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Foraminiferal distribution across the Maastrichtian/Danian boundary of Mangyshlak peninsula (West Kazakhstan)

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Abstract

The planktonic and benthic foraminiferal distribution, resulting from bed by bed sampling across the Maastrichtian/Danian boundary was studied in detail from the Koshak and Kyzylsai sections in the Mangyshlak peninsula (West Kazakhstan). The distribution of planktonic (PF), benthic (BF) Foraminifera and nannoplankton is analysed. The stratigraphically most important species are illustrated and the biostratigraphic distribution from the Mangyshlak is compared with that from other areas of northern Europe.

Key-words: K/T boundary - Mangyshlak - Kazakhstan - Foraminifera

Résumé

Sur base d'un échantillonnage banc par banc de part et d'autre de la limite Maastrichtien/Danien, la distribution des foraminifères planctoniques et benthiques a été étudiée en détail dans les sections de Koshak et Kyzylsai situées dans la péninsule du Mangyshlak (Kazakhstan occidental). La distribution des foraminifères planctoniques (PF) et benthiques (BF) ainsi que du nannoplancton est analysée. Les espèces les plus importantes au point de vue stratigraphique sont figurées; la répartition stratigraphique des espèces dans le Mangyshlak est comparée avec celle observée dans d'autres régions d'Europe septentrionale.

Mots-clefs: Limite K/T, Mangyshlak, Kazakhstan, foraminifères

Резюме

Изучено распределение планктонных и бентосных фораминифер в послойно собранных образцах из разрезов Кызылсай и Кошак (полуостров Мангышлак, Западный Казахстан). Проанализировано стратиграфическое значение фораминиферовых и наноланктонных комплексов и выделенные зональные подразделения сопоставлены с другими регионами. Приведены в таблицах изображения некоторых важных в стратиграфическом отношении видов.

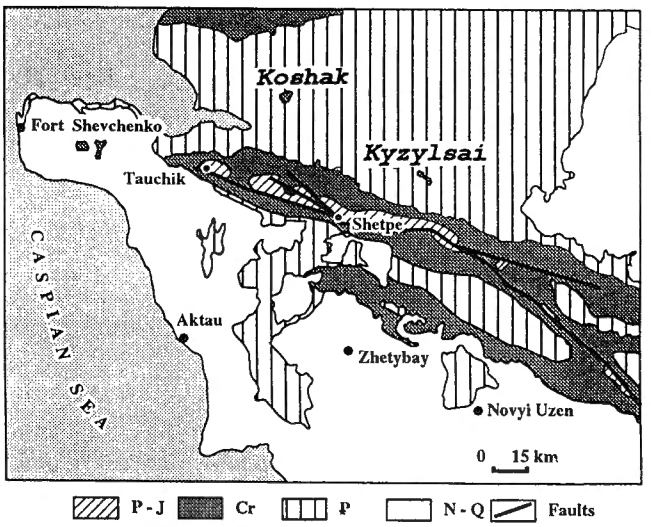
Ключевые слова: Граница мел/палеоген – Мангышлак, Казахстан, фораминиферы

Introduction

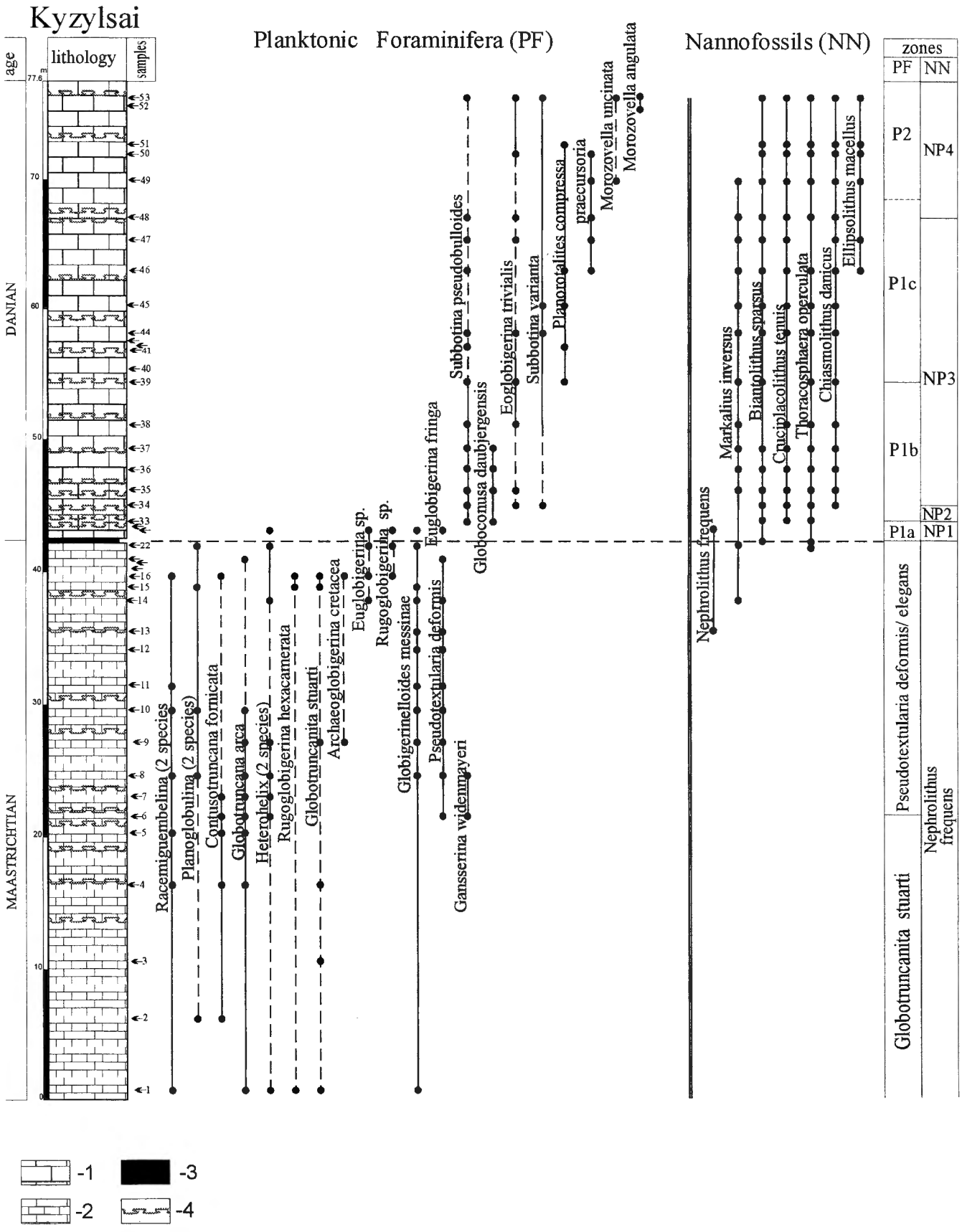
Herein the discussion on the K/T boundary is based on our field observations in western Mangyshlak, where Maastrichtian and Palaeocene are widespread and well exposed. When describing the extent of the exposures in Mangyshlak, ANDRUSOV wrote: "If in Central Russia we should number the outcrops, here we would number the unexposed sites" (ANDRUSOV, 1915, p. 111).

During the Late Cretaceous the Mangyshlak peninsula was covered by a relatively shallow marine basin belonging to the central part of the Tethys margin. This basin had a wide connection with the northern Tethys and with the Boreal seas of the Russian Platform. Because of the similarity in taxonomic composition of its marine fauna with fauna from northern Europe, it is generally included in the European palaeobiogeographical area — EPA (NAIDIN, 1969, Text-Fig. 1).

The Mangyshlak peninsula is a classic area for the study of the Upper Cretaceous and lower Palaeogene. The Cretaceous and Palaeogene stratigraphy in Mangyshlak were studied as early as the end of the nineteenth century (SEMENOV, 1899). Later on ANDRUSOV (1915), ALEKSEITCHIK (1941), TRIFONOV (1959), TRIFONOV & BURAGO



Text-figure 1 — Map of Mangyshlak peninsula, with location of Kyzylsai and Koshak sections. P-J: Permian to Jurassic; Cr: Cretaceous; P: Palaeogene; N-Q: Neogene to Quaternary.



Text-figure 2 — Distribution of the most important planktonic Foraminifera and the nannoflora in the Kyzylsai section around the K/T boundary. 1: limestones; 2: chalks and marls; 3: boundary clays; 4: hardground surfaces.

(1960) and BYKOVA (1960) studied this region. The most complete description of the sequences including their macro- and mainly micropalaeontological characteristics were published by VASSILENKO (1961), TRIFONOV & VASSILENKO (1963) and more recently by NAIDIN *et al.* (1984a, b, 1996). VASSILENKO proposed the first benthic foraminiferal zonation for all Upper Cretaceous of Mangyshlak.

In this paper data are presented on the distribution of the Foraminifera from two important K/T boundary sections — Koshak and Kyzylsai (see Text-Fig. 1). These sections, located on the slopes of the northern Aktau Mountains on Mangyshlak peninsula, West Kazakhstan, are continuous across the Cretaceous/Palaeogene (K/T) boundary, with only minor hardgrounds within the Upper Maastrichtian and Lower Danian. These sequences contain a rich macrofaunal assemblages composed of ammonites, belemnites, brachiopods, echinoids and bivalves. The microfossil assemblages are dominated by benthic components, typical for a rather shallow chalk facies. The first data on the K/T boundary from Mangyshlak were published by NAIDIN *et al.,* 1990a, b. These authors described the macro- and micropalaeontological assemblages; the Foraminifera from this interval, however, were not illustrated. A list of Foraminifera from the Koshak section was published by KELLER *in* OBERHÄNSLI *et al.*, (1998), without illustrations. In the present paper many taxa — planktonic and benthic — are illustrated and the correlation with other areas is discussed.

Geological setting

The detailed lithostratigraphic description of this region is published in NAIDIN (1986, 1987), HERMAN *et al.* (1988), SARKAR *et al. (*1992), OBERHÄNSLI *et al.* (1998). In these sections 140-150 m of Maastrichtian chalks and marls are overlain by 40-60 m of Danian limestones. The Maastrichtian soft chalks are composed almost exclusively of biogenic carbonates. The chalks are intercalated with yellowish-brown marls containing hardground horizons. The K/T transition is marked by a 1-4 cm thick dark layer, with remarkably sharp boundaries with the carbonates above and below. This dark layer is the boundary clay and coincides with the K/T boundary. In some exposures the clay is replaced by equally thin greenish-gray marls (75-85% $CaCO_3$), containing glauconite, plagioclase and angular quartz grains, as well as limonite and pyrite concretions. Abundant, minute fish bones and scales have also been observed; they are very similar to those in the ''Fish Clay'' at Stevns Klint, in Denmark (ROSENKRANTZ, 1924). The boundary clay contains illite, mixed-layer illite/smectite and chlorite (HERMAN *et al.,* 1988). Palygorskite is present throughout the Maastrichtian and Danian, reaching peak abundance in samples just above the K/T boundary (25-40 cm). Mineralogically the boundary clay is similar to the clay fraction of rocks in the K/T sections from other localities (RAMPINO & REYNOLDS, 1983). Furthermore, palygorskite is widely distributed in the Mangyshlak section and in sections from other areas (CALLEN, 1984).

In this boundary clay between Maastrichtian and Danian strata an Ir enrichment of maximum 7 ppb and 3-4 ng/g, respectively has been reported (NAZAROV *et al.*, 1983; HERMAN *et al.*, 1988). The basal Danian is an 1.5 m thick extremely hard yellowish-brown and white limestone with burrows in the Kyzylsai section. In the Koshak section the boundary clay is overlain by about 2.5 m light-yellow, coarse chalk. The basal layers grade into a white fine-grained hard limestone with irregular marly intercalations and several hardground surfaces (Text.-Fig. 2-5).

Material and methods

Eighty two samples, taken at intervals of 30 cm to 2.5 m, were collected from the Koshak and Kyzylsai sections. Samples weight varied from 150 to 200 g and they were disintegrated in water, then washed through a 63 μm sieve and dried in an oven before biostratigraphic analysis. The preservation is good to fair in the chalks of the Maastrichtian of the two sections examined. In contrast, preservation is generally poor in the coarse chalks and chalky limestones of the base of the Danian but it is better in the white fine-grained hard limestones of the upper part of the Danian. Planktonic foraminiferal identifications are based on commonly used taxonomy and illustrations including ROBASZYNSKI *et al.* (1984), MACLEOD & KELLER (1994). Identification of benthic Foraminifera are mainly based on BROTZEN (1948), VASSILENKO (1961) and GAWOR-BIEDOWA (1992).

PALAEONTOLOGY

Macrofossils

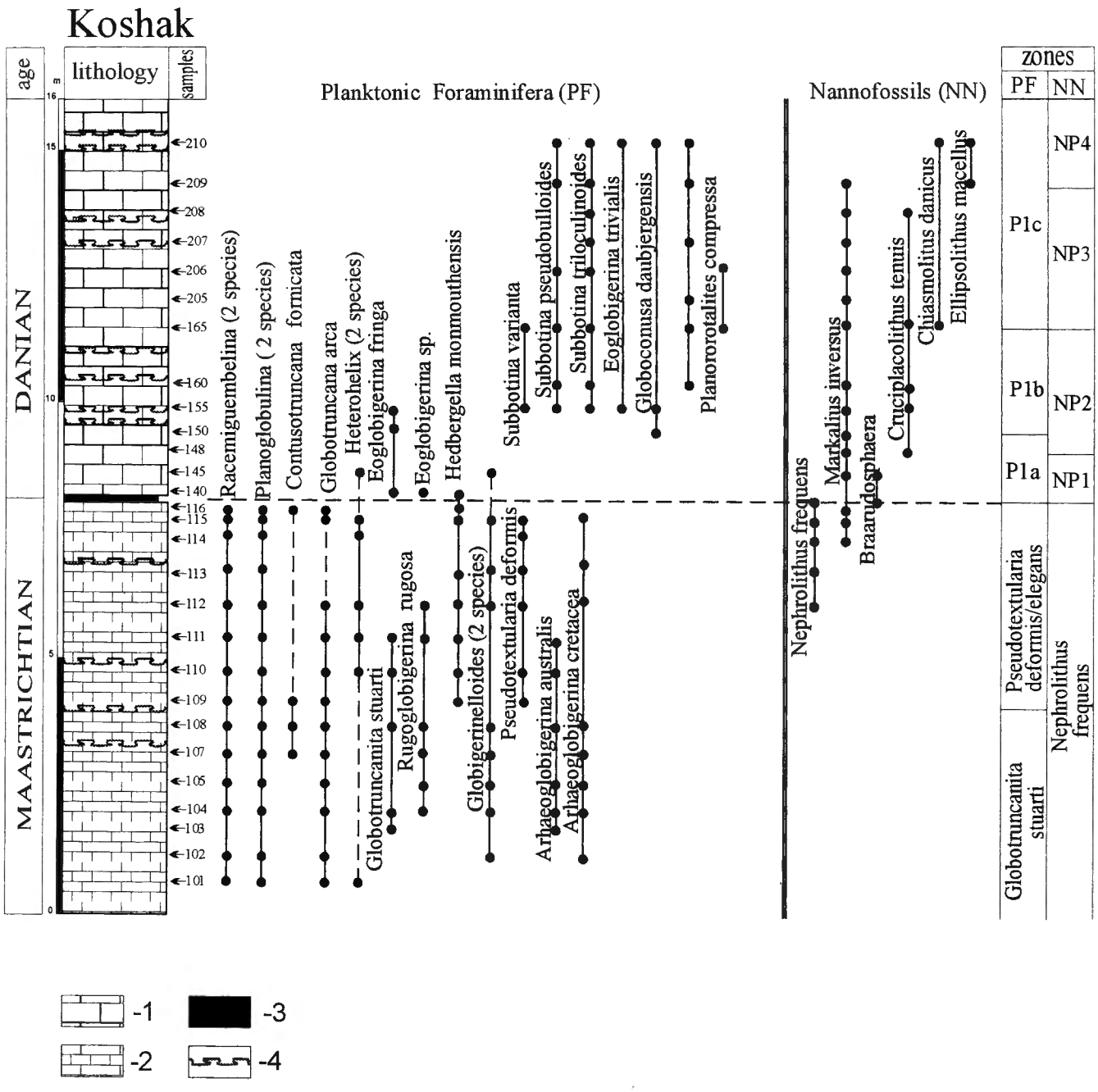
The following Upper Maastrichtian index fossils are present in the uppermost of Cretaceous of both sections: ammonites: *Hoploscaphites constrictus* (J. Sowerby), *H. constrictus crassus* (Lopuski). Abundant belemnites — *Neobelemnella kazimiroviensis* (Skolozdrowna) extend to the top of Maastrichtian. Echinoids are also common: *Cyclaster integer* Seunes, *Echinocorys ciplyensis* Lambert, *E. arnaudi* Seunes, *E. meudonensis* Lambert, *E. pyramidata* Portlock, *Gauthieria radiata broecki* Lambert and *Salenidia pygmea* (von Hagenow). Corals, bryozoans and brachiopods have also been observed.

The Danian limestones contain numerous echinoderms dominated by *Brissopneustes aturicus* Seunes, *Cyclaster danicus* Schlüter, *Echinocorys obliqua* (Ravn) and *E. pyrenaica* Seunes. Corals, bryozoans and brachiopods were also frequently encountered.

There is a marked macrofaunal change at the K/T boundary (HERMAN *et al.*, 1988; NAIDIN *et al.*, 1990a).

Foraminiferal Zonation

Planktonic Foraminifera (PF). Planktonic foraminiferal



Text-figure 3 — Distribution of the most important planktonic Foraminifera and the nannoflora in the Koshak section around the K/T boundary. 1: limestones; 2: chalks and marls; 3: boundary clay; 4: hardground surfaces.

assemblages in the Upper Maastrichtian of Mangyshlak peninsula show a low diversity. They are dominated by *Globigerinelloides*, heterohelicids and hedbergellids which comprise up to 80-90% of the planktonic part of the thanatocoenosis. Globotruncanids are very rare except in the intervals characterized by a high planktonic/benthic ratio (P/B). Among the globotruncanid assemblages, shallow-water species of the genera *Globotruncana* and *Rugoglobigerina* occur most frequently. The PF assemblage consists here of *Globotruncana arca* (Cushman), *Contusotruncana fornicata* (Plummer), *Globotruncanella petaloidea* (Gandolfi), *G. havanensis* (Voorwijk), *Globotruncanita stuarti* (de Lapparent), *Rugoglobigerina rugosa* (Plummer), *R. hexacamerata* Brönnimann, *Archaeoglobigerina cretacea* (d'Orbigny), *Globigerinelloides messinae* Brönnimann, *Gl. volutus* White, *Gl. clavatus* Brönnimann, *Hedbergella monmouthensis* (Olsson), *Heterohelix globulosa* (Ehrenberg), *H. striata* (Ehrenberg), *Pseudotextularia deformis* (Kikoine), *Planoglobulina brazoensis* Martin, *P. carseyae* (Plummer), *Racemiguembelina fructicosa* (Egger) (Text-Fig. 2,3). *Gansserina wiedenmayeri* (Gandolfi), a typical Tethyan

species was found only in two samples (6,7) of the Kyzylsai section. The higher Maastrichtian samples only contain poor assemblages of ubiquitous PF species. The first Danian forms — *Eoglobigerina* sp. - appears already in the uppermost samples of the Maastrichtian chalk in both sections.

The tropical-subtropical zonation (BOLLI, 1966; ROBASZYNSKI *et al.,* 1984; CARON, 1985) cannot be used in Mangyshlak because of the rarity or the absence of its index forms: *Globotruncana aegyptiaca* (Nakkady), *Gansserina gansseri* (Bolli) and *Abathomphalus mayaroensis* (Bolli).

Another zonation was proposed by MASLAKOVA (1978); she subdivided the Maastrichtian in two Zones. In her scale a *Globotruncanita stuarti* Zone (Lower Maastrichtian) and an *Abathomphalus mayaroensis* Zone (Upper Maastrichtian) are used. A recent study of Crimean sections showed, that the upper part of the *Globotruncanita stuarti* Zone coincides with the lower part of the Upper Maastrichtian - the beginning of *Neobelemnella kazimiroviensis* macropalaeontological Zone (ALEKSEEV & KOPAEVICH, 1997, p. 110, Text-Fig. 6) that is the standard Upper Maastrichtian zone for the eastern part of EPA (NAIDIN *et al.,* 1984). The presence of the zonal species allows to recognise the upper part of the *Globotruncanita stuarti* Zone in the Kyzylsai and Koshak sections. The next correlatable level is at the sharp increase of representatives of the genera *Pseudotextularia, Planoglobulina* and *Racemiguembelina.* This level coincides with the base of the *Pseudotextularia elegans* or *P. deformis* Zone (uppermost part of the Maastrichtian) in many sections of the EPA and of North America: Germany, Russian Platform, Mangyshlak (WICHER, 1953; KOCH, 1977) NAIDIN *et al.,* 1990 b; BENIAMOVSKII & KOPAEVICH, 1998; JONES *et al.,* 1987; KELLER, 1989). In Central Poland the equivalent of this zone is easily recognized by the presence of abundant representatives of heterohelicids, considerable numbers of *Rugoglobigerina* and *Globigerinelloides* and the absence of *Globotruncana* (PERYT, 1980). According to KELLER *in* CANUDO *et al.* (1991, p. 327) ''the *Abathomphalus mayaroensis* Biozone is geographically and ecologically restricted and an alternative biozone, *Pseudotextularia deformis* was proposed for shallow water sequences''.

In the boundary clay no PF were found. However, this PF ''barren-interval'' (KAIHO & SAITO, 1986) is the equivalent of the P0 (?) Zone of SMIT (1982) established for the K/T boundary sequence near Caravaca (Spain) and at El-Kef (Tunisia) and it coincides with the boundary clay (KELLER *et al.,* 1988 a, b).

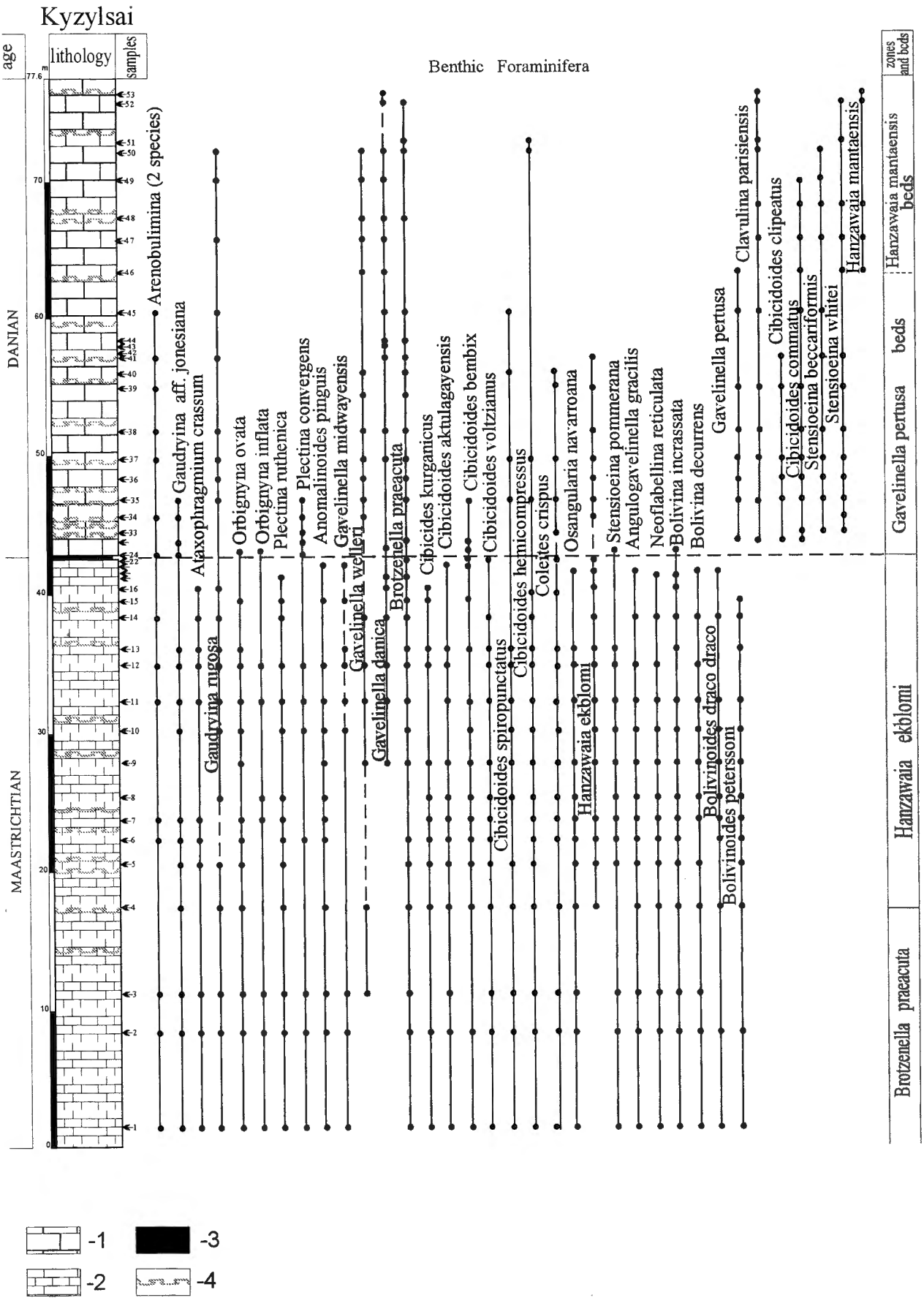
The first, very rare Tertiary species, including *Eoglobigerina fringa* (SUBBOTINA), *Eoglobigerina* sp. and rare ''survivor'' Maastrichtian species — small *Heterohelix-Hedbergella-Globigerinelloides* taxa — are present in the base of the Danian (Text-Fig. 2, 3). Occasionally sections of tiny (0.1-0.12 mm), compressed foraminiferal tests, similar to *Parvulorogoglobigerina eugubina* (Luterbacher & Premoli Silva) were observed in thin sections. This interval is correlated with the *Parvulorugoglobigerina eugubina* Zone (LUTERBACHER & PREMOLI SILVA, 1964; PREMOLI SILVA & BOLLI, 1973) or P1a Zone. The thickness of this Zone is about 1.5 m thick at Kyzylsai and about 2.5 m in the Koshak sections.

Higher up, in a 27 m thick interval at Kyzylsai and a 20 m thick interval at Koshak, PF become more abundant and their overall size increases. The following typical Danian taxa have been identified: *Subbotina pseudobulloides* (Bolli), *S. varianta* (Subbotina), *S. triloculinoides,* (Plummer), *Eoglobigerina trivialis* (Subbotina) and a single *Globoconusa daubjergensis* (Brönnimann). This assemblage is attributable to the *Subbotina pseudobulloides* Zone or P Ib Zone (CAVELIER & POMEROL, 1983, 1986). This zone was first described by LEONOV & ALIMARINA (1961) as *Globigerina pseudobulloides-Globigerina daubjergensis* Zone and the shortened name was introduced by BOLLI, (1966). The next zone - the *Planorotalites compressa* Zone is characterized by the FA of the index-species *Planorotalites compressa* (Plummer) and *Morozovella praecursoria* (Morozova) and also by the presence of *Subbotina pseudobulloides* (Bolli), *Globoconusa daubjergensis* (Brönnimann) (Text-Fig. 2,3). This interval is the equivalent of the *Morozovella trinidadensis* Zone - P1c (CAVELIER & POMEROL, 1983, 1986; TOUMARKINE & LUTERBACHER, 1985). The uppermost part of the Kyzylsai section (samples 49-55) is marked by the presence of *Morozovella uncinata* (Bolli) — P2 Zone (BOLLI, 1966; CAVELIER & POMEROL, 1983, 1986; TOUMARKINE & LUTERBACHER, 1985).

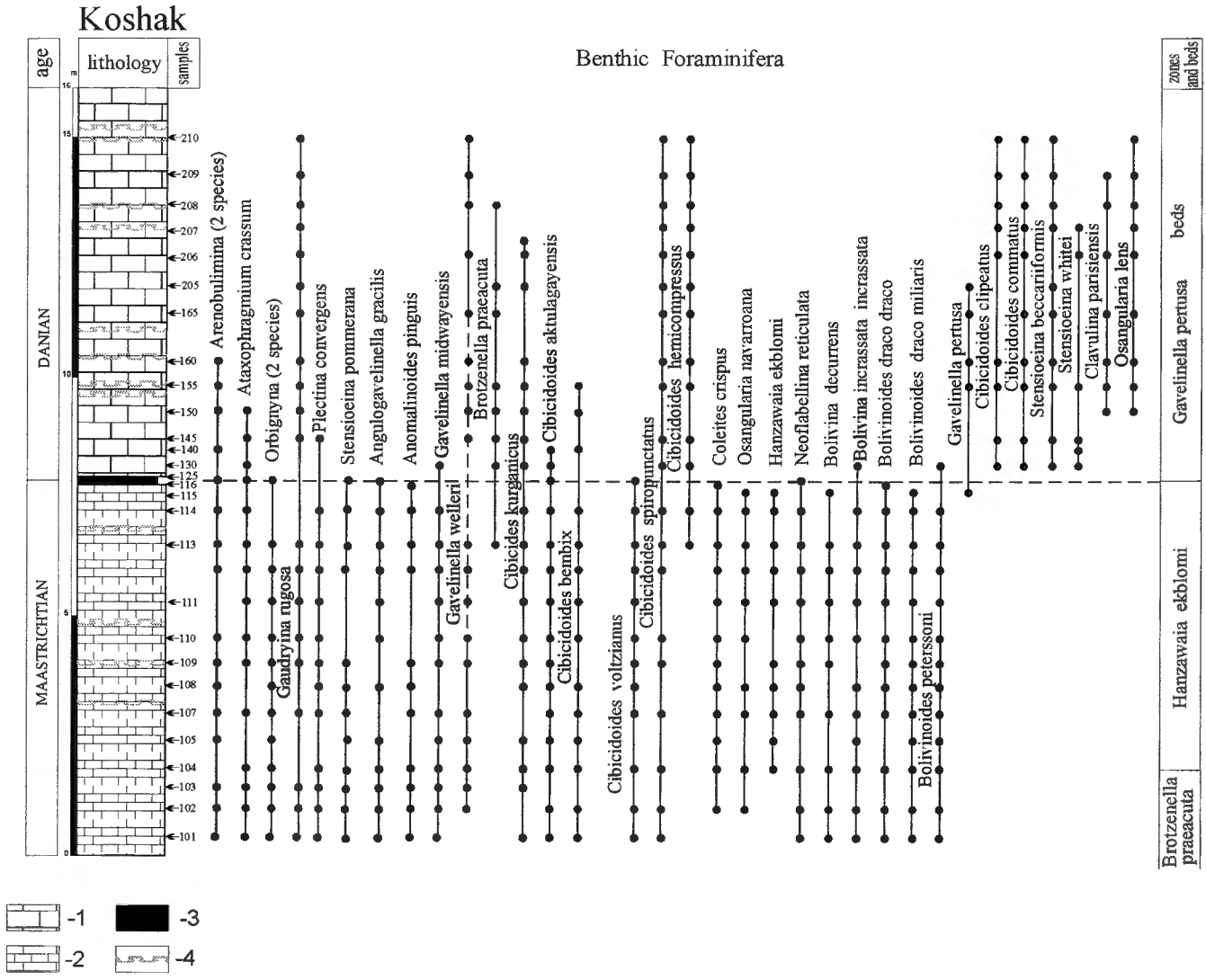
Benthic Foraminifera (BF). Maastrichtian and Danian deposits in both sections are very rich in BF. The uppermost part of the Maastrichtian contains stratigraphically important taxa of the genera *Bolivinoides, Neoflabellina, Bolivina* and other taxa of *Gavelinella, Brotzenella* and *Cibicidoides.* On the basis of the BF distribution in Mangyshlak the following zonation is presented: for the Maastrichtian the *Brotzenella praeacuta* Zone - BF12 for the lower part and the *Hanzawaia ekblomi* Zone BF13 for the upper part of both sections (NAIDIN *et al.,* 1984, a, b; BENIAMOVSKII & KOPAEVICH, 1998). This zonation was proposed for the eastern part of EPA by NAIDIN *et al.,* (1984) and was recognised without any difficulties in following regions: Peri-Caspian depression, Crimea, northern part of Turgai Straight and southern Urals (ALEKSEEV & KOPAEVICH, 1997; AMON *et al.,* 1997; BENIAMOVSKII & KOPAEVICH, 1998).

The general taxonomic composition of BF assemblages from both studied sections is very similar to those from northern Europe - Belgium (ROBASZYNSKI *et al.,* 1985; ROBASZYNSKI & CHRISTENSEN, 1989) and Northern Germany (SCHÖNFELD, 1990; SCHÖNFELD & BURNETT, 1991; BENIAMOVSKII & KOPAEVICH, 1998).

The boundary clay contains a very poor and particular BF assemblage. Only agglutinated BF show a good preservation and high diversity, whereas calcareous BF are few in number and show traces of dissolution. The limestones from the Kyzylsai and the coarse chalk from the



Text-figure 4 — Distribution of the most important benthic Foraminifera near the K/T boundary in the Kyzylsai section. 1: limestones; 2: chalks and marls; 3: boundary clay; 4: hardground surfaces.

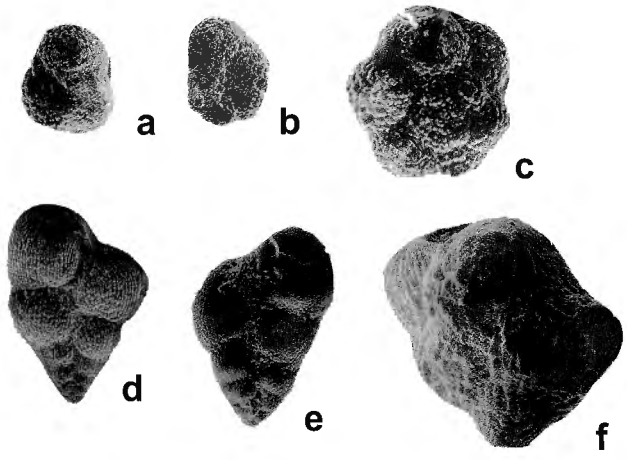


Text-figure 5 — Distribution of the most important benthic Foraminifera near the K/T boundary in the Koshak section. 1: limestones; 2: chalks and marls; 3:boundary clay; 4: hardground surfaces.

Koshak sections just above the boundary clay, also contain a poor BF assemblage, including a few Maastrichtian species. Gradually a few, new Danian species appear higher up such as *Stensioeina whitei* (Morozova), *S. beccariiformis* (White), *Osangularia lens* (Brotzen), *Cibicidoides clipeatus* (Vassilenko), *Spiroplectammina dentata* (Alth), *Clavulina parisiensis* (d'Orbigny) and *Hanzawaia mantaensis* (Galloway & Murrey) (Text-Fig. 4, 5). Several typical Maastrichtian species also still occur in the lowermost Danian. In younger Danian horizons the taxonomic diversity was restored to the same level as existing in the Upper Maastrichtian (Text-Fig. 4, 5).

Calcareous nannofossils

The calcareous nannofossils were studied by K. Perch-Nielsen (see HERMAN *et al.*, 1988) for the Kyzylsai section and by G. Kalinitchenko (see NAIDIN *et al.*,1990 b) for both sections. In all Maastrichtian samples, the calcareous nannofossils are moderately to well preserved. They include *Nephrolithus frequens* (Górka) the marker species for the Late Maastrichtian in high latitudes, and *Cribrosphaerella daniae* Perch-Nielsen, also a high latitude form restricted to the uppermost Maastrichtian in the Kyzylsai section. *Arkhangelskiella cymbiformis* Vekshina, *Cribrosphaerella ehrenbergi* (Arkhangelsky), *Lithraphidites quadratus* Bramlette & Martini, *Biscutum* sp. , also are present. *Micula mura* (Martini), the marker for low latitude Late Maastrichtian is rarely present in a few samples of the Kyzylsai section. Very rare *Obliquipithonella operculata* (Bramlette & Martini), *Braarudosphaera bigelowii* (Gran & Braarud) and *B. discula* Bramlette & Riedel were found about 2-5 cm below the K/T boundary. Very rare *Obliquipithonella cf. operculata* Bramlette & Martini fragments were found in the boundary clay itself. *Markalius inversus* (Deflandre) and *Biantholithus sparsus* Bramlette & Martini, the marker of the basal Danian in Denmark, are present here and in good preservation. The remainder of the assemblage in



Text-figure 6 — Planktonic Foraminifera from the P1a Zone.
a. *Eoglobigerina fringa* (Subbotina): umbilical side, Koshak section, sample 140 (X70)
b. *Globigerinelloides messinae* Brönnimann: Koshak section, sample 141 (X70).
c. ? *Hedbergella monmouthensis* (Olsson): Koshak section, sample 141 (X70).
d and e. *Heterohelix striata* (Ehrenberg): Koshak section, sample 141 (X70).
f. *Planoglobulina brazoensis* Martin: Koshak section, sample 140 (X80).

the boundary clay is identical to the underlying Maastrichtian assemblages, however, calcareous nannofossils are rare and poorly preserved. Just above the boundary clay the sediments contain a poor assemblage of nannofossils: *Markalius inversus* (Deflandre) (80% of all taxa), *Biantolithus sparsus* Bramlette & Martini, *Coccolithus cavus* Hay & Mohler, *Obliquipithonella operculata* Bramlette & Martini, *Braarudosphaera bigelowii* (Gran & Martini), *B. discula* Bramlette & Riedel are common and several Maastrichtian species are still present here. This interval represents the Lower Danian the NP1 (*Markalius inversus*) Zone (Text-Fig. 2, 3).

In the younger samples, the presence of *Cruciplacolithus tenuis* Stradner, zonal species of NP 2 suggests that the base of this Zone lies at the level of sample 33 in the Kyzylsai section and of sample 146 in the Koshak section. *Chiasmolithus danicus* (Brotzen), the marker of the Danian NP3 Zone was found in sample 35 of the Kyzylsai section and in sample 165 of Koshak section. Only typical Palaeocene species characterize this zonal assemblage. The appearance of *Ellipsolithus macellus* (Bramlette & Sullivan) and other species suggest the presence of the NP4 Zone in Kyzylsai section.

Correlations

The correlation of the K/T boundary interval for the two studied sections on PF data with other regions of EPA is straightforward. The *Pseudotextularia deformis/elegans* Zone is a typical subdivision for shallow water sequences (see above). This zone is characterised by the presence of the index-species associated with that of other species of multiserial heterohelicids such as *Racemiguembelina* and *Planoglobulina*, but also by a similar very sharp increase in the P/B ratio. This change of P/B ratio is probably related to a eustatic sea-level rise and an influx of warm Tethyan water-mass into the EPA, the so-called "elegans-transgression" (WICHER, 1953; NAIDIN *et al.*, 1990 b; BENIAMOVSKII & KOPAEVICH, 1998). The sea-level rise prior to the K/T boundary is supported by the reappearance of *Abathomphalus mayaroensis* (Bolli) in the youngest samples just below the boundary both in Zumaya (Spain) and Ain Settara (Tunisia) (MOLINA *et al.*, 1998). It is interesting that the presence of a short-term warming at the end of the Maastrichtian is also present in Southern hemisphere, in the South Atlantic (LI & KELLER, 1998 a,b). Stable isotope analysis showed a major warm pulse between 66.45 and 65.11 Ma, which increased temperatures by 2-3° C in intermediate waters, and decreased the vertical thermal gradient to an average of 2.7°C.

Planktonic Foraminifera provide a high resolution biozonation for the K/T boundary and various zonal schemes have been proposed (Text-fig. 6). Among these, the zonal scales of SMIT (1982), KELLER (1988 a; 1993; also *in* CANUDO *et al.*,1991) and the scale of the present paper are very similar, but differ from that proposed by BERGGREN & MILLER, 1988. The presence of Zone P0 marks the boundary clay and Zone P1a marks the base of the Danian. The Mangyshlak PF data show a close similarity with Danish sections (BANG, 1979; HÅKANSSON & HANSEN, 1979). In both regions towards the end of the *Pseudotextularia deformis* Zone, the genus *Globotruncana* disappeared and the *Heterohelix - Hedbergella - Globigerinelloides* assemblage became dominant and some of them can be followed into the base of the Danian. The PF assemblages of the terminal Maastrichtian, just below the boundary clay are very poorly preserved in Denmark and in Mangyshlak.

PF are practically absent within the boundary clay (P0 Zone), except for a few small survivors species of *Heterohelix, Hedbergella* and *Globigerinelloides* in Denmark and in Mangyshlak.

PF are very scarce in the base of the Danian, represented by a few Palaeocene species in Mangyshlak: *Eoglobigerina fringa* (Subbotina), *Eoglobigerina* sp. and possibly *Parvulorugoglobigerina eugubina* (Luterbacher & Premoli Silva). In the subzone P1a Cretaceous survivors disappeared. In several sections of North Jutland (Kjölby Gaard and "Dania" Quarry) just above the boundary clay PF are absent (equivalent of the "a-planktonic zone" of HOFKER, 1978), but sometimes (section Nye Kløv) *Eoglobigerina danica* Zone was recognized. In addition to the genus *Eoglobigerina,* this Zone is characterized by *Chiloguembelina* spp., *Woodringia* sp. and *Guembelitria* spp. The thickness of this interval at Dania is about 2-5 m (BANG, 1979; HÅKANSSON & HANSEN, 1979), very similar with P1a Subzone of the Mangyshlak sections. The upper boundary of the *Eoglobigerina danica* Zone is defined by the first occurrence of *Globoconusa daubjergensis* (Brönnimann).

Higher Danian deposits in Mangyshlak contain typical

Palaeocene PF, among which *Subbotina pseudobulloides* (Plummer) and *Globoconusa daubjergensis* (Brönnimann) are very important. The PF zonation of Mangyshlak is closely correlatable with the standard nannofossil zonation (MARTINI, 1970; THIERSTEIN, 1976; SISSINGH, 1978; PERCH-NIELSEN, 1979; OKADA & BUKRY, 1980).

The distribution of BF in the terminal Maastrichtian and Lower Danian is practically identical all over the EPA (see BENIAMOVSKII & KOPAEVICH, 1998).

Conclusions

1. According to foraminiferal data, the zonation across the K/T boundary of Mangyshlak can be applied without any difficulty to coeval strata in western Europe and especially in the Danish sections.
2. A deepening of the basin and warmer environmental conditions are indicated in the terminal chalk of the *Pseudotextularia deformis/elegans* Zone of both Mangyshlak sections (last 2-2.5 m), by the high P/B ratio. This terminal P/B increasing coincides with the short Late Maastrichtian *elegans* - transgression (WICHER, 1953).
3. The disappearance of PF inside the boundary clay coincided with the peak of the biotic crisis, generally attributed to a "global catastrophic event." This represented the time of lowest productivity for PF (PERCIVAL & FISCHER, 1977; GERSTEL *et al.*, 1986; KELLER, 1996). Our data show that the extinction of Cretaceous species occurred throughout an interval that extends from the uppermost *Pseudotextularia deformis/elegans* Zone through the Danian P1a Zone.
4. The occurrence of typical Danian species and the coeval disappearance of "Cretaceous" species begins in the *Subbotina pseudobulloides* Zone.

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References

ALEKSEEV, A. S. & KOPAEVICH, L. F., 1997. Foraminiferal biostratigraphy of the uppermost Campanian-Maastrichtian in SW Crimea (Bakhchisaray and Chakhmakhly sections). *Bulletin Institut royal Sciences naturelles de Belgique, Sciences de la Terre,* **67**: 103-118.

ALEKSEITCHIK, S. N. Geologicheskoe stroenie i neftenosnost poluostrova Mangyshlaka. *Trudy NIGRI,* n.s., **16**: 1-235 [in Russian].

AMON, E. O., BLUEFORD, J. R., DE WEVER, P. & ZHELEZKO, V. I., 1997. An essay on regional geology and stratigraphy of the Upper Cretaceous deposits of Southern Urals territories. *Geodiversitas,* **19** (2): 293-317.

ANDRUSOV, N. I., 1915. Materials for the Transcaspian Geology: Mangyshlak (Descriptive Part). *Trudy Aralo-Kaspiiskoi Ekspeditsii,* **8**: 1-458 [in Russian].

BANG, I., 1979. Foraminifera in the lowermost Danian of Denmark. *In:* BIRKELUND, T. & BROMLEY, R. (eds). Proceedings of Symposium on Cretaceous — Tertiary Boundary Events: Copenhagen, Denmark. University of Copenhagen, **1:** 108-114.

BENIAMOVSKII, V. N. & KOPAEVICH, L. F., 1998. Foraminiferid Zonation in the Upper Santonian — Maastrichtian of the European Palaeobiogeographical Area (EPA). *Zentralblatt für Geologie und Paläontologie, Teil I,* 1996, 11/12: 1149-1169.

BERGGREN, W. A. & MILLER, K. G., 1988. Paleogene tropical foraminiferal biostratigraphy and magnetobiochronology. *Micropaleontology,* **34:** 362-380.

BOLLI, H. M., 1966. Zonation of Cretaceous to Pliocene marine sediments based on planktonic foraminifera. *Boletino Informativo Asociacion Venezolano de Geologia, Mineria y Petroleo.* **9:** 3-32.

BYKOVA, N. K., 1960. Danian and Paleogene deposits of North Mangyshlak and South Emba area. *International Geological Congress. XXI session. Reports of soviet geologists.* Problem 5. The Cretaceous-Tertiary boundary. 148-161 [in Russian].

CANUDO, J. I., KELLER, G. & MOLINA, E., 1991. Cretaceous/Tertiary boundary extinction pattern and faunal turnover at Agost and Caravaca, S. E. Spain. *Marine Micropaleontology,* **17**: 319-341.

CARON, M., 1985. Cretaceous planktonic Foraminifera. *In:* H. M. BOLLI, J. B. SAUNDERS & K. PERCH-NIELSEN, Plankton stratigraphy, pp. 17-86. Cambridge University Press.

CAVELIER, C. & POMEROL, C., 1983. Echelle de corrélation stratigraphique du Paléogène. Stratotypes, étages standards, biozones, chimiozones et anomalies magnétiques. *Géologie de la France,* **3**: 261-262.

CAVELIER, C. & POMEROL, C., 1986. Stratigraphy of the Paleogene. *Bulletin Société géologique de France,* (8) **2**: 255-265.

GAWOR-BIEDOWA, E., 1992. Campanian and Maastrichtian Foraminifera from the Lublin Upland, Eastern Poland. *Acta Palaeontologica Polonica,* **52**: 3-187.

GERSTEL, J., THUNNEL, R., ZACHOS, J. C. & ARTHUR, M. A.. 1986. The Cretaceous/Tertiary boundary events in the North Pacific: Plankton foraminifera results from Deep Sea Drilling Project Site 577, Shatsky Rise. *Paleoceanography,* **1**, 2: 97-117.

HÅKANSSON, E. & HANSEN, J. M., 1979. Guide to Maastrichtian and Danian boundary strata in Jylland. *In:* BIRKELUND, T. & BROMLEY, R. (eds.). Proceedings of Symposium on Cretaceous - Tertiary Boundary Events: Copenhagen, Denmark. University of Copenhagen, **1:** 171-188.

HERMAN, Y., BHATTACHARAYA, S. K., PERCH-NIELSEN, K., KOPAEVITCH, L. F., NAIDIN, D. P., FROLOV, V. T., JEFFERS, J. D. & SARKAR, A. 1988. Cretaceous-Tertiary boundary marine extinctions: The Russian Platform record. *Revista Española de Pa-*

leontologia, Numero Extraordinario. Paleontology and evolution: Extinction events, pp. 31-40.

HOFKER, J., 1978. Analysis of a large succession of samples through Upper Maastrichtian and the Lower Tertiary of drillhole 47-2 Shatsky Rise, Pacific, Deep Sea Drilling Project. *Journal of Foraminiferal Research,* **8** (1): 46-75.

JONES, D. S., MUELLER, P. A., BRYAN, J. R., DOBSON, J. P., CHANNELL, J. E. T., ZACHOS, J. C. & ARTHUR, M. A. 1987. Biotic, geochemical and paleomagnetic changes across the Cretaceous/Tetiary boundary at Braggs, Alabama. *Geology,* **15:** 311-315.

KAIHO, K. & SAITO, T., 1986. Terminal Cretaceous Sedimentary Sequence recognized in the Northernmost Japan based on Planktonic Foraminiferal Evidence. *Proceedings of the Japan Academy,* (5) **62**: 145-148.

KELLER, G., 1988 a. Extinction, survivorship and evolution of planktic foraminifers across the Cretaceous/Tertiary boundary at El-Kef, Tunisia. *Marine Micropaleontology,* **13:** 239-263.

KELLER, G., 1988 b. Biotic turnover in benthic foraminifera across the Cretaceous/Tertiary boundary at El-Kef, Tunisia. *Palaeogeography, Palaeoclimatology, Palaeoecology,* **66:** 153-171.

KELLER, G., 1989. Extended period of extinctions across the Cretaceous — Tertiary boundary in planktonic foraminifers of continental shelfs sections: applications for impact and volcanism theories. *Geological Society of America Bulletin,* **101**, 11: 140-1419.

KELLER, G., 1993. The Cretaceous-Tertiary boundary transition in the Antarctic Ocean and its global implications. *Marine Micropaleontology,* **21:** 1-45.

KELLER, G., 1996. The Cretaceous-Tertiary mass extinction on planktic Foraminifera: Biotic constraints for catastrophe theories. *In:* MACLEOD, N. & KELLER, G., Eds., Cretaceous-Tertiary mass extinctions. W.W.Norton & Co. New York; pp. 45-84.

KELLER, G., ADATTE, Th., HOLLIS, Ch., ORDONEZ, M., ZAMBRANO, M., JIMENEZ, N., STINNESBECK, W., ALEMAN, A. & HALE-ERLICH, W. 1997. The Cretaceous/Tertiary boundary event in Ecuador: reduced biotic effects due to eastern boundary current setting. *Marine Micropaleontology,* **31:** 97-133.

KELLER, G. & MACLEOD, N., 1995. The Cretaceous/Tertiary boundary stratotype section at El Kef, Tunisia: how catastrophic was the mass extinction? *Palaeogeography, Palaeoclimatology, Palaeoecology,* **119**: 221-254.

KOCH, W., 1977. Stratigraphie der Oberkreide in Nordwestdeutschland (Pompeckjische Scholle). T. 2. Biostratigraphie in der Oberkreide und Taxonomie von Foraminifera. *Geologisches Jahrbuch,* **A 38**: 3-123.

LEONOV, G. P. & ALIMARINA, V. P., 1961. Stratigraphy and planktonic foraminifers of the ''transitional'' Cretaceous to Paleogene beds of the Central Precaucasus. Sbornik Trudov Geologicheskogo Fakulteta Moskovskogo Universiteta: pp. 29-53 [in Russian].

LI, L. & KELLER, G., 1998. Abrupt deep-sea warming at the end of the Cretaceous. *Geology,* **26**: 995-998.

LUTTERBACHER, H. P. & PREMOLI-SILVA, I., 1964. Biostratigraphia del limite Cretaceo-Terziario nell' Appennino centrale. *Rivista Italiana Paleontologia i Stratigrafia,* **70:** 67-128.

MACLEOD, N. & KELLER, G., 1994. Comparative biogeographic analysis of planktic foraminiferal survivorship across the Cretaceous/Tertiary boundary. *Paleobiology,* **20** (2): 143-177.

MALMGREN, B. A., 1982. Biostratigraphy of planktic Foraminifera from the Maastrichtian white chalk of Sweden. *Geologiska Föreningens Stockholm Förhandlingar,* **103**: 357-375.

MARTINI, E., 1970. Standard Palaeogene calcareous nannoplankton zonation. *Nature,* **226:** (5245), 560-561.

MASLAKOVA, N. I., 1978. Globotruncanids from the southern part of European USSR. Nauka, Moscow. 166 pp. [in Russian].

MOLINA, E., ARENILLAS, I. & ARZ, J. A. 1998. Mass extinction in planktic foraminifera at the Cretaceous/Tertiary boundary in subtropical and temperate latitudes. *Bulletin Société géologique de France,* **169** (3): 351-363.

NAIDIN, D. P., 1969. Biostratigraphie und Paläogeographie der Oberen Kreide der Russischen Tafel. *Geologisches Jahrbuch,* **A 87**: 157- 186.

NAIDIN, D. P., 1986. Cretaceous/Tertiary boundary in Mangyshlak and proposed events on the limit of the Maastrichtian and Danian. *Izvestia vuzov. Geologia i razvedka,* **9**: 3-13 [in Russian].

NAIDIN, D. P., 1987. The Cretaceous-Tertiary boundary in Mangyshlak. U.S.S.R. *Geological Magazine,* **124**, 1: 11-19.

NAIDIN, D. P., BENIAMOVSKII, V. N. & KOPAEVICH, L. F., 1984. A scale for a biostratigraphic subdivision of the Upper Cretaceous of the European palaeobiogeographical area. *Vestnik Moskovskogo Universiteta. (4) Geologia,* **5:** 3-15.

NAIDIN, D. P., BEN'YAMOVSKII, V. N. & KOPAEVICH, L. F., 1996. Paleocene reference sections of Mangyshlak. *Stratigraphy and Geological Correlation,* **4** (3): 254-268.

NAIDIN, D. P., KOPAEVICH, L. F., MOSKVIN, M. M., SHIMANSKAYA, N. V., KALINITCHENKO, G. P. & ANDREEV, Ju. N., 1990a. Macropaleontological data on the Maastrichtian/Danian boundary from continuous sections in Mangyshlak. *Izvestia Akademii Nauk SSSR, Serija Geologia,* **11**: 3-15 [in Russian].

NAIDIN, D. P., KOPAEVICH, L. F., MOSKVIN, M. M., SHIMANSKAYA, N. V., KALINITCHENKO, G. P. & ANDREEV, Ju. N., 1990 b. Micropaleontological data on the Maastrichtian/Danian boundary of continuous sections in Mangyshlak. *Izvestia Akademii Nauk SSSR, Serija Geologia,* **12**: 68-82 [in Russian].

NAZAROV, M. A., BARSUKOVA, L. D., KOLESOV, G. M., NAIDIN, D. P. & ALEKSEEV, A. S., 1983. Origin of the iridium anomaly at the boundary between the Maastrichtian and Danian stages. *Geokhimia,* **8**: 1160-1178 [in Russian].

OBERHÄNSLI, H., KELLER, G., ADATTE, T. & PARDO, A., 1998. Diagenetically and environmentally controlled changes across the K/T transition at Koshak, Mangyshlak (Kazakhstan). *Bulletin Société géologique de France* **169**, 4: 493-501.

OKADA, H. & BUKRY, D., 1980. Supplementary modification and introduction of code numbers to the lowlatitude coccolith biostratigraphic zonation. *Marine Micropaleontology,* **5** (3): 321-325.

PERCH-NIELSEN, K., 1979. Calcareous nannofossils in Cretaceous /Tertiary boundary sections on Denmark. *In:* BIRKELUND, T. & BROMLEY, R. (eds). Proceedings of Symposium on Cretaceous — Tertiary Boundary Events: Copenhagen, Denmark. University of Copenhagen, **1:** 115-135.

PERCIVAL, S. F. & FISCHER, A. G., 1977. Changes in calcareous nannoplankton in the Cretaceous-Tertiary biotic crisis at Zumaya, Spain. *Evolutionary Theory,* **2**: 1-35.

PERYT, D., LAHODYNSKY, R., ROCCHIA, R. & BOCLET, D., 1993. The Cretaceous/Paleogene boundary and planktonic foraminifera in the Flyschgosau (Eastern Alps, Austria). *Palaeogeography, Palaeoclimatology, Palaeoecology,* **104**: 239-252.

PREMOLI SILVA, I., 1977. Upper Cretaceous-Paleocene magnetic stratigraphy at Gubbio, Italy. Biostratigraphy. *Geological Society of America, Bulletin,* **88**, 2: 371-374.

PREMOLI-SILVA, I. & BOLLI, H. M., 1973. Late Cretaceous to Eocene planktonic foraminifera and stratigraphy of Leg 15 sites in Caribbean Sea. *In:* N. T. EDGAR *et al., Initial Report Deep Sea Drilling Project,* **15:** 449-547.

RAMPINO, M. R. & REYNOLDS, R.G., 1983. Clay mineralogy of Cretaceous/Tertiary boundary clay. *Science,* **219** (4584): 495-498.

ROBASZYNSKI, F., BLESS, M. J., FELDER, P. J., FOUCHER, J.-C., LEGOUX, O., MANIVIT, H., MEESSEN, J.P.M.Th. & VAN DER TUUK, L. A., 1985. The Campanian-Maastrichtian boundary in the chalky facies close to the type-Maastrichtian area. *Bulletin Centre de Recherche, Exploration, Production Elf-Aquitaine,* **9**: 1-113.

ROBASZYNSKI, F. & CHRISTENSEN, W. K., 1989. The Upper Campanian - Lower Maastrichtian chalks of the Mons basin: a preliminary study of belemnites and foraminifera in the Harmignies and Ciply areas. *Geologie en Mijnbouw,* **68:** 391-408.

ROSENKRANTZ, A., 1924. Nye lagtagelser over Ceritiumkalken i Stevns Klint med Bemaerkninger om Graeng sen mellom Kridt og Tertiaer. *Meddedelser Danske Geologiske Foreningerne,* **6:** 28-31.

SARKAR, A., BHATTACHARYA, S. K., SHUKLA, P. N., BHANDARI, N. & NAIDIN, D. P., 1992. High resolution profile of stable isotopes and iridium across a K/T/ boundary section from Koshak Hill, Mangyshlak, Kazakhstan. *Terra Nova,* **4:** 585-590.

SCHÖNFELD, J., 1990. Zur Stratigraphie und Ökologie benthischer Foraminiferen in Schreibkreide-Richtprofil von Lägerdorf/ Holstein. *Geologisches Jahrbuch,* **A 117**: 3-151.

SCHÖNFELD, J. & BURNETT, J. A., 1991. Biostratigraphical correlation of the Campanian-Maastrichtian boundary: Lägerdorf-Hemmoor (northwestern Germany), DSDP Site 548A, 549 and 551 (eastern North Atlantic) with palaeobiogeographical and palaeoceanographical implications. *Geological Magazine,* **128,** 5: 479-503.

SEMENOV, V. P., 1899. Fauna of Cretaceous Deposits of Mangyshlak and other Areas of the Transcaspian Region. *Trudy St.-Peterburgskogo Ob-va Estestvoispytatelei Prirody. Otdelenie Geologii i Mineralogii,* **28** (5)**:** 1-178 [in Russian].

SISSINGH, W., 1978. Microfossil biostratigraphy and stage stratotypes of the Cretaceous. *Geologie en Mijnbouw,* **57** (3): 440-443.

SMIT, J., 1977. Discovery of a planktonic foraminiferal association between the Abathomphalus mayaroensis Zone and the Globigerina eugubina Zone at the Cretaceous-Tertiary boundary in the Barranco del Gredero (Caravaca, Spain). *Proceedings of the Nederlandse Akademie der Wetenschappen,* **B 80**: 280-301.

SMIT, J., 1982. Extinction and evolution of planktonic Foraminifera after a major impact at the Cretaceous/Tertiary boundary. *Geological Society American. Special Paper,* **190:** 329-352.

STENESTAD, E., 1979. Upper Cretaceous foraminifera from Danish Basin. *In:* BIRKELUND, T. & BROMLEY, R. (eds.). Proceedings of Symposium on Cretaceous — Tertiary Boundary Events: Copenhagen, Denmark. University of Copenhagen, **1:** 101-107.

THIERSTEIN, H. R., 1976. Mesozoic calcareous nannoplankton biostratigraphy of marine sediments. *Marine Micropaleontology,* **1:** 325-362.

TOUMARKINE, M. & LUTERBACHER, H., 1985. Paleocene and Eocene planktic foraminifera. *In:* H. M. BOLLI, J. B. SAUNDERS & K. PERCH-NIELSEN, Plankton stratigraphy, pp. 87-154. Cambridge University Press.

TRIFONOV, N. K., 1959. Novye dannye po stratigrafii verkhnego mela poluostrova Mangyshlaka. *Trudy Vsesoyuznogo Nauchno-Issledovatelskogo Geologo-Razvedochnogo Neftianogo Instituta (VNIGRI),* **131:** 297-301 [in Russian].

TRIFONOV, N. K. & BURAGO, A. M., 1960. Verkhnemelovye otlozhenia Mangyshlaka. Stratigrafia i fatsii. *Trudy Vsesoyuznogo Nauchno-Issledovatelskogo Geologo-Razvedochnogo Neftianogo Instituta (VNIGRI),* **157:** 195 pp. [in Russian].

VASSILENKO, V. P., 1961. Upper Cretaceous Foraminifera of Mangyshlak peninsula. *Trudy Vsesoyuznogo Nauchno-Issledovatelskogo Geologo-Razvedochnogo Neftianogo Instituta (VNIGRI),* **61:** 1-487. Leningrad [in Russian].

WICHER, C. A., 1953. Micropaläontologische Beobachtungen in der höheren borealen Oberkreide, besonders im Maastricht. *Geologisches Jahrbuch,* **B 68**: 1-26.

WIDMARK, J.G.V. & SPEIJER, R.P., 1997. Benthic foraminiferal ecomarker species of the terminal Cretaceous (late Maastrichtian) deep-sea Tethys. *Marine Micropaleontology,* **31**: 135-155.

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Explanation of Plates

All the figured specimens are preserved in the collection of the micropaleontological unit of Palaeontology, Geological Faculty, Moscow State University

Plate 1

Figure 1 — *Orbignyna ovata* (von Hagenow): Kyzylsai section, sample 4 (X50).
Figure 2 — *Orbignyna inflata* (Reuss): Kyzylsai section, sample 6 (X50).
Figure 3 — *Arenobulimina acuta* Woloschyna: Koshak section, sample 111 (X100).
Figure 4 — *Gaudryina* aff. *jonesiana* Wright: Koshak section, sample 107 (X80).
Figure 5 — *Gaudryina rugosa* d'Orbigny: Koshak section, sample 103 (X80).
Figure 6 — *Arenobulimina vialovi* Woloschyna: Koshak section, sample 108 (X80).
Figure 7 — *Plectina convergens* (Keller): Koshak section, sample 101 (X70).
Figure 8 — *Ataxophragmium crassum* (d'Orbigny): Kyzylsai section, sample 10 (X70).
Figure 9 — *Plectina ruthenica* (Reuss): Kyzylsai section, sample 34 (X70).
Figure 10 — *Neoflabellina reticulata* (Reuss): Koshak section, sample 104 (X60).
Figure 11 — *Angulogavelinella gracilis* (Brotzen): spiral side; Kyzylsai section, sample 6 (X80).
Figure 12 — *Angulogavelinella gracilis* (Brotzen): umbilical side; Kyzylsai section, sample 6 (X70).
Figure 13 — *Gavelinella danica* (Brotzen): spiral side; Koshak section, sample 155 (X100).
Figure 14 — *Gavelinella danica* (Brotzen): umbilical side; Koshak section, sample 145 (X100).

Plate 2

Figure 1 — *Cibicidoides aktulagayensis* (Vassilenko): spiral side; Koshak section; sample 101 (X60).
Figure 2 — *Stensoeina pommerana* Brotzen: Kyzylsai section, sample 1 (X100).
Figure 3 — *Angulogavelinella gracilis* (Brotzen): umbilical side; Kyzylsai section, sample 6 (X100).
Figure 4 — *Cibibcides kurganicus* Neckaja: spiral side; Kyzylsai section, sample 4 (X100).
Figure 5 — *Cibibcides kurganicus* Neckaja: umbilical side; Kyzylsai section, sample 4 (X100).
Figure 6 — *Karreria fallax* Rzehak: spiral side; Kyzylsai section, sample 34 (X70).
Figure 7 — *Coleites crispus* Vassilenko: Koshak section, spiral side, sample 113 (X70).
Figure 8 — *Brotzenella praeacuta* (Vassilenko): spiral side; Kyzylsai section, sample 35 (X100).
Figure 9 — *Brotzenella praeacuta* (Vassilenko): umbilical side; Kyzylsai section, sample 35 (X100).
Figure 10 — *Cibicidoides voltzianus* (d'Orbigny): spiral side; Koshak section, sample 109 (X70).
Figure 11 — *Cibicidoides voltzianus* (d'Orbigny): umbilical side; Koshak section, sample 109 (X70).
Figure 12 — *Gyroidinoides turgidus* (d'Orbigny): spiral side; Koshak section, sample 108 (X70).
Figure 13 — *Gyroidinoides turgidus* (d'Orbigny): umbilical side; Koshak section, sample 108 (X70).
Figure 14 — *Gyroidinoides turgidus* (d'Orbigny): peripheral side; Koshak section, sample 108 (X70).
Figure 15 — *Anomalinoides pinguis* (Jennings): spiral side; Koshak section, sample 113 (X70).
Figure 16 — *Anomalinoides pinguis* (Jennings): umbilical side; Koshak section, sample 113 (X70).
Figure 17 — *Anomalinoides pinguis* (Jennings): umbilical side; Kyzylsai section, sample 3 (X100).

Plate 3

Figure 1 — *Bolivina decurrens* (Ehrenberg): Kyzylsai section, sample 2 (X100).
Figure 2 — *Bolivina incrassata incrassata* (Reuss): Kyzylsai section, sample 6 (X70).
Figure 3 — *Bolivina incrassata crassa* (Vassilenko): Kyzylsai section, sample 13 (X70).
Figure 4 — *Bolivinoides decoratus* (Jones): Koshak section, sample 101 (X50).
Figure 5 — *Bolivinoides decoratus* (Jones): Koshak section, sample 101 (X50).
Figure 6 — *Bolivinoides peterssoni* Brotzen: Koshak section, sample 101 (X50).
Figure 7 — *Bolivinoides draco draco* Marsson: Koshak section, sample 112 (X100).
Figure 8 — *Praebulimina laevis* (Beissel): Koshak section, sample 112 (X50).
Figure 9 — *Pyramidina cimbrica* (Brotzen): Kyzylsai section; sample 6 (X140).
Figure 10 — *Pseudouvigerina cristata* (Marsson): Kyzylsai section; sample 4 (X100).
Figure 11 — *Cibicidoides commatus* (Morozova): spiral side; Koshak section, sample 155 (X100).
Figure 12 — *Hanzawaia ekblomi* (Brotzen): spiral side; Kyzylsai section, sample 37 (X100).
Figure 13 — *Hanzawaia ekblomi* (Brotzen): umbilical side; Kyzylsai section, sample 37 (X100).

Figure 14 — *Cibicidoides hemicompressus* (Morozova): spiral side; Koshak section, sample 145 (X60).
Figure 15 — *Cibicidoides hemicompressus* (Morozova): umbilical side; Koshak section, sample 145 (X80).
Figure 16 — *Anomalinoides subcarinatus* (Cushman & Deaderick): spiral side; Kyzylsai section, sample 16 (X90).
Figure 17 — *Gavelinella midwayensis* (Plummer): spiral side; Kyzylsai section, sample 2 (X60).
Figure 18 — *Gavelinella midwayensis* (Plummer): umbilical side; Kyzylsai section, sample 2 (X100).
Figure 19 — *Gavelinella pertusa* (Marsson): spiral side; Koshak section, sample 155 (X100).
Figure 20 — *Gavelinella pertusa* (Marsson): umbilical side; Koshak section, sample 155 (X100).

PLATE 4

Figure 1 — *Hedbergella monmouthensis* (Olsson): umbilical side, Kyzylsai section, sample 9 (X100).
Figure 2 — *Heterohelix striata* (Ehrenberg): Koshak section, sample 112 (X100).
Figure 3 — *Pseudotextularia deformis* (Kikoine): Koshak section, sample 112 (X100).
Figure 4 — *Globigerinellodes volutus* White: umbilical side, Koshak section; sample 108 (X100).
Figure 5 — *Globotruncana arca* (Cushman): spiral side; Koshak section, sample 112 (X70).
Figure 6 — *Globotrucana bulloides* Vogler: spiral side; Koshak section; sample 112 (X70).
Figure 7 — *Globotruncana ventricosa* White: spiral side; Kyzylsai section; sample 8 (X70).
Figure 8 — *Rugoglobigerina* sp. : spiral side; Koshak section; sample 112 (X70).
Figure 9 — *Eoglobigerina trivialis* (Subbotina): spiral side; Koshak section, sample 165 (X100).
Figure 10 — *Eoglobigerina trivialis* (Subbotina): umbilical side; Koshak section, sample 165 (X100).
Figure 11 — *Subbotina varianta* (Subbotina): spiral side; Koshak section, sample 155 (X130).
Figure 12 — *Subbotina varianta* (Subbotina): umbilical side; Koshak section, sample 155 (X130).
Figure 13 — *Subbotina pseudobulloides* (Plummer): spiral side; Kyzylsai section, sample 35 (X130).
Figure 14 — *Subbotina pseudobulloides* (Plummer): umbilical side; Kyzylsai section, sample 35 (X130).
Figure 15 — *Subbotina triloculinoides* (Plummer): spiral side; Koshak section, sample 155 (X130).
Figure 16 — *Globoconusa daubjergensis* (Brönnimann): spiral side; Koshak section, sample 150 (X130).
Figure 17 — *Globoconusa daubjergensis* (Brönnimann): umbilical side; Koshak section, sample 150 (X150).
Figure 18 — *Planorotalites compressa* (Plummer): spiral side; Kyzylsai section, sample 45 (X130).
Figure 19 — *Planorotalites compressa* (Plummer): umbilical side; Kyzylsai section, sample 45 (X160).

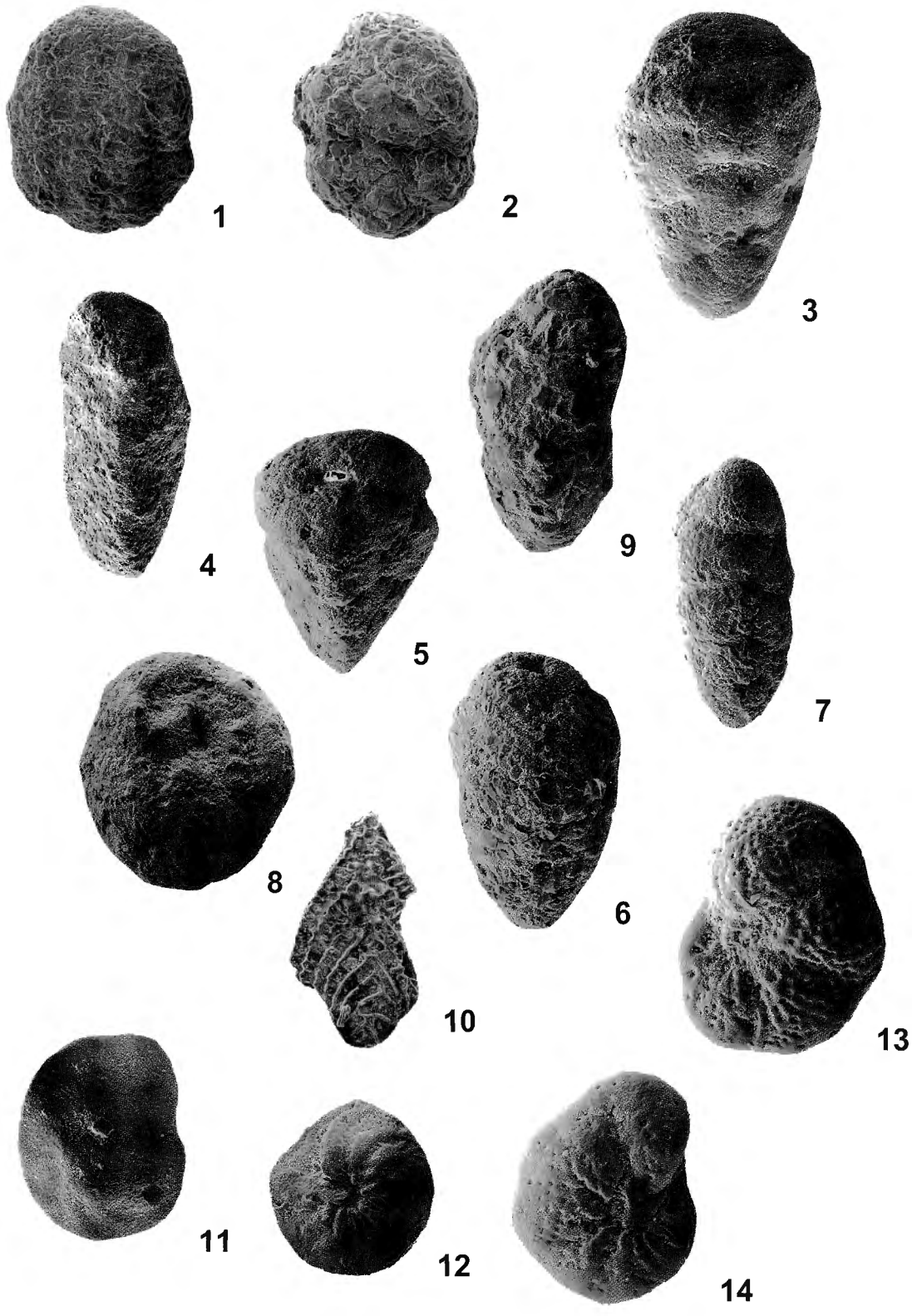

PLATE 1

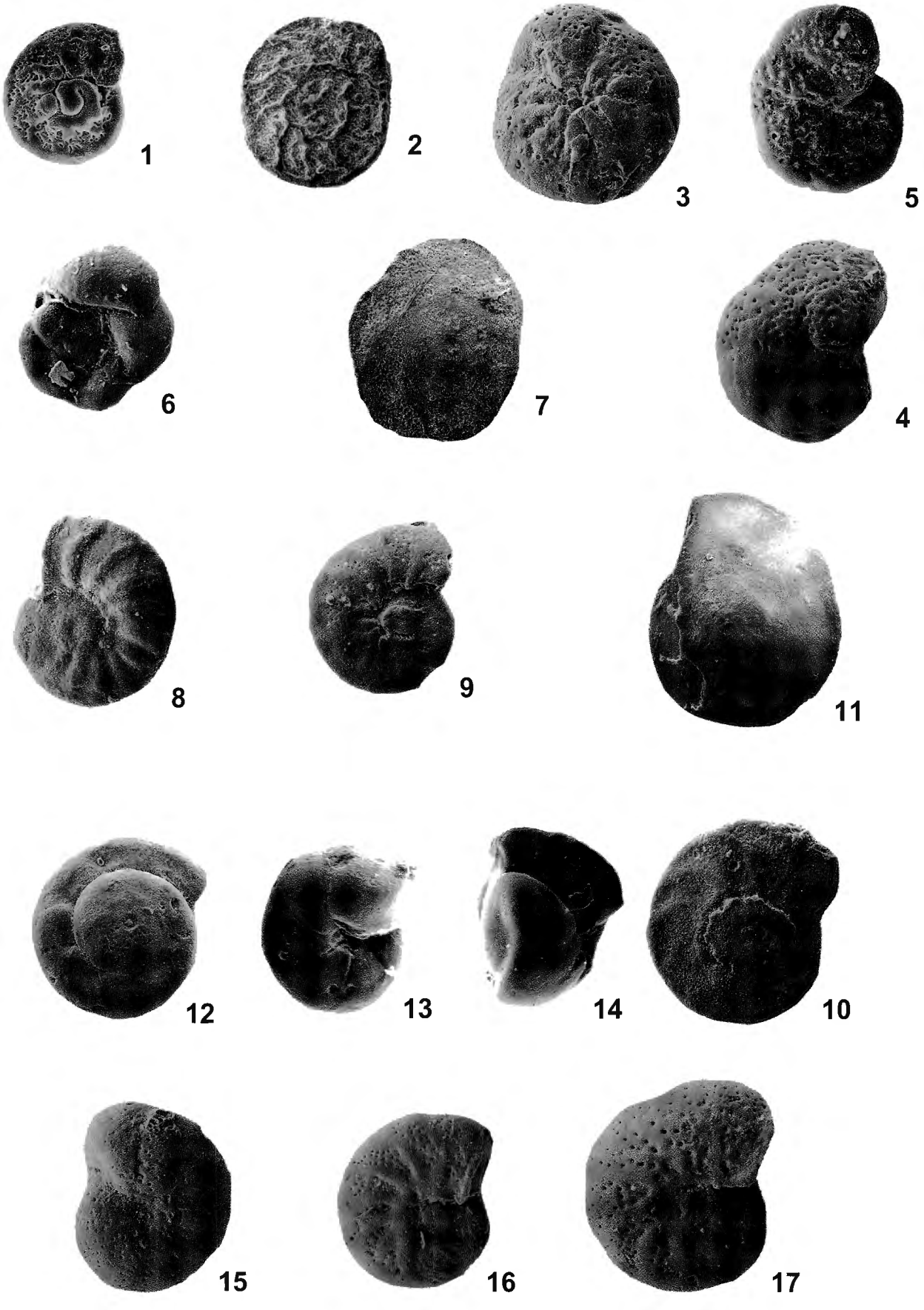

PLATE 2

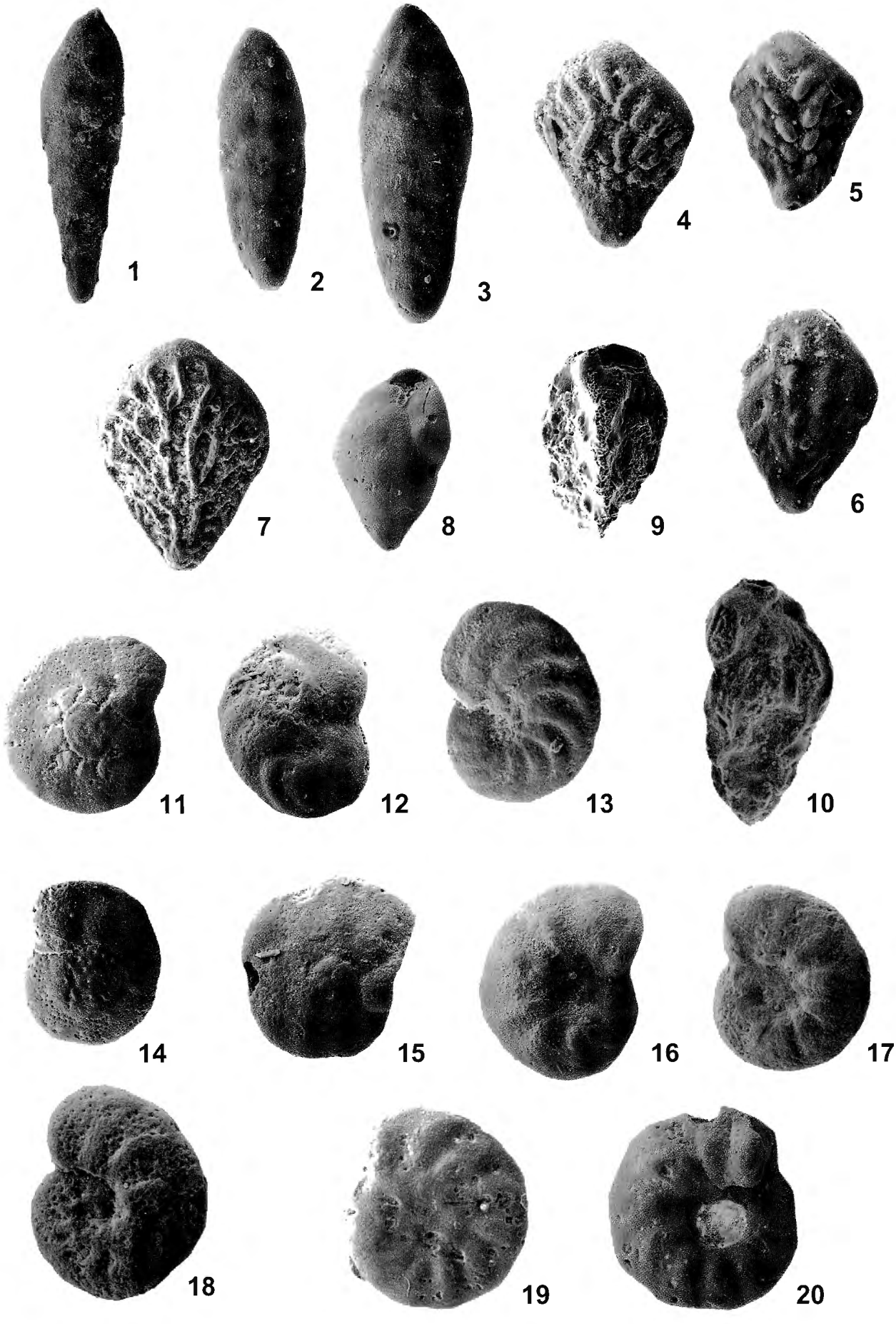

PLATE 3

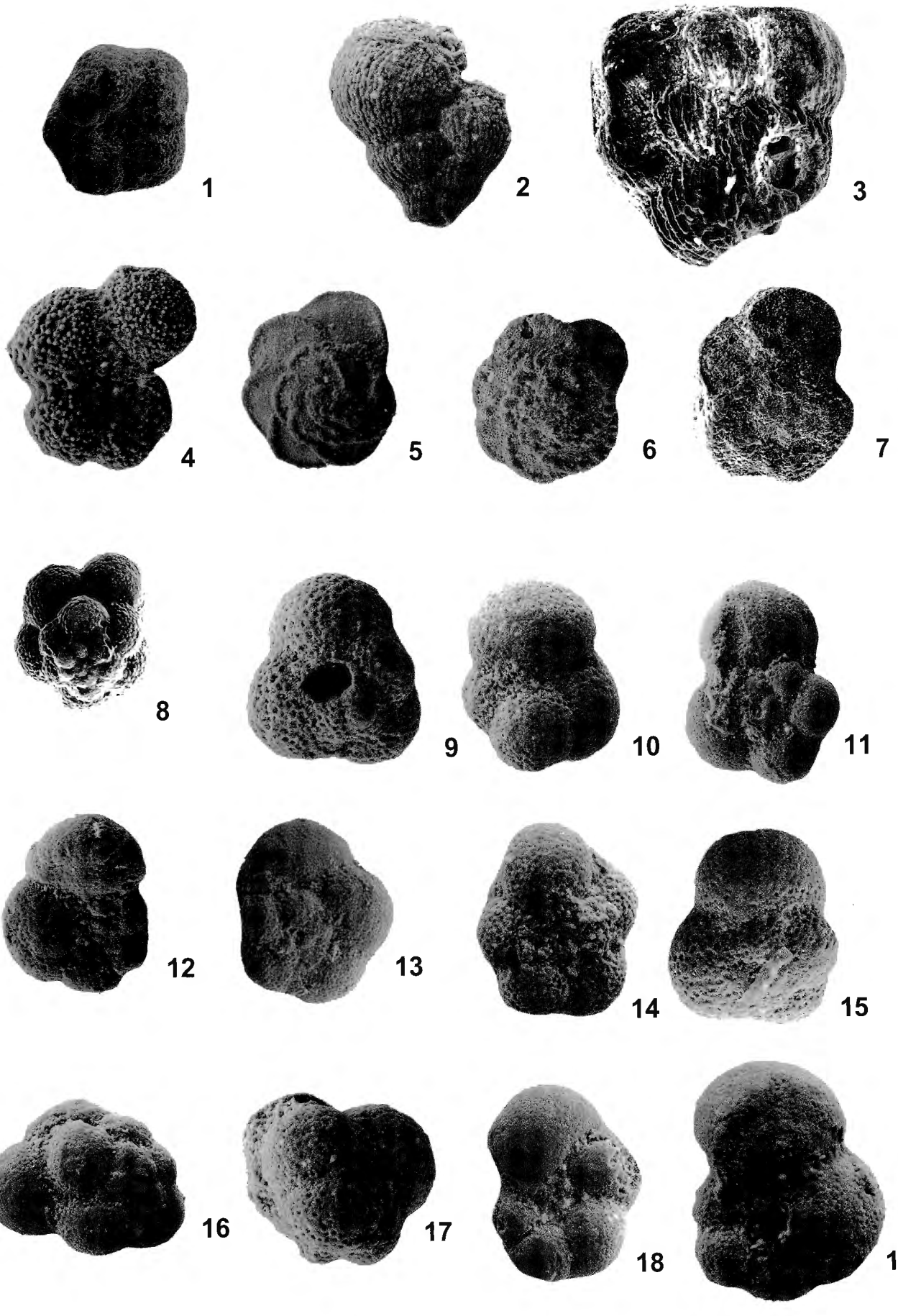

PLATE 4