. 81. The reconstruction of the depositional systems (modified after Eschard et al., 2004) and location of the agglutinated foraminifera assemblages (according to Kaminski & Gradstein, 2005) (SMA – slope assemblages, FTA – "flysch type" assemblages, AA – abyssal assemblages)

The slopes assemblages were identified in several outcropping areas: Şimişna 2, Spermezeu 2, Spermezeu 3, Fabrică. The foraminifera specific to the slope assemblages in the Hida Formation are represented by taxa with carbonate or arenaceous cement: *Ammodiscus incertus, A. miocenicus*, *Budashevaella laevigata, Budashevaella multicamerata, Cribrostomoides subglobosus, Karrerulina conversa, Karrerulina horida, Haplophragmoides* sp*, Miliammina* sp.

The diversity indices calculated for the slope assemblages are included within the following limits: Shannon H – 1.7-3.8; Fischer α – 11-27. These values correspond to the diversity of the slope assemblages described in the present environments (Murray, 1991). Generally, the depth where we identified slope assemblages ranges between approximately 100 m and 350 m, depths that are specific to the bathial and outer shelf areas. The dissolved oxygen values range between 1.5 – 3 ml/l, specific to an oxic environment.

The "flysch type" assemblages occur in several locations: Suciu de Sus, Rebra, Gersa, Coşbuc, Dumbrăveni 1, Şimişna 1, Cristolț 2, Dragu. As compared to the slope assemblages, the diversity of the agglutinated foraminifera is generally higher in the "flysch type" assemblages. Tubular forms dominate these assemblages: *Bathysiphon, Nothia, Rhabdammina, Rizammina*, *Hyperammina, Psammosiphonella* together with globular forms (*Psammosphaera, Saccammina*) or coiling forms (*Recurvoides, Haplophragmoides, Glomospira*). The occurrence of the coarse grain agglutinated foraminifera represents a peculiarity of these assemblages.

The "flysch type" assemblages with abyssal influences. We identified the "flysch type" assemblages but with some peculiarities specific to abyssal environments such as the fine-granular structure of the test, small sizes of the tubular forms. These have been identified in Chiuieşti, Strâmbu, Dumbrăveni 2, Ceaca 1. As compared to the specific abyssal assemblages the abundance and diversity is high. These are due to the location of the depositional environments above the CCD, so that calcareous benthic and planktonic foraminifera occur also.

4.3. Paleoecologic and paleogeographic implications of planktonic foraminifera assemblages

In the Hida Formation, we have noticed the existence of at least three episodes characterized by high abundance of the specific planktonic foraminifera assemblages:

- Assemblages with *Streptochilus pristinum*
- Assemblages with large globigerinids (*Globigerina* sp.)
- Assemblages with small globigerinids (*Globigerina* sp., *Tenuitella* sp. and *Tenuitellinata* sp.)

These assemblages were separated mainly based on the taxonomic composition. Between the last two types of assemblages, besides the taxonomic composition, the morphometric character of the individuals was a determining criterion in their separation, as the size of the planktonic foraminifera test reflects the specific environmental conditions.

4.3.1. *Streptochilus pristinum* assemblages

A particular assemblage was found in Ciceu-Giurgeşti, Zagra and Şoimeni in the clays deposits to the upper part of the Hida formation. Here we identified an assemblage composed almost exclusively (>90%) of biserial small-sized foraminifera (Beldean et al., 2009). The investigations performed at the electronic microscope have indicated that the foraminifera from Ciceu-Giurgeşti and Zagra contain almost exclusively small-sized forms belonging to the *Streptochilus* genus, planktonic taxa with Indo-Pacific origin. This type of assemblage is for the first time documented in the Lower Miocene of the Transylvanian Depression and, probably, from the Paratethys area (Beldean et al., 2010b). Thus, the assemblage is monospecific, distinctly dominated by *Streptochilus pristimum*. In Şoimeni, the assemblage we considered as equivalent contains only *Bolivina* species.

The lower Miocene *Streptochilus/Bolivina* assemblages had an explosive development as a reaction to the organic matter fluctuations caused by the transgressive event or due to a massif invasion from the Indian Ocean stimulated by the surface waters circulation. The difference between the foraminifera assemblages in the western Europe demonstrates clear evidences of the connection with the Indo-Pacific area; this assemblage is replaced by Mediterranean type of fauna only when the marine connections with the Mediterranean sea were re-established at the beginning of the Badenian.

4.3.2. Large globigerinids assemblages (*Globigerina* sp.)

These assemblages are characterized by the presence of individuals with large-sized, well-preserved tests, where the dominant species are *Globigerina praebulloides, Globigerina bulloides, Globigerina ciperoensis, Globigerina gnaucki, Globigerina steiningeri, Globigerina lentiana, Globigerina conicina, Globigerina dubia*, *Globigerina* cf. *wagneri, Globigerina ottnangiensis, Globigerinodes sicanus.* This type of assemblage was identified in several outcropping areas of the Hida Formation: Chiuieşti, Fabrică, Şimişna 1, Ceaca 1.

The large size of the foraminifera in these assemblages is probably due to the existence of some oligotrophic conditions with stable environmental parameters (Schmidt et al., 2003). Similar assemblages were identified in the Lower Miocene in Austria (the Molassic Basin) where the identified foraminifera indicated warm-temperate waters (Rögl & Spezzaferri, 2003).

4.3.3. Small globigerinids assemblages (*Globigerina* sp., *Tenuitella* sp. and *Tenuitellinata* sp.)

In Dragu, Cristolţ, Fântânele and Strâmbu, together with species of the *Gobigerina* genus, the assemblages are characterized by high percentages of taxa belonging to the *Tenuitella şi Tenuitellinata* genera. The prevailing species in these areas are *Tenuitellinata angustiumbilicata, Tenuitellinata juvenilis*, *Tenuitellinata pseudoedita, Tenuitella clemenciae, Tenuitella munda, Globigerina ottnangiensis, Globigerina tarchanensis, Globigerinella obesa, Globigerina dubia*, *Globigerina woodi, Paragloborotalia* sp. This assemblage is individualized by the small sizes of the individuals and the numerous presences of the juvenile forms belonging to the above-mentioned species.

The small size of the planktonic foraminifera test is due to the existence of some fluctuating environmental parameters in the surface waters, and the development of individuals was outside the optimum ecological parameters, so that they cannot reach the maximum size potential of the test (Al-Sabouni et al., 2007). The organic flow and temperature are the main factors influencing these assemblages.

The high abundance of the trochospiral microperforate planktonic foraminifera, of the *Tenuitella* and *Tenuitellinata* genera were associated with a transgressive event (Filipescu & Silye, 2008). In the Lower Miocene in Austria, such assemblages were identified at two stratigraphic intervals in Lower Miocene. Rögl & Nagymarosy (2004) have described a small-sized planktonic foraminifera assemblage in the Upper Aquitanian – Lower Burdigalian interval (biozone N5 according to Blow, 1969). Another small-sized planktonic foraminifera assemblage was identified at the base of the Ottnangian in Austria. In this region, the existence of the upwelling currents was highlighted. These currents bring periodically cold waters rich in nutrients to the surface and there is a sedimentary input from the land area (Roetzel et al., 2006; 2007).

The presence in the Hida Formation of these assemblages where the *Tenuitella* and *Tenutellinata* genera have a significant contribution, suggests the existence of a transgressive episode and probably a marine connection in the Indo-Pacific areas.

4.4. The paleogeographic zonation of the foraminifera assemblages

The Lower Miocene deposits are represented by the sedimentary fill of a flexural basin that developed in the central-northern part of the Transylvanian Depression as response to the final thrusting and emplacement of the Pienides thrust nappes. These deposits are bounded at the base by an unconformity that can be traced as correlative surface towards north. The Lower Miocene sedimentary succession is wedge-like: it thickens toward the Pienides (thrust front) and thins toward the forebulge area (i.e. the central parts of the Transylvanian Basin) (Krézsek & Bally, 2006).

For the complete interpretation of the foraminifera assemblages in the Hida Formation, we used four seismic profiles performed by S.N.G.N. Romgaz S.A. Most of them have a general N-S orientation (profiles 2, 3, 4), one is E-W oriented (profile 1) (fig. 85). The Hida Formation was defined both based on the observed seismic reflectors and on the geographic boundaries from various formations.

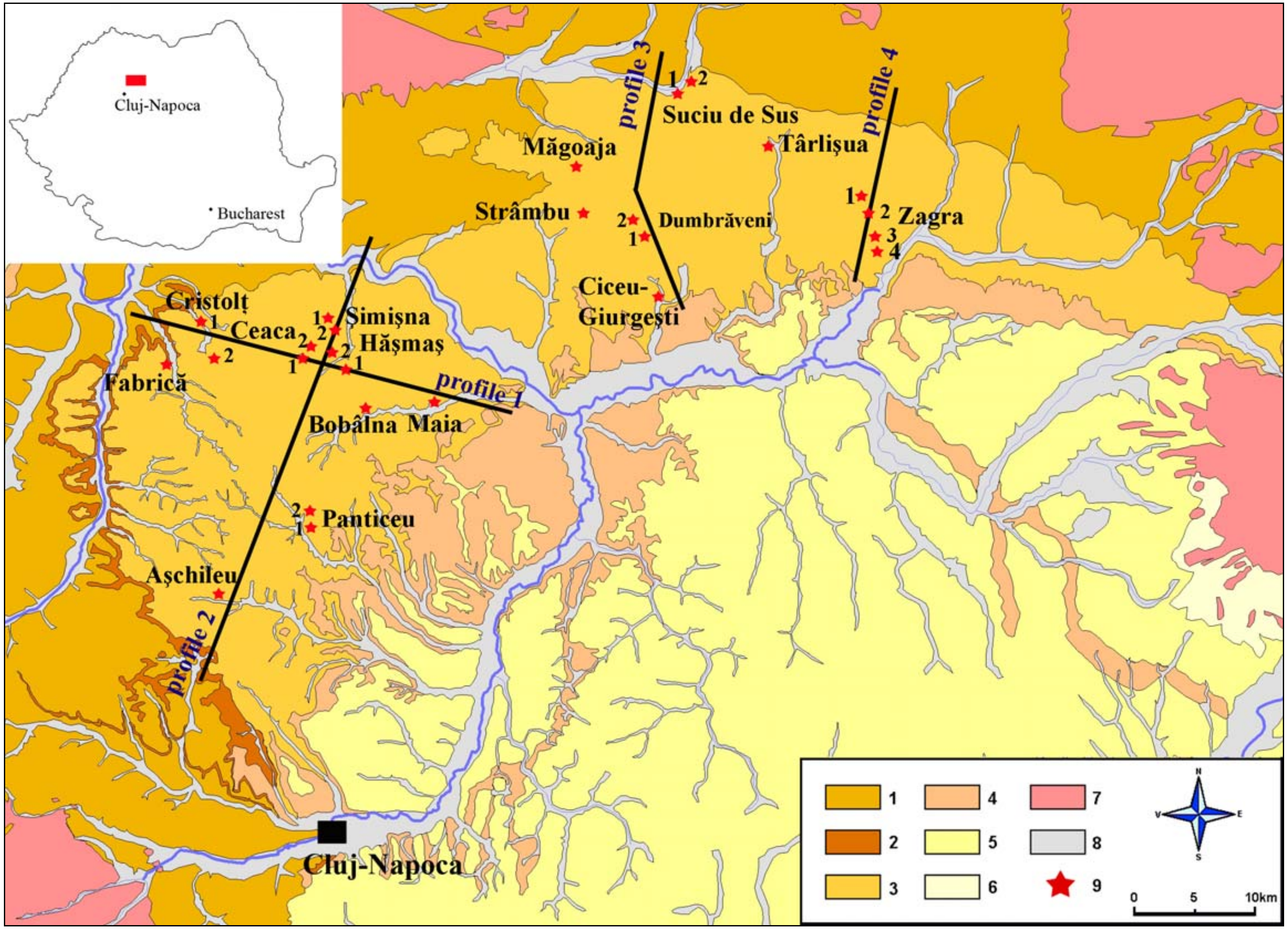

Fig. 85. Location of seismic profiles

✓ 3rd seismic profile

This seismic profile is North-South oriented (fig. 88). At least three unconformities separating the various seismic packages are identified. The reflectors observed above these discordances are amalgamated, have higher amplitude and a canalized external form suggesting the deposition of coarse grain sediments. These unconformities correlated to the changes of seismic facies indicate a sin-sedimentary tectonic activity, which caused transgressions and regressions at the basin level (Krézsek & Bally, 2006).

The analyzed samples from Suciu de Sus are the oldest and probably the deepest. The newer deposits in this region were probably eroded together with the elevation of the Pienides. Agglutinated forms indicating bathial environments with abyssal influences dominate the foraminifera assemblages identified here. At the top of the succession, these migrate into slope assemblages (*Budashevaella*), where the abundance of the calcareous benthic foraminifera increases considerably.

The Târlişua deposits are composed of centimetre and decimetre alternations of sandstones and clays, representing middle fan turbidites (Tb-Td). The samples collected from these deposits are poor in foraminifera, so that it is difficult to define the depositional environment.

In Măgoaja, the sedimentary succession is composed of conglomerates and sandstones representing the Ta and Tb divisions of the Bouma sequence. These were formed in high-energy flow regime in the upper part of the submarine fans. The erosion basis of the sediments indicates a channel depositional environment. These coarse deposits might represent one of the discordances remarked in the Lower Miocene formed under the circumstances of a low relative sea level (Krézsek & Bally, 2006).

Fine with thin sandstones intercalations was identified at Strâmbu. Small-sized planktonic foraminifera (*Globigerina ottnangiensis, Globigerina tarchanensis, Globigerinella obesa, Tenuitella* sp.) dominate the foraminifera assemblage identified here. Planktonic foraminifera have an abundance higher than >70%, which corresponds to wide-sea environments, beyond the continental slope (Murray, 1991). The agglutinated foraminifera present a low abundance, being represented by large-sized individuals of the genus *Ammodiscus* and *Bathysiphon.*

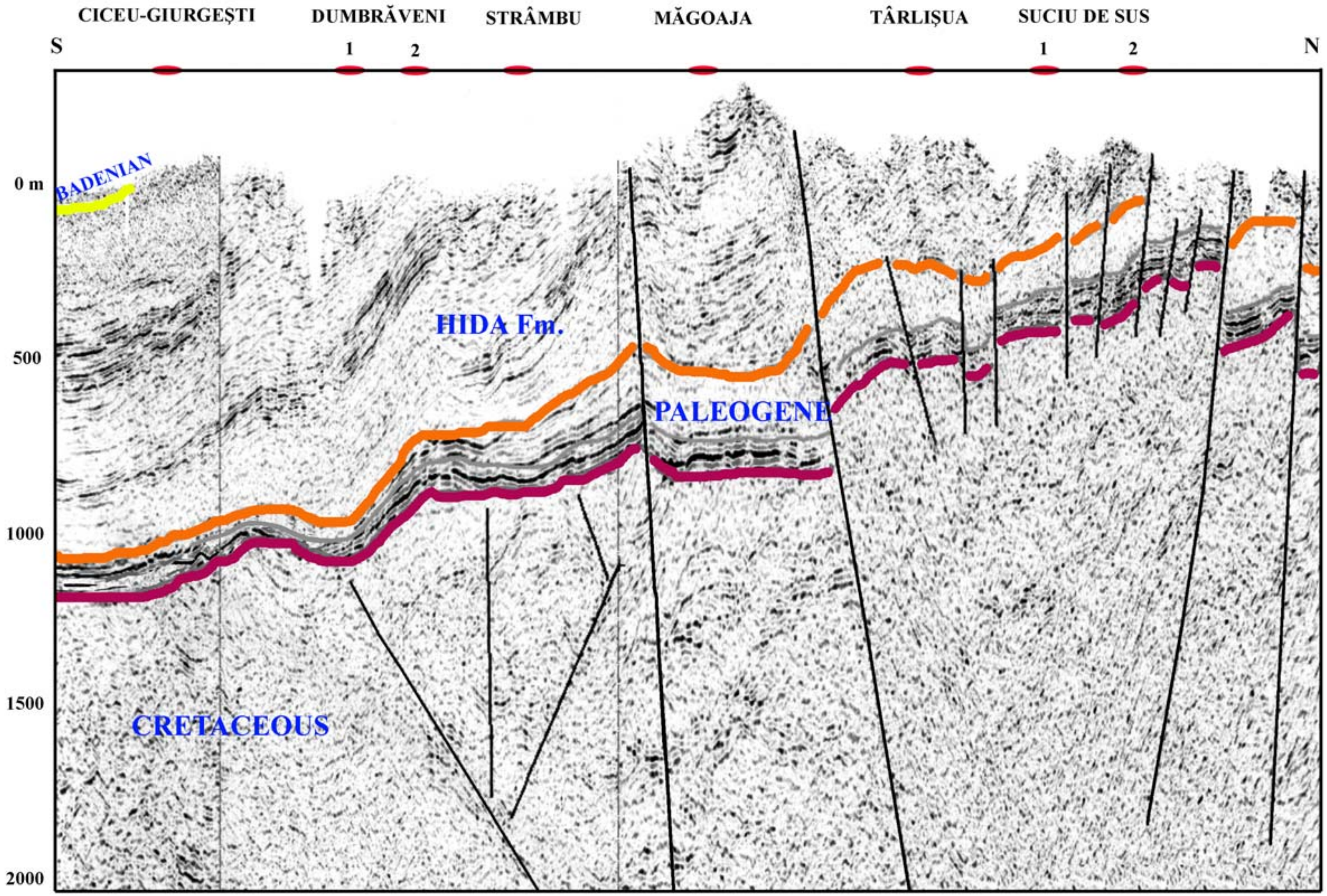

Fig. 88. Seismic N – S oriented profile (profile 3) (according to Krézsek & Bally, 2006)

4. 5. Biostratigraphy of the Hida Formation

4.5.1. Biostratigraphic implications of the planktonic foraminifera assemblages

The planktonic foraminifera are well represented in several intervals from the Hida Formation, where we have identified numerous species, such as: *Globigerina praebulloides, G. bulloides, G. officinalis, G. gnaucki, G. steiningeri, G. lentiana, G. obesa, G. conicina, Globigerinodes sicanus, Tenuitellinata pseudoedita*, *Globigerina ottnangiensis, Globigerina tarchanensis, Globigerinella obesa, Globigerina dubia*, *Globoquadrina langhiana.* Unfortunately, these foraminifera have a wide stratigraphic distribution, being specific to the entire Lower Miocene. Such planktonic foraminifera assemblages were described by Rögl (1985) in the Central Paratethys area where the author assigns them Eggenburgian-Ottnangian age and correlates them to the *Globigerinoides trilobus* zone (Iaccarino, 1985) described for the Mediterranean area and the *Globigerina bollii* zone in the Carpathian area (Pishvanova, 1968 in Rögl, 1985).

4.5.2. Biostratigraphic implications of the biserial planktonic foraminifera assemblages

In the Hida Formation, the planktonic foraminifera assemblages contain taxa such as: *Globigerina ottnangiensis, Globigerina dubia, Globigerina tarchanensis, Globigerina praebulloides, Globigerina officinalis.* Rögl (1994) and Rögl et al. (2002) have mentioned such planktonic assemblages as common in the Lower Miocene from the Central Paratethys. The biseriate foraminifera assemblages (*Streptochilus pristinum*) from Ciceu-Giurgeşti and Zagra, is biostratigraphically located between these globigerinids assemblages and the first Badenian assemblages with *Praeorbulina* (M5a biozone according to Berggren et al., 1995 – fig. 90).

The calcareous nannoplankton in the same deposits indicates the Biozone NN4 with *Helicosphaera ampliaperta.*

The particular occurrence of biserial foraminifera in relationship with transgressive trends confers the assemblage a high correlation potential. This is the reason that we considered the separation of a new biozone completely justified:

The *Streptochilus – Bolivina* abundance Biozone

Definition: it is represented by the body of strata belonging to a distinct transgressive interval in the upper part of the Burdigalian (fig. 90), with a high abundance of the biserial foraminifera of the genera *Streptochilus* (*Streptochilus pristinum*) and *Bolivina* (*B. dilatata dilatata*, *B. dilatata brevis*, *B. molassica*).

Age: Latest Burdigalian (?Ottnangian—Karpatian), above the Early Miocene assemblage with small trochospiral globigerinids (*Globigerina* spp., *Tenuitellinata* spp.) and below the first occurrence of Middle Miocene *Praeorbulina*. Probably the optimum abundance interval was between 16.8 and 16.4 Ma in the classification of Rögl et al. (2008).

Representative sections: Ciceu-Giurgeşti, Zagra, Şoimeni.

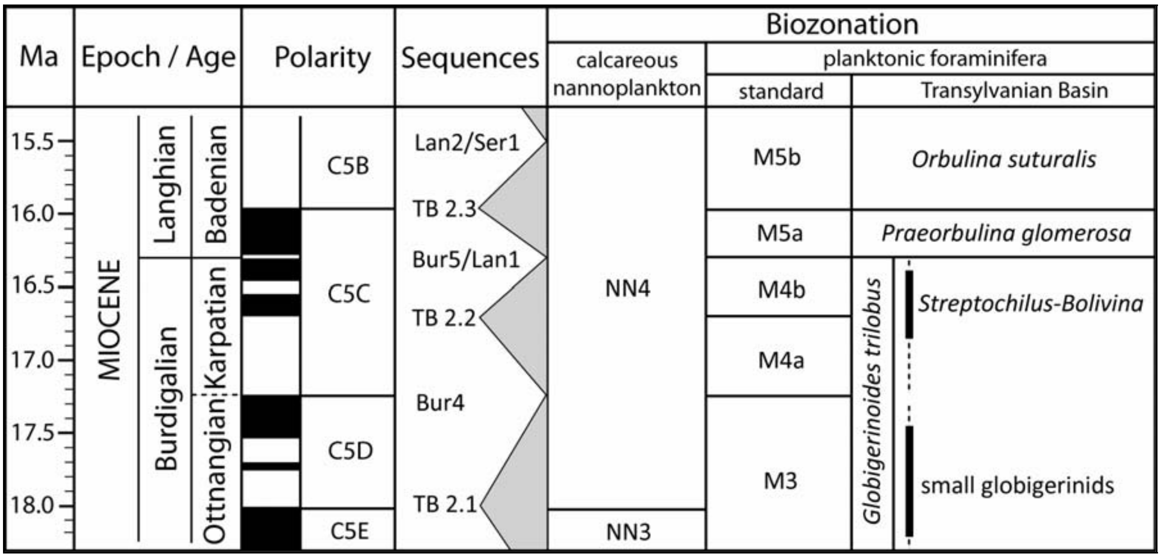

Fig. 90. Position of the *Streptochilus-Bolivina* Abundance Biozone within the stratigraphic zonations in use (zones based to Rögl et al., 2008, Haq et al., 1988; Hardenbol et al., 1998; Berggren, 1995; Popescu, 1975)

4.5.3. Biostratigraphic implications of the calcareous nannoplancton assemblages

In order to attempt to calibrate the foraminifera assemblages, we have tried to date some parts of the formation using the calcareous nannoplankton assemblages. In the Dragu succession (Western part of the formation), the Zones NN1 and NN2 were identified. The NN1 Zone with *Triqutrorhabdulus carinatus* was defined between the last occurrence (LO) of the species *Helicopshaera recta* and the first occurrence (FO) of the species *Discoaster druggii* and indicates the Upper Egerian age – Lower Eggenburgian (Aquitanian – Lower Burdigalian).

The calcareous nannoplancton assemblages existing in the samples of Şimişna 2 are dominated by species typical for the Lower Miocene (*Helicosphaera scissura,* *Helicosphaera mediterranea, Sphenolithus belemnos, Helicosphaera ampliaperta*), but wide distribution taxa also occur (*Coccolithus pelagicus, Helicosphaera carteri, Cyclicargolithus floridanus*). The presence of the species *Sphenolithus belemnos* indicates the Zone NN3 (according to Martini's biozoning, 1971), defined by the LO of the species *Triquetrorhabdulus carinatus* and the LO of the species *Sphenolithus belemnos*, characteristic to the Upper Eggenburgian interval – Lower Ottnangian (Burdigalian).

In Ciceu-Giurgeşti and Zagra the identified nanoplancton Zone NN4 with *Helicosphaera ampliaperta* (defined from the LO of the *Sphenolithus belemnos* and LO of the species *Helicosphaera ampliaperta*) in the upper part of the Burdigalian (according to Martini's classification, 1971).

The calcareous nannoplankton we have identified in the Hida Formation (*Coccolithus pelagicus, Helicosphaera carteri, Helicosphaera scissura, Reticulofenestra minuta*) indicates larger age intervals for this unit, respectively the entire Lower Miocene (fig. 91). We consider that the lower part of the Hida Formation is synchronous with the Coruş and Chechiş Formations, which represent shallow marine environments. The superposition of these lithostratigraphic units was performed during the transgressive interval (proximal environments of the Coruş type were covered by shelf environments of the Chechiş type and partially by deep turbiditic environments of the Hida type) and finally by the ample regression corresponding to the upper part of the Hida Formation, cased by the elevation of Pienides.

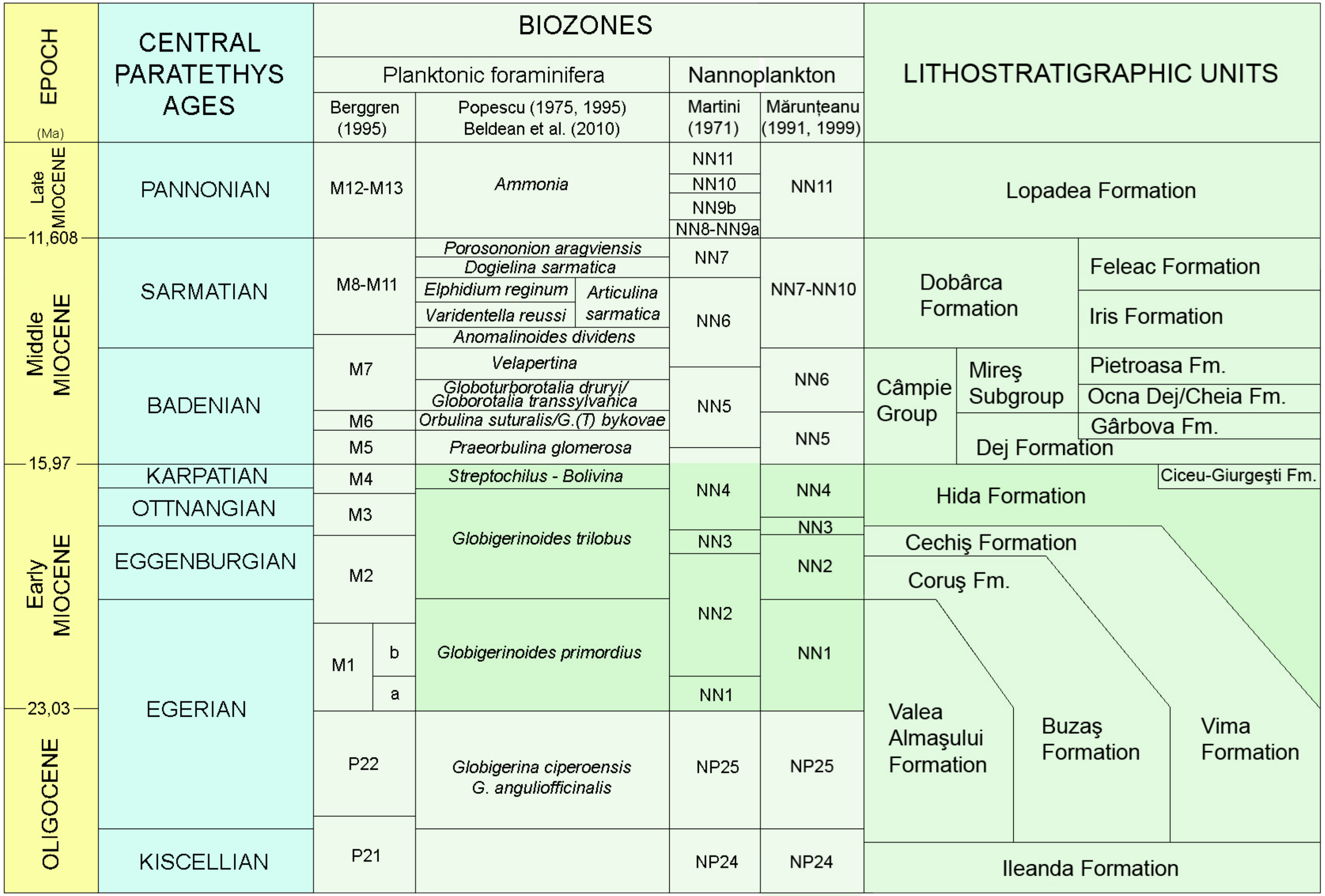

Fig. 91. The correlation between the Lower and Middle Miocene Biozones based on the foraminifera and calcareous nannoplankton with the lithostratigraphic units in the Transylvanian Depression (acc. to Berrgren 1995; Blow, 1969; Popescu, 1975, 1995; Martini, 1971; Filipescu, 2001, 1996a; Mărunțeanu, 1991, 1999; Beldean et al., 2010b)

CHAPTER 5

Systematic description of the foraminifera identified in the Hida Formation

Our investigations in the Hida Formation have identified over 250 species of foraminifera. The benthic foraminifera are exposed in taxonomic order based on Loeblich & Tappan's (1987) suprageneric classifications for the calcareous ones and Kaminki's (2004a) for the agglutinated ones. The planktonic foraminifera were taxonomically ordered according to Kennett and Srinivasan (1983).

The taxonomic identification of species is based mainly on the following papers: Kaminski & Gradstein (2005), Kennett & Srinivasan (1983), Cicha et al., 1998, Popescu, 1975, Spezzaferri, 1994 etc.

CHAPTER 6

Conclusions

The present study has approached the specific foraminifera assemblages in the Hida Formation, largely considered a sedimentary unit which has evolved in a complex context, in a flexural basin influenced by the regional tectonics.

The well represented deep-water foraminifera assemblages, the distribution of the agglutinated foraminifera morphogroups and the sedimentologic characteristics of the Hida Formation demonstrates the presence of the deep marine environments (from bathial to outer shelf). These deep environments were found in almost all the areas where the formation outcrops as turbiditic deposits (Fântânle, Ceaca, Chiuieşti, Hăşmaş, Dragu, Cristolţ, Suciu de Sus, Spermezeu, Şimişna). Consequently, we consider inappropriate the use of the "molasses" or "fluvial-deltaic" deposits terms for the Hida Formation, as it was till recently considered.

The various lithostratigraphic units described in the Lower Miocene from the Transylvanian Depression (the Coruş, Chechiş, Vima, Hida Formations) represented synchronous depositional environments at the beginning of the basin evolution. The superposition of these units was performed during the transgressive interval (the proximal environments of the Coruş type were covered by shelf environments of the Chechiş type and partially by deep turbiditic environments of the Hida type) and finally by the ample regression corresponding to the upper part of the Hida Formation, caused by the elevation of the Pienides.

After analyzing the agglutinated foraminifera morphogroups we have identified several types of assemblages, similar to those described by Kaminski & Gradstein (2005):

- ✓ The "flysch type" assemblages in the Hida Formation were identified in several locations: Suciu de Sus, Rebra, Gersa, Coşbuc, Dumbrăveni 1, Şimişna 1, Cristolț 2, Dragu, where the highest values of the agglutinated diversity were recorded. Tubular forms dominate these assemblages: *Bathysiphon, Nothia, Rhabdammina, Rizammina*, *Hyperammina, Psammosiphonella* together with globular forms (*Psammosphaera, Saccammina*) or coiling forms (*Recurvoides, Haplophragmoides, Glomospira*). These are characterized by the development of large-sized tests. The "flysch type" assemblages are common in the bathial environments, in the distal turbidites at the bottom of the continental slope. These were found at depth ranging between 200 and 800m in the samples analyzed in the Transylvanian Depression.
- ✓ The slope assemblages found in the samples collected from Şimişna 2, Spermezeu 2, Spermezeu 3, Fabrică are characterized by the presence of foraminifera with calcareous cement. The assemblages identified in these deposits contain species such as *Ammodiscus incertus, Ammodiscus miocenicus, Budashevaella laevigata, Haplophragmoides fragilis, Subreophax* sp., *Cribrostomoides subglobosus*. Generally, the depth we identified the slope assemblages ranges between approximately 100 and 350 m, depths specific to the bathial areas and outer shelf areas.
- ✓ We have not identified typical abyssal assemblages in the Hida Formation, only "flysch type" assemblages with abyssal influences (Chiuieşti, Strâmbu, Dumbrăveni 2, Ceaca 1) where the genera *Reticulophragmium, Haplophragmoides, Karrerulina* are common. Beside these, *Rhizammina, Bathysiphon* and *Hyperammina* also occur, but, as compared to the representatives of these genera from the "flysch type" assemblages, in this type of environment the tests are more fragile and have small sizes. As compared to the specific abyssal assemblages, the abundance and diversity of the assemblages we identified is high. These are due to the location of the depositional environments above the CCD, so that calcareous benthic and planktonic foraminifera assemblages also occur.

Based on the analysis of the calcareous benthic foraminifera assemblages and their preferences for the particular habitats, we have established the dissolved oxygen within the basin for different areas within the Hida Formation. Generally, the values achieved indicate oxygenated environments (1.5 – 3 ml/l dissolved oxygen), with rare suboxic episodes (0.3

– 1.5 ml/l dissolved oxygen). Where possible, the oxygen level was correlated to the water depth so that it was noticed that the high relative sea level intervals corresponds to the low values of oxygen.

Following the evolution in time of the foraminifera assemblages, one can notice the existence of several transgressive-regressive cycles, with several important decreases of the relative sea level (conglomerates from Măgoaja, Spermezeu 2, Cristolț 1, Şimişna 2).

The sediments in the northern part of the Hida Formation are the oldest (Suciu de Sus). These have at the base Paleogene formations. The deposits in the Western part of the formation (Fabrică, Cristolț) are newer and overthrust progradantly from the north over lower Miocene formations (Coruş şi Chechiş). In the Southeastern part, the newest deposits of the formation outcrop. The boundary with the Badenian formations is identified here (Ciceu-Giurgeşti, Zagra, Şoimeni).

The identification of particular biserial planktonic foraminifera assemblages in Ciceu-Giurgeşti, Zagra and Şoimeni has offered the possibility to separate a new biozone – **The *Streptochilus – Bolivina* Abundance Biozone** in the upper part of the formation (Beldean et al. 2010b).

Planktonic foraminifera assemblages with small-sized *Globigerina* sp., *Tenuitella* sp. and *Tenuitellinata* sp. were correlated to the nannoplankton Zones of NN1 and NN2 (Upper Egerian – Eggenburgian, according to Martini, 1971).

The identification of the calcareous nannoplankton NN1 – NN4 zones in the Hida Formation imposes the expansion of time distribution of the formation during the entire lower Miocene interval (Aquitanian – Burdigalian).

The presence of the particular planktonic foraminifera assemblages with *Tenuitella* and *Tenutellinata* as well as of the *Streptochilus* assemblage in the Hida Formation, suggests the existence of transgressive episodes and marine connections with the Indo-Pacific area, in at least two distinct stratigraphic intervals: one at the base of the lower Miocene (the NN1 area – Dragu, Fântânele), and another at the limit between Lower and Middle Miocene (NN4 – Ciceu-Giurgeşti, Zagra).

The highlight of the relationship between the de foraminifera assemblages and the depositional environments based on the quantitative methods was clearly confirmed by the sedimentologic and seismic observations. An overview was thus acquired on the geographic distribution of assemblages, on the fossil population succession and thus on the evolution of the sedimentary basin during the deposition of the Hida Formation.

SELECTIVE REFERENCES

AL-SABOUNI, N., KUCERA, M., SCHMIDT, D. N., 2007: Vertical niche separation control of diversity and size disparity in planktonic foraminifera. *Marine Micropaleontology*, **63**(1-2): 75-90.

BELDEAN, C., FILIPESCU, S., 2008: Abundance, diversity and similarity of agglutinated foraminifera assemblages of the Hida Formation (NW Transylvanian Basin, Romania). *Eighth International Workshop on Agglutinated Foraminifera, Cluj University Press* (abstracts volume)*,* 2-2 pg.

BELDEAN, C., FILIPESCU, S., AROLDI, C., IORDACHE, G., 2010 (in press): Foraminifera assemblages and Early Miocene paleoenvironments in the NW Transylvanian Basin. *Acta Paleontologica Romaniae*, **7**: xx-yy.

BELDEAN, C., FILIPESCU, S., BALC, R., 2009: "Bolivinid event" in the Early Miocene of Transylvanian Basin. *Neogene of Central and South-Eastern Europe, Presa Universitara Clujeana* (abstracts volume), 5-5.

BELDEAN, C., FILIPESCU, S., BĂLC, R., 2010 (in press): An Early Miocene biserial foraminiferal event in the Transylvanian Basin (Romania). *Geolologica Carpathica*, **61**(3): xx-yy.

BERGGREN, W.A., KENT, D.V., SWISHER III, C.C., AUBRY, M.P.A, 1995: Revised Cenozoic geochronology and chronostratigraphy. In: BERGGREN, W.A., KENT, D.V., HARDENBOL, J., (eds.), Geochronology, time scale and global stratigraphic correlations: a unified temporal framework for a historical geology. S*ociety of Economic Paleontologists and Mineralogists, Special Publication,* **54**: 129-212.

BLOW, W.H. 1969: Late Middle Eocene to Recent planktonic foraminiferal biostratigraphy. In: BRÖNNIMANN, P., RENZ, H.H. (eds.), *Proceedings of the First International Conference on Planktonic Microfossils, Geneva, Leiden*, **1**: 199-421.

CETEAN, C.G. 2009. Cretaceous foraminifera from the southern part of the eastern Carpathians, between Stoenesti and Cetateni. Paleoecology and Biostratigraphy. *Ph.D. Thesis*, Babes-Bolyai University, 214 pg.

CICHA, I., RÖGL, F., RUPP, C., CTYROKA, J., 1998: Oligocene - Miocene foraminifera of the Central Paratethys. *Abhandlungen der Senckenbergischen Naturforschenden Gesellschaft*, **549**: 1-325.

CIULAVU, D., 1999: Tertiary tectonics of the Transylvanian Basin. *Phd thesis, Vrije Universiteit, Amsterdam*, 152 pg.

CIUPAGEA, D., PAUCĂ, M., ICHIM, T., 1970: Geologia Depresiunii Transilvaniei. *Editura Academiei RSR*, Bucuresti, 256 pg.

CSONTOS, L., NAGYMAROSI, A., HORVATH, F., KOVAC, M., 1992: Tertiary evolution of the intra-Carpathian area; a model. *Tectonophysics*, **208**: 221-241.

DUMITRESCU, I., 1957: Asupra faciesurilor şi orizontării Cretacicului superior şi Paleogenului din bazinul Lăpuşului (nordul Depresiunii Transilvaniei). *Lucrările Instutului de Petrol şi Gaze,* **3**: 13-45.

FILIPESCU, S., 2001: Cenozoic Lithostratigraphic Units in Transylvania. in BUCUR, I.I., FILIPESCU, S., SĂSĂRAN, E. (eds), Algae and carbonate platforms in western part of Romania. 4th Regional Meeting of IFAA Cluj-Napoca 2001 - Field Trip Guidebook. Cluj-Napoca: *Cluj University Press*, 75-92.

FILIPESCU, S., BELDEAN, C., 2008: Foraminifera in the deep-sea environments of the Hida Formation (Transylvanian Basin, Romania). *Acta Paleontologica Romaniae*, **6**: 105-114.

FILIPESCU, S., SILYE, L., 2008: New Paratethyan biozones of planktonic foraminifera described from the Middle Miocene of the Transylvanian Basin (Romania). *Geologica Carpathica,* **59**(6): 537-544.

HAQ, B. U., HARDENBOL, J., VAIL, P. R. 1988: Chronology of fluctuating sea level since the Triassic. *Science*, **235**: 1136–1167.

HARDENBOL J., THIERRY J., FARLEY M.B., JACQUIN T., DE GRACIANSKY P.C., VAIL P.R., 1998: Mesozoic and Cenozoic sequence chronostratigraphic framework of European Basins. In: *Mesozoic and Cenozoic sequence stratigraphy of European Basins* (de Graciansky, P.C., Hardenbol, J., Jacquin, T., Vail, P.R., Ed.), *Society for Sedimentary Geology,* Special Publication, **60**: 3-13.

HAUER, F.R. VON, STACHE, G., 1863: Geologie Siebenbürgens. Wien, *Braumüller*, 637 pg.

HOFMANN, K., 1887: Geologische Notizen uber die krystallinische Schiferinsel von Preluka und uber das nordlich und südlich anschlissende Tertiarland. *Jahr. k. ung. geol.* (1885), 31-61.

HORVÁTH, F., BADA, G., SZAFIÁN, P., TARI, G., ÁDÁM, A., CLOETINGH, S., 2006: Formation and deformation of the Pannonian Basin: constraints from observational data. In : Gee, D. G., Stephenson, R. A.(eds.), European Lithosphere Dynamics. *The Geological Society of London,* **32:** 191-206.

ICCARINO, S., 1985: Mediterranean Miocene and Pliocene planktic foraminifera. In: BOLLI, H. M., SAUNDERS, J. B., PERCH-NIELSEN, K., (eds.), Plankton Stratigraphy. *Cambridge University Press*, **1**: 283-314.

JONES, R. W., CHARNOCK, M. A., 1985: "Morphogroups" of agglutinating foraminifera. Their life position and feeding habits and potential applicability in (paleo)ecological studies. *Revue de Paleobiologie*, **4**, (2): 311-320.

KAMINSKI, M.A. 2004a: The year 2000 classification of the agglutinated foraminifera. In: BUBÍK, M., KAMINSKI, M.A. (eds), Proceedings of the Sixth International Workshop on Agglutinated Foraminifera. *Grzybowski Foundation Special Publication*, **8**: 237-255.

KAMINSKI, M.A., GRADSTEIN, F.M. (eds.), BÄCKSTRÖM, S., BERGGREN, W.A., BUBÍK, M., CARVAJAL-CHITTY, H., FILIPESCU, S., GEROCH, S., JONES, G.D., KUHNT, W., MCNEIL, D.H., NAGY, J., PLATON, E., RAMESH, P., RÖGL, F., THOMAS, F.C., WHITTAKER, J.E., YAKOVLEVA-O'NEIL, S., 2005: Atlas of Paleogene Cosmopolitan Deep-Water Agglutinated Foraminifera., *Grzybowski Foundation Special Publication*, 574 pg.

KAMINSKI, M.A., 2005: The utility of Deep-Water Agglutinated Foraminiferal acmes for correlating Eocene to Oligocene abyssal sediments in the North Atlantic and Western Tethys. *Studia Geologica Polonica*, **124**: 325–339.

KAMINSKI, M.A., GRADSTEIN, F.M. BERGGREN, W.A, 1988: Flysch-type agglutinated foraminiferal assemblages from Trinidad: taxonomy, stratigraphy and paleobathymetry. *Abh. Geol. B.-A*. **41**: 155-227.

KENNETT, J. P., SRINIVASAN, M. S., 1983: Neogene planktonic foraminifera: a phylogenetic atlas. *Hutchinson Ross Publishing Company*, 265 pg.

KOCH, A., 1900: Die Tertiärbildungen des Beckens der Siebenbürgische Landestheile. *Il Neogene Abtheilung*, Budapest, 370 pg.

KRÉZSEK, C., FILIPESCU, S., 2005: Middle to late Miocene sequence stratigraphy of the Transylvanian Basin (Romania). *Tectonophysics*, **410**(1-4): 437-463.

KUHNT, W., KAMINSKI, M.A., 1990: Paleoecology of Late Cretaceous to Paleocene deep-water agglutinated foraminifera from the North Atlantic and Western Tethys. In: HEMLEBEN, C., KAMINSKI, M.A, KUHNT, W., SCOTT, D.B (eds), Paleoecology, Biostratigraphy, Paleoceanography and Taxonomy of Agglutinated Foraminifera. *Kluwer Academic Publishers*, 433-505.

LĂZĂRESCU, V., 1957: Asupra unei noi speciide *Coeloma* şi consideraţii paleoecologice aupra brachiurilor. *Bul. Şt. Acad. ser. Geol.-Geogr*, **II**(3-4): 665-682.

LOEBLICH, A.R., TAPPAN, H. 1987:. Foraminiferal Genera and their Classification. *Van Nostrand Reinhold*, New York, vol. 2, 1182 pg.

MARTINI, E., 1971: Standard Tertiary and Quaternary Calcareous Nannoplankton Zonation. In: FARINACCI, A., (ed.), *Proceedings of the II Planktonic Conference,* Roma, 739-785.

MENDESA, I., GONZALEZA, R., DIASB,J.M.A., LOBOA, F., MARTINS, V., 2004: Factors influencing recent benthic foraminifera distribution on the Guadiana shelf (Southwestern Iberia). *Marine Micropaleontology*, **51**: 171-192

MOISESCU, V., 1972: Mollusques et échinides stampiens et égériens de la région Cluj-Huiedin-Românaşi (Nord-Ouest de la Transylvanie). *Mémoires - Institut de Géologie*, **XVI** :1-152.

MURRAY, J., W., 1991: Ecology and paleoecology of benthic foraminifera. *John Wiley & Sons Inc. New York*. 397 pg.

NAGY, J., GRADSTEIN, F.M., KAMINSKI, M.A., HOLBOURN, A.E., 1995: Foraminiferal morphogroups, paleoenvironments and new taxa from Jurassic to Cretaceous strata of

Thakkhola, Nepal. In: KAMINSKI, M.A., GEROCH, S., GASIŃSKI, M.A. (eds), Proceedings of the Fourth International Workshop on Agglutinated Foraminifera. *Grzybowski Foundation Special Publication*, **3**: 181-209

POPESCU, G., 1975: Études des foraminifères du Miocène inférieur et moyen du nord-ouest de la Transylvanie. *Mémoires - Institut de Géologie et de Géophysique*, **XXIII**: 1-121.

POPESCU, G., MARUNTEANU, M., FILIPESCU, S. 1995: Neogene from Transylvania Depression. X . Congress RCMNS, Bucureşti 1995, Guide to excursion A1. *Romanian Journal of Stratigraphy*, **76**: 1-27.

RAI, A.K., SINGH, V.B., 2001: Late Neogene deep-sea benthic foraminifera at ODP Site 762B, eastern Indian Ocean: diversity trends and palaeoceanography. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **173**: 1-8.

RĂILEANU, G., SAULEA, E., 1956: Paleogenul din regiunea Cluj şi Jibou (NW Bazinului Transilvaniei). *Analele Comitetului de Geologie*, **XXIX**: 271-308.

ROETZEL, R., ĆORIĆ, S., GALOVIĆ, I., RÖGL, F., 2006: Early Miocene (Ottnangian) coastal upwelling conditions along the southeastern scarp of the Bohemian Massif (Parisdorf, Lower Austria, Central Paratethys). *Beitr. Paläont.*, **30**: 387-413.

ROETZEL, R., ĆORIĆ, S., GALOVIĆ, I., RÖGL, F., 2007: Early Miocene (Ottnangian) coastal upwelling conditions along the southeastern scarp of the Bohemian Massif (Parisdorf, Lower Austria, Central Paratethys). *Scripta Fac. Sci. Nat. Univ. Masaryk.* Brun, **36**: 15-16.

RÖGL, F., 1985: Late Oligocene and Miocene planktic foraminifera of the Central Paratethys. In: BOLLI, H.M, SAUNDERS, J.B., PERCH-NIELSEN, K. (eds.), Plankton stratigraphy. *Cambridge University Press*, **1**: 315-328.

RÖGL, F., ĆORIĆ, S., HARZHAUSER, M., JIMENEZ-MORENO, G., KROH, A., SCHULTZ, O., WESSELY, G., ZORN, I., 2008: The Middle Miocene Badenian stratotype at Baden-Sooss (Lower Austria). *Geologica Carpathica,* **59**(5): 367-374.

RÖGL, F., NAGYMAROSY, A., 2004: Biostratigraphy and correlation of the Lower Miocene Michelstetten and Ernstbrunn sections in the Waschberg Unit, Austria (Upper Egerian to Eggenburgian, Central Paratethys). *Courier Forschungsinstitut Senckenberg*, **246**: 129-151.

RUSU, A., 1969: Sur la limite Oligocène – Miocène dans le Bassin de Transylvanie. *Rev. Roum. G. G. G., Geologie*, **13**(2): 203-216.

SCHMIDT, D.N., RENAUD, S., BOLLMANN, J., 2003: Response of planktic foraminiferal size to late Quaternary climate change. *Paleoceanography*, **18**(2), doi:10.1029/2002PA000831.

SPEZZAFERRI, S., 1994: Planktonic foraminiferal biostratigraphy and taxonomy of the Oligocene and lower Miocene in the oceanic record. An overview. *Paleontographia Italica*, **81**: 1-187.

VANCEA, A., 1960: Neogenul din Bazinul Transilvaniei. Bucureşti, *Editura Academiei RSR*, 262 pg.