GEOLOGICA CARPATHICA, OCTOBER 2017, 68, 5, 419–444 doi: 10.1515/geoca-2017-0028

Foraminiferal, ostracod, and calcareous nannofossil biostratigraphy of the latest Badenian–Sarmatian interval (Middle Miocene, Paratethys) from Poland, Romania and the Republic of Moldova

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(Manuscript received October 10, 2016; accepted in revised form June 9, 2017)

Abstract: This study presents detailed foraminiferal, ostracod, and calcareous nannofossil analyses of five Middle Miocene sections located in the Central Paratethyan realm, namely in Poland, Romania and the Republic of Moldova. Based on foraminiferal distribution, five biostratigraphically important assemblages (labelled A–E) are distinguished. Foraminifera data combined with ostracoda and nannofossil evidence allowed correlation between the studied sections, and a comparison with the deposits of similar age from the Transylvanian, Vienna and Pannonian basins, as well as with the Transcarpathian regions. The micropaleontological record across the Badenian–Sarmatian boundary interval is also presented.

Keywords: Central Paratethys, Badenian–Sarmatian boundary, Carpathian Foredeep, foraminifera, ostracoda, calcareous nannofossils.

Introduction

During the Middle Miocene the studied areas from Poland, Romania and the Republic of Moldova were covered by the Paratethys Sea, which was formed in the Early Oligocene as a result of the collision between the African–Arabian Plate and Eurasian Plate related to the Alpine tectonics (Seneš 1988; Steininger & Rögl 1985; Pisera 1996). From the Oligocene, this gigantic inland sea was periodically connected with the Mediterranean and the Indo–Pacific Ocean (Rögl & Steininger 1984; Paramonova 1995; Rögl 1998, 1999; Iljina 2000; Kováč 2000; Popov et al. 2004, 2005; Nevesskaja et al. 2006; Harzhauser & Piller 2007; Harzhauser et al. 2007). The Paratethys intercontinental domain with its specific paleobiogeography, hydrological regimes and sedimentation dynamics (e.g., Báldi 1980; Popov et al. 2004) is subdivided into the Central Paratethys (Alpine–Carpathian) and the Eastern Paratethys (Euxinian–Caspian). The Badenian and Sarmatian sediments of those two basins were studied separately, leading to differences in chronostratigraphic subdivision (for a synthesis, see Piller et al. 2007). The Sarmatian deposits of the Central Paratethys exposed in many countries such as Austria, Czech Republic (Moravia), Hungary, Slovakia, Romania (regions from extra and intra Carpathian area), northern part of the Republic of Moldova, and Poland are assigned to the Sarmatian *sensu stricto* (Suess 1866), while the Eastern Paratethys deposits of the same age are mainly exposed in Romania (regions from extra Carpathian area), southern Republic of Moldova, Ukraine, Georgia and Bulgaria, and are attributed to the Sarmatian *sensu lato* (Barbot de Marny 1866) (see Gradstein et al. 2012). The Sarmatian *sensu lato* was subdivided into Volhynian, Bessarabian and Chersonian substages (Andrusov 1899; Simionescu 1903) corresponding to the lower, middle and upper Sarmatian respectively. Additionally, the lower part of the Sarmatian of the Moldavian Platform (NE Romania) is assigned to the Buglovian substage, *sensu* Laskarew 1903 (Ionesi 1968, 1991; Paghida Trelea 1969; Ionesi & Guevarra 1993; Brânzilă 1999; Ionesi 2006). The term Buglovian derives from the "Buglovka Beds" from Ukraine, where Laskarew (1903) remarked for the first time that the sediments are characterized by the presence of intermediare fauna, between the Badenian normal marine fauna and the brackish Sarmatian one. The stratigraphic position of this substage has been discussed for a very long time and many contradictory opinions have appeared, for example that it was part of the latest Badenian (Vyalov & Grishkevich 1965) or a first substage of the Sarmatian (Atanasiu 1945; Ionesi 1968; Paghida Trelea 1969; Brânzilă 1999; Ionesi et al. 2005; Ionesi 2006).

Microfossils, namely foraminifera, ostracoda, calcareous nannoplankton, and dinoflagellates are very important stratigraphically, hence, they are commonly studied in the whole Paratethys. The first foraminiferal zonations were established by Grill (1941) and Papp (1956), for the Central Paratethys (Vienna Basin) and by Venglinsky (1958) for the Eastern Paratethys. The last author distinguished some foraminiferal zones that were correlated with the mollusc zones for several Transcarpathian areas. Numerous foraminiferal studies have been carried out up to now, to accurately assign the sediment age (Subbotina et al. 1960; Łuczkowska 1964; Ionesi 1968; Jiříček 1972; Boda 1974; Brestenská 1974; Venglinsky 1975; Darakchieva 1989; Görög 1992; Popescu 1995; Koiava 2006; Filipescu & Silye 2008). In general, these studies have been realized for distinct regions of the Paratethys Basin; hence, different microfossil zonations were published, not allowing or hampering the correlation of Middle Miocene or Sarmatian, deposits at the scale of the whole Paratethyan basin. The foraminiferal zonation for the Polish part of the Carpathian Foredeep, comprising most of the Sarmatian *s.s.* units, was published by Łuczkowska (1964). This zonation was commonly referred and/or slightly modified in further studies by Odrzywolska-Bieńkowa (1966, 1972), Czepiec (1996), Olszewska (1999), Szczechura (2000), Gąsiewicz et al. (2004), Garecka & Olszewska (2011), and Paruch-Kulczycka (2015). The foraminiferal zonation of the Moldavian Platform (strata exposed in NE Romania and the Republic of Moldova) for the Sarmatian *s.l.* sediments was defined by Ionesi (1968, 1991) and Bobrinskaya (1981, 1986, 2014).

The ostracod biostratigraphy of the Sarmatian Paratethyan deposits, especially from the Eastern Paratethys received considerably less attention than the foraminiferal biostratigraphy. Some papers presenting the stratigraphic utility and/or ostracod zonation of the Middle Miocene of the Central Paratethys were published (Jiříček 1983; Zelenka 1990; Jiříček & Říha 1991; Ionesi & Chintăuan 1994; Gross 2006; Tóth 2008, Filipescu 1996; Filipescu et al. 1999, 2014; ter Borgh et al. 2014; Miclăuş et al. 2015). Additionally, some published papers about ostracods also focus on the paleoenvironment and taxonomy (Szczechura 2000; Aiello & Szczechura 2004; Filipescu 1996; Filipescu et al. 1999, 2005, 2014; ter Borgh et al. 2014; Loghin 2014). Unfortunately, apart from Ionesi and Chintăuan (1974, 1975, 1978, 1994), who presented the ostracod zonation of the Moldavian Platform, only a few ostracod studies of this region are available (Radu & Stoica 2005).

Calcareous nannofossils, which are extremely important for correlating the Paratethys with the Mediterranean realms, were studied in Poland by Krzywiec et al. (2008), Lelek et al. (2010), and Garecka & Olszewska (2011) and in Romania (Moldavian Platform) by Mărunţeanu (in Brânzilă & Mărunţeanu 2001), and Chira (in Brânzilă & Chira 2005).

The aim of this paper is to produce an integrated biostratigraphical work, by combining the detailed foraminiferal and ostracod studies from five sections of Poland, Romania and the Republic of Moldova, and nannofossil analyses of two lower Sarmatian successions from Romania and the Republic of Moldova. Note that the calcareous nannofossils from the Polish sections were previously published, as mentioned above. This kind of approach will fill in a gap of knowledge, since so far the correlation of the Badenian and Sarmatian strata of these regions of the Paratethys Basin has been based only on the published data (see Ionesi 1968; Paghida Trelea 1969). A revision of the Miocene ostracod collection, mostly the stratigraphically important species, of Ionesi & Chintăuan (1994), from the Paleontological Collections of the Museum of "Alexandru Ioan Cuza" University (Iaşi, Romania), was also done.

Geological setting

The studied deposits of SE Poland and NW Romania belong to the Carpathian Foredeep, which was developed as a typical peripheral foreland basin related to the Carpathian frontal movement (Oszczypko & Oszczypko-Clowes 2012), resulting from the flexural subsidence of a craton under an orogenic belt (DeCelles & Gilles 1996) (Fig. 1A). In turn, the investigated sediments from the Republic of Moldova belong to the back-bulge depozone of the foreland system basin of the Eastern Carpathians (Grasu et al. 2002).

The Polish successions are placed in the central part of the Polish Carpathian Foredeep Basin which is about 300 km long and up to 100 km wide. The basin is subdivided into external and internal parts which are situated at the front of the Carpathians and below the Carpathians flysch nappes respectively (Ney 1968; Oszczypko 1999). To the west, the Carpathian Foredeep of Poland links up, by the Moravian Gate, with the Moravian part of the Carpathian Foredeep, Slovakia and Vienna basins, whereas to the SE it continues into the Ukrainian, Republic of Moldova and Romanian foreland basins (Oszczypko 1999). During the Miocene, the depocentre was moving southeastward, resulting in late sedimentation in the southeastern area which lasted until the latest Sarmatian (Oszczypko 1999). The Polish Carpathian Foredeep Basin is filled up with Middle Miocene (Badenian and Sarmatian) marine deposits, which range from a few hundred metres thick in the northern — marginal part, up to 3000 m in the south-eastern — more central part (Ney et al. 1974; Oszczypko & Oszczypko-Clowes 2012). Deposits which belong to the Machów Formation include "Pecten beds", "Syndesmya beds" and "Krakowiec Clays" (Alexandrowicz et al. 1982; Oszczypko 1996). The "Pecten beds" have been dated as upper Badenian (Kosovian) by Odrzywolska-Bieńkowa (1966) based on microfaunal assemblages of *Hanzawaia crassiseptata* (Łuczkowska 1964). The $^{40}Ar/^{39}Ar$ age determination placed the Badenian/Sarmatian boundary at the base of the "Syndesmya beds" (Śliwiński et al. 2012). Based on the micropaleontological analyses, the Krakowiec Clays have been assigned by Odrzywolska-Bieńkowa (1972) and Łuczkowska (1972) to the early Sarmatian age. Additionally, *Anomalinoides dividens* and *Elphidium hauerinum* zones were recently confirmed (Olszewska 1999; Krzywiec et al. 2008; Lelek et al. 2010). This age is also confirmed by more recent studies carried out on calcareous nannofossils by Peryt (1997) and Garecka & Olszewska (2011), which distinguished in the "Krakowiec Clays" the upper part of the NN6 biozone (early

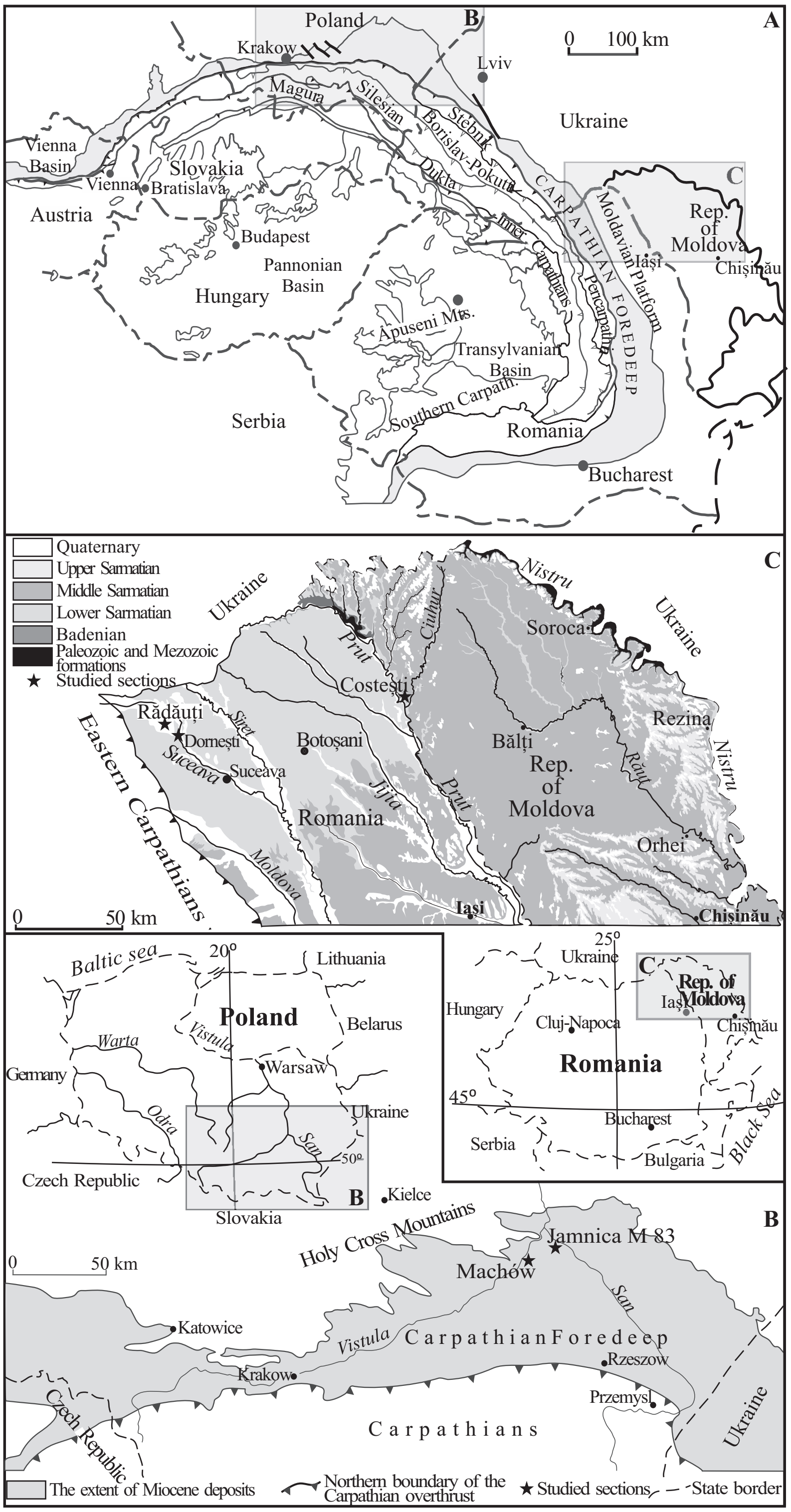

Fig. 1. Geological map of the studied areas. **A** — Simplified geological sketch map of the Carpathian Foredeep and Carpathian Orogen (modified after Pawlewicz 2006; Kováč et al. 2003); **B** — location of the studied Polish sections (Machów and Jamnica M-83 core) in Poland and the extension of the Sarmatian deposits in the extra-Carpathian area from Poland (modified after Ney et al. 1974; Paruch-Kulczycka 2015); **C** — location of the studied Romanian (FH_3P_1 Rădăuţi and Dorneşti) and the Republic of Moldova (Costeşti) sections and the simplified geological sketch map of the north-eastern Romania and northern Republic of Moldova area (modified after Geological maps of Romania and the Republic of Moldova, scale 1:200,000).

Sarmatian *s.s.* in age, Harzhauser & Piller 2007) and the NN7 biozone (covering the late Sarmatian *s.s.* — early Pannonian in age, according to Harzhauser & Piller 2007).

The studied sediments from Romania and the Republic of Moldova (FH_3P_1 Rădăuţi core, Dorneşti and Costeşti outcrops) belong to the Moldavian Platform (Ionesi & Ionesi 1968; Ionesi 1968; Ionesi 1994; Ionesi et al. 2005). These deposits, situated in the external part of the Eastern Carpathians, are attributed to the last marine accumulation cycle of the Moldavian Platform (Ionesi 1994) and are characterized by a significant increase in thickness of the Volhynian deposits with the approach of the Carpathian Orogen. The thickness of these deposits is around 500 metres between the Moldova and Siret rivers and reaches up to 800 metres in the front of the Carpathian Orogen (Ionesi 1968; Ionesi 1994).

Ionesi & Ionesi (1968) dated these deposits as Volhynian based on the macrofossil association, including *Inaequicostata inopinata* (Grischevich) and *Obsoletiforma lithopodolica* (Dubois), and the foraminiferal association, with *Cycloforina karreri ovata*, *Cycloforina karreri karreri*, *Elphidiella serena* and *Elphidium reginum* among the foraminifers. The Early Sarmatian age of these deposits has also been confirmed by the other foraminiferal studies (Ionesi 1968, 1991; Ionesi & Guevarra 1993). The studied sediments from the Republic of Moldova section are part of the lithostratigraphic units known as the “Darabani–Mitoc Clays” (Ionesi & Ionesi 1981) and “Stânca Limestone” (Simionescu 1902). The Volhynian age of these sediments was first assigned by Simionescu (1902), and has been confirmed by more recent paleontological studies (Paghida Trelea 1969; Ionesi & Ionesi 1981, 1982; Brânzilă 1999).

Materials and methods

The material analysed here comes from 3 outcrops and 2 drilling cores from Poland, Romania and the Republic of Moldova. The investigated sections from Poland are the historical Machów sulphur mine (N 50°31’59.60” E 21°39’43.47”) and Jamnica M-83 core (N 50°36’40.18” E 21°58’15.50”) which are situated in SE Poland (Fig. 1B) while the Romanian sections, FH_3P_1 Rădăuţi core (N 47°49’32.34” E 25°54’27.54”) and Dorneşti outcrop (N 47°52’52.1” E 25°52’3.4”), are located in NE Romania (Fig. 1C). The studied section from the Republic of Moldova (N 47°51'27.5" E 27°14'56") is situated on the left side of the Prut River, near the Stânca–Costeşti Lake (Fig. 1C).

The lower part of the Machów section is represented by clays with intercalations of marls. Following the succession, the sediments continue with sandstones followed by clays with mudstone intercalations. In the Jamnica core the lithology is very similar to the Machów section excluding the sandstones. The sediments of the FH_3P_1 Rădăuţi core and Dorneşti outcrop are mostly composed of ashy-grey clays partially compacted and/or laminated with some fine intercalations of sand, sandstones and coal films. Lithologically, the succession analysed from Republic of Moldova contains ashy-grey clays and can be compacted or laminated. Some fine intercalations of sand may also be encountered.

In total 128 samples have been analysed for foraminiferal and ostracod studies: 34 samples from Machów sulphur mine (Poland), 18 from the Jamnica M-83 core (Poland), 29 from the FH_3P_1 Rădăuţi core (Romania), 26 from Dornești outcrops (Romania) and 21 samples from the Costești outcrop (Republic of Moldova). We also revised the Miocene ostracod collection, mostly the stratigraphically important species, of Ionesi & Chintăuan, from the Paleontological Collections of the Museum of "Alexandru Ioan Cuza" University of Iaşi, Romania; the aforementioned collection was used for the ostracod biozonation of the Moldavian Platform (Ionesi 1991; Ionesi & Chintăuan 1994). The calcareous nannoplankton analyses were done on the FH_3P_1 Rădăuţi core, as well as the Dorneşti and Costeşti sections.

For the foraminiferal and ostracod analyses, the weight of each sample was approximately 200 g. The samples were washed using the decantation method. We analysed the entire material. The samples were sieved through 3 sieves to produce 4 fractions. Accordingly, the material >0.466; >0.236; >0.122 and <0.122, including the material <0.063 have been analysed. The foraminiferal specimens were handpicked using a binocular stereo microscope Carl Zeiss Jena SM XX and Nikon SMZ 800. SEM images of foraminifera and ostracoda were taken using a Merlin Gemini II microscope (in the Microcosmos laboratory of the Geological Institute of Romania) and a Vega/Tescan SEM microscope (in the Polish Academy of Science and Faculty of Biology of the "Alexandru Ioan Cuza" University of Iaşi, Romania). The investigated material from Romania (FH_3P_1 Rădăuţi core and Dorneşti outcrop) and the Republic of Moldova (Costeşti outcrop) is deposited in the Paleontological Collection of the Museum of "Alexandru Ioan Cuza" University of Iași, Romania. The material from Poland (Machów sulphur mine and Jamnica M-83 core) is hosted in the Polish Geological Institute–National Research Institute, Warsaw, Poland.

The calcareous nannofossils were investigated in the fraction of 2–30 μm separated by decantation method using 7 % of H_2O_2. From the obtained material, smear-slides were mounted by Canada balsam and analysed at 1200× magnification, using an oil-immersion objective on an Olympus transmitting light microscope, both in transmitted and polarized light.

All identified foraminifera, ostracoda, and calcareous nannofossil species are listed within the Appendix.

Results

In total, 131 species of foraminifera, 53 species of ostracoda, and 16 species of calcareous nannofossils were identified in the analysed samples. In general, the microfossils are well preserved and abundant (usually more than one hundred foraminiferal specimens per sample).

Foraminifers

In all 5 sections 108 species of calcareous benthic foraminifera and 13 species of plankonic foraminifera were identified. The most abundant benthic taxa belong to Miliolida (the following genera are *Affinetrina, Articularia, Articulina, Cycloforina, Miliolinella, Nodobaculariella, Pseudotriloculina, Varidentella, Sigmoilinita, Triloculina, Quinqueloculina*); elphidiids (*Elphidium, Cribroelphidium, Porosononion*), anomalinids (*Anomalinoides, Heterolepa, Hanzawaia*), cibicidids (*Cibicides, Lobatula*), nonioniids (*Elphidiella, Melonis, Nonion, Pullenia*), bolivinids (*Bolivina, Fursenkoina*), buliminids (*Bulimina*), uvigerinids (*Uvigerina*), textularinids (*Semivulvulina*), sphaeroidinds (*Sphaeroidina*), within Rotaliida and Lagenida (*Glandulina, Favulina, Fissurina, Hylinonetrion, Lagena*) (supra-ordinal classification follows Pawlowski et al. 2013). Some agglutinated taxa (10 species), such as *Nothia, Haplophragmoides, Reticulophragmium* and *Textularia* species have been also recorded.

Machów

A total of 78 species of both benthic and planktonic foraminifera were identified in the Machów section. In the lowermost part of the section, comprising the interval 75–67 m in depth, there is an abundant occurrence of the species *Sigmoilinita tenuis, Hanzawaia crassiseptata, Globigerina bulloides* which are accompanied by *Globigerina praebulloides, G. concinna, Sphaeroidina bulloides, Pullenia bulloides, Heterolepa dutmeplei, Bulimina aculeata, Bolivina dilatata* and *Melonis pompiloides* (Fig. 2). The interval 67–56.5 m in depth is dominated by the species *Anomalinoides dividens* (≈2000 specimens in all samples). Additionally, some miliolid species (in relatively smaller number — 142 specimens) were recorded at this level including *Cycloforina fluviata, Pseudotriloculina consobrina, Quinqueloculina akneriana, Q. akneriana argunica, Varidentella rosea* and *V. reussi*. Following the section upwards, the interval 56–45m in depth is marked by the disappearance of the species *Anomalinoides dividens* and by the occurrence of the species *Cycloforina karreri ovata* in samples 15 and 16. Other species of miliolids, elphidiids and lagenids progressively appear in a larger

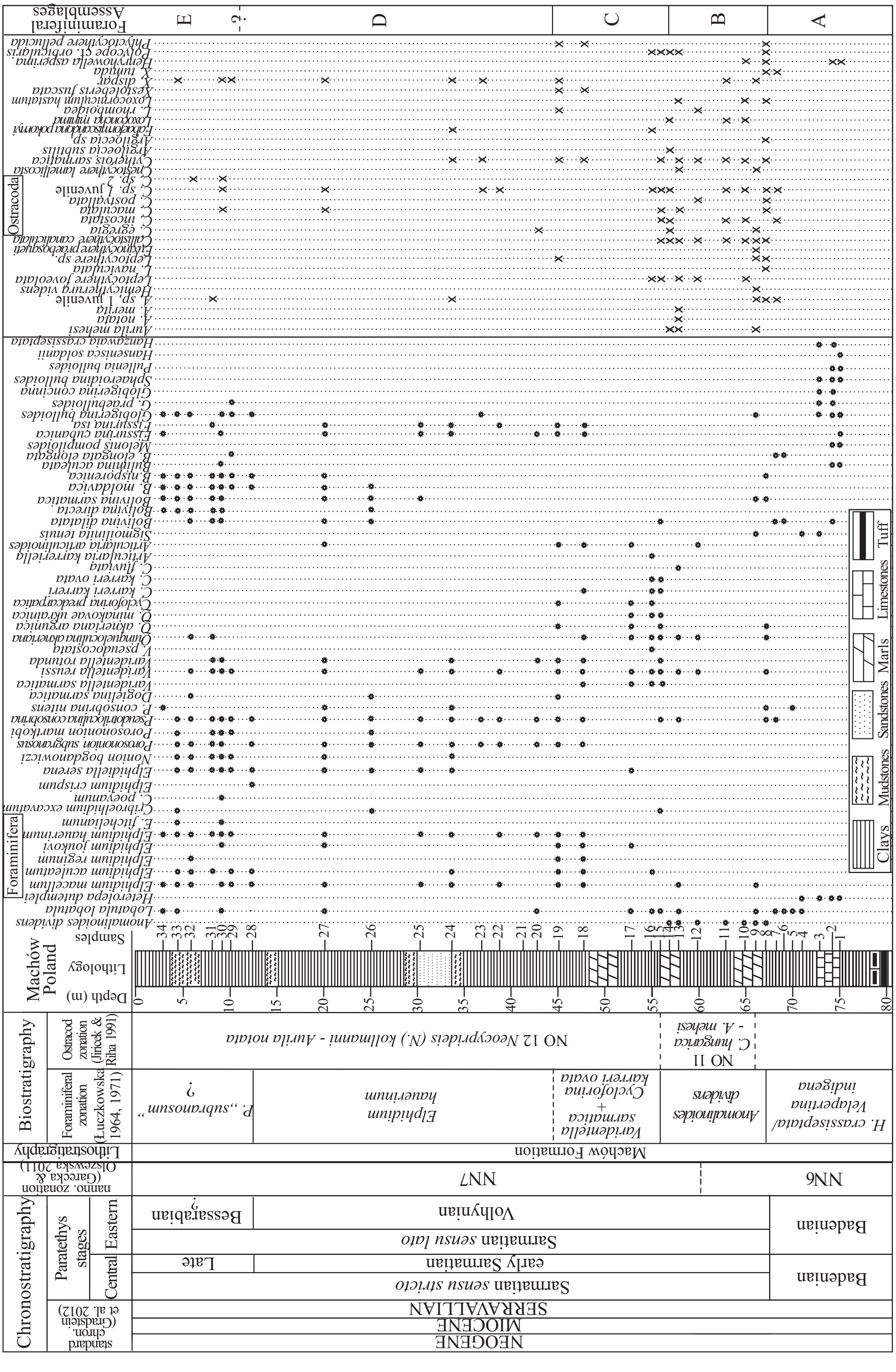

Fig. 2. Foraminifera and ostracoda distribution in the Machów section.

number and their diversity increases within the succession, for example, *Articularia articulinoides, A. karreriella, Cycloforina predcarpatica, C. karreri karreri, Miliolinella selene, M. subrotunda, Varidentella sarmatica, V. rotunda, V. pseudocostata, V. latecunata, Quinqueloculina minakovae ukrainica, Q. perelegantissima, Affinetrina cubanica, Elphidium hauerinum, E. aculeatum, E. macellum, E. reginum, E. joukovi, Elphidiella serena, Porosononion subgranosus, Fissurina isa, F. cubanica* and *F. toga* (Fig. 2).

In the interval 43–5 metres in depth, the ribbed milliolids are totally absent and only miliolids with a fine test are still present (*Varidentella reussi*). Elphidiids and nonionids appear in a large number and are represented by such species as *Elphidium hauerinum, E. fitchelianum, E. excavatum, E. crispum, E. macellum, Porosononion subgranosus, P. martkobi, Cribroelphidium poeyanum Elphidiella serena* and *Nonion bogdanowiczi*.

The top of the Machów section (samples 28–34) is dominated by the presence of species belonging to the genus *Bolivina*, such as *Bolivina directa, B. moldavica, B. nisporenica, B. sarmatica. Ammonia beccarii* and *Cassidulina* sp. are also quite common here. Moreover, a small number of planktonic *Globigerina bulloides* have been identified in most of the samples from this interval (Fig. 2).

Jamnica M-83 core

In the Jamnica M-83 core succession, 93 species of benthic and planktonic foraminifera were recorded. The lowermost interval, 235–225 m in depth (Fig. 3), is characterized by the abundant occurrence of *Globigerina bulloides, G. praebulloides, Velapertina indigena, Heterolepa dutemplei, Bulimina elongata elongata, Favulina hexagona* and *Sigmoilinita tenuis*. The sample 16 yielded a large number (50 specimens) of agglutinated species belonging to the genus *Nothia, Rhizammina, Reticulophragmium, Reophax, Haplophragmoides, Cyclamina, Budashevaella*, as well as representatives of the genus *Uvigerina*; the most common species are *Uvigerina semiornata, U. brunnensis*. The next interval, 220–214 m deep, is characterized by the occurrence of the species *Anomalinoides dividens* (at 220 metres deep) and the common appearance of fine test miliolids such as *Pseudotriloculina consobrina, Triloculina pseudoinflata, Affinetrina ukrainica, Quinqueloculina akneriana, Q. akneriana argunica, Cycloforina gracilis. Lobatula lobatula* is a common and important component of this assemblage. In the overlaying strata (the interval 202–182 m in depth) the species *Anomalinoides dividens* disappears and miliolid species such as *Cycloforina karreri ovata, C. karreri karreri, Quinqueloculina minakovae ukrainica* and *Articularia karreriella* clearly dominate this interval. Some of the elphidiids species (*Elphidium hauerinum, E. macellum* and *Elphidiella serena*) additionally occur but in smaller numbers. The uppermost part of the Jamnica core (the interval 180–35 m in depth) is defined by an increase in diversity of the foraminiferal species. In sample 7, bolivinids occur in large numbers, being strongly represented by *Bolivina moldavica* and *B. sarmatica*. Sample 2 is represented by the species *Articularia articulinoides*, which is very abundant in this part of the section. Apart from *Articularia*, the most abundant foraminifera of this interval are miliolids represented by *Varidentella reussi, V. rotunda, Quinquloculina akneriana, Miliolinella subrotunda* and *M. selene*, along with some representatives of the genera *Nonion, Elphidium* and *Porosononion* (Fig. 3).

Rădăuţi FH_3P_1 core

The foraminiferal assemblages of the FH_3P_1 Rădăuţi core section are composed of 29 species, of which 2 are planktonic ones. In sample 467, from the lower part of the section (239 metres deep), foraminifera are rare; only some specimens of planktonic species (*Globigerina bulloides* and *Globorotalia miocenica*) were recorded. The upper part of the section, comprising the interval 200–180 m, is characterized by a high number of foraminiferal species. Sample 470 yields a very numerous and diversified range of foraminiferal species including *Elphidium reginum, E. macellum, Elphidiella serena, Lobatula lobatula, Cycloforina cristata, C. predcarpatica, Varidentella pseudocostata, V. rotunda, Quinqueloculina akneriana, Q. akneriana argunica* and *Q. minakovae ukrainica.* In the middle part of the section (175–80 m in depth) the following species *Elphidium reginum, E. macellum, E. reussi* and *Ammonia beccarii* are presented in large numbers, while the uppermost part of the section (77–46 m in depth) is clearly dominated by the presence of ribbed miliolids, such as *C. karreri ovata, C. karreri karreri, C. predcarpatica* and *C. fluviata* (Fig. 4).

Dorneşti section

In total, 36 species of foraminifera (4 species are planktonic) have been identified in the samples collected from the Dorneşti section. The assemblages from the lower part of the succession (samples 164, 440, 2a, 163, 108, 146, 102, 2b) are characterized by rotaliids such as *Elphidium reginum, E. hauerinum, E. macellum, E. subumbilicatum, Elphidiella serena* and *Nonion bogdanowiczi* (Fig. 5). The most abundant species are *E. reginum* and *L. lobatula* in sample 440. In the upper part of the profile (samples 109, 4b, 98, 4a, 96, 108, 95, 93, 94) the occurrence of a large number of the ribbed miliolids including *Articularia karreriella, Cycloforina karreri ovata, C. karreri karreri* and *C. predcarpatica* has been recognized (Fig. 5).

Costeşti section

In the samples from the Costeşti outcrop, 16 species of benthic foraminifera have been identified. Planktonic foraminifera are totally absent. The samples collected from the lower part of the section (samples 491/A, 491/B, 491/C, 491/D, 491/G) yielded scarce foraminiferal association; only a few specimens of miliolid species, such as *Pseudotriloculina consobrina, P. consobrina nitens, Articulina problema,* *Articularia articulinoides* and *Quinqueloculina akneriana* have been found. In the overlying strata, an increase in diversity and number of the foraminiferal species is noticeable. The assemblages of the samples 491/1, 491/2, 491/3 are clearly dominated by the presence of numerous representatives of species *A. articulinoides, P. consobrina*, *P. consobrina nitens* and *A. problema,* while the assemblages of the samples 491/4 and 491/5 display a decrease in abundance in the number of the miliolids and a bloom of the species *Porosononion subgranosus* and *P. martkobi*. Additionally, some lagenids including *Fissurina cubanica, F. isa, F. mironovi,* appear in some samples (491/1, 491/2, 491/3, 491/4, 491/5, 491/7 and 496) (Fig. 6).

Ostracods

In all the analysed sections 53 species were identified. In general, ostracods are less frequent than foraminifera in all studied samples. The most abundant taxa belong to the family *Leptocytheridae*, which includes the genera *Leptocythere* and *Callistocythere*, encountered in all the analysed sections, followed by the species of the *Aurila* genus. Additionally, the species *Cytherois sarmatica* occurs in a great number of specimens in the analysed samples.

In the Machów section, we identified 30 ostracod species (Fig. 2). In the lowermost part of the section, (samples 1, 2), only one species, *Henryhowella asperrima,* occurs. Slightly further up, within the interval 67–55 m in depth, the ostracod assemblages are dominated by the presence of the species *Callistocythere canaliculata, C. incostata, Cytherois sarmatica* and *Aurila mehesi.* Beside these taxa, the species *Polycope orbicularis* and *Phlyctocythere pellucida* are quite abundant in this

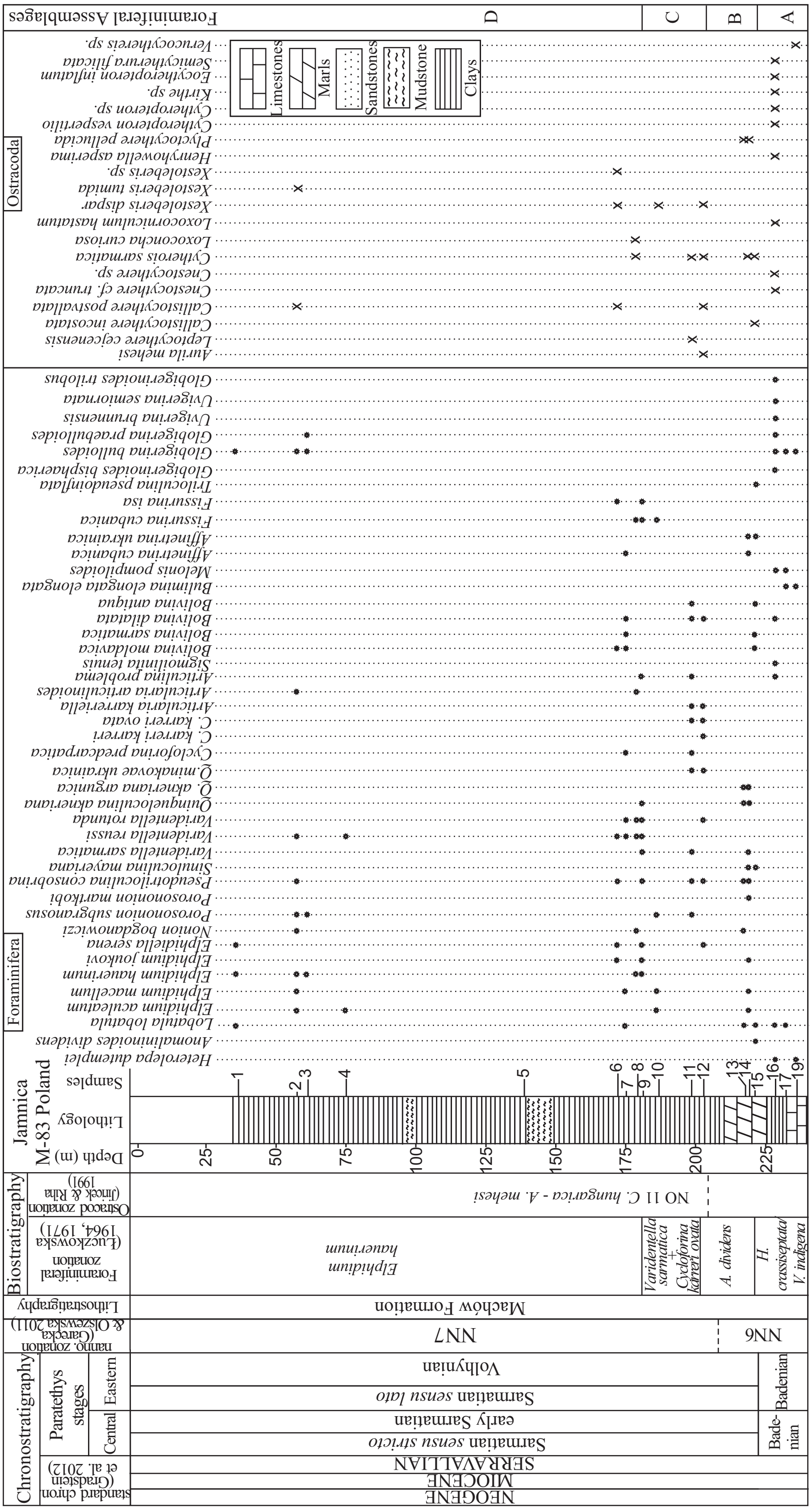

Fig. 3. Foraminifera and ostracoda distribution in the Jamnica M-83 section.

interval. In the upper part of the section, the ostracod assemblages are scarce. The most common species is *Cytherois sarmatica*, which ranges up to 34 metres in depth (sample 24). The presence of the species *Xestoleberis dispar* throughout almost the entire section (65–55 m) is also noticed.

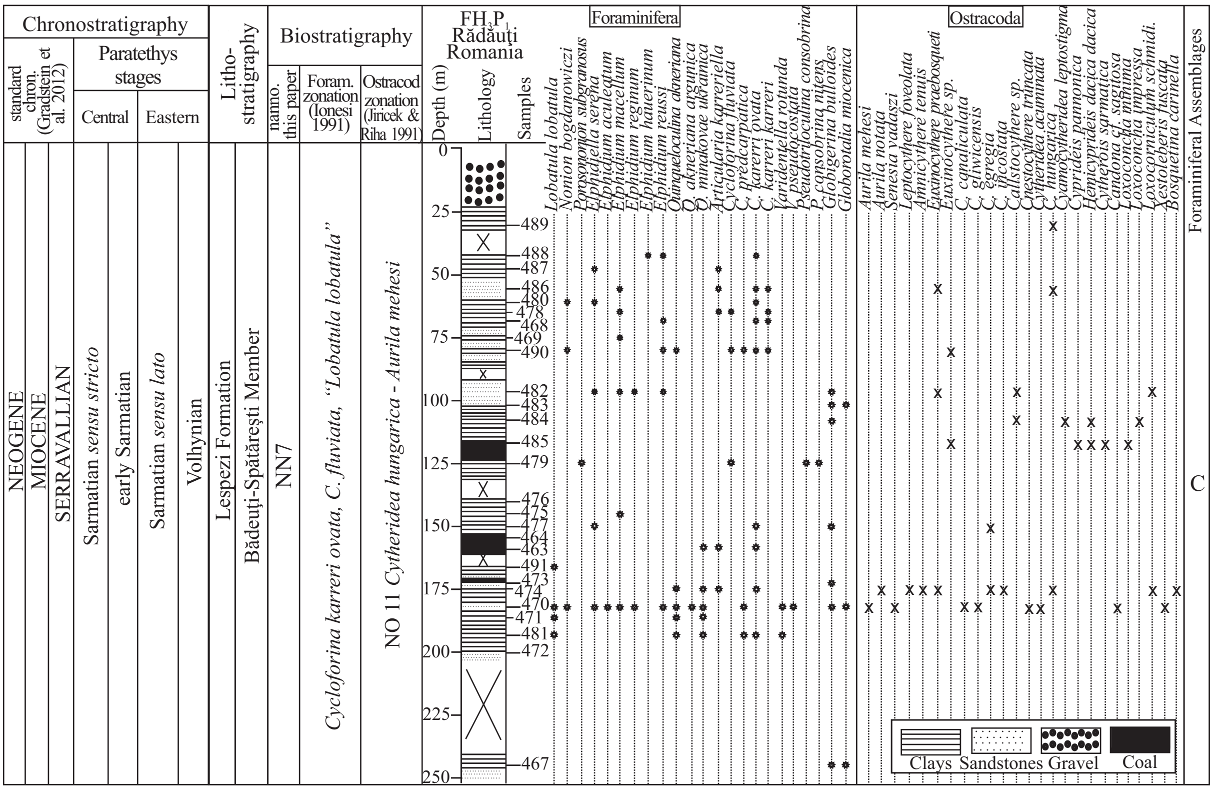

Fig. 4. Foraminifera and ostracoda distribution in the FH_3P_1 Rădăuţi section.

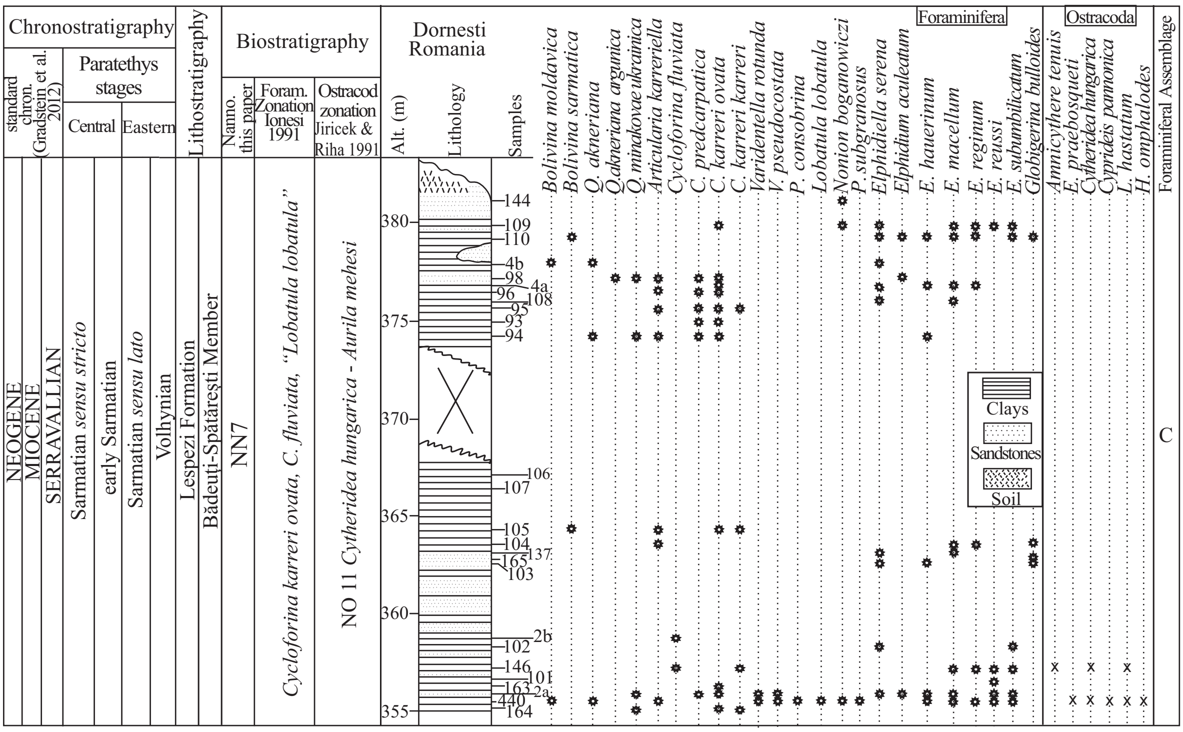

Fig. 5. Foraminifera and ostracoda distribution in the Dorneşti section.

The ostracod fauna from the Jamnica section is represented by 20 species (Fig. 3). The lowermost part of this core (samples 16 and 19) is characterized by the presence of the species *Cnestocythere truncata, Henryhowella asperrima, Cytheropteron vespertilio* and, *Semicytherura filicata.* Higher up in the succession, the most abundant species is *Cytherois sarmatica* (recorded in the interval between 220–175 m in depth), followed in abundance by *Callistocythere postvallata, C. incostata* and *Aurila mehesi.* In the upper part of the Jamnica section, only 2 ostracod species have been encountered, *Callistocythere postvallata* and *Xestoleberis tumida* (sample 2).

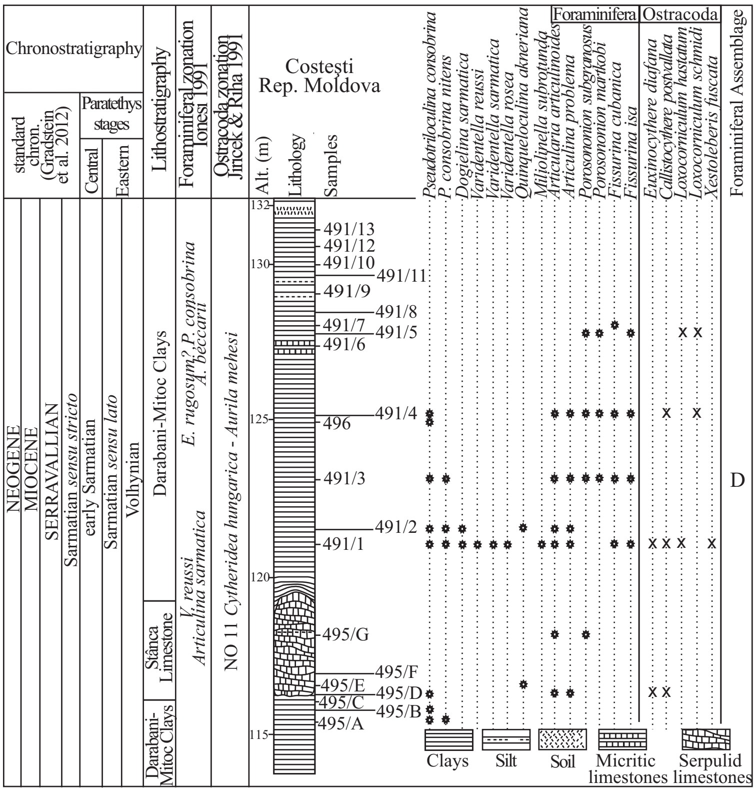

Fig. 6. Foraminifera and ostracoda distribution in the Costeşti section.

In the Rădăuți section, 20 ostracod species were identified (Fig. 4). In the lower part of the section (samples 470 and 474) the most frequent species are *Aurila mehesi, A. notata, Callistocythere canaliculata, C. egregia, C. incostata, Cytheridea acuminata* and *Xestoleberis fuscata.* The upper part of the section (samples 482, 484 and 485) is characterized by the dominance of the species *Euxinocythere praebosqueti, Cyprideis pannonica* and *Xestoleberis fuscata.* The common taxa in the Rădăuți section also include the species *Loxoconcha minima.* Towards the top of the studied section (samples 486 and 489), *Cytheridea hungarica* dominates the ostracod assemblage.

The Dornești section yielded 6 ostracod species which were indentified in samples 440 and 146 from the lowermost part of the outcrop. The most abundant species are *Cytheridea hungarica* and *Cyprideis pannonica* (Fig. 5).

In the Costești section 5 ostracod species have been recorded. The most frequent species are *Callistocythere postvallata* and *Loxocorniculum* spp. (*L. hastatum* and *L. schmidi*) (samples 495/D, 491/1, 491/4 and 491/5) (Fig. 6).

Calcareous nannofossils

Several samples (440 from Dorneşti, 470, 482 and 488 from FH_3P_1 Rădăuți and 491/4 and 495/D from Costeşti) were analysed for their calcareous nannofossil content. The greatest abundance of the calcareous nannofossils was recognized in the sample 440 that contains *Discoaster kugleri*, *D. deflandrei*, *Reticulofenestra pseudoumbilicus*, *Triquetrorhabdulus rugosus, R. minuta*, *R. minutula*, *Coccolithus pelagicus, Sphenolithus moriformis, Calcidiscus leptoporus, Pontosphaera multipora, Helicospahera carteri.* Additionally, reworked nannofossils (around 30 %) from the older Upper Cretaceous, Paleogene and Lower Miocene sediments were recorded. In sample 482, 80% of the assemblage represents reworked specimens from the Upper Cretaceous and Paleogene deposits; nevertheless, species that have a long distribution range, including the Middle Miocene, such as *Reticulofenestra pseudoumbilicus*, *R. minuta*, *R. minutula*, *Coccolithus pelagicus*, *Sphenolithus morifomis* and *Calcidiscus leptoporus* were identified. Sample 488 commonly contains taxa of the genus *Reticulofenestra*, namely *R. pseudoumbilicus*, *R. minuta*, *R. minutula*, along with *C. pelagicus*, *S. moriformis*, *Calcidiscus leptoporus, C. macintyrei*, *Discoaster musicus* and *D. deflandrei*. The samples FH_3P_1 No. 470 and Costeşti 491/4 provided only reworked nannofossil specimens from the Upper Cretaceous and Paleogene strata, while the sample Costeşti 495/D was barren of nannofossils.

Biostratigraphy

Rich foraminiferal associations from the studied areas (Poland, Romania and the Republic of Moldova), showing similar trends of successive foraminiferal assemblages, enabled the identification of five foraminiferal assemblages (named A–E), which are stratigraphically important (Fig. 7). Based on these assemblages we correlate the investigated sections and relate them to different local zonations distinguished in different Paratethyan regions (Fig. 8). Morover, beside the foraminiferal assemblages we also identified several stratigraphically important ostracods. The selected foraminifera, ostracoda as well as calcareous nannofossils are presented in Figs. 9–14.

Assemblage A is characterized by the abundant occurrence of *Sigmoilinita tenuis* (Fig. 9A)*, Globigerina bulloides* (Fig. 9B,C)*, G. praebulloides, G. concinna, Globigerinoides*

Paratethys stages: Central		Paratethys stages: Eastern		ostracods stratigraphically important	Foraminiferal Assemblages	
late Sarmatian		Sarmatian	? Bessarabian		E	- the Assemblage is characterized by the presence in a large number of the small specimens belonging to the genus *Bolivina* (*B. sarmatica, B. moldavica, B. antiqua*) and common occurrence of *Elphidum macellum*, *E. joukovi*, *E. crispum*, *E. hauerinum*, *Porosononion subgranosus P. martkobi, Nonion bogdanowiczi* species.
early Sarmatian		Sarmatian	Volhynian	*Aurila mehesi, A. merita, A. notata, Callistocythere incostata, C. postvallata, Loxocorniculum hastatum, L. schmidi Fabaeformiscandona pokornyi, Xestoleberis dispar, X. tumida*	D	- the Assemblage is characterized by the totall absence of the ribbed miliolids, species as *Elphidium hauerinum, E. macellum, E. excavatum, Elphidiella serena, Porosononion subgranosus, P. martkobi, Nonion bogdanowiczi, Varidentella reussi,V. rotunda, Articularia articulinoides, Articulina problema, Pseudotriloculina consobrina* are present in a large number.
					C	- the Assemblage is characterized by the presence in a large number of the ribbed miliolids, species as *Cycloforina karreri ovata, C. karreri karreri, C. predcarpatica, C. fluviata, Articularia karreriella, Varidentella pseudocostata,Quinqueloculina minakove ukrainica* accompanied by keeled elphidiids as *Elphidium reginum* and *E. aculeatum,* species as *A. articulinoides, V. reussi, V. rotunda, Miliolinella selene,M. subrotunda, Pseudotriloculina consobrina, E. macellum, Elphidiella serena, Porosononion subgranosus* and *Lobatula lobatula* also occur.
					B	- the Assemblage is characterized by the first occurrence and by the great abundance of the species *Anomalinoides dividens,* species as *Varidentella reussi, V. rosea, Pseudotriloculina consobrina, Triloculina pseudoinflata, T. inflata, Affinetrina ukrainica, Elphidium macellum, Bolivina dilatata, B. sarmatica* also occur.
late Badenian	Kossovian	late Badenian	Konkian	*C. vespertilio, S. filicata*	A	- the Assemblage is characterized by the common occurrence of the *Velapertina indigena, Globigerina bulloides, G. preabulloides, G. concinna, Globigerinoides triloba, G. bisphaerica, Sigmoilinita tenuis, Bulimina elongata, elongata, B. aculeata, Bolivina dilatata, Heterolepa dutemplei,* accompaniedby other species as *Sphaeroidina bulloides, Pullenia bulloides, Melonis pompiloides, Hansenisca soldanii, Uvigerina brunnesis, U. semiornata* and *Textularia* spp.

Fig. 7. Stratigraphically important foraminiferal assemblages (A–E) and ostracoda identified in the analysed sections.

trilobus, G. bisphaerica, Velapertina indigena (Fig. 9D,E,F), *Sphaeroidina bulloides, Pullenia bulloides* (Fig. 9G,H), *Hetrolepa dutemplei* (Fig. 9I,J), *Hansenisca soldanii* (Fig. 9K), *Bulimina elongata elongata* (Fig. 9L), *B. aculeata* (Fig. 9M), *Bolivina dilatata, Fursenkoina acuta* (Fig. 9N). The assemblage is recognized in the Machów section within the interval 75–67 metres in depth and in the Jamnica M-83 core 235–225 metres in depth. Between the ostracods, the species *Kirthe* sp. (Fig. 9O), *Semicytherura filicata* (Fig. 9P) and *Cytheropteron vespertilio* (Fig. 10A,B), were encountered in the Assemblage A. The assemblage is characteristic for the late Badenian interval.

Assemblage B is defined by the abundance of *Anomalinoides dividens* (Fig. 10C,D), though some other foraminifer species such as *Varidentella reussi* (Fig. 10E,F), *V. rosea, Pseudotriloculina consobrina* (Fig. G,H,I), *Quinqueloculina akneriana* (Fig. 10J,K,L), *Affinetrina ukrainica* and *Elphidium macellum* appear in a small number in this assemblage. It occurs in the Machów section, in the interval 67–56.5 m and in the Jamnica core section, in the interval 222–214 m and indicates the lowermost Sarmatian (lowermost Volhynian).

Assemblage C is defined by the abundance of the ribbed miliolid species, such as *Cycloforina karreri ovata* (Fig. 10M,N,O), *C. karreri karreri* (Fig. 10P, Q,R), *C. predcarpatica* (Fig. 11A,B), *C. fluviata* (Fig. 11C,D), *Articularia karreriella* (Fig. 11E,F), *A. articulinoides* (Fig. 11G), *Varidentella pseudocostata* (Fig. 11H,I), *V. reussi, V. sarmatica* (Fig. 11J), *V. rotunda* (Fig. 11K,L) and *Quinqueloculina minakovae ukrainica* (Fig. 11M,N), accompanied by elphidiids namely *Elphidium reginum* (Fig. 11O,P), *E. aculeatum* (Fig. 11Q,R), *Elphidiella serena* (Fig. 12A), *Porosononion subgranosus* (Fig. 12B,C) and the species *Lobatula lobatula* (Fig. 12D,E,F). Some other miliolid species, such as *V. rosea, Miliolinella subrotunda, M. selene,* and *Pseudotriloculina consobrina* are also present in the assemblage. This assemblage was found in all samples from the Romanian sections (FH_3P_1 Rădăuţi core and Dorneşti outcrop) and in the Machów section comprising the interval 56–45 m, as well as in the Jamnica core, from the interval 202–182 m. Assemblage C indicates early Volhynian age.

Assemblage D, recorded in the Machów section comprising the interval 45–13, in Jamnica, the interval 180–35 m, and in all samples from the Republic of Moldova section, is characterized by the total absence of the ribbed miliolids. The most common species of this assemblage are *Elphidium hauerinum* (Fig. 12G,H), *E. excavatum* (Fig. 12I), *E. macellum* (Fig. 12J), *E. tumidulus, Elphidiella serena, Porosononion subgranosus, P. martkobi* (Fig. 12K) and *Nonion bogdanowiczi* (Fig. 12L), accompanied by specimens of *V. reussi, V. rotunda* and *Articularia articulinoides*, *Articulina problema* (Fig. 12M), *Pseudotriloculina consobrina* and *Pseudotriloculina nitens* indicating middle to late Volhynian age.

The early Sarmatian age is also confirmed by the ostracod assemblages, which comprise *Cytherois sarmatica* (Fig. 12N,O), *Aurila mehesi* (Fig. 12P), *A. notata* (Fig. 12Q), *Callistocythere incostata* (Fig. 12R, Fig. 13A), *A. merita* (Fig. 13B), *C. postvallata* (Fig. 13C,D), *C. egregia* (Fig. 13E), *C. maculata* (Fig. 13F), *Xestoleberis dispar* (Fig. 13G), *X. tumida, X. fuscata* (Fig. 13H), *Loxocorniculum hastatum* (Fig. 13I,J) and *L. schmidi* (Fig. 13K,L), *Cytheridea hungarica* (Fig. 13M,N)

Assemblage E, recorded in the top of the Machów section, is characterized by the abundant presence of the bolivinids with small tests, species such as *Bolivina directa, B. moldavica* (Fig. 13O), *B. nisporenica*, *B. sarmatica* (Fig. 13P) and by the common presence of elphidiids such as *Elphidum macellum*, *E joukovi*, *E. crispum*, *E. hauerinum*, *Porosononion subgranosus*, *P. martkobi* as well as *Nonion bogdanowiczi* and possibily indicates lowermost Bessarabian age.

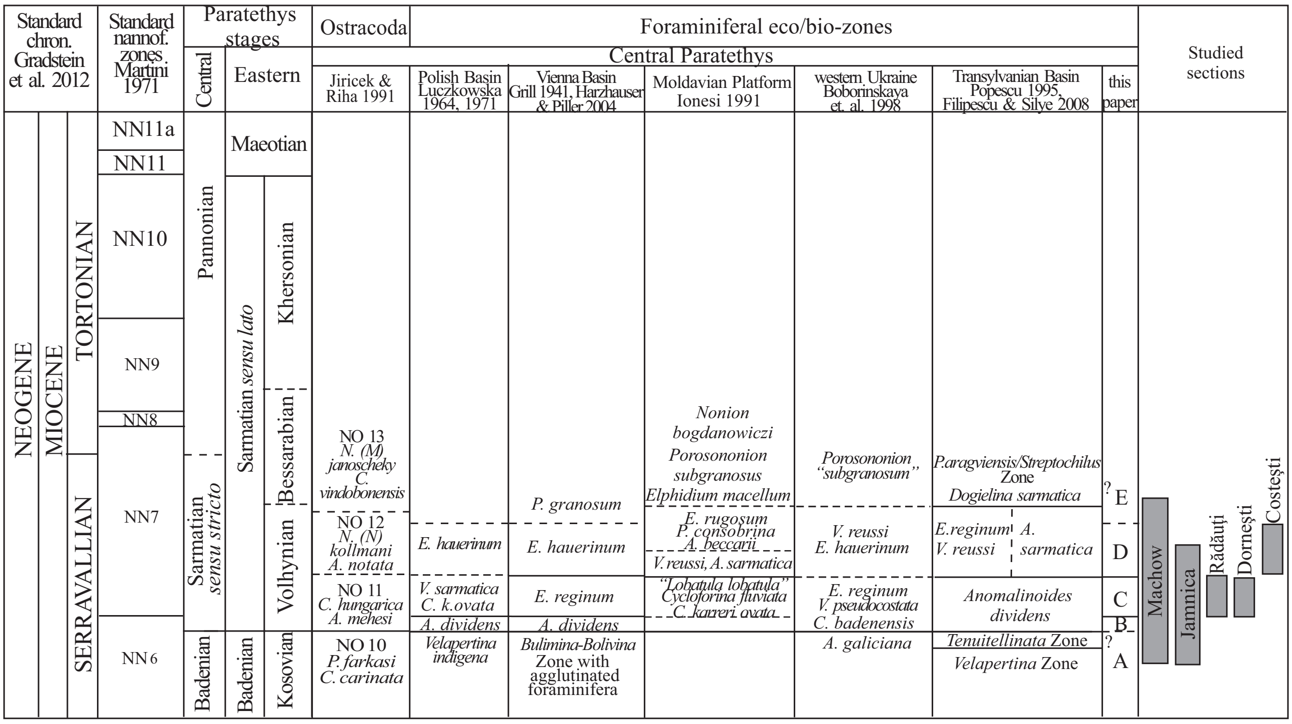

Fig. 8. Regional biostratigraphic subdivision of the Badenian and Sarmatian Paratethys.

Discussion

The lowermost sediments of the studied Machów and Jamnica sections display the foraminiferal Assemblage A. The assemblage is similar in foraminiferal composition, which means the occurrence of *Globigerina bulloides, G. praebulloides, Velapertina indigena, Sphaeroidina bulloides, Bulimina elongata elongata, B. aculeata, Sigmoilinita tenuis, Hanzawaia crassiseptata* and agglutinated forms such as *Textularia*, to the upper Badenian *Hanzawaia crassiseptata* Zone, distinguished by Łuczkowska (1964, 1974) from the Tarnobrzeg–Chmielnik area, and also recorded in other parts of the Polish Carpathian Foredeep (Odrzywolska-Bieńkowa 1975; Gonera 1997; Szczechura 1982, 2000; Paruch-Kulczycka 2015). Many foraminiferal species characteristic of Assemblage A were additionally identified in similar stratigraphic position in other regions of the Paratethys. The co-occurrence of *Globigerina bulloides, G. praebulloides, G. concinna, Globigerinoides trilobus, B. elongata elongata, Uvigerina brunnensis, U. semiornata* and *Velapertina indigena* was also recorded in the upper Badenian deposits of the Vienna Basin (Kováčová & Hudáčková 2009; Kováčová et al. 2009; Paulissen et al. 2011; Zlinská et al. 2013), Transcarpathians (western Ukraine) and the Republic of Moldova (Bobrinskaya 1967, 1970; Bobrinskaya et al. 1998; Peryt et al. 2014). The other taxa which occur in Assemblage A (see Fig. 7) were commonly described in the Upper Badenian deposits of the Vienna basin (Papp et al. 1978), Transylvanian Basin (Popescu 1979, 1995; Ionesi & Enache-Bouau 1987; Filipescu 1996), and Polish Carpathians (Szczechura 1982, 2000). Accordingly, based on the similarity in taxonomic composition of foraminiferal communities (Fig. 7.) and on the presence of the index species *Velapertina indigena*, in these distinct basins of the Paratethys, Assemblage A as described here can be correlated with the *Velapertina indigena* Zone, originally described by Łuczkowska (1971) for the area of the inner and outer Carpathians from Poland, Romania, the Czech Republic and Slovakia, with the *Velapertina* Zone described by Popescu (1975) for the deposits from Romania, as well as with the upper Badenian *Bulimina–Bolivina* Zone and Zone with agglutinated foraminifera of the Vienna Basin (Cicha 1960, 1998) and with the *Ammonia galiciana* Zone from Western Ukraine (Venglinsky 1962; Bobrinskaya et al. 1998). Additionally, we did not observe the abundant presence of the *Tenuitellinata* and *Tenuitella* taxa, as mentioned by Filipescu & Silye (2008) in the latest Badenian deposits of the Transylvanian Basin. Possibly, this lack is due to a different paleobiogeographic setting.

The upper Badenian age is also supported by the observed ostracod assemblages that contain significant biostratigraphic taxa *Henryhowella asperrima* (samples 1, 2 in the Machów section) and *Cytheropteron vespertilio, Semicytherura filicata, Cnestocythere truncata* (samples 19, 16 in the Jamnica borehole); the aforementioned species were described as proxies for the upper Badenian deposits of the Vienna Basin, while their last occurrences marked the Badenian–Sarmatian boundary (Gross 2006). However, in the studied area the last occurrence of some of the species previously assigned as being exclusively Badenian (see Gross 2006), such as *Henryhowella asperrima* and *Cnestocythere lamellicosta*, are placed in the *Anomalinoides dividens* Zone, thus above the Badenian–

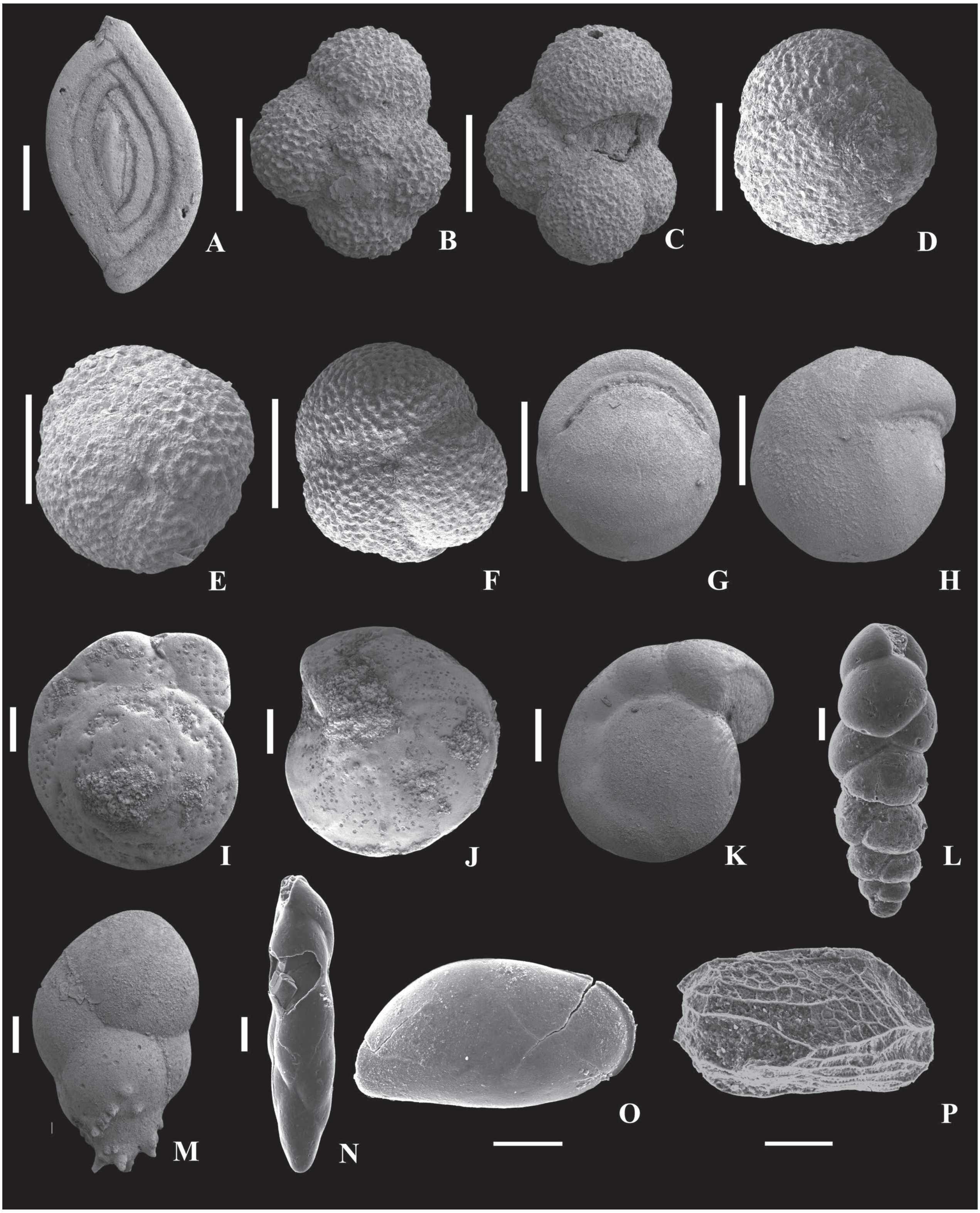

Fig. 9. SEM photographs of the representative foraminifera and ostracoda species identified in the analysed samples. **A** — *Sigmoilinita tenuis*, lateral view, sample 3 Machów. **B, C** — *Globigerina bulloides*, B: lateral view, C: apertural view, sample 2 Machów. **D, E, F** — *Velapertina indigena*, D, E: lateral view, F: apertural view, sample 19 Jamnica M-83. **G, H** — *Pullenia bulloides*, G: apertural view, H: lateral view, sample 2 Machów. **I, J** — *Heterolepa dutemplei*, lateral view, sample 3 Machów. **K** — *Hansenisca soldanii*, lateral view, sample 1 Machów. **L** — *Bulimina* cf. *elongata elongata*, lateral view, sample 19 Jamnica M-83. **M** — *Bulimina aculeata*, lateral view, sample 2 Machów. **N** — *Fursenkoina acuta*, lateral view, sample 19 Jamnica M-83. **O** — *Kirthe* sp., right valve, lateral view, sample 16 Jamnica M-83. **P** — *Semicytherura filicata*, right valve, lateral view, sample 16 Jamnica M-83. Scale bars: 100 µm.

Fig. 10. SEM photographs of the representative foraminifera species and ostracoda identified in the analysed samples. **A** — *Cytheropteron vespertilio*, right valve, lateral view, sample 16 Jamnica M-83. **B** — *Cytheropteron vespertilio*, right valve, dorsal view, sample 16 Jamnica M-83. **C, D** — *Anomalinoides dividens*, C: lateral view, D: apertural view, sample 11 Machów. **E, F** — *Varidentella reussi*, lateral view, F: gerontic stage, sample 18 Machów. **G, H, I** — *Pseudotriloculina consobrina*, G, H: lateral view, I: apertural view, sample 491/2 Costeşti. **J, K, L** — *Quinqueloculina akneriana*, J, K: lateral view, L: apertural view, sample 470 FH_3P_1 Rădăuţi. **M, N, O** — *Cycloforina karreri ovata,* M, N: lateral view, sample 486 FH_3P_1 Rădăuţi, O: apertural view, sample 490 FH_3P_1 Rădăuţi. **P, Q, R** — *Cycloforina karreri karreri,* P, Q: lateral view, R: apertural view, sample 490 FH_3P_1 Rădăuţi. Scale bars: 100 µm.

Fig. 11. SEM photographs of the representative foraminifera species identified in the analysed samples. **A, B** — *Cycloforina precarpatica,* A: lateral view, B: apertural view, sample 490 FH$_3$P$_1$ Rădăuţi. **C, D** — *Cycloforina fluviata*, C: lateral view, D: apertural view, sample 490 FH$_3$P$_1$ Rădăuţi. **E, F** — *Articularia karreriella*, E: quinqueloculin form, F: lateral view, sample 440 Dorneşti. **G** – *Articularia articulinoides*, lateral view, sample 19 Machow. **H, I** — *Varidentella pseudocostata*, H: lateral view, I: apertural view, sample 2 Dorneşti. **J** — *Varidentella sarmatica*, lateral view, gerontic stage, sample 17 Machów. **K, L** — *Varidentella rotunda*, K: lateral view, L: apertural view, sample 482 FH$_3$P$_1$ Rădăuţi. **M, N** — *Quinqueloculina minakove ukrainica*, M: lateral view, sample 474 FH$_3$P$_1$ Rădăuţi, N: apertural view, sample 440 Dorneşti. **O, P** — *Elphidium reginum*, O: lateral view, P: apertural view, sample 470 FH$_3$P$_1$ Rădăuţi. **Q, R** — *Elphidium aculeatum,* Q: lateral view, R: apertural view, sample 470 FH$_3$P$_1$ Rădăuţi. Scale bars: 100 µm.

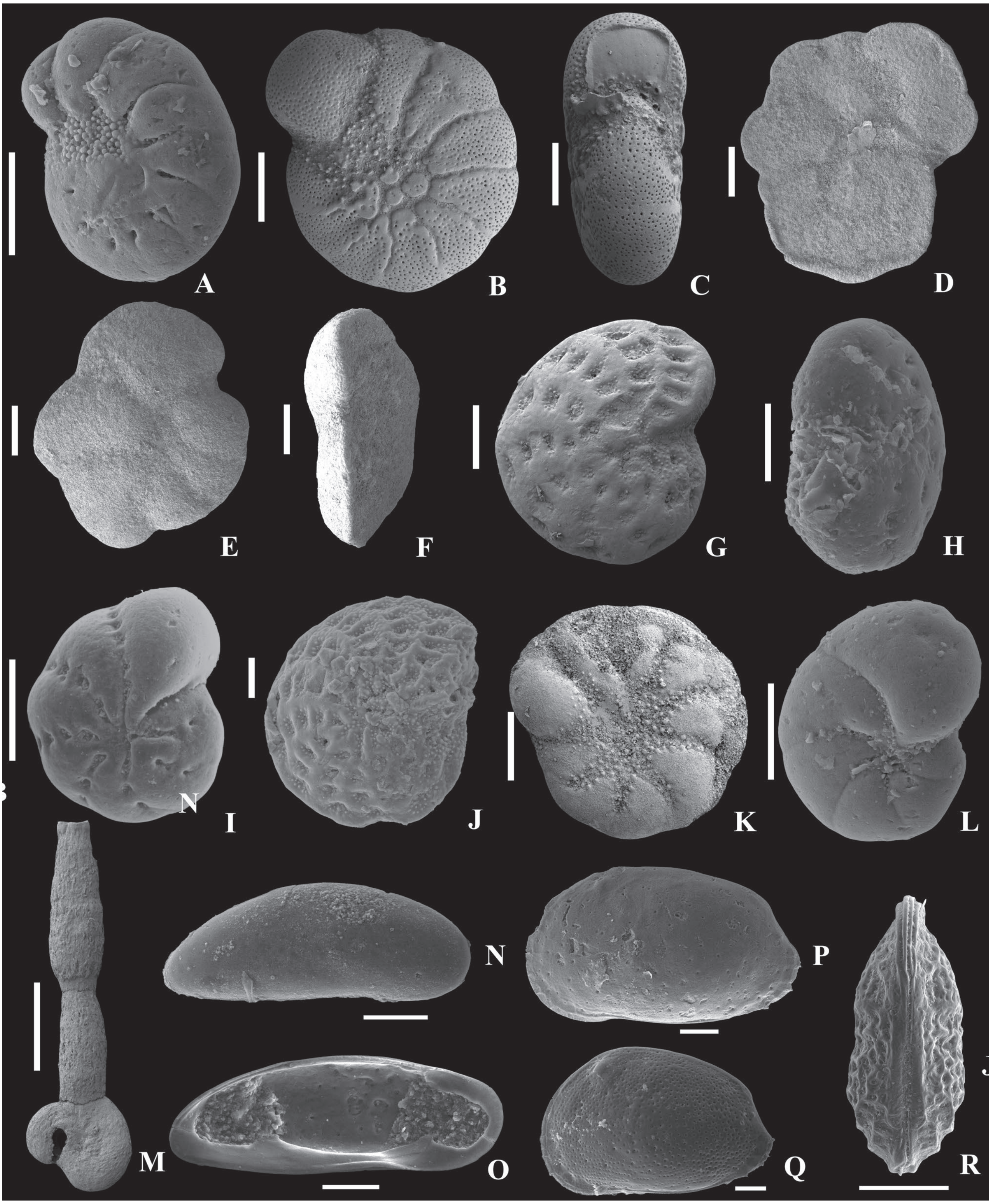

Fig. 12. SEM photographs of the representative foraminifera and ostracoda species identified in the analysed samples. **A** — *Elphidiella serena*, lateral view, sample 29 Machów. **B, C** — *Porosononion subgranosus*, B: lateral view, C: apertural view, sample 491/5 Costeşti. **D, E, F** — *Lobatula lobatula*, D, E: lateral view, F: apertural view, sample 471 FH_3P_1 Rădăuţi. **G, H** — *Elphidium hauerinum*, G: lateral view, H: apertural view, sample 1 Jamnica M-83. **I** — *Elphidium excavatum*, lateral view, sample 30 Machów. **J** — *Elphidium macellum*, lateral view, sample 34 Machów. **K** — *Porosononion martkobi*, lateral view, sample 491/5 Costeşti. **L** — *Nonion bogdanowiczi*, lateral view, sample 35 Machow. **M** — *Articulina problema*, lateral view, sample 491/3 Costeşti. **N** — *Cytherois sarmatica,* right valve, lateral view sample 9 Machów. **O** — *Cytherois sarmatica*, left valve, internal view, sample 8 Machów. **P** — *Aurila mehesi*, left valve, lateral view, sample 9 Machów. **Q** — *Aurila notata*, left valve, lateral view, sample 474 FH_3P_1 Rădăuţi. **R** — *Callistocythere incostata*, left valve, lateral view, sample 440 Dorneşti. Scale bars: 100 µm.

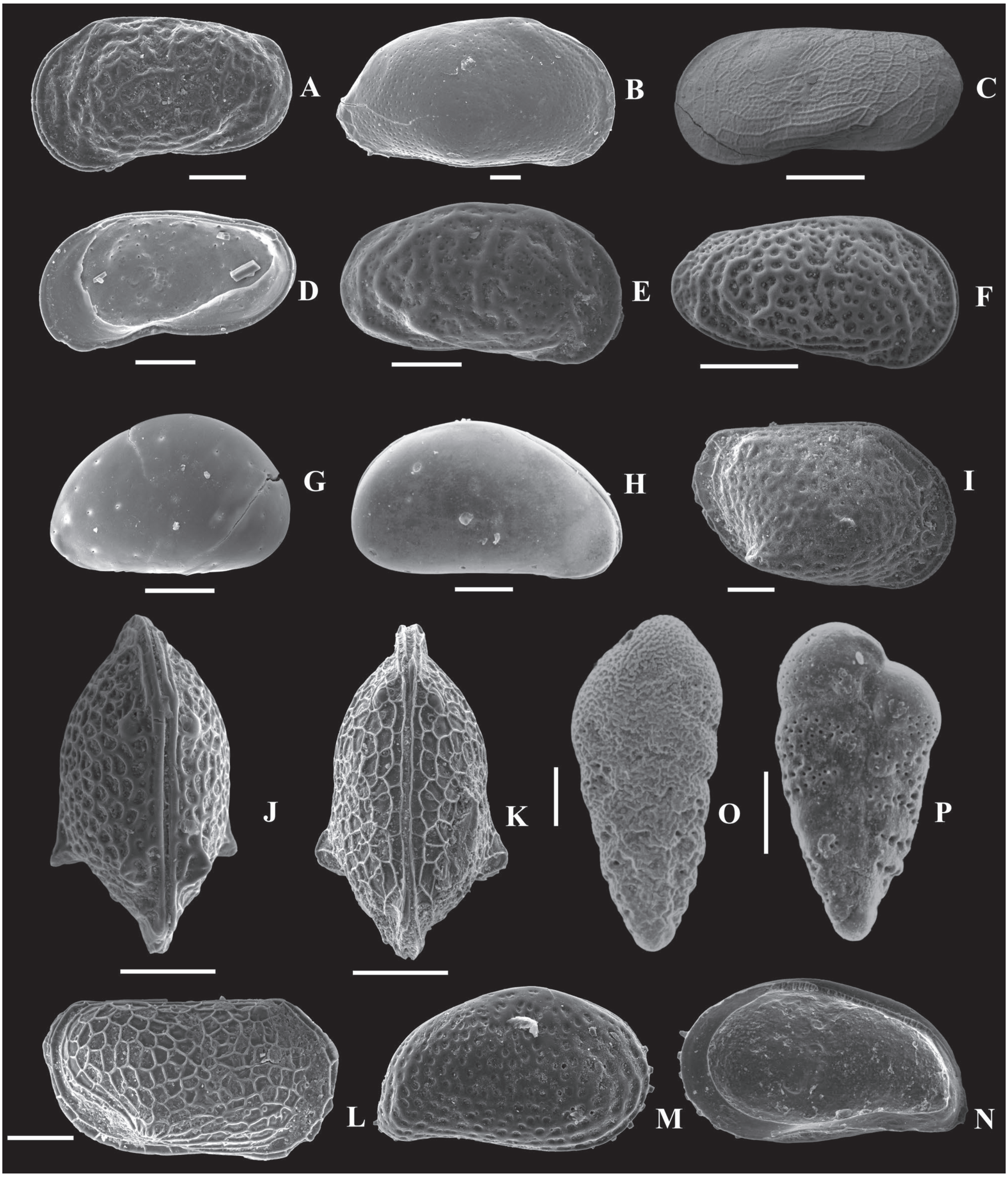

Fig. 13. SEM photographs of the representative foraminifera and ostracoda species identified in the analysed samples. **A** — *Callistocythere incostata*, dorsal view, sample 440 Dorneşti. **B** — *Aurila merita*, right valve, lateral view, sample 13 Machów. **C** — *Callistocythere postvallata*, right valve, lateral view, sample 482 FH_3P_1 Rădăuţi. **D** — *Callistocythere postvallata*, right valve, internal view, sample 12 Machów. **E** — *Callistocythere egregia*, right valve, lateral view, sample 474 FH_3P_1 Rădăuţi. **F** — *Callistocythere maculata*, right valve, lateral view, sample 15 Machów. **G** — *Xestoleberis dispar*, right valve, lateral view, sample 11 Machów. **H** — *Xestoleberis fuscata*, right valve, lateral view, sample 18 Machów. **I** — *Loxocorniculum hastatum*, right valve, lateral view sample 13 Machów. **J** — *Loxocorniculum hastatum,* dorsal view, sample 440 Dorneşti. **K** — *Loxocorniculum schmidi*, dorsal view, sample 491/5 Costeşti. **L** — *Loxocorniculum schmidi* right valve, lateral view, sample 491/5 Costeşti. **M** — *Cytheridea hungarica*, right valve, lateral view, sample 440 Dorneşti. **N** — *Cytheridea hungarica*, right valve, internal view, sample 440 Dorneşti. **O** — *Bolivina moldavica*, lateral view, sample 34 Machów; **P** — *Bolivina sarmatica*, lateral view, sample 34 Machów. Scale bars: 100 µm.

Sarmatian boundary, indicated by the foraminiferal assemblages. Jiříček & Říha (1991) assigned the uppermost Badenian sediments (*Bulimina–Bolivina* foraminiferal Zone, *sensu* Grill 1941) of the Central Paratethys to the NO 10 Zone, which is defined by the authors as the occurrence interval of *Phlyctenophora farkasi* and *Carinocythereis carinata* species. However, we did not identify these species in the studied sediments. A few ostracod species mentioned by Gross (2006) as having their last occurrence in the Badenian deposits of the Vienna Basin, such as *Bosquetina carinella, Callistocythere canaliculata, Cytheridea acuminata, Henryhowella asperrima*, were found in the Sarmatian deposits studied by us.

The Sarmatian foraminiferal assemblages of the Paratethys are dominated by benthic forms, whereas planktonic foraminifera are scattered and taxonomically much more depleted compared with Mediterranean assemblages of the same age. They are mainly represented by *Globigerina, Tenuitella, Tenuitellinata* and *Streptochilus* (Venglinsky 1975; Czepiec 1996; Filipescu & Silye 2008; Koubová & Hudáčková 2010).

Some recent studies (Filipescu & Silye 2008) provide new biozonations for the Sarmatian interval, based on the planktonic foraminifera. The aforementioned biozonation is still very difficult to apply since the planktonic foraminifera encountered in the Sarmatian deposits are still considered by many authors as reworked from the Badenian deposits (i.e. Łuczkowska 1964; Ionesi 1968; Paghida Trelea 1969; Odrzywolska-Bieńkowa 1974; Brânzilă & Chira 2005; Ionesi 2006). Consequently, the standard planktonic foraminiferal zonation (Gradstein et al. 2012), based mainly on Mediterranean species, cannot always be succesfully applied in the Sarmatian of the Paratethys. By contrast, the Paratethyan benthic foraminiferal zonations (e.g., Grill 1941; Ionesi 1991; Popescu 1995; Cicha 1998) are most appropriate for biostratigraphical purposes.

The foraminiferal Assemblage B, recognized in the lower part of the Machów and Jamnica sections, is marked by the extinction of the following species (e.g., *Velapertina indigena, Heterolepa dutemplei, Melonis pomiloides, Sphaeroidina bulloides*) and by the mass occurrence of the species *Anomalinoides dividens*, accompanied by miliolid species (e.g., *Varidentella reussi, Quinqueloculina akneriana, Pseudotriloculina consobrina, Articularia karreriella*) and may be correlated with Łuczkowska's (1964, 1974) *Anomalinoides dividens* Zone. The author located the Badenian–Sarmatian boundary at the base of this biozone, which is defined by the bloom of *Anomalinoides dividens* that is still commonly accepted as the informal definition of this boundary in Poland (Odrzywolska-Bienkowa 1966; Garecka & Olszewska 2011; Paruch-Kulczycka 2015), and was also applied by us to locate the Badenian–Sarmatian boundary in the studied sections. The bloom of *Anomalinoides dividens* is often associated with the base of the Sarmatian in other areas of the Central Paratethys as well (Filipescu 2004; Piller et al. 2007). Additionally, the *Anomalinoides dividens* Zone was determined in the Vienna (Papp 1974; Harzhauser & Piller 2004) and Transylvanian basins (Popescu 1995).

While the definition of the base of the *Anomalinoides dividens* Zone in these basins is rather the same as in Poland, its upper boundary is defined entirely differently. In Poland, the top of the Zone (correlated with the base of Assemblage C) is placed at the FO and mass occurrence of the species *Cycloforina karreri ovata* (Łuczkowska 1964, 1974), whereas in the Vienna Basin it is placed at the level of the abundant occurrence of the large elphidiids such as *Elphidium reginum* (Papp 1974; Cicha 1998) and in the Transylvanian Basin at the first occurrence of the species *Varidentella reussi* (Popescu 1995). Accordingly, the correlation of the upper part of the *Anomalinoides dividens* Zone of these distinct regions is very difficult. In the lowermost part of the Sarmatian of Western Ukraine, Bobrinskaya et al. (1998) distinguished the "*Cibicides badenensis*" Zone, which is marked by the common appearance of the index species accompanied by miliolids. This Zone, described by Bobrinskaya et al. (1998) may approximately correspond to the *Anomalinoides dividens* Zone identified by us, since the species "*Cibicides badenensis*" was treated by the authors as synonymous with *Anomalinoides dividens*, in agreement with Brestenská (1974) and Popescu (1995). Moreover, the zone includes taxa (*Varidentella reussi, Psedotriloculina consobrina, Articularia karreriella*) which commonly occur in the *Anomalinoides dividens* Zone (*sensu* Łuczkowska 1964, 1974). We note that *Anomalinoides dividens* was also presented by Szczechura (1982, 2000) as an ecophenotype of the species *Lobatula lobatula* (Walker & Jacob 1798).

Assemblage C, identified in all the studied sections from Poland and Romania, apparently corresponds to the *Cycloforina karreri ovata* and *Varidentella sarmatica* zones of the Polish Basin established by Łuczkowska (1964, 1974) and with the *Cycloforina karreri ovata, Cycloforina fluviata* and *"Lobatula lobatula"* Zone from the Moldavian Platform, which we assume indicates early Volhynian age.

In this Assemblage C, numerous specimens of the taxa *Cycloforina karreri ovata* occur, along with abundant miliolid species such as *C. predcarpatica, C. fluviata, Articularia karreriella, A. articulinoides, Varidentella reussi, V. rotunda, V. rosea, Miliolinella subrotunda* and *Miliolinella selene* accompanied by *Elphidium reginum* and *Lobatula lobatula*. In previous studies (Ionesi 1968, 1991; Paghida Trelea 1969; Brânzilă 1999; Ionesi 2006) the *Cycloforina karreri ovata, Cycloforina fluviata* and *"Lobatula lobatula"* Zone was attributed to the Buglovian age *sensu* Laskarew (1903).

Łuczkowska (1964, 1974) defined the *Cycloforina karreri ovata* Zone mostly based on the numerous occurrence of the index taxon, whereas *Varidentella sarmatica* was defined by the mass presence of the species *V. sarmatica.* Since in the studied sections both species occur together and do not display any significant blooms, these two zones seem to be more subjective and we treat them as being a single zone. Another species occurring in large numbers in Assemblage C is *Elphidium reginum*, which is also commonly used in dating the Paratethyan sediments. This species is an index taxon of the Zone defined in the Vienna Basin (Grill 1941; Papp 1956, 1963;

Harzhauser & Piller 2004b; Schütz et al. 2007), the Transylvanian Basin (Popescu 1995; Filipescu et al. 1999) and the Zsámbék basin, included in the Pannonian Basin of Hungary (Görog 1992). It is considered a proxy for the early Sarmatian interval also called the *Elphidium reginum* Zone of the above mentioned regions and for the Moldavian Platform as well (Ionesi 1968, 1991; Ionesi 2006). On the basis of its foraminiferal composition, Assemblage C can be correlated with the *Elphidium reginum* Zone of the Vienna and Zsámbék basins and with the *Varidentella pseudocostata* and *Elphidium reginum* Zone of Western Ukraine (Bobrinskaya et al. 1998).

The lower Sarmatian age is also supported by the nannofossil assemblage identified by us (Fig. 14). Two index species have been identified in sample 440 from the Dorneşti section (*Discoaster kulgeri*) and in sample 448 from FH_3P_1 Rădăuţi (*Discoaster deflandrei*). The LO (lowermost occurrence) of *Discoaster kugleri* is globally placed in the Serravallian (Young 1998), at the base of the NN7 zone of Martini (1971), while its LCO (lowest common occurrence) is situated in the Mediterranean at 11.9 Ma and the HCO (highest common occurrence) of this nannofossil is at 11.596 Ma (Raffi et al. 2006). As within the upper part of the global stage Seravallian, situated on the boundary between the Badenian and Sarmatian Paratethyan stages (Piller & Harzhauser 2005), the presence of *Discoaster kugleri* in the studied sediments is indicative for the presence of lower Sarmatian (=Volhynian) sediments. The HO (highest occurrence) of the species *Discoaster deflandrei*, and the HO of *Discoaster kugleri* (Young 1998), nannofossil events are also situated in the NN7 zone of Martini (1971). Based on the aforementioned data, we attribute the deposits from Romania (FH_3P_1 Rădăuţi core and Dorneşti outcrop) to the NN7 calcareous nannoplankton zone, which is lower Sarmatian. Our results are supported by previous studies of Peryt (1997) and Garecka & Olszewska (2011) who dated the Krakowiec Clays as belonging to the NN7 Zone.

Assemblage D, identified in the upper parts of the Machów and Jamnica sections as well as in the entire Costeşti section, seems to correspond to the *Elphidium hauerinum* Zone *sensu* Łuczkowska (1964, 1974) and to the *Varidentella reussi* and *Articulina sarmatica* Zone and the *Elphidium rugosum, Pseudotriloculina consobrina, Ammonia beccarii* Zone established by Ionesi (1991) for the Moldavian Platform indicating the upper part of the early Sarmatian interval, based on the common appearance of the foraminiferal species *Elphidium hauerinum, E. joukovi, E. fitchelianum, E. excavatum, Elphidiella serena, Nonion bogdanowiczi, Porosononion subgranosus, P. martkobi,* and the subordinate number of miliolids. Moreover, Assemblage D could be correlated with the *E. hauerinum* Zone from the Vienna Basin (Grill 1941; Cicha 1998) and *E. hauerinum* and *V. reussi* Zone from western Ukraine (Venglinsky 1953, 1959; Didkowski 1961), and the *Elphidium hauerinum* Zone from Zsámbék Basin (Görög 1992), based on similar foraminiferal content (namely common occurrence of *Elphidium hauerinum, E. macellum, Porosononion subgranosus, Varidentella reussi, Articularia articulinoides*) which occur in all these zones. All of the above-mentioned zones identified in distinct Paratethyan basins are placed in the middle to upper parts of the early Sarmatian.

Assemblage E recorded in the top of the Machów section (samples 28–34) is characterized by the abundance of comparatively small and thin tested bolivinids and common elphidiid

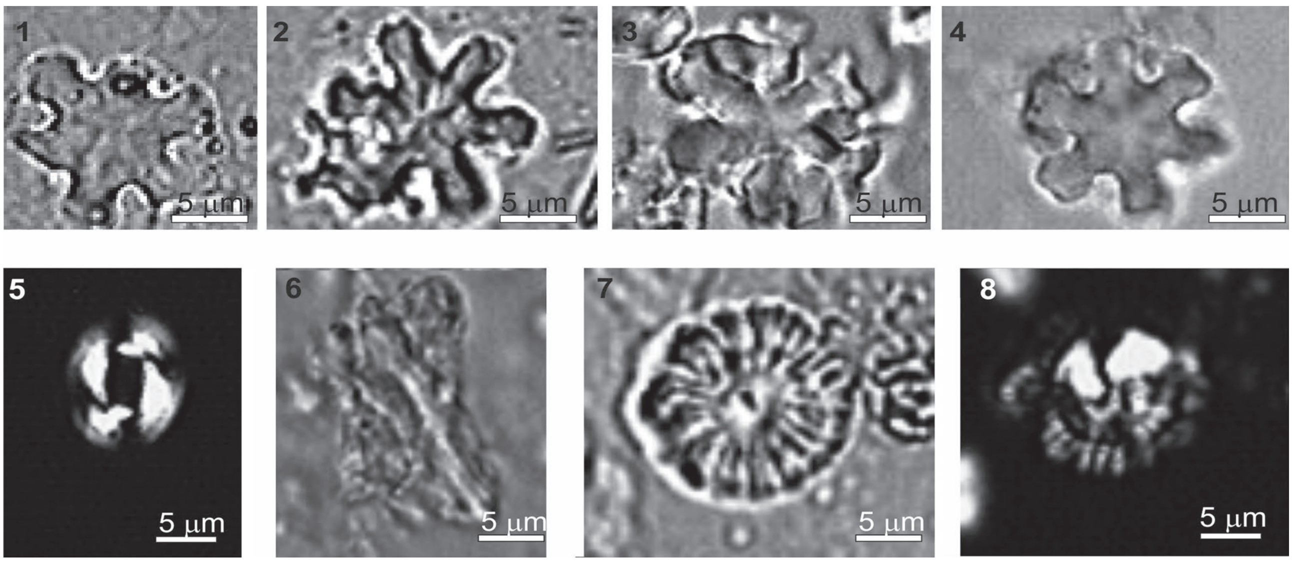

Fig. 14. All microphotographs at LM (light microscope); N+ crossed nicols; NII transmitted light; scale bar in microns. **1** — *Discoaster kugleri* Martini and Bramlette, 1963, NII, Dorneşti section. **2** — *Discoaster musicus* Stradner, 1959; NII, Dorneşti section. **3** — *Discoaster deflandrei* Bramlette and Riedel, 1954, NII, Dorneşti section. **4** — *Discoaster deflandrei* Bramlette and Riedel, 1954, NII, Dorneşti section. **5** — *Reticulofenestra pseudoumbilicus* (Gartner, 1967) Garten, 1969, N+, Dorneşti section. **6** — *Triquetrorhabdulus rugosus* (Bramlette et Wilcoxon, 1967), NII, Dorneşti section. **7**, **8** — *Calcidiscus macintyrei* (Bukry et Bramlette, 1969) Loeblich et Tappan, 1978, 7 – NII, 8 – N+, Dorneşti section.

presence. The assemblage resembles the foraminiferal association with the *Porosononion "subgranosum"* Zone from western Ukraine (Venglinsky 1975) and Slovakia (Fordinál et al. 2006; Fordinál & Zlinská 1998). Moreover, a similar association with small bolivinids accompanied by planktonic species belonging to the planktonic genus *Streptochilus* has been described recently in the Transylvanian Basin in upper Sarmatian deposits (Filipescu & Silye 2008). Accordingly, we do not exclude the possibility that the top of the Machów section represents the lowermost part of the upper Sarmatian *s.s.* which corresponds to the lowermost Bessarabian, albeit an increase in the number of bolivinid species was also noticed in the lower Sarmatian deposits of the Vienna Basin and Zsámbék Basin (Jiříček 1972; Görög 1992; Tóth et al. 2010), as well as in the eastern part of the Moldavian Platform (Paghida Trelea 1969).

In the Sarmatian parts of the analysed sections (*Anomalinoides dividens, Cycloforina karreri ovata* + *Varidentella sarmatica* and *Elphidium hauerinum* foraminiferal zones) we have found straigraphically important ostracod species, such as *Aurila mehesi, A. merita, Senesia vadaszi, Cytheridea hungarica, Callistocythere canaliculata, C. incostata, C. postvallata, Loxocorniculum hastatum, L. schmidi, Xestoleberis dispar* and *X. tumida*. In general, they are characteristic for the early Sarmatian (Gross 2006; Tóth 2008) and support the early Sarmatian age established on the basis of foraminifera. The ostracod assemblages from the lower part of the Machów (the interval from 66–57 m) and Jamnica sections (sample 12, 202 m), as well as from Rădăuți (175–30 m in depth) and Dornești sections (samples 440, 146 respectively 356, 358m in altitude) may be attributed to the NO 11 *Cytheridea hungarica–Aurila mehesi* Zone defined by Jiříček (1983) and Jiříček & Říha (1991) for the Lower Sarmatian of the Central Paratethys and Lower Volhynian of the Eastern Paratethys. In the studied area, the NO 11 Zone approximately corresponds to the depth interval which is correlated with the *Anomalinoides dividens* and *Elphidium reginum* foraminiferal zones (see discussion above) of Grill (1941) and Harzhauzer & Piller (2004b). Our correlation agrees with the correlation made by Jiříček & Říha (1991) and Gross (2006).

The next species, traditionally regarded as stratigraphically very important, is *Aurila notata*. The species has been found in the Machów section (sample 13, 58 m depth), within the *Anomalinoides dividens* Zone, in the lower part of the lower Sarmatian deposits. This species also co-occurs with abundant *Aurila mehesi*, defining NO 11 Zone. The species *A. notata* characterizes the NO 12 *Neocyprideis (N.) kollmanni–Aurila notata* Zone, as defined by Jiříček & Říha (1991). According to them, the Zone NO 12 corresponds to foraminiferal *Elphidium hauerinum* Zone as well as to the *Aurila notata* Total Range Zone (Zelenka 1990) and to the foraminiferal *Elphidium hauerinum* and *Porosononion "subgranosum"* zones in the meaning of Grill (1941) and Harzhauzer & Piller (2004b), indicating early to middle Sarmatian age. Similarly, *Aurila notata* was mentioned by Kollmann (1960) as part of the characteristic ostracod fauna of the *Elphidium reginum* Zone. Additionally, Gross (2006) marked its stratigraphic range from the Badenian–Sarmatian boundary in the Pannonian of the Vienna Basin, therefore, we do not consider this species as a reliable taxon indicating either the *Elphidium hauerinum* Zone (upper part of the early Sarmatian) or the middle Sarmatian. The early Sarmatian age is supported by other ostracod taxa recorded in these deposits namely *Callistocythere postvallata, C. incostata, Cytheridea hungarica, A. mehesi, A. merita* and *Senesia vadaszi*. These species were identified by Tóth (2008) in the *E. reginum* Zone from Zsámbék Basin (part of the Pannonian Basin, Hungary). Additionally, Gross (2006) determined the last occurrence of the following taxa: *A. merita, C. postvallata, L. hastatum, L. schmidi, Senesia vadaszi, Xestoleberis dispar* and *X. tumida* in the lower Sarmatian deposits of the Central Paratethys. Accordingly, they are important markers for the Lower Sarmatian across Central Paratethys. The occurrences of *C. postvallata, L. hastatum* and *L. schmidi* (Gross 2006) in the samples of Costești section (Republic of Moldova) confirm the appartence of these deposits to the early Sarmatian.

It should be mentioned that Ionesi & Chintăuan (1994) established an ostracod biozonation for the Moldavian Platform. Within the lower Sarmatian deposits, the authors distinguished the *Cytheridea acuminata* Zone and *Leptocythere mironovi* Zone, the latter of which was subdivided into two subzones *Xestoleberis lutrae–Leptocythere bosqueti* and *Xestoleberis elongata*. Unfortunately, we could not apply this biozonation because of the lack of most of the important taxa defining this zonation in our material. Moreover, the collection of Ionesi & Chintăuan (1994) was restudied during the research for this work and it was found out that a large part of the collection is either very poorly preserved, making the proper designation impossible, or incorrectly determined, for example, in the case of *Aurila mehesi*, the species described as typical taxa for the lower Bessarabian. We found that all of the *Aurila mehesi* specimens of the collection were incorrectly determined, so the above mentioned zonation is not reliable and is not supported by adequate material.

Conclusions

Integrated micropaleontological studies were carried out in detail on five Middle Miocene sections of the Central Paratethys (Poland, Romania and Republic of Moldova), to assess their biostratigraphic utility. In addition, nannofossil analyses were done for the Romanian and Republic of Moldova sections and correlated with the already published data from the Polish sections.

Five foraminiferal assemblages, one Badenian (Assemblage A) and four Sarmatian (Assemblages B–E), were identified, corresponding to Łuczkowska's (1964, 1974) division. These assemblages display stratigraphic potential, being therefore useful for correlation of upper Badenian–lower Sarmatian deposits from the Central Paratethyan domain. The Badenian

Assemblage A corresponds to *Hanzawaia crassispetata* Zone (*sensu* Łuczkowska 1964, 1974), as well as to the *Bulimina–Bolivina* Zone and Zone with agglutinated foraminifera from the Vienna Basin and to the *Ammonia galiciana* Zone from western Ukraine. Based on the planktonic foraminiferal species, Assemblage A can be additionally correlated with the *Velapertina indigena* planktonic foraminiferal zone of Łuczkowska (1971) and with the *Velapertina Zone* of Popescu (1975).

The mass occurrence of the species *Anomalinoides dividens* (the base of Assemblage B) allowed the establishment of the Badenian–Sarmatian boundary. Assemblage C seems to correspond to the *Cycloforina karreri ovata* and *Varidentella sarmatica* zones from the Polish Basin (*sensu* Łuczkowska 1964, 1974) and *Cycloforina karreri ovata, Cycloforina fluviata, "Lobatula lobatula"* Zone from the Moldavian Platform (Ionesi 1991). The foraminiferal distributions recorded in the studied sections do not reflect a clear separation between the *Cycloforina karreri ovata* and *Varidentella sarmatica* Zones (*sensu* Łuczkowska 1964, 1974) and thus they should be applied as one biostratigraphic division. Moreover, based on the presence of other indicator species such as *Elphidium reginum* we correlated this assemblage with the *Elphidium reginum* Zone from the Vienna Basin (*sensu* Grill 1941) and Zsámbék Basin (Görög 1992) and with the *Varidentella pseudocostata* and *Elphidium reginum* zones (Bobrinskaya et al. 1998) from Western Ukraine.

Assemblage D approximately corresponds to the *Elphidium hauerinum* Zone (*sensu* Łuczkowska 1964, 1974), the *Elphidium hauerinum* Zone (*sensu* Grill 1941) from the Vienna Basin, and the *Elphidium hauerinum* and *Varidentella reussi* Zone from western Ukraine, as well as to the *Varidentella reussi* and *Articulina sarmatica* Zone and *Elphidium rugosum*, *Pseudotriloculina consobrina, Ammonia beccarii* Zone from the Moldavian Platform (Ionesi 1991), and the *Elphidium hauerinum* Zone from Zsámbék Basin, Hungary (Görög 1992). Assemblage E, characterized mainly by smaller and thin tested bolivinids, possibly corresponds to the *Porosononion "subgranosum"* Zone from western Ukraine (Venglinsky 1975) and Slovakia (Fordinál et al. 2006; Fordinál & Zlinská 1998) of the lowermost Bessarabian, lowermost part of the upper Sarmatian *s.s.*

The studied ostracod content allowed us to recognize the NO 10 and NO 11 zones originally described in the Vienna Basin (Jiříček & Říha 1991). We identified 11 ostracod species which are stratigraphically significant (*Aurila mehesi, A. merita, Senesia vadaszi, Cytheridea hungarica, Callistocythere canaliculata, C. incostata, C. postvallata, Loxocorniculum hastatum, L. schmidi, Xestoleberis dispar* and *X. tumida*) and may allow correlation between the Badenian and Sarmatian deposits in the Central Paratethys. The Badenian–Sarmatian boundary based on foraminifers, located at the base of the Assemblage B (*Anomalinoides dividens* Zone), is placed close to the ostracod faunal turnover, which means the disappearance of the typical Badenian species (*Henryhowella asperrima, Cytheropteron vespertilio, Semicytherura filicata, Eucytheropteron inflatum, Cnestocythere truncata*) and the appearance of new forms (*Aurila mehesi, A. merita, Senesia vadaszi, Cytheridea hungarica, Callistocythere canaliculata, C. incostata, C. postvallata, Loxocorniculum hastatum, L. schmidi, Xestoleberis dispar* and *X. tumida*) specific for the Lower Sarmatian in the entire Central Paratethys. Some of the ostracod species, traditionally believed to be exclusively Badenian, such as *Henryhowella asperrima, Cnestocythere truncata* and *Hemicytherura videns*, became extinct slightly higher, in the *Anomalinoides dividens* foraminiferal Zone, which is earliest Sarmatian in age. *Aurilla notata*, the index taxon of the NO 12 Zone, commonly treated as a proxy for the upper part of the lower Sarmatian and middle Sarmatian as well, was identified in the *Anomalinoides dividens* Zone. This finding casts doubt on its utility as a biostratigraphic marker for the NO 12 Zone.

Based on our integrated data we managed to correlate the studied Polish, Romanian and Republic of Moldova sections from the Central Paratethys. Furthermore, we demonstrate that the Sarmatian microfossil associations, regarded as rather stratigraphically useless mostly based on paleoenvironmental changes, can be applied not only for regional correlations, but also for interregional ones between the Paratethyan basins.

Acknowledgements: This work was funded by grant number UMO-2013/09/D/ST10/04059 from the Polish National Science Centre (NCN). The SEM photography was partly supported by the project "Microcosmos — Laboratory of Electronic Microscopy" funded by European Regional Development Fund no. 650/25.04.2014 implemented by the Geological Institute of Romania. The authors wish to express their gratitude to Dr. Igor Nicoară from the Institute of Geology and Seismology of Republic of Moldova for providing the geological maps and to Daniel Bîrgăoanu for the help in realizing the SEM photos. The comments of Lilian Švábenická and two anonymous reviewers are gratefully acknowledged.

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Appendix

Index of listed foraminifera taxa:
Affinetrina cubanica (Bogdanowicz, 1947)
Affinetrina ukrainica (Serova, 1952)
Ammonia beccarii (Linné, 1758)
Anomalinoides dividens Łuczkowska, 1967
Articularia articulinoides (Gerke & Issaeva, 1952)
Articularia karreriella (Venglinsky, 1958)
Articulina problema (Bogdanowicz, 1952)
Articulina sarmatica (Karrer, 1877)
Asterigerinata planorbis (d'Orbigny, 1846)
Aubignyna perlucida (Herron-Allen & Earland, 1913)
Bolivina antiqua d'Orbigny, 1846
Bolivina dilatata Reuss, 1850
Bolivina directa Cushman, 1936
Bolivina moldavica Didkowski, 1959
Bolivina nisporenica Maissuradze, 1988
Bolivina sarmatica Didkowski, 1959
Bolivina subdilatata Reuss, 1850
Budashevaella laevigata (Voloshinova, 1961)
Bulimina aculeata d'Orbigny, 1826
Bulimina elongata elongata d'Orbigny, 1826
Bulimina insignis Łuczkowska, 1960
Cibicides boueanus (d'Orbigny, 1846)
Lobatula lobatula (Walker & Jacob, 1798)
Cibicidoides austriacus (d'Orbigny, 1846)
Cribroelphidium poeyanum (d'Orbigny, 1826)
Cursina porocostata Popescu & Crihan, 2004
Cyclammina cancellata Brady, 1879
Cycloforina cristata (Millett, 1898)
Cycloforina fluviata (Venglinsky, 1958)
Cycloforina gracilis (Karrer, 1867)
Cycloforina predcarpatica (Serova, 1955)
Cycloforina karreri ovata (Serova, 1955)
Cycloforina karreri karreri (Reuss, 1869)
Cycloforina suturalis (Reuss, 1869)
Dogielina sarmatica (Bogdanowicz & Didkowski, 1951)
Elphidiella serena (Venglinsky, 1958)
Elphidium aculeatum (d'Orbigny, 1846)
Elphidium crispum (Linné, 1758)
Elphidium excavatum (Terquem, 1875)
Elphidium fichtelianum (d'Orbigny, 1846)
Elphidium hauerinum (d'Orbigny, 1846)
Elphidium incertum Williamson, 1858
Elphidium josephinum (d'Orbigny, 1846)
Elphiudium joukovi Serova, 1955
Elphidium macellum (Fitchel & Moll, 1803)
Elphidium macellum tumidocamerale Bogdanowicz, 1932
Elphdium reginum d'Orbigny, 1846
Elphidium reussi Marks, 1951
Elphidium rugosum (d'Orbigny, 1846)
Elphidium subumbilicatum Czjzek, 1848
Elphidium ungeri (Reuss, 1850)
Favulina hexagona (Williamson, 1848)
Fissurina cubanica (Bogdanowicz, 1947)
Fissurina isa (Venglinsky, 1958)
Fissurina mironovi (Bogdanowicz, 1947)
Fissurina toga Popescu, 1983
Fursenkoina acuta d'Orbigny, 1846
Glandulina ovula d'Orbigny, 1846
Globigerina bulloides d'Orbigny, 1826
Globigerina concinna Reuss, 1850
Globigerina dubia Egger, 1857
Globigerina praebulloides Blow, 1959
Globigerina triloba Reuss, 1850
Globigerinoides bisphaericus Todd, 1954
Globigerinita uvula Ehrenberg, 1861
Globorotalia mayeri Cushman & Ellisor, 1939
Globorotalia miocenica Palmer, 1945
Hansenisca soldanii (d'Orbigny, 1826)
Hanzawaia crassiseptata Łuczkowska, 1955
Heterolepa dutemplei (d'Orbigny, 1846)
Hyalinonetrion clavatum (d'Orbigny, 1846)
Lagena gracilis Wiliamson, 1848
Lagena striata (d'Orbigny, 1839)
Melonis pompiloides (Fichtel & Moll, 1798)
Miliolinella selene (Karrer, 1868)
Miliolinella subrotunda (Montagu, 1803)
Neoeponides schreibersi (d'Orbigny, 1846)
Nodobaculariella ovalis Venglinsky, 1958
Nodobaculariella sulcata (Reuss, 1850)
Nonion bogdanowiczi Voloshinova, 1952
Nonion commune (d'Orbigny, 1846)
Nonion tumidulus Pishvanova, 1959
Nothia excelsa (Grzybowski, 1898)
Orbulina bilobata d'Orbigny, 1846
Orbulina suturalis (Brönnimann, 1951)
Ortomorphina dina Venglinsky, 1958
Pappina parkeri Karrer, 1877
Parafissurina subovata Parr, 1950
Porosolenia tibiscens Popescu, 1983
Porosononion subgranosus (Egger, 1857)
Porosononion martkobi (Bogdanowicz, 1947)
Praeglobulimina pyrula d'Orbigny, 1846
Protobotellina vermicula Łuczkowska, 1990
Pseudotriloculina consobrina (d'Orbigny, 1846)
Pseudotriloculina consobrina nitens (Reuss, 1850)
Pullenia bulloides (d'Orbigny, 1846)
Reophax globosus Sliter, 1968
Reticulophragmium rotundidorsatum Hantken, 1875
Rhabdammina abyssorum Carpenter, 1869
Quinqueloculina alexandri Łuczkowska, 1974
Quinqueloculina akneriana d'Orbigny, 1846
Quinqueloculina akneriana argunica Gerke, 1938
Quinqueloculina akneriana longa Gerke, 1938
Quinqueloculina bogdanowicz (Serova, 1955)
Quinqueloculina minakovae ukrainica Didkowski, 1961
Quinqueloculina perelegantissima Didkowski, 1961
Schackoinella imperatoria (d'Orbigny, 1846)
Semivulvulina pectinata (Reuss, 1850)
Sigmoilinita tenuis (Czjzek, 1848)
Sphaeroidina bulloides d'Orbigny, 1826
Textularia beregoviensis Venglinsky, 1958
Textularia concava (Terquem & Berthelin, 1875)
Triloculina circularis Bornemann, 1855
Triloculina gibba d'Orbigny, 1826
Triloculina gibba latodentata Didkowski, 1961
Triloculina inflata d'Orbigny, 1846
Triloculina inflata konkia (Didkowski, 1961)
Triloculina trigonula (Lamarl, 1804)
Uvigerina brunensis Karrer, 1877
Uvigerina grilli Schmid, 1971
Uvigerina liesingensis Toula, 1914
Uvigerina peregrina Cushman, 1923
Uvigerina rutila Cushman & Todd, 1941
Uvigerina semiornata d'Orbigny, 1846
Varidentella latecunata (Venglinsky, 1958)

Varidentella pseudocostata (Venglinsky, 1958)
Varidentella reussi (Bogdanowicz, 1947)
Varidentella rosea (d'Orbigny, 1839)
Varidentella rotunda (Gerke, 1938)
Varidentella sarmatica Karrer, 1877
Velapertina indigena Łuczkowska, 1955

Index of listed ostracod taxa:
Amnicythere tenuis (Reuss, 1850)
Argiloecia sp.
Argiloecia subtilis Barra, Aiello & Bonaduce, 1996
Aurila mehesi (Zalányi, 1913)
Aurila merita (Zalányi, 1913)
Aurila notata (Reuss, 1850)
Aurila sp.
Bosquetina carinella (Reuss, 1850)
Callistocythere bituberculata (Sheremeta, 1961)
Callistocythere canaliculata (Reuss, 1850)
Callistocythere egregia (Méhes, 1908)
Callistocythere gliwicensis Aiello & Szcechura, 2004
Callistocythere incostata Pietrzeniuk, 1973
Callistocythere maculata Pietrzeniuk, 1973
Callistocythere postvallata Pietrzeniuk, 1973
Callistocythere sp. 1
Callistocythere sp. 2
Cnestocythere lamellicosta Triebel, 1950
Cnestocythere sp.
Cnestocythere truncata (Reuss, 1850)
Cyamocytheridea leptostigma (Reuss, 1850)
Cyprideis pannonica (Méhes, 1908)
Cytheridea acuminata Bosquet, 1852
Cytheridea hungarica Zalányi, 1913
Cytherois sarmatica (Jiřiček, 1974)
Cytheropteron sp.
Cytheropteron vespertilio (Reuss, 1850)
Eocytheropteron inflatum Schneider, 1949
Euxinocythere praebosqueti (Suzin, 1956)
Euxinocythere sp.
Fabaeformiscandona pokornyi (Kheil, 1964)
Hemicyprideis dacica dacica (Héjjas, 1895)
Hemicytheria omphalodes (Reuss, 1850)
Hemicytherura videns (Müller, 1894)
Henryhowella asperrima (Reuss, 1850)
Kirthe sp.
Leptocythere cejcenensis Zelenka, 1990
Leptocythere foveolata Moyes, 1965
Leptocythere naviculata (Schneider, 1939)
Leptocythere sp.
Loxoconcha impressa Baird, 1850
Loxoconcha minima Müller, 1894
Loxoconcha rhomboidea (Fischer, 1855)
Loxocorniculum hastatum (Reuss, 1850)
Loxocorniculum schmidi (Cernajsek, 1974)
Phlyctocythere pellucida (Müller, 1894)
Polycope orbicularis Sars, 1866
Polycope sp.
Semicytherura filicata (Schneider, 1939)
Senesia vadaszi (Zalányi, 1913)
Xestoleberis dispar Müller, 1894
Xestoleberis fuscata Schneider, 1953
Xestoleberis tumida (Reuss, 1850)

Index of listed calcareous nannofossil taxa:
Calcidiscus leptoporus (Murray et Blackman, 1898), Loeblich et Tappan, 1978
Calcidiscus macintyrei (Bukry et Bramlette, 1969) Loeblich et Tappan, 1978
Coccolithus pelagicus (Wallich, 1877), Schiller, 1930
Discoaster deflandrei Bramlette et Riedel, 1954
Discoaster kugleri Martini et Bramlette, 1963
Discoaster musicus Stradner, 1959
Helicospahera carteri (Wallich, 1877) Kamptner, 1954
Pontosphaera multipora (Kamptner, 1948 ex Deflandre in Deflandre et Fert, 1954) Roth, 1970 *Reticulofenestra minuta* Roth, 1970,
Reticulofenestra minutula (Gartner, 1967), Haq et Berggren, 1978
Reticulofenestra pseudoumbilicus (Gartner, 1967) Garten, 1969
Sphenolithus moriformis (Bronnimann et Stradner, 1960), Bramlette et Wilcoxon, 1967
Triquetrorhabdulus rugosus (Bramlette et Wilcoxon, 1967)