CAMPANIAN-MAASTRICHTIAN CALCAREOUS NANNOFOSSILS FROM THE ROMANIAN BLACK SEA OFFSHORE

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Abstract: The work presents the calcareous nannoplankton associations corresponding to the Campanian-Maastrichtian stratigraphic interval of the Romanian offshore area. The calcareous nannofossil analysis led to the identification of seven calcareous nannoplankton biozones for the mentioned chronostratigraphic segment.

Key words: calcareous nannofossils, Campanian-Maastrichtian, biozones, Romanian offshore.

1. INTRODUCTION

The present work is focused on calcareous nannoplankton associations found in the mechanical cores and in the cuttings (sieve samples) taken out from the wells drilled in the Black Sea shelf area (the Romanian sector) and, implicitly, the bio-stratigraphy and the nannoplankton biozones, specific to the above mentioned region.

The work aimed to present the nannofossil assemblages from the latest Cretaceous of the Romanian Black Sea Continental Platform. For this task, an impressive volume of biostratigraphical data had to be inventoried, mainly, from the wells drilled on the North Dobrogean Orogene submersed extension (Fig. 1).

2. MATERIAL AND METHODS

Considering that most structures explored by research drillings belong to the submersed prolongation of the North-Dobrogean Orogene (21 structures with 86 exploration wells), the data volume is out of proportion to that of the submersed compartment of Central Dobrogea (4 structures and 4 research wells) and of the one of South Dobrogea (2 structures and 3 research wells). From the Cretaceous sedimentary deposits, over 560 cores were recovered and thousands of cuttings have been studied under polarized microscope for qualitative nannofossil determination. Our preparation method consists in rock sample trituration, ultrasoning, decantation and attachment with Canada balm on smear-slides.

Fig. 1 Location of the investigated area

3. GEOLOGICAL SETTING

From N to S, the Romanian Black Sea shelf includes several tectonic units like the Pre-Dobrogean Depression, the North Dobrogean Orogene, as well as the Central Dobrogean and South Dobrogean sectors of the Moesian Platform (Dinu *et al.*, 2002).

These tectonic units are separated by very important faults, like the Sfântu Gheorghe Fault (which separates Pre-Dobrogean Depression from North Dobrogean Orogene), the Peceneaga-Camena Fault (which separates North Dobrogean Orogen from Central Dobrogea) and, the Capidava-Ovidiu Fault, between the Central Dobrogea and the South Dobrogea (Ţambrea *et al.*, 2002). The trend of these faults is generally NW-SE (Fig. 1).

The main part of the exploration wells was drilled, as said above, in the submersed sector of the North Dobrogean Orogene, mainly, in the so-called Istria Depression.

A special situation is represented by well 1 Ovidiu East from the structure with the same name which seems to have crossed the sediments of South Dobrogea, tectonically overlaying the ones of North Dobrogea (Şindilar and Costea, 2000).

Out of the Mesozoic deposits crossed by the wells, in the stratigraphic column of the Romanian sector of the Black Sea shelf, the Cretaceous ones are the best represented. The Cretaceous sequence comprises the whole pile of deposits from Berriasian to Maastrichtian, which contains, at different levels, gaps of sedimentation or erosive surfaces (Fig. 2).

Throughout the Cretaceous period, three different sedimentation cycles were separated on the Romanian Black Sea offshore (Grădinaru *et al.* 1989, modified by Dragastan 2007):

1. A pelitic-siltic one that characterizes the Early Cretaceous (*i.e.* Berriasian-Barremian interval), seems to continue the Jurassic sedimentation and corresponds to the Member B of the Heracleea Formation;
2. A detrital-carbonate one (which characterizes the Barremian-Albian-Cenomanian stages and corresponds to the Tomis Member of Lebăda Formation);
3. A carbonate one (which characterizes the Coniacian-Maastrichtian interval and corresponds to the Unirea Member of Lebăda Formation) (Fig. 2).

Between the last two cycles, there is an uniform transition representing the Turonian-Coniacian interval, which corresponds to the Member Sinoe of Lebăda Formation, when the facies changes progressively, from a detrital-carbonate one to a carbonate one.

4. RESULTS

Along with the other biostratigraphical methods, the calcareous nannoplankton has fully contributed in determining the ages of the sedimentary sequences crossed by the drillings performed on the Romanian Black Sea offshore area.

Out of the entire Mesozoic sedimentary sequence, the Campanian-Maastrichtian interval is best represented, both quantitatively and qualitatively, from a calcareous nannofloral point of view. The identified nannofloras correspond to seven biozones of nannoplankton defined in the Romanian Continental Platform of the Black Sea for the Campanian-Maastrichtian stratigraphic interval.

In Table 1, the encountered biozones of calcareous nannoplankton, as correlated to the standard scale (Sissingh 1977, emend. Perch-Nielsen, 1985a) and to the scale set by Costea, Comşa (1979) for the onshore Romanian areas of petroleum interest, are presented.

Table 1 Campanian-Maastrichtian calcareous nannofossil biozones

<table>
<tr><th colspan="3">Zonations / Age</th><th>Nannofossil Standard Scale Sissingh 1977</th><th>CC</th><th>Nannofossil Biozones of Perch-Nielsen, 1985 found for the first time in the Black Sea offshore by Şindilar (this paper)</th><th>Nannofossil Biozones identified by Costea, Comşa (1979) in Romania</th></tr>
<tr><td rowspan="12">CRETACEOUS</td><td rowspan="12">UPPER</td><td rowspan="6">MAASTRICHTIAN</td><td>Nephrolithus frequens</td><td>26</td><td>Nephrolithus frequens</td><td rowspan="3">Micula murus</td></tr>
<tr><td rowspan="3">Arkhangelskiella cymbiformis</td><td rowspan="3">25</td><td>Micula murus</td></tr>
<tr><td>Lithraphidites quadratus</td></tr>
<tr><td rowspan="3">Lithraphidites praequadratus</td><td rowspan="3">Lithraphidites quadratus</td></tr>
<tr><td>Reinhardtites levis</td><td>24</td></tr>
<tr><td rowspan="2">Tranolithus phacelosus</td><td rowspan="2">23</td></tr>
<tr><td rowspan="6">CAMPANIAN</td><td rowspan="2">Quadrum trifidum</td><td rowspan="2">Quadrum trifidum</td></tr>
<tr><td>Quadrum trifidum</td><td>22</td></tr>
<tr><td>Quadrum nitidum</td><td>21</td><td rowspan="2">Ceratolithoides aculeus</td><td rowspan="2">Ceratolithoides aculeus</td></tr>
<tr><td>Ceratolithoides aculeus</td><td>20</td></tr>
<tr><td>Calculites ovalis</td><td>19</td><td rowspan="2">Aspidolithus parcus</td><td rowspan="2">Kamptnerius magnificus</td></tr>
<tr><td>Aspidolithus parcus</td><td>18</td></tr>
</table>

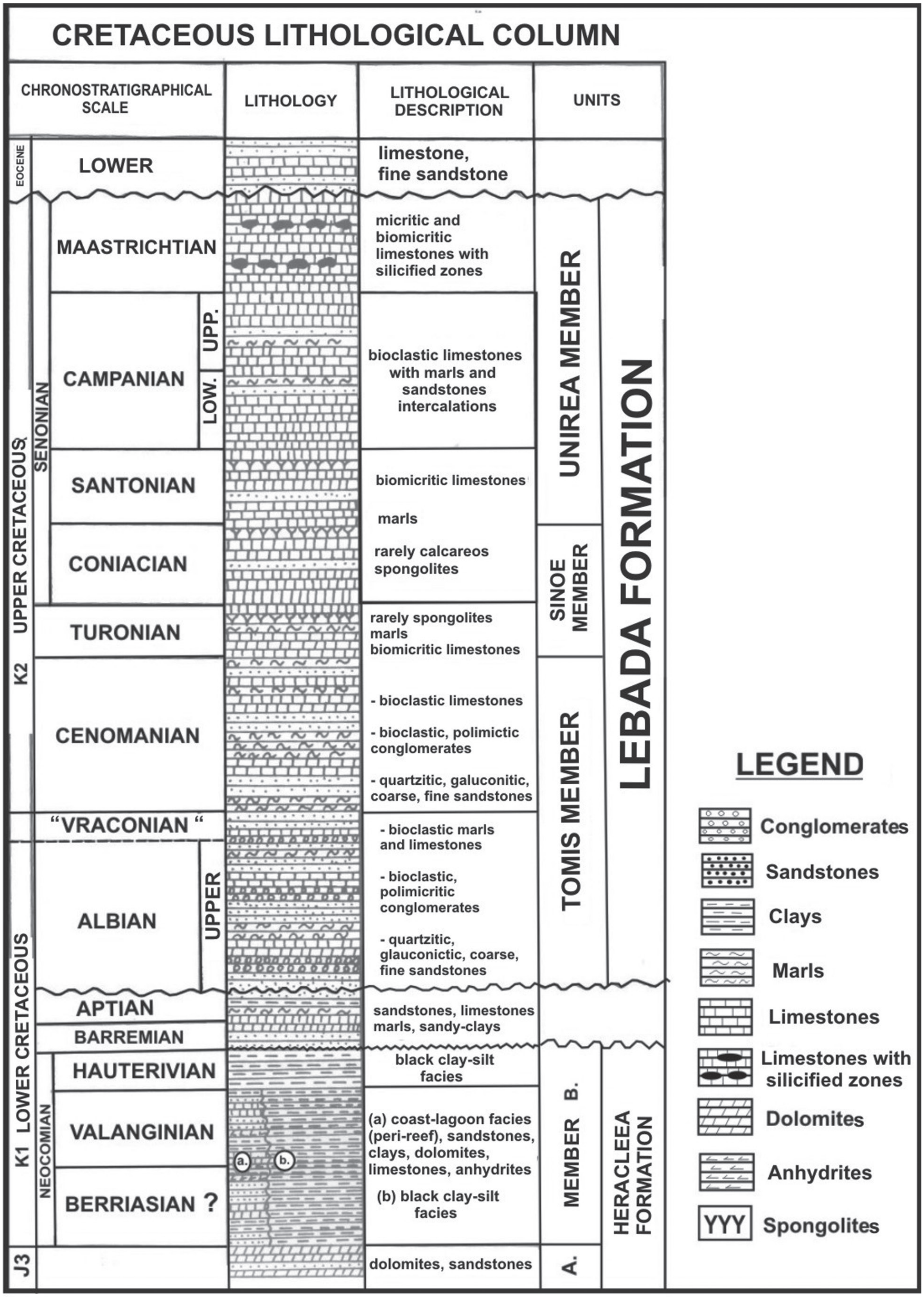

Fig. 2. The Cretaceous litho-stratigraphical column (after E. Grădinaru *et al.* 1989, modified by O. Dragastan, 2007)

The calcareous nannofossil biozones identified in the sediments of the Black Sea offshore are the following (earliest first) (Plates 1 and 2):

1. The *ASPIDOLITHUS PARCUS* Biozone

Definition: the stratigraphic interval between the first occurrence of ***Aspidolithus parcus*** *s.l.* Perch-Nielsen, 1986 and the first occurrence of ***Ceratolithoides aculeus*** (Stradner, 1961) Prins & Sissingh, 1977.

Observations: this zone comprises the following nannoplankton species: *Tranolithus phacelosus* Stover, *Prediscosphaera cretacea* (Arkhangelsky) Gartner, *Eiffellithus turriseiffelii* (Deflandre) Reinhardt, *Cribrosphaerella ehrenbergii* (Arkhangelsky) Deflandre, *Gartnerago obliquum* (Stradner) Noel, *Watznaueria barnesae* (Black) Perch-Nielsen, etc.

This biozone correlates to the zones of the same denomination, defined by Sissingh (1977), Roth (1978), Verbeek (1977), Doeven (1983) and to the upper part of *Kamptnerius magnificus* biozone of Costea, Comşa (1979).

The characterized stratigraphical interval: Early Campanian.

2. The *CERATOLITHOIDES ACULEUS* Biozone

Definition: the interval between the first occurrence of ***Ceratolithoides aculeus*** (Stradner, 1961) Prins & Sissingh, 1977 and the first occurrence of ***Quadrum trifidum*** (Stradner, 1961) Prins & Perch-Nielsen, 1977.

Observations: the nannoplankton association of this biozone frequently comprises *Biscutum constans* (Gorka) Black, *Arkhangelskiella cymbiformis* Vekshina, *Cribrosphaerella ehrenbergii* (Arkhangelsky) Deflandre, *Tranolithus phacelosus* Stover, *Placozygus fibuliformis* (Reinhardt) Hoffmann, *Microrhabdulus decoratus* Deflandre, etc.

This biozone correlates to the zones *Ceratolithoides aculeus* and *Quadrum nitidum* defined by Sissingh (1977), to the zones having the same name of Roth (1978) and Costea, Comşa (1979).

The characterized stratigraphic interval: Late Campanian (the lower half).

3. The *QUADRUM TRIFIDUM* Biozone

Definition: the stratigraphic interval from the first occurrence of ***Quadrum trifidum*** (Stradner, 1961) Prins & Perch-Nielsen, 1977 to the first occurrence of ***Lithraphidites praequadratus*** Roth, 1978.

Observations: this biozone association mostly comprises *Reinhardtites anthophorus* (Deflandre) Perch-Nielsen, *Aspidolithus parcus constrictus* (Hattner) Perch-Nielsen, *Tranolithus phacelosus* Stover, *Cylindralithus serratus* Bramlette & Martini, *Cribrosphaerella ehrenbergii* (Arkhangelsky) Deflandre, *Arkhangelskiella cymbiformis* Vekshina, etc.

The biozone correlates to the zones having the same name defined by Sissingh (1977), Roth (1978), Doeven (1983), Müller (1984) and Costea, Comşa (1979).

The characterized stratigraphic interval: latest Campanian – earliest Maastrichtian.

4. The *LITHRAPHIDITES PRAEQUADRATUS* Biozone

Definition: the stratigraphic interval between the first occurrence of ***Lithraphidites praequadratus*** Roth, 1978 and the first occurrence of ***Lithraphidites quadratus*** Bramlette & Martini, 1964.

Observations: the species that are mainly characterizing this biozone are *Eprolithus floralis* (Stradner) Stover, *Biscutum constans* (Gorka) Black, *Chiastozygus litterarius* (Gorka) Manivit, *Glaukolithus diplogrammus* (Deflandre) Reinhardt, *Calculites obscurus* (Deflandre) Prins & Sissingh, *Quadrum gothicum* (Deflandre) Prins & Perch-Nielsen, *Cribrosphaerella ehrenbergii* (Arkhangelsky) Deflandre, *Arkhangelskiella cymbiformis* Vekshina, *Micula decussata* Vekshina, etc.

The biozone correlates to the *Lithraphidites praequadratus* zone defined by Roth (1978), to the biozone *Lithraphidites quadratus* defined by Müller (1984), and to the zones *Tranolithus phacelosus* (upper part), *Reinhardtites levis* and *Arkhangelskiella cymbiformis* (lower part) defined by Sissingh (1977), as well as to the zone *Lithraphidites quadratus* defined by Costea, Comşa (1979).

The characterized stratigraphic interval: Early Maastrichtian.

5. The *LITHRAPHIDITES QUADRATUS* Biozone

Definition: the stratigraphic interval between the first occurrence of ***Lithraphidites quadratus*** Bramlette & Martini, 1964 and the first occurrence of ***Micula murus*** (Martini, 1961) Bukry, 1973.

Observations: the species frequently occurring in this biozone are *Markalius inversus* (Deflandre) Bramlette & Martini, *Biscutum constans* (Gorka) Black, *Chiastozygus litterarius* (Gorka) Manivit, *Glaukolithus diplogrammus* (Deflandre) Reinhardt, *Calculites obscurus* (Deflandre) Prins & Sissingh, *Quadrum gothicum* (Deflandre) Prins & Perch-Nielsen, *Cribrosphaerella ehrenbergii* (Arkhangelsky) Deflandre etc.

The biozone correlates to the zones having the same name defined by Verbeek (1977), Roth (1978), Doeven (1983), and to the basal part of the biozone *Micula murus* separated by Costea, Comşa (1979).

The characterized stratigraphic interval: Early/Late Maastrichtian.

6. The *MICULA MURUS* Biozone

Definition: the stratigraphic interval between the first occurrence of ***Micula murus*** (Martini, 1961) Bukry, 1973 and its last occurrence, or to the first occurrence of ***Nephrolithus frequens*** Gorka, 1957.

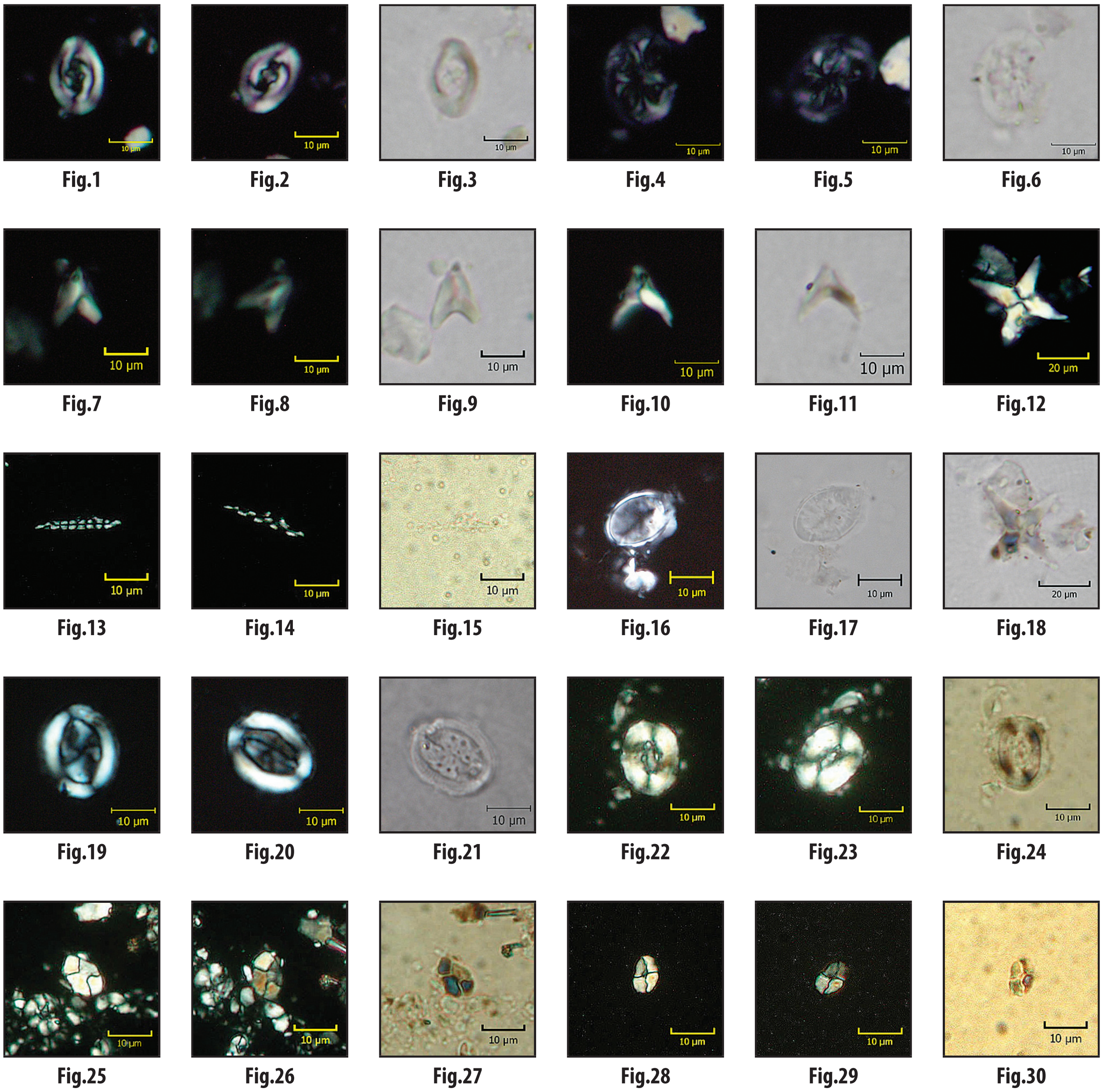

PLATE I. Campanian calcareous nannofloras
LM (light microscope)

Fig. 1-3. *Placozygus fibuliformis* (Reinhardt) Hoffmann – East Lebăda field. **Fig. 4-6.** *Ahmuellerella octoradiata* (Gorka) Reinhardt – East Lebăda field. **Fig. 7-9.** *Ceratolithoides aculeus* (Stradner) Prins & Sissingh < 900 – Histria structure. **Fig. 10, 11.** *Ceratolithoides aculeus* (Stradner) Prins & Sissingh > 900 – Histria structure. **Fig. 12, 18.** *Quadrum sissinghii* Perch-Nielsen – Pescăruş field. **Fig. 13-15.** *Microrhabdulus decoratus* Deflandre – Histria structure. **Fig. 16, 17.** *Kamptnerius magnificus* Deflandre – East Lebăda field. **Fig. 19-21.** *Arkhangelskiella cymbiformis* Vekshina – East Lebăda field. **Fig. 22-24.** *Aspidolithus parcus constrictus* (Hattner) Perch-Nielsen – East Lebăda field. **Fig. 25-27.** *Calculites obscurus* (Deflandre) Prins & Sissingh – East Lebăda field. **Fig. 28-30.** *Calculites ovalis* (Stradner) Prins & Sissingh – East Lebăda field

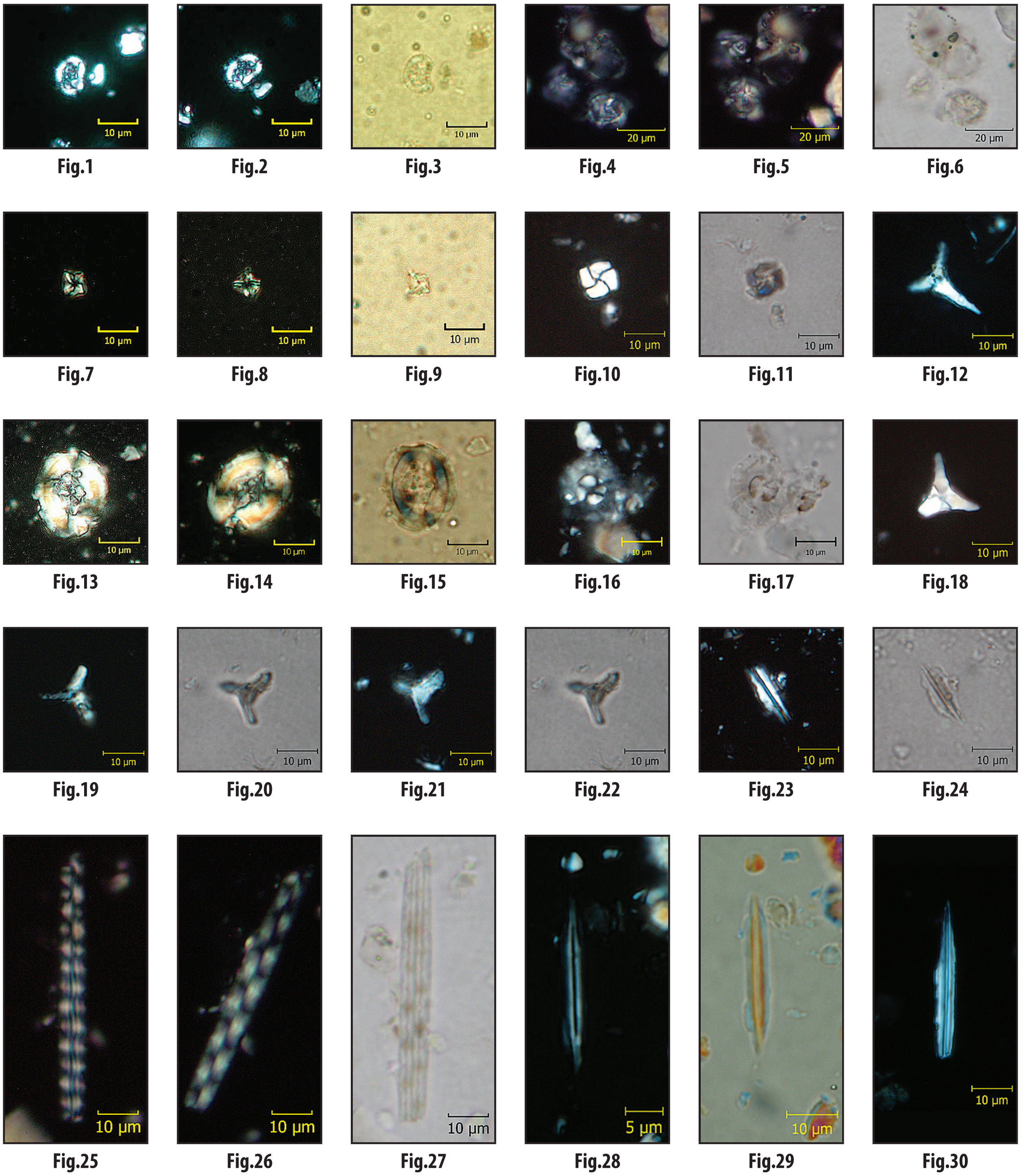

PLATE II. Maastrichtian calcareous nannofloras
LM (light microscope)

Fig. 1-3. *Nephrolithus frequens* Gorka – Egreta structure. **Fig. 4-6**. *Prediscosphaera spinosa* (Bramlette & Martini) Gartner şi *Prediscosphaera cretacea* (Arkhangelsky) Gartner – Lotus structure. **Fig. 7-9.** *Micula murus* (Martini) Bukry – Egreta structure. **Fig. 10, 11.** *Micula praemurus* (Stradner) Perch-Nielsen – Pescăruş field. **Fig. 12.** *Quadrum trifidum* (Stradner) Prins & Perch-Nielsen – East Lebăda field. **Fig. 13-15.** *Aspidolithus parcus expansus* (Wise & Watkins) Perch-Nielsen – Egreta structure. **Fig. 16, 17.** *Markalius inversus* (Stradner) Hay & Mohler – East Lebăda field. **Fig. 18-22.** *Quadrum trifidum* (Stradner) Prins & Perch-Nielsen – East Lebăda field. **Fig. 23, 24.** *Lithraphidites praequadratus* Roth – Egreta structure. **Fig. 25-27.** *Microrhabdulus undosus* Perch-Nielsen – Egreta structure. **Fig. 28, 29.** *Lithraphidites carniolensis carniolensis* Deflandre – East Lebăda field. **Fig. 30.** *Lithraphidites carniolensis serratus* Shumenko – East Lebăda field

Observations: other common species are *Arkhangelskiella cymbiformis* Vekshina, *Lithraphidites quadratus* Bramlette & Martini, *Cribrosphaerella ehrenbergii* (Arkhangelsky) Deflandre, *Eiffellithus turriseiffelii* (Deflandre) Reinhardt, *Placozygus fibuliformis* (Reinhardt) Hoffmann, *Quadrum gothicum* (Deflandre) Prins & Perch-Nielsen, *Prediscosphaera cretacea* (Arkhangelsky) Gartner, etc.

The biozone correlates to the lower part of the zones having the same name defined by Verbeek (1977), Müller (1984), to the upper part of the biozone of *Arkhangelskiella cymbiformis* defined by Sissingh (1977) and to the median part of the biozone of *Micula murus* separated by Costea, Comşa (1979).

The characterized stratigraphic interval: Late Maastrichtian.

7. The *NEPHROLITHUS FREQUENS* Biozone

Definition: the stratigraphic interval between the first and the last occurrence of ***Nephrolithus frequens*** Gorka, 1957.

Observations: this zone also comprises common *Cribrosphaerella ehrenbergii* (Arkhangelsky) Deflandre, *Micula murus* (Martini) Bukry, *Microrhabdulus decoratus* Deflandre, *Eiffellithus turriseiffelii* (Deflandre) Reinhardt, *Tranolithus phacelosus* Stover, *Quadrum gartneri* Prins & Perch-Nielsen etc. The range of *Nephrolithus frequens*, defines, according to many nannoworkers, a stratigraphic interval above the first occurrence of the nannofossil *Micula murus* and characterizes a boreal influence. There is a possibility that the occurrence of *Nephrolithus frequens*, in a northern structure of Istria Depression, illustrates the transition from a warm climate to a cooler one, with boreal influences, a climate change recognised in the Tethyan Realm at the end of the Cretaceous.

The biozone correlates to the zones having the same name defined by Sissingh (1977), Thierstein (1976), Roth (1978), Doeven (1983), Perch-Nielsen (1983) and to the upper part of the zone of *Micula murus* of Costea, Comşa (1979).

The characterized stratigraphic interval: latest Maastrichtian.

5. CONCLUSIONS

Concerning the youngest nannofossil zone described above (i.e., *Nephrolithus frequens*), there are certain questions related to its areal extension. Previous published papers (Verbeek 1977, Roth 1978, Doeven 1983, Perch-Nielsen 1985a) considered that *Nephrolithus frequens* Gorka, which defines the youngest Cretaceous nannofossil zone, is either isochronous or in superposition with *Micula murus* zone, both placed in the latest Maastrichtian. Until now, the nannofossil workers of the petroleum industry of Romania have said nothing about the species of *Nephrolithus frequens* Gorka. Its presence was firstly recorded in the Egreta structure of the northern flank of the Istria Depression, from the Romanian shelf of the Black Sea (Şindilar and Costea, 1999). We assume that the occurrence, with a very rare abundance, of *Nephrolithus frequens* Gorka is related to its affinity for mid to high palaeolatitudes.

For the correct characterization of *Nephrolithus frequens* zone, additional information is required, concerning the presence of this species also in other sectors of the Romanian Continental Platform of the Black Sea. This occasion offers us the possibility to show that, since 1989 – the year of the first drilling on Egreta structure of the Black Sea offshore - up to now, this species has not been encountered, with one exception: a well drilled on Tândală structure, far southwards from Egreta structure (Melinte 2006).

Another obvious finding is that, as opposed to the Late Cretaceous nannofossil assemblages of the Moesian Platform (mainly described in *in house* works), the nannofossil associations of the Romanian Continental Platform of the Black Sea are poorer, both from quantitative and qualitative points of view. We are tempted to attribute this fact to certain bionomic conditions which adversely influenced the fossil preservation process. The presented biostratigraphy based on calcareous nannofossils tried, as much as possible, to recognize the biozones of Sissingh, 1977, emended by Perch-Nielsen in 1985, in the investigated Upper Cretaceous sediments of the Black Sea offshore. Taking into account the fact that, during Cretaceous times, the present-day Romanian territory was part of the Mesogean Domain of Tethys (more precisely, Peri-Tethys), it is obvious that many of the biozones identified by us are identical with the ones defined by Sissingh (1977), emend by Perch-Nielsen (1985). The biozonation presented herein, mainly used the first occurrence of several taxa, because the last occurrences could give fault indices, due to the reworking. The seven nannofossil biozones described in this paper, for the Campanian-Maastrichtian interval, correspond to the nine biozones defined by Sissingh in 1977, for the same interval (*i.e*. from CC 18 to CC 26 biozones).

APPENDIX WITH THE IDENTIFIED TAXA

Acuturris scotus (Risatti 1973) Wind & Wise 1977 **

Ahmuellerella octoradiata (Gorka 1957) Reinhardt 1964 ***

Arkhangelskiella cymbiformis Vekshina 1959 ****

Axopodorhabdus albianus (Black 1967) Wind & Wise 1977 **

Aspidolithus bevieri (Bukry 1969) Perch-Nielsen 1984 ****

Aspidolithus parcus Perch-Nielsen 1986 ***

Biscutum constans (Gorka 1957) Black 1959 ****

Braarudosphaera bigelowii (Gran & Braarud 1935) Deflandre 1947 ****

Calculites obscurus (Deflandre 1959) Prins & Sissingh 1977 ****

Calculites ovalis (Stradner 1963) Prins & Sissingh 1977 ***

Ceratolithoides aculeus (Stradner 1961) Prins & Sissingh 1977 *

Chiastozgus litterarius (Gorka 1957) Manivit 1971 ****

Cretarhabdus conicus Bramlette & Martini 1964 ****

Cribrosphaerella ehrenbergii (Arkhangelsky 1912) Deflandre 1952 ***

Cylindralithus serratus Bramlette & Martini 1964 ***

Eiffellithus eximius (Stover 1966) Perch-Nielsen 1968 ***

Eiffellithus turriseiffelii (Deflandre 1954) Reinhardt 1965 ****

Eprolithus floralis (Stradner 1962) Stover 1966 ****

Glaukolithus diplogrammus (Deflandre 1954) Reinhardt 1964 ****

Garnerago obliquum (Stradner 1963) Noel 1974 ***

Helicolithus trabeculatus (Gorka 1957) Verbeek 1977 ****

Kamptnerius magnificus Deflandre 1959 ***

Lithraphidites carniolensis Deflandre 1963 ****

Lithraphidites praequadratus Roth 1978 **

Lithraphidites quadratus Bramlette & Martini 1964 *

Lucianorhabdus cayeuxii Deflandre 1959 **

Lucianorhabdus maleformis Reinhardt 1966 ****

Manivitella pemmatoidea (Deflandre 1965) Thierstein 1971 ****

Markalius astroporus (Stradner 1961) Hay & Mohler 1967 ***

Markalius inversus (Stradner 1961) Hay & Mohler 1967 ***

Microrhabdulus belgicus Hay & Towe 1963 **

Microrhabdulus decoratus Deflandre 1959 ***

Microrhabdulus undosus Perch-Nielsen 1973 **

Micula concava Verbeek 1977 ***

Micula decussata Vekshina 1959 ****

Micula murus (Martini 1961) Bukry 1963 **

Micula praemurus (Bukry 1973) Stradner & Steinmetz 1984 *

Nephrolithus frequens Gorka 1957 *

Orastrum campanensis (Cepek 1970) Wind & Wise 1977 *

Placozygus fibuliformis (Reinhardt 1964) Hoffmann 1970 ***

Prediscosphaera cretacea (Arkhangelsky 1912) Gartner 1968 ****

Prediscosphaera spinosa (Bramlette & Martini 1964) Gartner 1968 ***

Quadrum gartneri Prins & Perch-Nielsen 1977 ***

Quadrum gothicum (Deflandre 1959) Prins & Perch-Nielsen 1977 **

Quadrum trifidum (Stradner 1961) Prins & Perch-Nielsen 1977 *

Reinhardtites anthophorus (Deflandre 1959) Perch-Nielsen 1968 ***

Rhagodiscus splendens (Deflandre 1953) Verbeek 1977 ****

Stradneria crenulata (Bramlette & Martini 1964) Noel 1970 ****

Tranolithus phacelosus Stover 1966 ****

Vekshinella stradneri Rood, Hay & Barnard 1971 ****

Watznaueria barnesae (Black 1959) Perch-Nielsen 1968 ****

Watznaueria biporta Bukry 1969 ****

Zeugrhabdotus embergeri (Noel 1959) Perch-Nielsen 1984 ***

Legend:
* Very scarce; ** Scarce; *** Frequent; **** Very frequent.

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