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Calibration of calcareous nannofossils and planktonic foraminifers' zonation in the Lower and Middle Paleocene of Bulgaria

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К. Стойкова, М. Иванов, С. Джуранов — Параллельное зонирование нижнего и среднего палеоцена в Болгарии по известковому нанопланктону и по планктонным фораминиферам. В работе показаны результаты первого детального сопоставления и корреляции зонально расчлененных осадочных пород нижнего и среднего палеоцена в Болгарии по известковому нанопланктону и по планктонным фораминиферам. Параллелизация обеих схем проведена на примере самой полной непрерывной седиментацонной последовательности Беленской свиты, обнаженной в разрезах около с. Горица, Варненский округ. В датском ярусе доказано присутствие нанофоссильных зон NP1-NP4 и планктонно-фораминиферовых зон Pα, P1a, P1b P1c, P3a. Несмотря на все еще недостаточное количество палеонтологических данных предположено наличие зоны P0 в основании датского яруса и зоны P2 — в его верхних отделах. На основании богатого и разнообразного планктонного сообщества в зеландском ярусе выделены нанофоссильная зона NP5 и соответствующая ей зона P3b. Палеонтологическая запись верхней части этого яруса прервана его скалывением и надвиганием верхнемеловых пород. Приведено сопоставление самых важных биологических событий в обеих планктонных группах. Такой подход при параллельных исследованиях повышает точность биостратиграфических заключений и датировок.

Abstract. This study represents first attempt to juxtapose and correlate the zonal schemes of calcareous nannofossils and planktonic foraminifers in the Lower and Middle Paleocene of Bulgaria. The calibration of the two schemes is accomplished in the most complete and continuous sedimentary succession of Byala Fm., cropping out in the sections around the village of Goritsa, Varna District. In the Danian Stage the presence of NP1-NP4 nannofossil zones as well as of the planktic foraminifera zones Pα, P1a, P1b, P1c, P3a is documented. In spite of the scarce paleontological data, the presence of P0 zone in basal Danian and P2 zone in the upper Danian is suggested. In the Selandian Stage, NP5 and respectively P3b zones are evidenced with exceptionally rich plankton associations. The upper part of the section is incomplete due to the overthrusting of Upper Cretaceous sediments. The most important bio-events in both group are calibrated, thus enable higher biostratigraphic resolution and accuracy of dating.

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Key words: biostratigraphy, calcareous nannofossils, planktonic foraminifers, Lower-Middle Paleocene, Bulgaria.

Introduction

To date, parallel subdivision and precise juxtaposition of calcareous nannofossils and planktonic foraminifers' schemes has not been performed in Bulgaria. There are just a few papers in which some single data is mentioned. This data concerns restricted intervals, mainly around the Cretaceous/Tertiary (K/T) boundary (Rögl et al., 1996; Adatte et al., 2002; Peybernes et al., 2004) and in the Lower Eocene (Аладжова-Хрисчева et al., 1983). For this reason, the present study aims to correlate and juxtapose in detail the zonal schemes of the main two groups — calcareous nannofossils and planktonic foraminifers. Its realization has been vastly supported and stimulated by recently discovered continuous sedimentary succession in the Lower and Middle Paleocene near Goritsa and Byala, Varna District (Fig. 1, Стойкова et al., 2000; Stoykova, Ivanov, 2004; Stoykova et al., 2004).

Fig. 1. Location of the studied area

Just the newly described section in the gully west of the village of Goritsa (Stoykova et al., 2004) has served as a basis for the present parallel study. The locality west of Goritsa demonstrates a continuous across the K/T boundary succession comprising entire Lower and lower part of the Middle Paleocene (Danian and Selandian Stage). The K/T boundary clay bed marker is accepted as a reference point, conventionally marked with 0 m. The distances below and above it are denoted respectively with (—) and (+) m (Fig. 2, 3).

Results

The studied part of the section exposed west of Goritsa is about 70 m thick. It includes 18 m below the K/T boundary (Upper Maastrichtian, Upper Cretaceous) and 50 m above it (Lower and Middle Paleocene, Danian and Selandian Stage). In the uppermost part of the gully, some +50 m above the K/T boundary, the Upper Cretaceous sediments occur again (thrusted over the Middle Paleocene). The Byala Fm. consists of marls, interbedded by marly limestones; besides marls are dominating in the Upper Maastrichtian and marly limestones — in the Upper Selandian. Microfossil associations of both planktonic groups (calcareous nannofossils and planktic foraminifers) are characterized by very good to excellent preservation and high species diversity, suggesting a relatively deeper, calm, low-energy depositional environment as compared to Byala sections. The zonal boundaries are drawn at the significant bio-events — first and last appearance datum of characteristic calcareous nannofossils and planktic forams taxa (First Appearance Datum, Last Appearance Datum — FAD, LAD). The thicknesses of the zones recognized, as well as some important bio-events are illustrated in Fig. 3.

Calcareous nannofossils (Fig. 2)

Calcareous nannofossil biostratigraphy is based on Martini's (1971) standard scheme. The last two Upper Maastrichtian zones, as well as all five Lower and Middle Paleocene zones are documented. Nannofloral associations display high diversity and abundance across the whole studied interval. They surpass the already known ones in Byala Fm. in this respect.

In the Upper Maastrichtian, CC25c и CC26 zones are proved. The zonal boundaries are drawn at FAD of the species *Micula murus* and *M. prinsii* respectively. The nannofossil associations reach an extreme abundance and diversity (over 70 identified species).

Danian Stage. The K/T boundary is lithologically marked by dark grey clay bed, 2-3 cm thick. Immediately above it, the FAD of *Cyclagelosphaera alta* (Fig. 2; Plate I, fig. 5) is recorded, as well as the bloom of *Thoracosphaera operculata* (Fig. 2; Plate I, fig. 17), *Braarudosphaera bigelowii* (Plate I, fig. 18-19) and *B. discula*. All these bio-events are well known and reported from the others K/T localities in Bulgaria (Ivanov, Stoykova, 1994; Stoykova, Ivanov, 2004). The nannofossil associations of the first Danian NP1 zone are dominated by "survivor" and "Cretaceous" species (reworked or survived?), whereas newly-evolved typical Paleocene taxa — *Cyclagelosphaera alta* and *Neobiscutum rom-*

einii occur relatively rare. FAD of *Cruciplacolithus intermedius*, tracing the NP1/NP2 zonal boundary, is fixed at +2 m above the K/T (Fig. 2).

The nannofloral associations of NP2 zone are substantially changed, but "Cretaceous" reworking species still occur. A sequence of successive FAD is recorded within this zone (Fig. 2): *Cruciplacolithus intermedius* (+2 m), *Prinsius africanus* (+2 m), *Futyania petalosa* (Plate I, fig. 6- +4 m), *Prinsius dimorphosus* (+4 m), *Ericsonia subpertusa* (Plate I, fig. 8- +4 m), *Cruciplacolithus tenuis* (Plate I, fig. 7- +6 m), *Coccolithus cavus* (+8 m).

The lower boundary of NP3 zone (Fig. 2) is marked by the FAD of *Cruciplacolithus edwardsii* at +14 m, while FAD of *Chiasmolithus danicus* is recorded higher, at +17 m, followed by FAD of *Prinsius martini* (Plate I, fig. 9). Nannofloral assemblages are more diversified and "Cretaceous" species occur sporadically.

Due to the rarity or lack of the zonal index species *Ellipsolithus macellus*, the NP3/NP4 boundary is drawn (Fig. 2) by the FAD of *Neochiastozygus saepes, N. eosaepes* and *N. imbriei* at +27 m. This approximation is based on our observations in the neighboring sections around Byala, where the FAD of *Ellipsolithus macellus* concurs with FAD of stated above species.

Selandian Stage. The lower stage boundary is situated in the uppermost part of NP4 zone, besides lately it is approximated to the base of NP5 nannofossil zone. The lower boundary of NP5

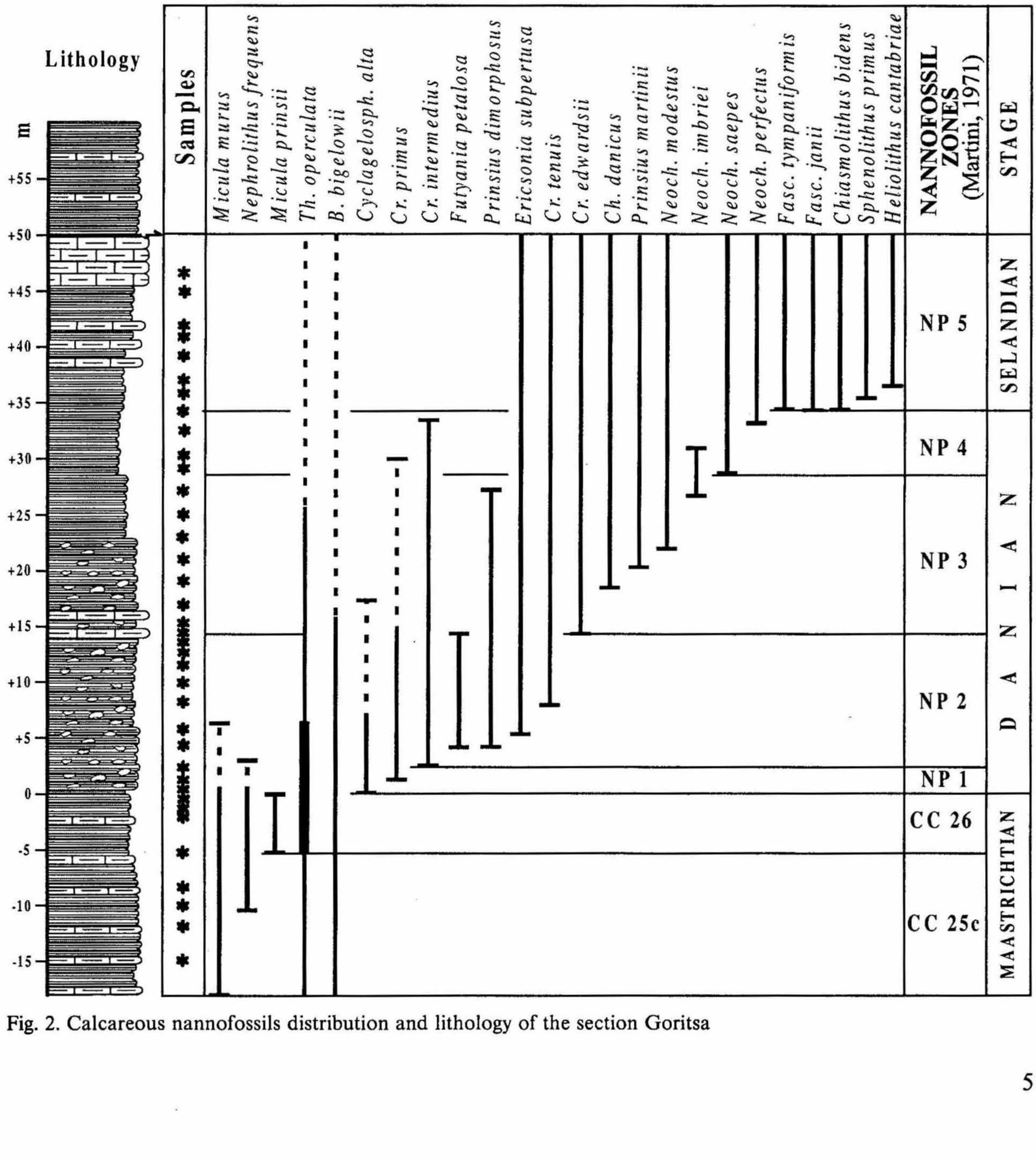

Fig. 2. Calcareous nannofossils distribution and lithology of the section Goritsa

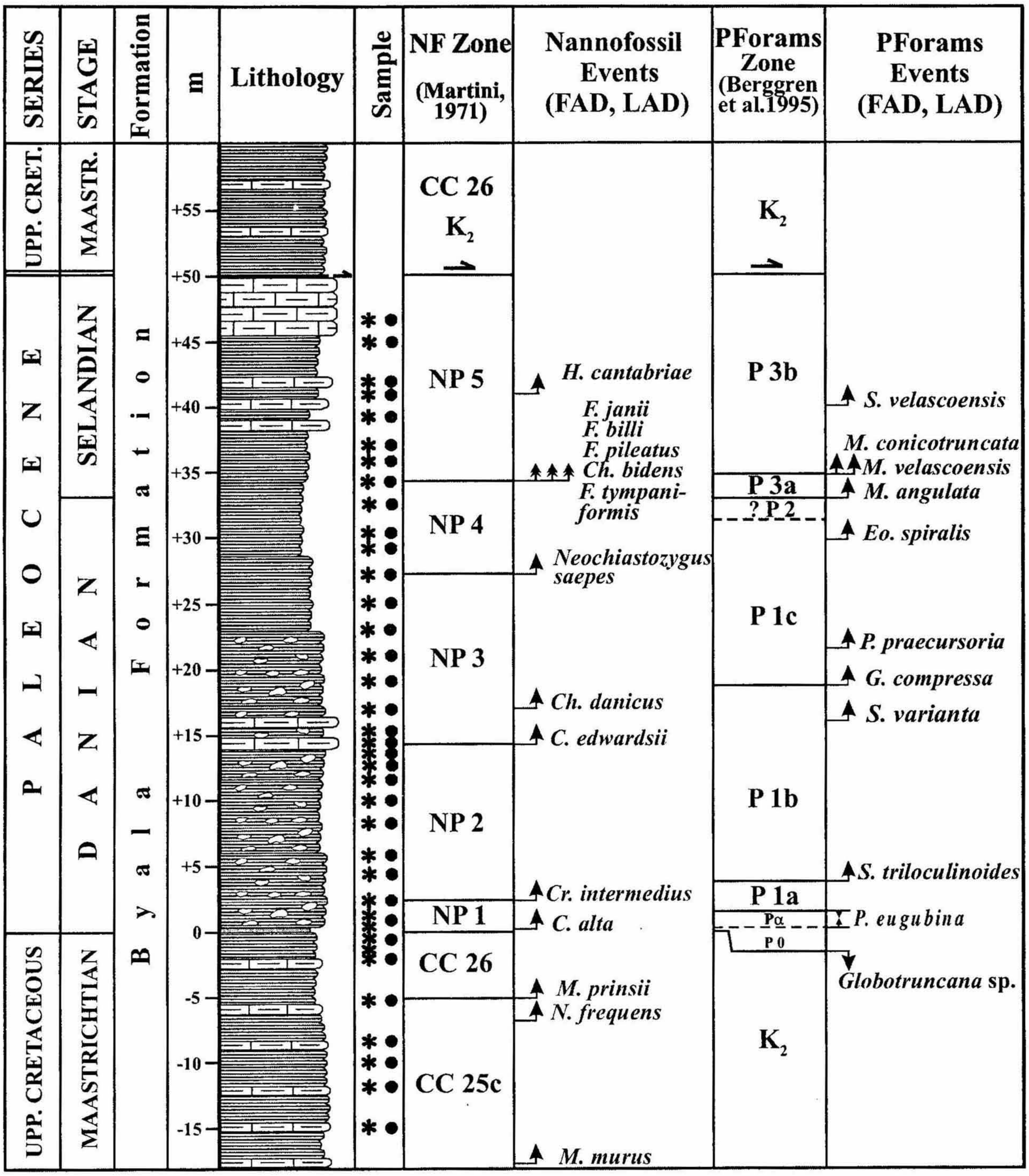

Fig. 3. Biostratigraphic subdivision of the section Goritsa: calibration of calcareous nannofossils and planktonic foraminiferal zones and bio-events

(Fig. 2) is marked by FAD of *Fasciculithus tympaniformis* (Plate I, fig. 10) at +34 m, along with large group of species of the genus *Fasciculithus*: *F. janii* (Plate I, fig. 11), *F. billi* (Plate I, fig. 12), *F. pileatus*. Another reliable event, which approximates this boundary, is FAD of *Chiasmolithus bidens* (Fig. 2; Plate I, fig. 14). In the middle part of the NP5 the FAD of *Heliolithus cantabriae* (+ 41 m, Fig. 2) is registered. This zone demonstrates relatively large thickness and nannofossil species diversity and abundance reaches its peak. The volume of this zone is incomplete due to the thrusting of Upper Cretaceous sediments in the upper part (Fig. 3).

Planktonic foraminifers

The study section comprises rich and diverse, well preserved planktic foraminifers, enabling identification and subdivision of the most of planktonic foraminifera zones in the Lower and Middle Paleocene (after Berggren and Miller, 1988).

In the Uppermost Maastrichtian, immediately below the K/T clay bed, planktic foraminifera association is typical for *A. mayaroensis* zone and consists of various species of the genera *Globotruncana, Heterohelix, Guembelitria,* etc.

Danian Stage. In the complete sections, in the basal part of Danian usually P0 zone is recognized with rather reduced thickness (several cm only). In the course of the present study it is not recorded due to the larger sampling distance.

Pα zone is under 1.9 m thick. Its lower boundary is not characterized precisely. Within this zone, reworked Upper Cretaceous taxa commonly occur. Paleocene species rarely occur and their size is below 0.2 mm. The dominating species is *Parvularugoglobigerina eugubina*, restricted only in this zone and defining its lower and upper boundary. The species *Guembelitria cretacea, Chiloguembelina morsei* and *Chiloguembelina midwayensis* are very common in the association, whereas *Parvularugoglobigerina alabamensis* and *Globanomalina* cf. *archaeocompressa* occur relatively rare.

Subzone P1a is about e 2-3 m thick (Fig. 3). It is defined as an interval between LAD of *Parvularugoglobigerina eugubina* and FAD of *Subbotina triloculinoides.* Similarly to the previous zone, in this zone reworked Upper Cretaceous species are abundant too. The association is dominated by *Guembelitria cretacea, Woodringina claytonensis* and abundant eoglobigerinds: *Eoglobigerina eobulloides, E. fringa, E. edita.* Comparatively rare occur *Parasubbotina pseudobulloides, Praemurica taurica, Pr. pseudoinconstans* and *Chiloguembelina morsei.*

Subzone P1b is about 15 m thick. In the lower 4 m, a lot of reworked Upper Cretaceous *Globotruncana* are recorded. Zonal association is dominated by *Parasubbotina pseudobulloides, Eoglobigerina eobulloides* and *Praemurica taurica. Subbotina triloculinoides* scarcely occurs in the basal part and becomes common in the upper part, where the FAD of *Subbotina varianta* и *Praemurica inconstans* is registered.

Subzone P1c is about 15 m thick. The planktic foraminiferal association is clearly dominated by subbotinids and eoglobigerinids. It comprises *Subbotina triloculinoides, Globanomalina compressa, Eoglobigerina edita, Subbotina pseudobulloides.* The abundance of *Globanomalina compressa* gradually increase upward, while in the upper part the transition forms to *Globanomalina ehrenbergii* are observed. Within this subzone, the FAD of *Praemurica praecursoria* and *Eoglobigerina spiralis* are documented (Fig. 3). The upper boundary is ambiguous.

The presence of P2 zone is not evidenced in the present study, possibly due to the large sampling distance. Its suggested thickness is not exceeding 1.50 m.

Selandian Stage. Subzone P3a has about 2 m thickness. Its upper boundary is marked by the FAD of *Morosovella velascoensis,* because of the missing of *Igorina albeari.* The recovered association is extremely rich, with abundant *Subbotina triloculinoides, S. pseudobulloides* and *S. varianta. Globanomalina compressa* and *Eoglobigerina spiralis* are commonly recorded species.

Subzone P3b is over 10 m thick. Its lower boundary was already discussed above, whereas its upper boundary is tectonic contact with thrusted Upper Cretaceous rocks. Typical association contains abundant subbotinids: *Subbotina triloculinoides, S. pseudobulloides* and *S. varianta.* The representatives of morozovellids exhibit high species richness: *Morosovella velascoensis, M. conicotruncata, M. simulatilis, M. angulata, M. apanthesma.* The presence of some other species, as *Globanomalina chapmanni* and *G. ehrenbergii* is noted as well.

Calibration between two zonal schemes

Precise juxtaposition between nannofossils and planktonic forams' schemes is shown in Fig. 3. The correlation of the bio-events in nannofloral and planktonic foraminiferal associations has led to the following conclusions:

- In the basal Danian, planktonic foraminifera succession displays higher biostratigraphic resolution, enabling separation of P0, Pα and P1a zones, which equates to NP1 nannofossil zone.
- In the lower and middle part of Danian, the parallel study can distinguish much more precisely lower, middle or upper part of particular nannofossil and/or planktic foraminifers' zone.
- In the upper part of Danian and Selandian, the biostratigraphic resolution in both groups increases significantly.
- Planktonic foraminiferal record ascerta-

PLATE I

(All microphotographs × 2500)

1. *Micula murus* (Martini, 1961) Bukry (1973). Sample G2 (–11.70 m), CC 25c Zone.
2. *Micula prinsii* Perch-Nielsen (1979). Sample G5 (–5.50 m), CC 26 Zone.
3. *Nephrolithus frequens* Gorka (1957). Sample G7a (–0.2 m), CC 26 Zone.
4. *Prediscosphaera grandis* Perch-Nielsen (1979). Sample G5 (–5.50 m), CC 26 Zone.
5. *Cyclagelosphaera alta* Perch-Nielsen (1979). Sample G7d (+0.10 m), NP 1 Zone.
6. *Futyania petalosa* (Ellis & Lohmann, 1973) Varol (1989). Sample G10 (+6.00 m), NP 2 Zone.
7. *Cruciplacolithus tenuis* (Stradner, 1961) Hay & Mohler (1967). Sample G12 (+10.00 m), NP 2 Zone.
8. *Ericsonia subpertusa* Hay & Mohler (1967). Sample G13 (+13.00 m), NP 2 Zone.
9. *Prinsius martinii* (Perch-Nielsen, 1969) Haq (1971). Sample G29 (+34.50 m), NP 5 Zone.
10. *Fasciculithus tympaniformis* Hay & Mohler (1967). Sample G29 (+34.50 m), NP 5 Zone.
11. *Fasciculithus janii* Perch-Nielsen (1971). Sample G29 (+34.50 m), NP 5 Zone.
12. *Fasciculithus billii* Perch-Nielsen (1971). Sample G29 (+34.50 m), NP 5 Zone.
13. *Placozygus sigmoides* (Bramlette & Sullivan, 1961) Romein (1979). Sample G35 (+45.00 m), NP 5 Zone.
14. *Chiasmolithus bidens* (Bramlette & Sullivan, 1961) Hay & Mohler (1967). Sample G35a (+46.00 m), NP 5 Zone.
15. *Neochiastozygus perfectus* Perch-Nielsen (1981). Sample G35a (+46.00 m), NP 5 Zone.
16. *Ellipsolithus bollii* Perch-Nielsen (1977). Sample G29 (+34.50 m), NP 5 Zone.
17. *Thoracosphaera operculata* Bramlette & Martini (1964). Sample G17 (+12.00 m), NP 2 Zone.

18-19. *Braarudosphaera bigelowii* (Graan & Braarud, 1935) Deflandre (1947). 18 — sample G7d (+0.10 m); 19 — sample G8 (+2.00 m), NP 1 Zone.

20. *Chiasmolithus consuetus* (Bramlette & Sullivan, 1961) Hay & Mohler (1967). Sample G33 (+41.00 m), NP 5 Zone.

PLATE II

1-5. *Parvularugoglobigrina eugubina* (Luterbacher & Premoli Silva,1964). Sample G7d (+0.1 m). Zone P α. 1 — umbilical side; × 450; 2 — umbilical side; × 400; 3 — wall surface; × 1500; 4 — umbilical side; × 350.

6. *Parvularugoglobigrina alabamensis* (Liu & Olsson). Sample G7d (+0,1 m). Zone P α. Spiral side; × 450.

7-9. *Guembelitria cretacea* Cushman. 7 — Sample G7d (+0.1 m); Zone P α; × 400; 8 — sample G7d (+0.1 m); Zone P a; × 300; 9 — sample G8 (+2 m); Zone P1a; × 450.

10-11. *Chiloguembelina morsei* (Kline). Sample G8 (+2 m). Zone P1a. Fig. 10 — × 300; 11— × 200.

12-13. *Eoglobigerina fringa* (Subbotina). Sample G7d (+0.1 m). Zone P α; 12 —spiral side; × 500; 13 — wall surface of the last chamber; × 2000.

14-15. *Eoglobigerina edita* (Subbotina). Sample G8 (+2 m); Zone P1a. 14 — spiral side; × 250; 15 — umbilical side; × 250.

16. *Eoglobigerina trivialis* (Subbotina). Sample G8 (+2 m); Zone P1a. Spiral side; × 270.

PLATE III

1, 2. *Eoglobigerina eobulloides* (Morozova). Sample G8 (+2 m); Zone P1a. 1 — spiral side; × 250; 2 — umbilical side; × 220.

3. *Eoglobigerina spiralis* (Bolli). Sample G28 (+32.5 m). Zone P3a, spiral side; × 300.

4. *Globanomalina* cf. *archaeocompressa* (Blow). sample G7d (+0,1mK/T); Zone Pα. umbilical side; × 300.

5-8. *Globanomalina compressa* (Plummer). 5, 6, 7 — sample G27 (+31 m); Zone P1c; 5 — spiral side; ×170; 6 — umbilical side; × 200; 7 — lateral side, × 250; 8 — Sample G21 (+19 m); Zone P1c; umbilical side; × 200.

9. *Globanomalina chapmani* (Parr). Sample G35 (+45 m). Zone P3b. umbilical side.

10. *Globanomalina ehrenbergii* (Bolli). Sample G29 (+34 m). Zone P3b. umbilical side; × 170.

11,12. *Praemurica inconstans* (Subbotina). Sample G28 (+32.5 m). Zone P3a; 11 — umbilical side; × 200; 12 — spiral side; × 200.

13. *Praemurica pseudoinconstans* (Blow). Sample G8 (+2m). Zone P1a. spiral side; × 200.

14. *Praemurica uncinata* (Bolli). Sample G28 (+32.5 m). Zone P3a. spiral side; × 270.

15,16. *Parasubbotina pseudobulloides* (Plummer). Sample G8 (+2 m). Zone P1a. 15 — umbilical side; × 200; 16 — spiral side; × 200.

PLATE IV

1, 2. *Parasubbotina pseudobulloides* (Plummer). Sample G8 (+2 m). Zone P1a. 15 — umbilical side; × 200; 16 — spiral side; × 200.

3, 4. *Parasubbotina varianta* (Subbotina). 3 — sample G21 (+19 m). Zone P1c, umbilical side; × 200; 4 — sample G22 (+21 m). Zone P1c, umbilical side, × 200.

5-7. *Subbotina triloculinoides* (Plummer). 5, 6 — sample G10 (+6 m). Zone P1b; 5 — umbilical side, × 250; 6 — sample G27 (+31 m); Zone P1c; spiral side; × 250; 7 — sample G16 (+17 m); Zone P1b; spiral side; × 220.

8, 9. *Subbotina velascoensis* (Cushman). Sample G33 (+41 m). Zone P3b. 8 — umbilical side; × 170; 9 — spiral side; × 170.

10-12. *Morozovella angulata* (White). Sample G29 (+34.5 m). Zone P3a; 10 — umbilical side; × 220; 11 — wall surface with nannofossils, × 1300; 12 — spiral side; × 200.

13-14. *Morozovella conicotruncata* (Subbotina). Sample G29 (+34.5 m). Zone P3a. 13 — umbilical side; × 200; 14 — spiral side; × 200.

15-16. *Morozovella velascoensis* (Cushman). Sample G30 (+36 m). Zone P3b, umbilical side; × 170.

PLATE I

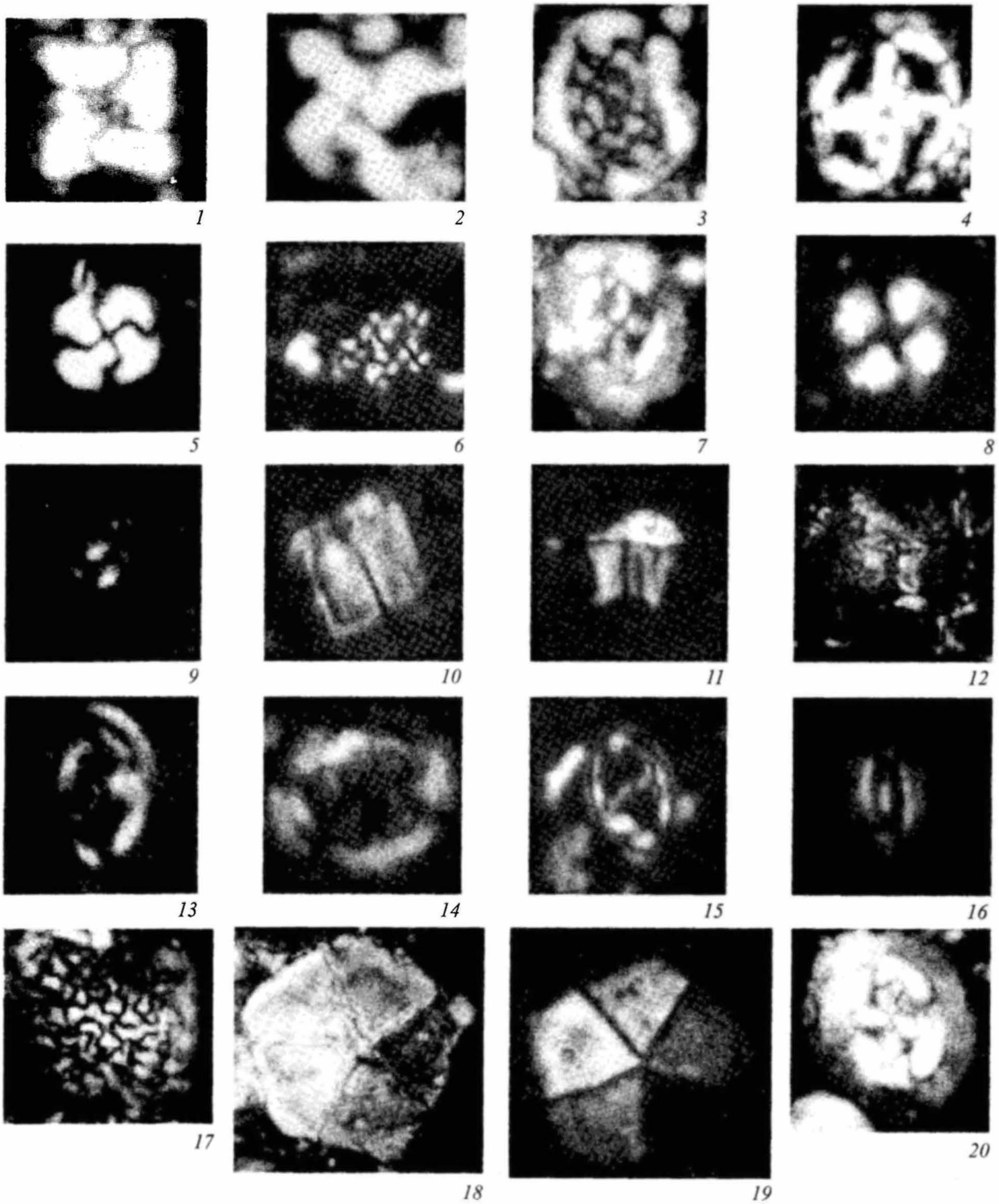

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PLATE II

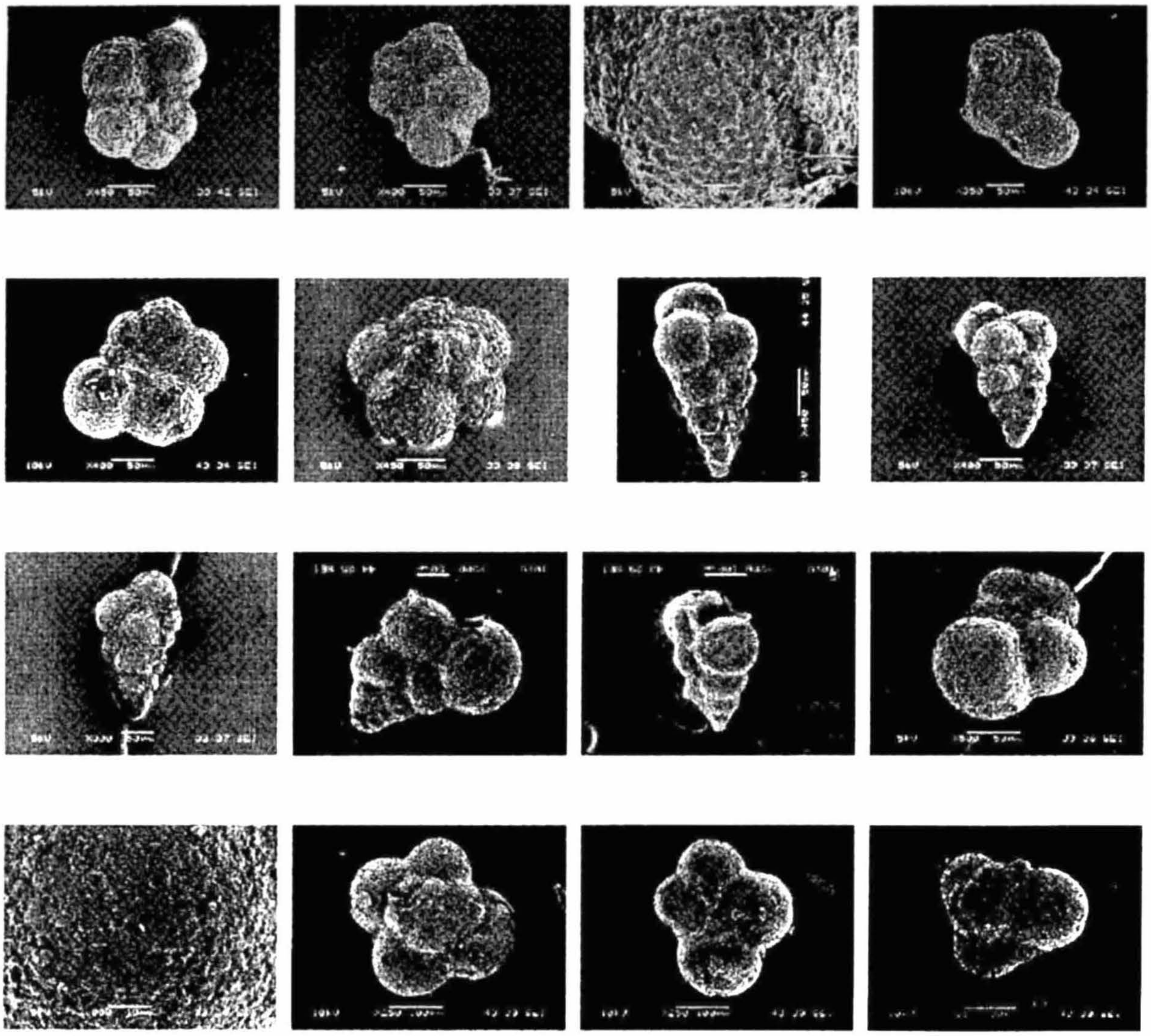


PLATE III

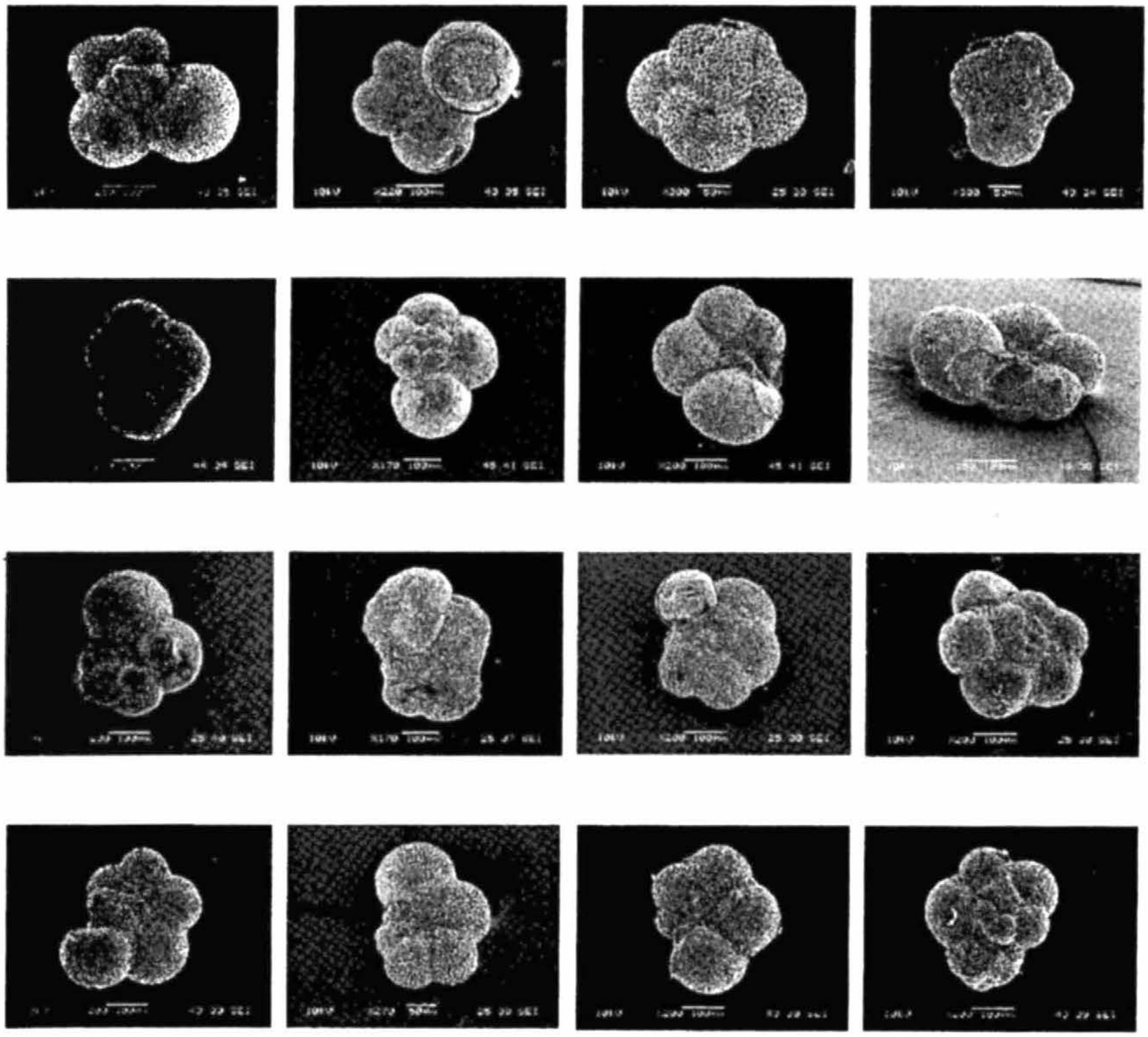
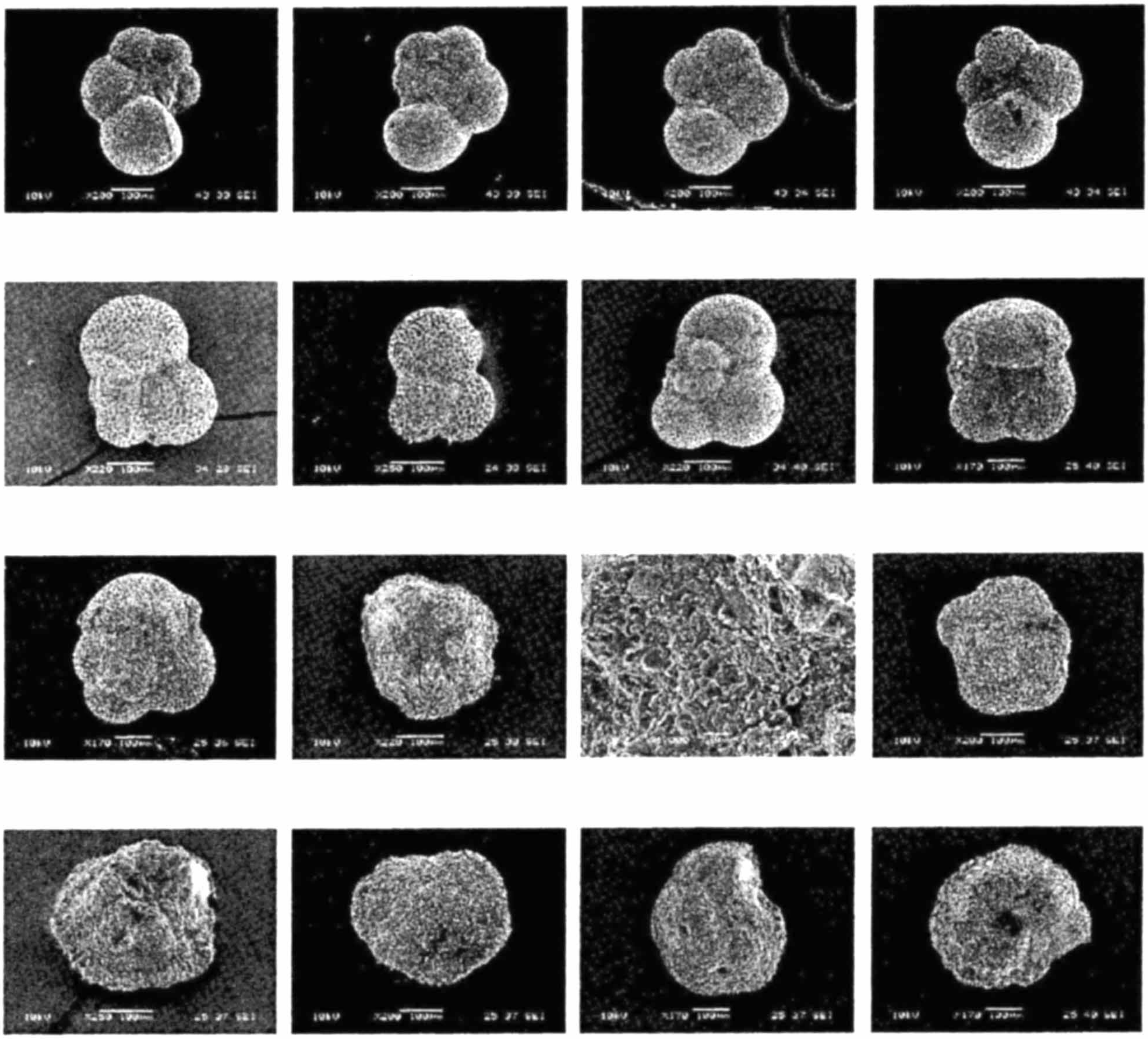


PLATE IV



ins the complete lack of the genera *Globoconusa, Acarinina* and *Igorina*. Nevertheless, the rest of the finds clearly fix the FAD-levels, identifying various P-zones.

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