

BIOSTRATIGRAPHIC AND PALEOECOLOGIC SIGNIFICANCE OF THE MACRO- AND MICROFOSSIL ASSEMBLAGES IN THE BOROD FORMATION (EASTERN BOROD DEPRESSION, NORTH-WEST ROMANIA)

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Abstract. Microfossil material collected from outcrops and several boreholes allow new interpretations on the age and environment of deposition at the time of deposition of the Borod Formation. There have been identified four types of mollusk assemblages (*Crassostrea*, *Granulolabium* - *Theodoxus* - *Tympanotonos*, *Turritella* - *Anadara*, and *Alvania* - *Ringicula* - *Pyramidella*) and some particular microfaunas, mainly with miliolids and *Ammonia*. The documented levels of increased salinity allow new possibilities of correlation. Some particular mollusk faunas and the range of several foraminifera taxa suggest the Badenian age of the entire Borod Formation.

Keywords: Mollusks, Foraminifera, Miocene, Borod Depression.

INTRODUCTION

Borod Formation has been described from the eastern part of the Borod Depression (Popa, 2000). It mainly consists of gray to black mudstones with intercalations of siltstones, sandstones, conglomerates and coal beds. These deposits include the most diverse fossil fauna from the whole Neogene succession from the eastern part of the Borod Depression (mollusks, foraminifera, ostracods, otolites,

pollen, calcareous nannoplankton, etc.).

The formation outcrops on the border of the metamorphites and riolites belonging to the Plopiș Mountains, between Cetea and Răchiți valleys in north (Figure 1), or are covered by younger Neogene deposits on wider areas (intercepted by several boreholes towards Gheghie, in west, Borod, in east, and Borod Valley, in south).

Fossil assemblages provide interesting data

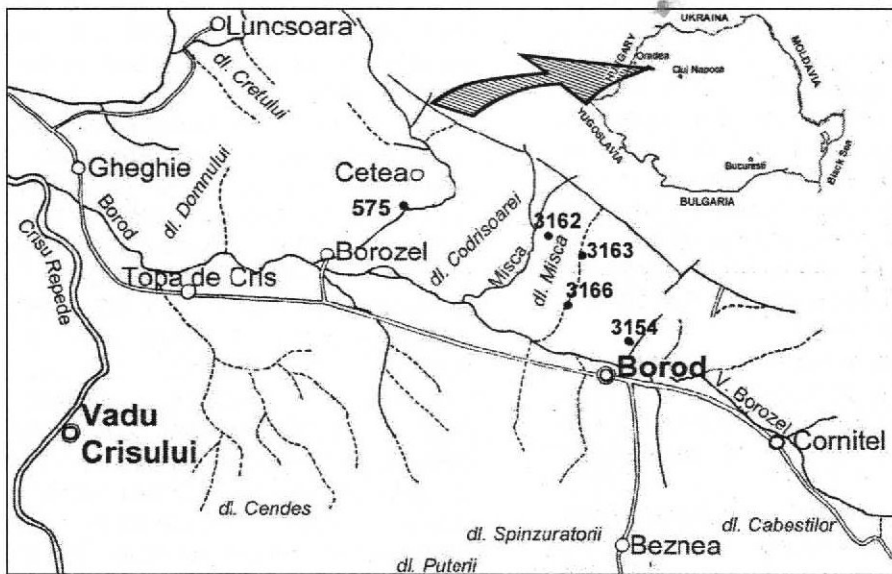


Figure 1. Location of the studied area

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Therefore we focused our study on some assemblages which could be representative for age determinations and correlation purposes, with priority on foraminifera.

MATERIAL AND METHODS

The fossil material was collected from several outcrops and well sites executed by Transgex S.A. Cluj in the 1980's. The outcrops are located on Lupului Brook and in the Piciorul Marianeii Hill. The well sites are located north of Borod locality (sites 3166, 3154, 3162, 3163) and at Cetea (site 575).

The core samples were processed by standard methods, mainly by immersion in water and sieving the disaggregated sediment on a 63- μ m mesh. The fossil fauna was picked from the entire >63- μ m residue. The foraminifera were photographed using a SEM microscope at University College London.

FOSSIL ASSEMBLAGES

Foraminifera

The fossil foraminifera faunas are poorly studied in the Borod Basin. Our attempt brings some new data on the possibilities of age determination and correlations, trying to help solving the existing discussions on this topic (i.e. Early versus Middle Miocene age).

Although at most levels the assemblages are of a low diversity caused by the decreased salinity of the environment, in all sites have been identified intervals with more diverse microfaunas. The reason for this increased diversity is the normal salinity levels, which might be related with regional events. Such levels with normal marine assemblages could be used for correlation purposes in the basin (Figure 2).

There have been identified mainly three types of microfauna assemblages: low salinity, brackish and normal marine.

1. *Low salinity assemblage* - includes rich assemblages of opportunistic foraminifera, mainly *Ammonia* div. sp., together with ostracods and rare miliolids or agglutinated foraminifera.

2. *Brackish assemblage* - is characterized by a more diverse microfauna, including many miliolids, *Elphidium* div. sp., *Porosonion* div. sp., agglutinated foraminifera, and ostracods.

3. *Normal marine assemblage* - includes the most diverse microfauna, with ornamented miliolids, lagenids, rotaliids, and even planktonic foraminifera.

Mollusks

Malacofauna in the Borod Formation is, in

general, abundant and very well preserved. Previous studies on the Site 575 Cetea allowed the separation of three types of assemblages: *Granulolabium* (=Pirenella) - *Theodoxus* - *Tympanotonos*, *Turritella* - *Anadara* and *Alvania* - *Ringicula* - *Pyramidella* (Popa, in Popa & Chira, 2000). These types have been recognized in the boreholes placed north of Borod, as well.

The following assemblages could be identified by our investigations:

1. *Crassostrea* assemblage - includes *Crassostrea aginensis* (TOURNOUER), *Crassostrea gryphoides* (SCHLOTHEIM) and *Cubitostrea digitalina* (EICHWALD emend. DUBOIS). It occurs on the outcrops in Lupului Brook (*Crassostrea gryphoides* and *Cubitostrea digitalina*), Piciorul Marianeii Hill (*Crassostrea aginensis*) and also in the sites 570 Borozel (432,80 m) and 3162 Borod (394,00m).

2. *Granulolabium* - *Theodoxus* - *Tympanotonos* assemblage - includes *Polymesoda convexa* (BRONGNIART), *Spisula subtruncata triangula* RENIERI, *Congeria sandbergeri* ANDRUSSOV, *Granulolabium plicatum* BRUGUIERE div. ssp., *Theodoxus pictus pictus* (FERUSSAC), *Tympanotonos margaritaceus grateloupi* (BROCCHI), *Nerita plutonis* BASTEROT, *Terebralia bidentata bidentata* (DEFRANCE in GRAT.), *Melanopsis impressa monregalensis* SACCO, *Dorsanum nodosocos-tatum* (HILBER). It has been identified in all well sites and in the Lupului Brook outcrop.

3. *Turritella* - *Anadara* assemblage - includes *Anadara diluvii* (LAMARCK), *Anadara diluvii* cf. *pertransversa* SACCO, *Loripes (Microloripes) dentatus* (DEFRANCE), *Ervilia pusilla* PHILIPPI, *Alveinus nitidus* (REUSS), *Gouldia minima* (MONTAGU), *Corbula (Varicorbula) gibba* (OLIVI), *Pitar* sp., *Veneridae* indet., *Turritella turris taurolaevus* SACCO, *T. partschi* ROLLE, *Putilla taurominima* (SACCO), *Alvania venus danubiensis* COSSMANN & PEYROT, *Alaba costellata ano-mala* (EICHWALD), *Teinostoma (Solariorbis) woodi* (HOERNES), *Euspira catena helicina* (BROCCHI), *Calyptraea (Calyptraea) chinensis* (LINNE), *Hinia basteroti* MICHELOTTI, *Clavatulina jouanneti* DESMOULINS, *Bela sparsa* (BOETTGER), *Pleurotoma* sp., *Pyramidella plicosa* (BRONN),

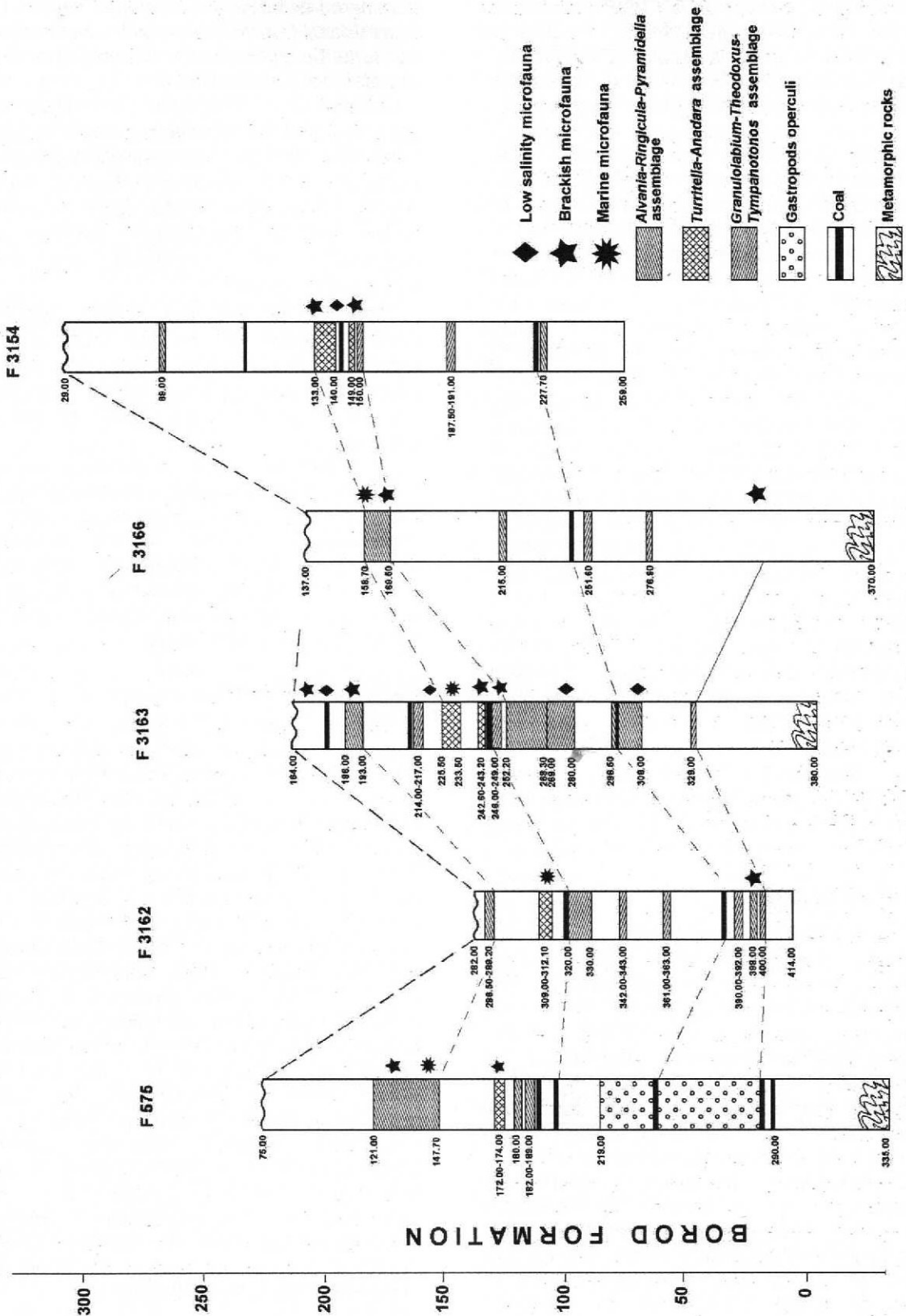


Figure 2. Distribution of the main types of fossil assemblages in the wells from the eastern part of the Borod Basin

Odostomia subintermedia (COSSMANN & PEYROT), *O. perrara* BOETTGER, *Eulimella (Ebalia) nitidissima* (MONTAGU), *E. conulus* EICHWALD, *Turbonilla scala* (EICHWALD), *Ringicula (Ringiculocosta) costata* (EICHWALD), *Cylichna cylindracea* (PENNANT). Together with the bivalves, some gastropods, scaphopods - *Dentalium (Dentalium) michelotti* HOERNES, *Dentalium (Antale) cf. vitreum* SCHROETER - and echinid remains occur. The assemblage has been identified in the sites 575, 3162, 3163 and 3154.

4. *Alvania - Ringicula - Pyramidella* - includes small taxa, mainly Pyramidellidae and Rissoidae: *Parvicardium subhispidum* (HILBER), *Gouldia minima* (MONTAGU), *Venerupis (Polititapes) vitalianus* (ORBIGNY), *Obsoletiforma kokkupica* (ANDRUSSOV), *Veneridae* indet., *Alvania venus danubiensis* COSSMANN & PEYROT, *A. cf. montagui ampulla* (EICHWALD), *Alaba costellata anomala* (EICHWALD), *Cerithium (Thericium) turonicum* MAYER, *Cerithiopsis tubercularis astensis* COSSMANN, *Bittium reticulatum* (COSTA), *Triphora perversa* (LINNE), *Calyptrea (Calyptrea) chinensis* (LINNE), *Euspira catena helicina* (BROCCHI), *Nassa dujardini* DESHAYES, *Hinia basteroti* MICHELOTTI *Bela sparsa* (BOETTGER), *Pyramidella plicosa* (BRONN), *Eulimella (Ebalia) nitidissima* (MONTAGU), *Odostomia dispar* BOETTGER, *Chrysallida interstincta* (MONTAGU), *Turbonilla scala* (EICHWALD) and *Ringicula (Ringiculocosta) costata* (EICHWALD). It has been identified at several levels in the five mentioned well sites, including the bottom of the succession (Site 3154).

PALEOECOLOGY

The valves of *Crassostrea* assemblage specimens are connex, indicating a rapid burial, therefore a high rate of sedimentation. The specimens are smaller compared with the ones from other sites in Europe. There are also present juvenile specimens attached to the adult shells. *Crassostrea* indicates a shallow marginal environment, agitated and with decreased salinity. The recent species prefer the estuarine and river mouth environments.

Granulolabium - Theodoxus - Tympanotonos assemblage is dominated by epifaunal suspension feeders, living in vegetated, well-oxygenated shallow environments, with variable levels of salinity and fine-grained substrate (mud or sand). Specimens of *Terebralia* indicate a partly restricted environment (probably lagoonal), while specimens of *Granulolabium* and *Tympanotonos* prefer open-sea environments (Poisson *et al.*, 1997).

Turritella - Anadara assemblage lived in

open-sea conditions, with normal salinity, and is dominated by infaunal suspension feeders (best represented trophic group) and subordinated by epifaunal herbivores (*Alvania*), predators (*Hinia*) or parasites (*Odostomia*).

Alvania - Ringicula - Pyramidella assemblage is dominated by epifaunal herbivores, with few parasites (*Chrysallida*) and predators. Small suspension-feeding bivalves (*Parvicardium*, *Gouldia*) also occur. Faunas are typical for a low-energy, shallow, well-oxygenated, richly vegetated, and normal salinity environment.

The foraminifera are mainly benthonic, therefore dependent on the local substrate conditions. The high abundance of miliolids is a proof for the well-vegetated environment, which contributed to the accumulation of the coal deposits.

The fluctuant saline environment enabled the successive replacement of the microfaunas between the three mentioned types of assemblages. Normal marine microfauna assemblages lived probably in prodelta-type conditions, while the brackish and low salinity assemblages shared the estuary and river mouth types of environments.

BIOSTRATIGRAPHY

Recent decades research on the sedimentary deposits from the eastern part of the Borod Basin evidenced several mollusc taxa which occur only in the Lower Miocene deposits of Central Paratethys, such as *Granulolabium plicatum* and *Tympanotonos margaritaceus*. Therefore, the general tendency was to assume the Eggenburgian age for the deposits in this area. (Şuraru & Şuraru, 1973; Nicorici *et al.*, 1977; Marinescu *et al.*, 1980; Papaianopol *et al.*, 1984; Moisescu, 1990, 1991, 1992; Popa, in Popa & Chira, 2000). Moisescu & Popescu (1980) considered the macrofauna as belonging to the *Chlamys gigas* Biozone of the Aquitanian (Eggenburgian), even if the index species is absent from the assemblage. The authors consider a series of taxa as typical for the mentioned biozone: *Anadara moltensis*, *Cubitostrea frondosa*, *Turritella eryna*, *T. eryna rotundata*, *Pirenella plicata* div. ssp., *Tympanotonos margari-taceus grateloupi*. *Crassostrea aginensis*, also identified by Popa (1998) in the eastern part of the depression, suggest the same Eggenburgian age.

Some taxa, such as *Granulolabium plicatum* div. ssp. *Tympanotonos margaritaceus grateloupi* (*Granulolabium - Theodoxus - Tympanotonos* assemblage) and *Crassostrea aginensis*, document the Eggenburgian age of

the deposits from the eastern part of the Borod Basin. The species of *Granulolabium* - *Theodoxus* - *Tympanotonos* assemblage resemble very well the species from the Eggenburgian faciostratotypes of Central Paratethys (Austria - Mold and "Judenfriedhof", Slovakia - Sverepec and Vel'ká Causa).

The Ottnangian deposits was documented by Şuraru & Şuraru (1973), based on macrofaunal assemblages similar to the ones from the base of the Hida Formation. Chira (in Popa & Chira, 2000) mentioned the presence of the NN4 (*Helicosphaera ampliaperta*) calcareous nannoplankton zone, which suggests the Ottnangian and possibly Badenian age.

Badenian age was documented by Nicorici *et al.* (1977), based on mollusk assemblages (*Clithon pictus pictus*, *Lunatia catena helicina*, *Terebralia bidentata*, *Alvania anabaptizata*). Popa (in Popa & Chira, 2000) considered that the upper part of the Borod Formation belongs to the Badenian, based again on mollusk assemblages.

The previously studied microfauna also suggested the presence of Badenian deposits in the eastern part of the Borod Basin. The ostracod genus *Falunia* suggests an Early Badenian age, while the foraminifer *Bogdanowiczia pocutica* could support a Late Badenian age (Marinescu *et al.*, 1980; Papaianopol *et al.*, 1984).

Although the decreased salinity and the paleogeographic setting could allow only very sporadic presence of planktonic foraminifera, we can restore the age of the formation by using some already known ranges of the benthic foraminifera (Table 1).

Our investigations have shown that the benthic assemblages are usually dominated by opportunistic species, mainly belonging to the genera *Ammonia* and miliolids with a wide stratigraphic range and highly depending on environment. Although the low biostratigraphic meaning of the most taxa, there are several species which are known only starting from the Early Badenian (e.g. the omnipresent *Cycloforina contorta*). Even if some taxa are known from older deposits (e.g. *Globulina striata*, *Elphidiella heteropora*, *Elphidium subtypicum*, etc.), their frequency is low and the stratigraphic range is wide, including the Badenian, too.

Taking into consideration the overall range of the identified taxa and the general composition of the assemblages, we can conclude that the

marine intervals with normal and slightly depleted salinity of the sedimentary succession of the Borod Formation were deposited during the Badenian. There are not enough lithological and paleontological data allowing the separation of different chronostratigraphic units within Badenian.

Turritella - *Anadara* and *Alvania* - *Ringicula* - *Pyramidella* assemblages are considered as a proof for the Badenian age, most of the species being widespread at the same stratigraphic level in the Central Paratethys. It has to be mentioned that a part of the taxa which are typical for this assemblage have been also recognized in the lowermost parts of the sedimentary successions crossed by boreholes. This fact suggests the Badenian age for the whole succession of the Borod Formation.

Considering the Eggenburgian-type macrofauna, we could suggest its re-sedimentation in the Badenian deposits, but only if we admit a very short transport of the specimens (there are present different ontogenetic stages and the preservation is very good). Another possibility, which might be closer to reality, would be the presence of an endemic benthic fauna within the Badenian, which continued the "tradition" of Eggenburgian assemblages due to the decreased-salinity conditions.

CONCLUSIONS

Our investigation tried to bring some new contributions to the possibilities of correlation within the sedimentary succession of the Borod Depression.

This was a very good opportunity to use a large number of samples collected from the boreholes for the study of microfauna. This helped in identification of several "salinity events", which might be used for correlations together with the four types of already known mollusk assemblages.

The identification of several benthic taxa, having a stratigraphic range starting in the Badenian, in the lower part of the sedimentary succession, gives new evidence on the age of the Borod Formation.

Acknowledgments

The authors are grateful to Dr. Michael A. Kaminski from University College London for supporting the SEM work.

Table 1. Stratigraphic ranges of the foraminifera species identified in the Borod Formation

Species	Eggenburgian	Ottngian	Karpatian	Badenian
<i>Textularia cf. candeiana</i> d'ORBIGNY				
<i>Textularia laevigata</i> d'ORBIGNY				
<i>Textularia mariae</i> d'ORBIGNY				
<i>Pseudotriloculina consobrina</i> (d'ORBIGNY)				
<i>Sinuloculina mayeriana</i> (d'ORBIGNY)				
<i>Cycloforina gracilis</i> (KARRER)				
<i>Cycloforina contorta</i> (d'ORBIGNY)				
<i>Cycloforina badenensis</i> (d'ORBIGNY)				
<i>Cycloforina vermicularis</i> (KARRER)				
<i>Quinqueloculina triangularis</i> d'ORBIGNY				
<i>Quinqueloculina boueana</i> d'ORBIGNY				
<i>Quinqueloculina alexandri</i> ŁUCZKOWSKA				
<i>Triloculina gibba</i> d'ORBIGNY				
<i>Sigmoilinita tenuis</i> (CZJZEK)				
<i>Sigmoilopsis foeda</i> (REUSS)				
<i>Lenticulina ?cultrata</i> (MONTFORT)				
<i>Lenticulina inornata</i> (d'ORBIGNY)				
<i>Guttulina communis</i> d'ORBIGNY				
<i>Globulina striata</i> (EGGER)				
<i>Globulina gibba</i> d'ORBIGNY				
<i>Fissurina marginata</i> (WALKER & BOYS)				
<i>Globigerina concinna</i> REUSS				
<i>Globigerina subcretacea</i> LOMNICKI				
<i>Globigerina bulloides</i> d'ORBIGNY				
<i>Globocassidulina oblonga</i> (REUSS)				
<i>Reussella spinulosa</i> (REUSS)				
<i>Cibicidoides ungerianus ungerianus</i> (d'ORB)				
<i>Riminopsis boueanus</i> (d'ORBIGNY)				
<i>Nonion commune</i> (d'ORBIGNY)				
<i>Pullenia quinqueloba</i> (REUSS)				
<i>Pararotalia aculeata</i> (d'ORBIGNY)				
<i>Aubignya perlucida</i> HERON-AL. & EARL.				
<i>Ammonia beccarii</i> (LINNE)				
<i>Ammonia pseudobeccarii</i> (PUTRYA)				
<i>Ammonia vienensis</i> (d'ORBIGNY)				
<i>Porosonion granosum</i> (d'ORBIGNY)				
<i>Elphidiella heteropora</i> (EGGER)				
<i>Elphidium fichtelianum</i> (d'ORBIGNY)				
<i>Elphidium reussi</i> MARKS				
<i>Elphidium ungeri</i> (REUSS)				
<i>Elphidium subtypicum</i> PAPP				

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PLATES (scale bar 100µm)

Plate I

1. *Textularia cf. candeiana* d'ORBIGNY: F575, m142
- 2,3. *Textularia laevigata* d'ORBIGNY: 2 - F3166, m169.5; 3 - F3154, m149
4. *Textularia mariae* d'ORBIGNY: F3162, m398
- 5,9. *Pseudotriloculina consobrina* (d'ORBIGNY): F3163, m178.5
- 6-8. *Cycloforina gracilis* (KARRER): 6 - F3163, m178.5; 7 - F3163, m188.2; 8 - F3162, m309
- 10-12. *Sinuloculina mayeriana* (d'ORBIGNY): F3163, m188.2

Plate II

- 1-5. *Cycloforina contorta* (d'ORBIGNY): 1,2 - F3154, m133; 3 - F575, m172; 4 - F3163, m192; 5 - F3163 m233.2
- 6-8. *Cycloforina badenensis* (d'ORBIGNY): F3163, m232.2
9. *Quinqueloculina triangularis* d'ORBIGNY: F3163, m178.5
- 10,11. *Sigmoilopsis foeda* (REUSS): 10 F3163, m232; 11 - F3162, m309

Plate III

- 1-2. *Quinqueloculina boueana* d'ORBIGNY: 1 - F3163, m189.1; 2 - F3154, m149
- 3,6,7. *Quinqueloculina alexandri* ŁUCZKOWSKA: 3 - F3154, m136; 6 - F3163, m243; 7 - F3162, m398
- 4,5. *Cycloforina vermicularis* (KARRER): F3163, m192
8. *Lenticulina ?cultrata* (MONTFORT) - juv.: F3166, m158.7
9. *Lenticulina inomata* (d'ORBIGNY): F3166, m158.7
10. *Globulina striata* (EGGER): F3166, m169.5

Plate IV

1. *Guttulina communis* d'ORBIGNY: 1 - F3162, m309; 2 - F3166 m150.7
2. *Globulina gibba* d'ORBIGNY: F575, m142.2
3. *Fissurina marginata* (WALKER & BOYS): F575, m142.2
4. *Fissurina saccula* (FORNASINI): F3163, m232
- 5,6. *Riminopsis boueanus* (d'ORBIGNY): F3163, m232.2
7. *Globigerina subcretacea* LOMNICKI: F575, m142.2
8. *Globigerina diplostoma* REUSS: F575, m142.2
9. *Reussella spinulosa* (REUSS): F3163, m232

Plate V

- 1,2. *Pararotalia aculeata* (d'ORBIGNY): F3162, m309
3. *Elphidiella heteropora* (EGGER): F3163, m189.1
4. *Elphidium fichtelianum* (d'ORBIGNY): F3163, m178.5
5. *Elphidium reussi* MARKS: F3166, m325
6. *Elphidium ungeri* (REUSS): F3166, m325
7. *Elphidium subtypicum* PAPP: F3163, m188.2
- 8,9. *Nonion commune* (d'ORBIGNY): 6,7 - F3154, m133; 8 - F3162, m309

Plate VI

- 1,2. *Aubignya perlucida* HERON-ALLEN & EARLAND: 1 - F3163, m252.2; 2 - F3163, m252.8
- 3,6. *Ammonia beccarii* (LINNE): 3 - 3154, m136; 6 - F3154, m149
- 4,5. *Ammonia pseudobeccarii* (PUTRYA): 4 - F3163, m189.1; F3163, m309.5
- 7,8. *Ammonia vienensis* (d'ORBIGNY): F3166, m169.5

