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CENOMANIAN TO LOWER EOCENE DEEP-WATER AGGLUTINATED FORAMINIFERA FROM THE ZUMAYA SECTION, NORTHERN SPAIN

Wolfgang KUHNT[1] & Michael A. KAMINSKI[2]

[1] *Geologisch-Paläontologisches Institute, CAU, Olshausenstr. 40, D-24118 Kiel, Germany*
[2] *Research School of Geological & Geophysical Sciences, Birkbeck College & University College London, Gower St. London, WC1E 6BT, U.K.*

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Abstract: An analysis of 71 samples from the Zumaya Section of northern Spain ranging in age from Cenomanian to lower Eocene enabled us to calibrate the biostratigraphic ranges of Deep-Water Agglutinated Foraminifera (DWAF) to the standard planktonic foraminiferal zonal schemes. Comparison with the standard "Geroch and Nowak" zonation of DWAF provides further evidence for the supraregional validity of this zonation, as well as new information on the palaeobiogeography of many of the species first described from the Flysch Carpathians. The nominate taxa of six of the seven Turonian–Palaeocene DWAF zones defined by Geroch and Nowak (1984) were observed in their proper stratigraphic succession at Zumaya (the *Ammobaculites problematicus, Uvigerinammina jankoi, Goesella rugosa, Hormosina ovulum gigantea*, and *Spiroplectammina spectabilis* zones of Geroch & Nowak). Only the index taxon of the lower Paleocene *Rzehakina fissistomata* Zone was not observed, however this zone may be recognised based on alternate criteria (the last occurrence of *Goesella rugosa*). The benthic foraminiferal extinction at the Palaeocene/Eocene boundary is proposed as an alternate criterion to delimit the top of the *Spiroplectammina spectabilis* Zone.

Abstrakt: Analiza 71 próbek z profilu Zumaya w północnej Hiszpanii, obejmującego utwory od cenomanu do dolnego eocenu, pozwoliła na wyznaczenie zasięgów stratygraficznych głębokowodnych otwornic aglutynujących oraz na korelacje tych zasięgów ze standardową biozonacją opartą na otwornicach planktonicznych. Analizując zasięgi otwornic aglutynujących z tego profilu profilu potwierdzono uniwersalny charakter biozonacji zaproponowanej przez Gerocha i Nowaka (1984) oraz stwierdzono jej przydatność również dla obszarów pozakarpackich. Praca dostarcza także nowych danych z zakresu paleobiogeografii gatunków otwornic aglutynujących, opisanych z fliszu karpackiego. Badania potwierdziły następstwo stratygraficzne pięciu poziomów (*Ammobaculites problematicus, Uvigerinammina jankoi, Goesella rugosa, Hormosina ovulum gigantea* oraz *Spiroplectammina spectabilis sensu* Geroch & Nowak) opartych na gatunkach wyznaczonych jako przewodnie przez Gerocha i Nowaka (1984). Jedynie gatunek indeksowy dla dolnopaleoceńskiego poziomu *Rzehakina fissistomata* nie został znaleziony w badanym profilu. W pracy zaproponowano zastępcze kryterium do wyznaczenia poziomu *Rzehakina fissistomata* – zanik gatunku *Goesella rugosa*. Zanik licznych gatunków otwornic bentonicznych na granicy paleocenu i eocenu może być dodatkowym kryterium do wyznaczenia górnej granicy poziomu *Spiroplectammina spectabilis*.

Key words: benthic Foraminifera, biostratigraphy, Cretaceous, Paleogene, Basque Basin, Spain.

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INTRODUCTION

The coastal section exposed along the coast of northern Spain near Zumaya is probably the most complete and expanded section of Upper Cretaceous and lower Palaeogene deep-water sediments in Europe. Studies of the planktonic foraminiferal biostratigraphy (Herm, 1965; Hillebrandt, 1965; Canudo *et al.*, 1995) indicate continuous sedimentation in the coastal section from the lower Campanian to the lower Eocene. In addition, relatively complete Cretaceous/Tertiary and Palaeocene/Eocene boundaries are exposed in the cliff section and have recently been the topic of detailed studies (Mount & Ward, 1986; Mount *et al.*, 1986; Ortiz, 1995).

Because of the possibility of undertaking precise biostratigraphical correlations to the standard planktonic fora-

Fig. 1. Map of the northern coast of Spain, showing the localities of the studied sections; 1 – investigated sections

miniferal zonal biostratigraphy, the Zumaya sections offer the unique opportunity to calibrate the biostratigraphy of the deep-water agglutinated foraminifera in this mid-latitude bathyal setting. Previous biostratigraphical studies of the Upper Cretaceous DWAF from nearby ODP sites on the Galicia Margin (Moullade *et al.*, 1988; Kuhnt & Collins, 1996) have not been able to directly calibrate the stratigraphic ranges of agglutinated species owing to the lack of calcareous microfossils in a sub-CCD setting.

The purpose of this study is to report the stratigraphic ranges of DWAF in the Zumaya section, and compare our biostratigraphy to the zonation of agglutinated foraminifera defined by Geroch and Nowak (1984) from the Polish Carpathians[1]. The Geroch and Nowak Zonation was previously accepted by a working group of IGCP Project 262 (Tethyan Cretaceous Correlation) as the working hypothesis against which other biostratigraphical schemes are to be tested. This comparison with the biostratigraphical succession in the Outer Carpathians provides new data on the palaeobiogeography of DWAF and their utility for biostratigraphy in areas outside the Carpathians.

STUDY AREA

The Basque Basin is one of the sedimentary basins along the North Iberian continental margin of the Bay of Biscay. The formation of these basins owes largely to the Cretaceous strike-slip tectonics associated with the Iberian rotation, which resulted in trench basins (Schwentke & Kuhnt, 1992). In this study, we present the stratigraphic distribution of DWAF in the Cenomanian to lower Eocene of the Zumaya Section, situated along the southern coast of the Bay of Biscay.

The Zumaya section consists of turbidites and deep-water limestones, and is continuously exposed along the base of the sea cliff from Punta Aitzuri to San Telmo beach in Zumaya. The sediments at Zumaya were deposited in a subsiding flysch trough below the wave base, but above the lysocline. Estimates of the water depth vary from 250–500 m during the Cenomanian–Turonian (Schwentke & Kuhnt, 1992) to 1000 m during the later part of the Cretaceous (Herm, 1965), and perhaps even deeper during the Palaeocene. Ortiz (1995) noted that the calcareous benthic foraminifera in the upper Palaeocene part of the section resemble a typical "Velasco-type" fauna, and assigned a lower bathyal palaeodepth. The planktonic foraminiferal biostratigraphy of the sections has been studied by Herm (1965) for the Upper Cretaceous and by Hillebrandt (1965) for the Palaeocene. Canudo *et al.* (1995) studied the planktonic foraminifera across the Palaeocene/Eocene boundary. Preliminary studies of the DWAF from the section initially carried out by Kaminski (1988), Schwentke and Kuhnt (1992), and by Kuhnt and Kaminski (1993). Ortiz (1995) studied the benthic foraminifera across the Palaeocene/Eocene transition at the top of the exposed section.

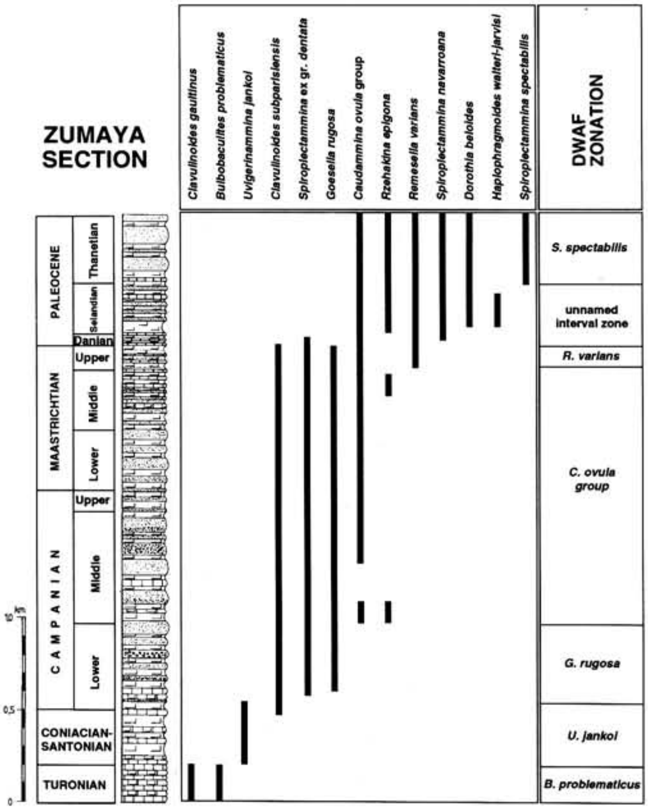

Fig. 2. Stratigraphic profile of the Upper Cretaceous to Paleocene of the Zumaya Section, with the ranges of stratigraphically important taxa observed in this study

Sample localities

The 71 samples examined in this study were collected from Punta Aitzuri to the top of the beach outcrop at San Telmo (sections 1, 3, 4, and 5 in Fig. 1). For the Coniacian–Santonian interval, which is lacking at the beach section due

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[1] This study is dedicated to the memory of our beloved teacher and co-worker Stan Geroch. One of us (MAK) recalls an occasion when Stan was presented with a few samples from Zumaya which an associate from Kraków had collected during one of the many geological field trips to the area. Stan was delighted to see so many of "his" favourite species in the material, and certainly would have liked to have the opportunity to examine the section in greater detail. We are pleased to present this synthesis of biostratigraphical data from Zumaya as a validation of Stan's work on the use of Deep-Water Agglutinated Foraminifera as zonal indicators both in the Carpathians and for stratigraphical correlation in other areas.

to a fault, an inland section along the road SS-V-1336 from Iciar to the Playa Zaconeta (section 2) has been sampled (Jonczyk, 1990). The composite lithological section from the Cretaceous part of the outcrop is shown in Figure 2. The base of the studied section is represented by a major fault. This section extends from the Turonian to the top of the Danian limestones. Overlying the Danian calciturbidites at Punta Aitzgorri, the upper Palaeocene to lower Eocene outcrop at San Telmo consists mostly of distal siliciclastic turbidites and associated marls. The samples reported in the Palaeocene part of the section correspond to the sample numbers of Hillebrandt (1965), who provided a detailed drawing of this part of the outcrop. The Palaeocene/Eocene boundary is exposed in the roadcut leading to the beach house, and is present as a characteristic dissolution horizon represented by grey claystone. For this part of the section, the data is compiled from Ortiz (1995), who studied 29 closely-spaced samples across the Palaeocene/ Eocene transition (Zones P4 to P6b).

METHODS

Samples were disaggregated using standard micropalaeontological techniques, and foraminifera were mounted on cardboard slides for microscopic examination. Identifications of the species are based on the work of Geroch and Nowak (1984), Kaminski *et al.* (1988), Kuhnt (1990), Kuhnt and Kaminski (1990), Kuhnt and Moullade (1991), Kaminski and Geroch (1993), and Kaminski *et al.* (1996). Data compiled from the Palaeocene/Eocene boundary study of Ortiz (1995) was standardized to our own taxonomical concepts. The planktonic foraminiferal zonation adopted for this study is that of Caron (1985) for the Cretaceous, and Berggren and Miller (1988) for the Palaeocene. Microfaunal slides are housed in the authors' collections.

RESULTS

Our analysis of the Turonian to lower Eocene succession in the Zumaya section yielded over 95 species and taxonomic groups of deep-water agglutinated foraminifera (Table 1). The whole succession contains foraminiferal assemblages typical of the "low to mid-latitude slope" DWAF biofacies of Kuhnt *et al.* (1989); Figs. 3–7. This biofacies is characterised by varying admixtures of calcareous benthic and planktonic foraminifera, and the DWAF include many calcareous-cemented forms such as ataxophragmiids. The presence of calcareous-cemented species belonging to the genera *Clavulinoides*, *Dorothia*, *Gaudryina*, and *Marssonella* contribute to the overall high diversity observed in the samples.

At the base of the studied section, the Cenomanian to basal Coniacian samples contain only sparse foraminifera. In our Turonian sample, the index species *Bulbobaculites problematicus* (Neagu) was observed. Above this level, samples collected from the Coniacian in the Iciar–Punta Zaconeta Road section contain common *Uvigerinammina jankoi* (Majzon). This species ranges into the lowermost Campanian in this section. The first occurrence of *Clavulinoides subparisiensis* (Grzybowski) was also found in the Coniacian.

Near the base of the lower Campanian, the first occurrences of *Spiroplectammina* ex gr. *dentata* (Alth) and *Goesella rugosa* (Hanzliková) are observed. This species is found sporadically in samples throughout the Campanian and Maastrichtian. Species diversity increases in the lower part of the middle Campanian when the first consistent occurrence *Caudammina ovula* (Grzybowski) is observed. Diversity again increases in the lower part of the upper Maastrichtian, when many of the typical "flysch-type" organically cemented agglutinated species appear in the section or become more common. One distinctive event is the FO of *Remesella varians* (Glaessner) in the upper Maastrichtian.

The Cretaceous/Tertiary boundary at Punta Aitzgorri is characterised by an assemblage dominated by organically cemented taxa such as *Ammodiscus*, *Aschemocella*, *Subreophax*, *Recurvoides*, and the tubular forms *Bathysiphon* and *Rhizammina*. Significantly, the LOs of *Goesella rugosa* and *Clavulinoides subparisiensis* are both associated with this horizon.

Above the K/T boundary, the DWAF assemblages from the lower Danian carbonate-rich sediments still contain common calcareous-cemented forms such as *Arenobulimina, Clavulinoides* and *Dorothia*. However, higher in the Danian the calciturbidites exposed in the beach outcrop at San Telmo are replaced by more terrigenous sediments, and the organically-cemented flysch-type forms become dominant. The LO of *Spiroplectammina* ex gr. *dentata* is observed in Zone P1b. The Paleocene assemblages above this level are dominated by tubular forms such as *Rhabdammina*, *Rhizammina*, *Nothia*, and organically cemented taxa such as *Saccammina placenta* (Grzybowski), *Psammosphaera* spp., *Recurvoides* spp, and *Paratrochamminoides* spp. The DWAF assemblages contain greater proportions of taxa that are typical of greater water depths, and bear a greater resemblance to the Palaeocene "Lizard Springs" fauna, which is interpreted as representing lower bathyal depths (Kaminski *et al.*, 1988). In his study of the calcareous benthic foraminifera, Ortiz (1995) also assigned a lower bathyal paleodepth to the uppermost Palaeocene part of the San Telmo outcrop.

A number of first occurrences are observed in the Paleocene. The FO of *Spiroplectammina navarroana* (Cushman) was observed in Zone P1c, but as this species is known from older strata in other sectors of the North Atlantic, it is likely that its appearance in Zumaya is associated with the facies change. A stratigraphically significant morphotype of *Haplophragmoides* that is transitional between *Haplophragmoides walteri* (Grzybowski) and *Reticulophragmoides jarvisi* (Cushman & Renz) is first observed in Zone P3b. This *H. walteri/R. jarvisi* transitional form has also been observed in Zone P4 in the Lizard Springs Formation, and it also occurs in the upper Palaeocene of the North Sea and Norwegian Sea. Also occurring at this level is the FO of *Dorothia beloides* (Hillebrand), a species first described from the Palaeocene of the Gosau unit in Austria. Surprisingly, the species *Spiroplectammina spectabilis* (Grzybowski) is rare in the studied samples, and its FO was not

Table 1

Occurrence of agglutinated Foraminifera in the investigated samples

SAMPLE	332	ZUM	134	135	136	138	145	53	67	312	356	344	344	346	360	365	ZUM	34S	44	54	184	325	334	352	353	367	368	371	374	404	407	438	323	324	35	47	152	330
	59	TUR	1	61	16	62N	95	84	18	65N	92	77T	77M	82	96	98	9b	3	8	85	24	53	64N	90	91	100	101	105	111	128	130	133	50	52	4	57	19	58
Ammobaculites jarvisi	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R?	.	.	.	.	.	.	.	.	.	.	.	R	.	.	.	R?	.	.	.	.	.
Ammodiscus cretaceus	.	C	R	F	.	.	R	.	R	R	F	.	.	.	R	.	.	.	.	.	R	.	.	.	.	.	R	R	.	.	R	R	.	.	.	.	.	.
Ammodiscus glabratus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.
Ammodiscus pennyi	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ammodiscus peruvianus	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.
Ammodiscus planus	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ammodiscus sp. (rough)	.	.	.	F	.	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.	R	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.
Ammosph. pseudopauciloculata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R?	.	.	.	.	.	.	.	.	.	.	R?	R?	.	.	.	.	.	.	.	.	.
Arenobulimina dorbignyi	.	.	.	.	.	.	.	.	R	.	R	.	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	.	.	.	.
Aschemocella spp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Bathysiphon spp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Bulbobaculites problematicus	.	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Caudammina ovuloides	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.
Caudammina ovula	.	.	.	.	.	.	.	.	.	.	R	.	.	.	.	.	F	.	.	.	.	.	.	.	.	.	.	R	R	.	.	R	.	R	R	.	R	.
Clavulinoides amorpha	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Clavulinoides aspera	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Clavulinoides gaultinus	.	F	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Clavulinoides globulifera	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Clavulinoides gr. eggeri	.	.	.	.	.	.	.	.	.	.	.	.	.	F	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Clavulinoides subparisiensis	.	.	.	.	R	R	C	R	R	R	F	R	F	.	F	C	F	.	R	F	F	.	.	.	F	.	.	.	R	.	.	.	.	.	R	.	.	.
Clavulinoides trilatera	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cribrostomoides spp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R?	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cystammina sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Dorothia beloides	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Dorothia crassa	.	.	.	R	.	.	.	F	F	R	.	.	.	.	.	.	C	.	R	F	C	.	.	.	F	F	.	R	R	R	.	.	.	.	.	.	R	.
Dorothia oxycona	R	.	R	.	R	R	F	C	F	R	.	.	R	R	F	R	R	.	.	R	.	.	.	R	F	.	.	R	.	.	.	.	.	.	R	.	R	.
Dorothia retusa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	R	.	.	.	.	.	R	.	R	.	.	.	.	.	R	.	R	.	.	R	.
Dorothia trinitatensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Eggerella trochoides	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Eggerellina spp.	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Gaudryina cretacea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	F	.	F	.	.	.	.	.	.	.	.	.	.	.
Gaudryina pyramidata	.	.	R	.	.	F	.	.	.	.	R	R	R	F	C	R	.	F	.	.	.	C	.	F	.	R	.	C	.	.	C	R	.	.	.	C	R	R
Gaudryina sp.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Glomospira charoides	.	R	R	R	.	.	R	.	.	.	.	.	.	.	.	.	.	.	R	.	.	.	R	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.
Glomospira gordialis	.	F	.	R	.	.	R	.	R	F	.	.	.	.	.	.	F	.	.	.	.	R	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Glomospira irregularis	.	C	.	C	.	F	.	.	.	R	R	.	.	.	.	.	F	.	.	R	.	.	R	.	R	.	.	.	.	.	R	R	.	.	.	.	.	.
Glomospira serpens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.
Glomospirella gaultina	R	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.	R	.	.	.	.	.	.	.	R	.	.	R	.	.	.	.	.	.	.	.	.	.
Glomospirella grzybowskii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Glomospirella spp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Goesella rugosa	.	.	.	.	.	.	.	.	.	.	C	.	.	.	R?	.	F	R	.	.	.	F	.	R	.	R	.	.	R	F	.	.	.	R	.	.	.	.
H. walteri - H(?) jarvisi (transitional)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Haplophragmium spp.	R	.	.	.	.	.	F	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Haplophragmoides eggeri	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Haplophragmoides horridus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Haplophragmoides spp.	.	C	.	C	.	.	.	.	F	.	F	.	.	.	R	.	C	.	.	.	.	.	.	.	R	R	.	R	.	.	.	.	F	R	R	.	.	R
Haplophragmoides walteri	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Hormosina velascoensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Hyperammina dilatata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.
Kalamopsis grzybowskii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Karrerulina conversa	.	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	.	.	.	F?	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Karrerulina horrida	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Karrerulina lenis	.	.	.	.	.	.	C	.	F	.	R	.	.	.	.	.	.	.	.	R?	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lituotuba lituiformis	.	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	.	.	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.
Nothia excelsa	.	C	.	.	.	C	.	.	.	.	.	.	.	.	.	.	C	.	.	.	.	.	.	.	.	R	.	.	.	.	.	.	.	R	.	.	.	.
Paratrochamminoides heteromorphus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Paratrochamminoides acervulatus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Paratrochamminoides irregularis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Paratrochamminoides spp.	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.	R	.	.	.	.	.	.	.	.	.
Paratrochamminoides subcoronatus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Popovia elegans	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Psammosphaera irregularis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	R	.
Pseudobolivina sp.	.	C	.	R	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R?	.	.	.	.	.	.	.	.	.	.
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Recurvoides gerochi	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Recurvoides nucleolus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Recurvoides spp.	.	F	.	A	.	F	.	.	.	.	C	R	.	R	F	F?	C	.	.	C	F	R	R	F	C	.	.	R	F	.	.	R	.	R	F	.	.	.
Remesella varians	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R?	.	.	.	.	.	.
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Reophax pilulifer	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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Rhabdammina spp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	.	.	.	.	.	.	.	R	R	R	.
Rhizammina grzybowskii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Rhizammina spp.	R	A	.	R	R	.	.	.	.	.	.	.	.	.	.	.	C	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Rzehakina epigona	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Saccammina grzybowskii	.	R	.	.	.	.	.	.	.	R	.	.	.	.	.	.	R	.	.	.	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.
Saccammina placenta	.	.	.	.	.	.	.	R	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.
Sculptobaculites barri	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Sphaerammina gerochi	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Spiroplectammina cretosa	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Spiroplectammina ex gr. dentata	.	.	.	.	.	.	.	.	.	R	.	R	F	.	.	.	F	.	.	.	.	.	.	.	R	.	F	F	.	.	R	.	F	R	R	.	.	R
Spiroplectammina israelskyi	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Spiroplectammina navarroana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Spiroplectammina spectabilis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Spiroplectinata annectens	F	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Subreophax pseudoscalaris	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Subreophax scalaris	.	F	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Subreophax splendidus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R?	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Tritaxia spp.	.	R	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Trochammina spp.	R	C	.	C	R	.	.	.	F	F	C	R	.	R	.	.	F	R	.	.	.	R	F	.	R	F	R	R	.	.	.	R	.	R	.	.	.	.
Trochamminoides dubius	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Trochamminoides proteus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Uvigerinammina jankoi	.	.	.	C	C	.	.	R	R	.	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Verneuilina cretacea	.	.	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Verneuilinoides polystrophus	.	F	.	F	R	.	.	.	.	.	.	.	.	R?	.	.	.	.	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	C	T	CON					SAN			CAMPANIAN																								MAA			
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36	56	244	383	396	ZUM	ZUM	326	327	ZUM	160	328	369	370	430	465	ZUM	ZUM	400	400	400	400	40	40	40	40	40	40	40	40	40	400	40	SAMPLE
117	88	39	119	124	5	6/1	54	55	1	139	56	103	104	132	135	KT2	KT1	1	2	5	6	12	16	19	22	30	39	40	53	57	60	64	
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R	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	C	A	.	.	.	.	.	.	.	.	.	R	R	C	.	.	.	Aschemocella spp.
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.	.	.	.	.	R	C	.	.	.	.	.	.	.	.	.	C	F	R	F	R	R	C	F	.	F	F	C	F	F	F	C	C	Rhizammina spp.
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.	.	.	.	.	F	F	.	R	.	.	.	.	.	R	.	F	C	C	C	C	C	C	C	C	F	F	C	C	C	F	F	C	Saccammina placenta
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.	.	.	.	.	.	F	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	.	.	F	.	.	.	R	R	Subreophax splendidus
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.	.	.	.	.	F	C	R	.	.	.	R	R	.	.	R	F	C	C	C	C	.	C	R	.	C	R	C	F	F	R	F	F	Trochammina spp.
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MAASTRICHTIAN																	PALEOCENE																
MIDDLE					UPPER												P1a	P1b		P1c		P2	P3a		P3b			P4			P5		

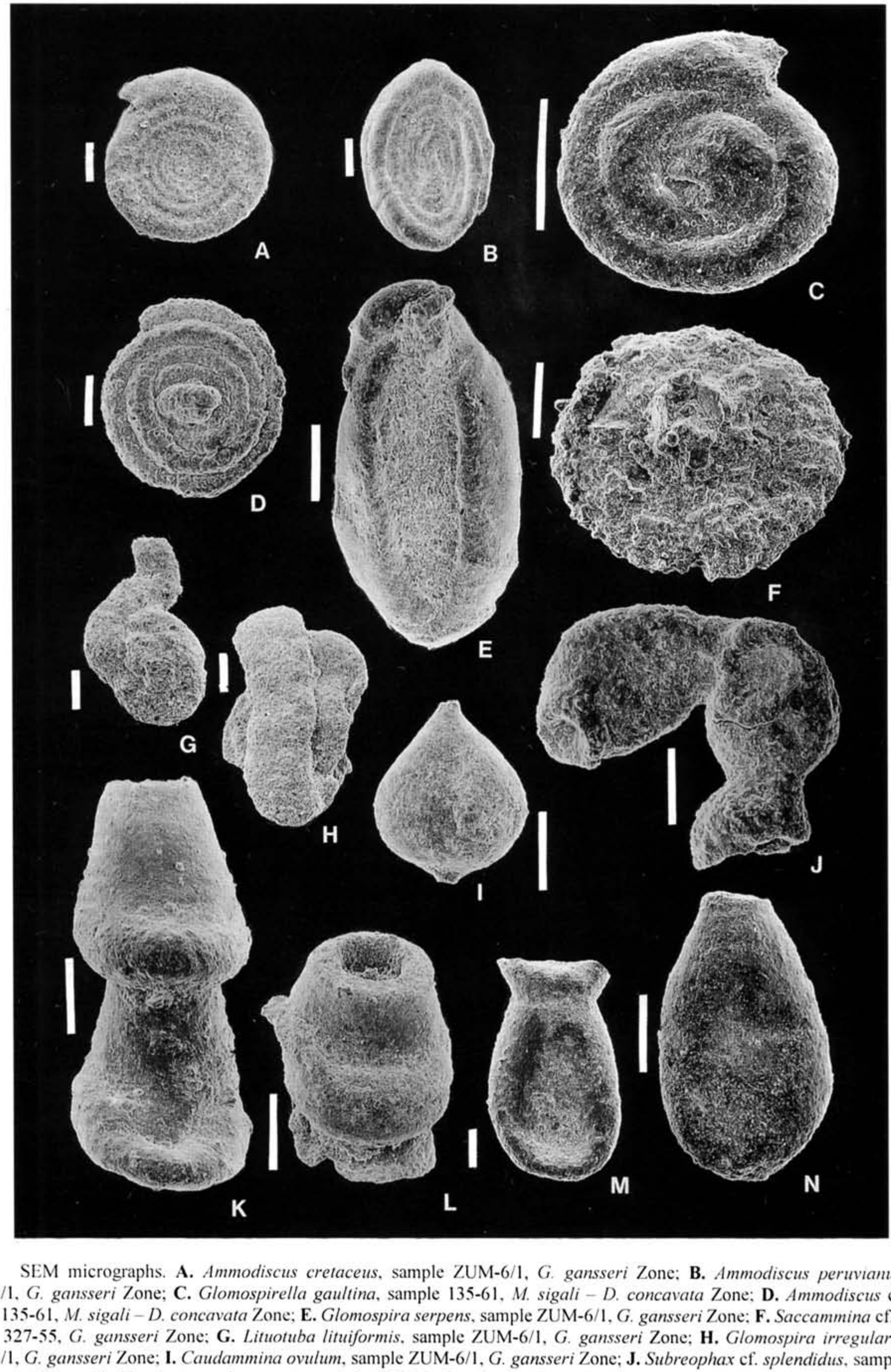

Fig. 3. SEM micrographs. **A.** *Ammodiscus cretaceus*, sample ZUM-6/1, *G. gansseri* Zone; **B.** *Ammodiscus peruvianus*, sample ZUM-6/1, *G. gansseri* Zone; **C.** *Glomospirella gaultina*, sample 135-61, *M. sigali – D. concavata* Zone; **D.** *Ammodiscus* cf. *pennyi*, sample 135-61, *M. sigali – D. concavata* Zone; **E.** *Glomospira serpens*, sample ZUM-6/1, *G. gansseri* Zone; **F.** *Saccammina* cf. *placenta*; sample 327-55, *G. gansseri* Zone; **G.** *Lituotuba lituiformis*, sample ZUM-6/1, *G. gansseri* Zone; **H.** *Glomospira irregularis*, sample ZUM-6/1, *G. gansseri* Zone; **I.** *Caudammina ovulum*, sample ZUM-6/1, *G. gansseri* Zone; **J.** *Subreophax* cf. *splendidus*, sample 327-55, *G. gansseri* Zone; **K.** *Hormosina velascoensis*, sample 327-55, *G. gansseri* Zone; **L.** *Hormosina velascoensis*, sample ZUM-6/1, *G. gansseri* Zone; **M.** *Hyperammina dilatata*, sample Ma-42, Danian; **N.** *Hyperammina dilatata*, sample Ma-42, Danian. Length of scale bar – 200 μm

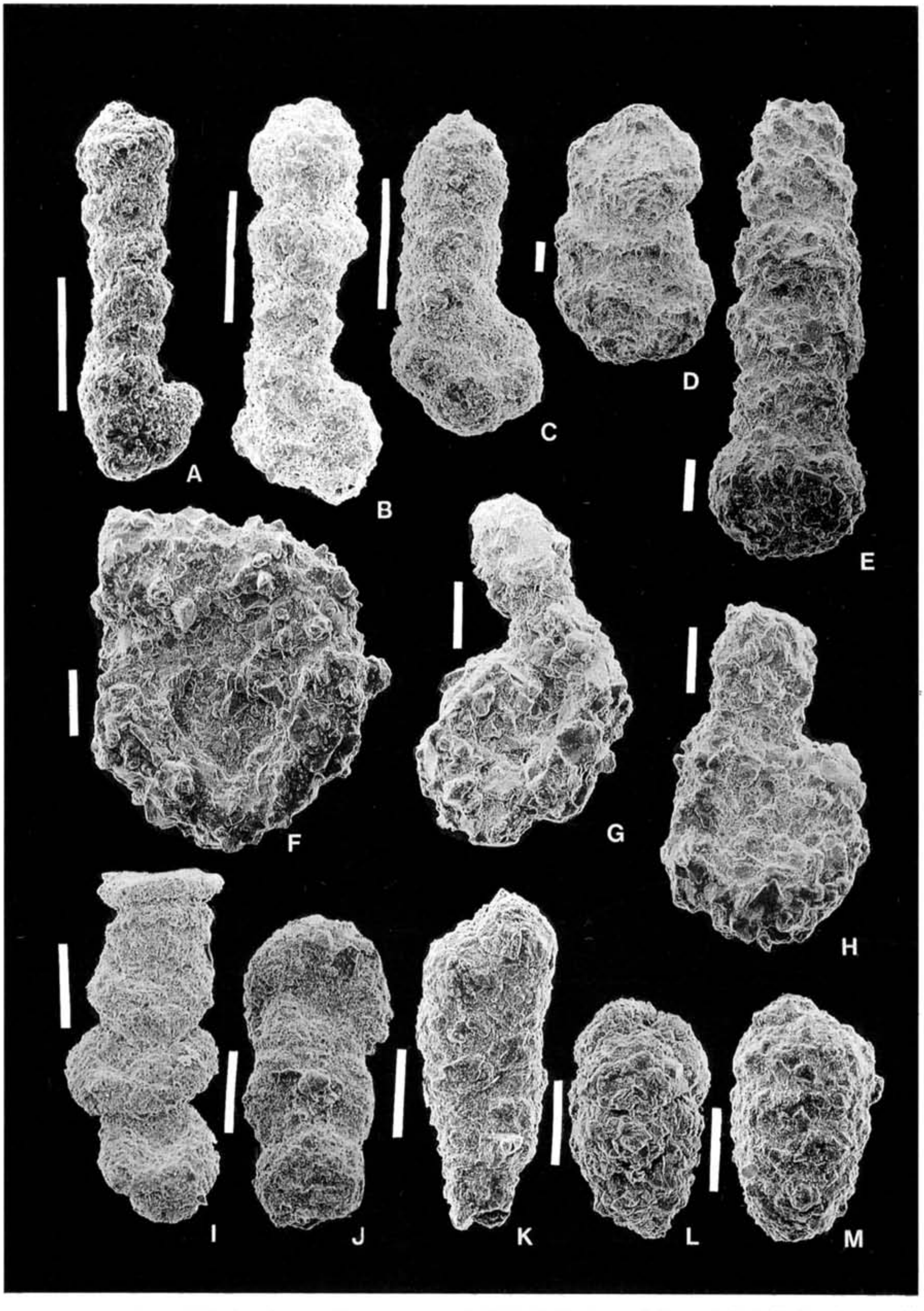

Fig. 4. SEM micrographs. **A.** *Bulbobaculites problematicus*, sample ZUM-TUR, *M. sigali* Zone; **B-C.** *Bulbobaculites problematicus*, sample ZUM-TUR, *M. sigali* Zone; **D.** *Ammobaculites* cf. *jarvisi*, sample 369-103, *A. mayaroensis* Zone; **E.** *Ammobaculites* sp., sample ZUM-KT1, *G. eugubina* Zone; **F-H.** *Ammobaculites* sp. 3, sample ZUM-KT1, *G. eugubina* Zone; **I.** *Subreophax* cf. *scalaris*, sample ZUM-6/1, *G. gansseri* Zone; **J.** *Reophax* sp.; sample ZUM-6/1, *G. gansseri* Zone; **K.** *Pseudobolivina* sp., sample 135-61, *M. sigali – D. concavata* Zone; **L.** *Verneuilinioides polystrophus*, sample 135-61, *M. sigali – D. concavata* Zone; **M.** *Karreriella horrida*, sample 145-95, *M. sigali – D. concavata* Zone. Length of scale bar – 200 µm

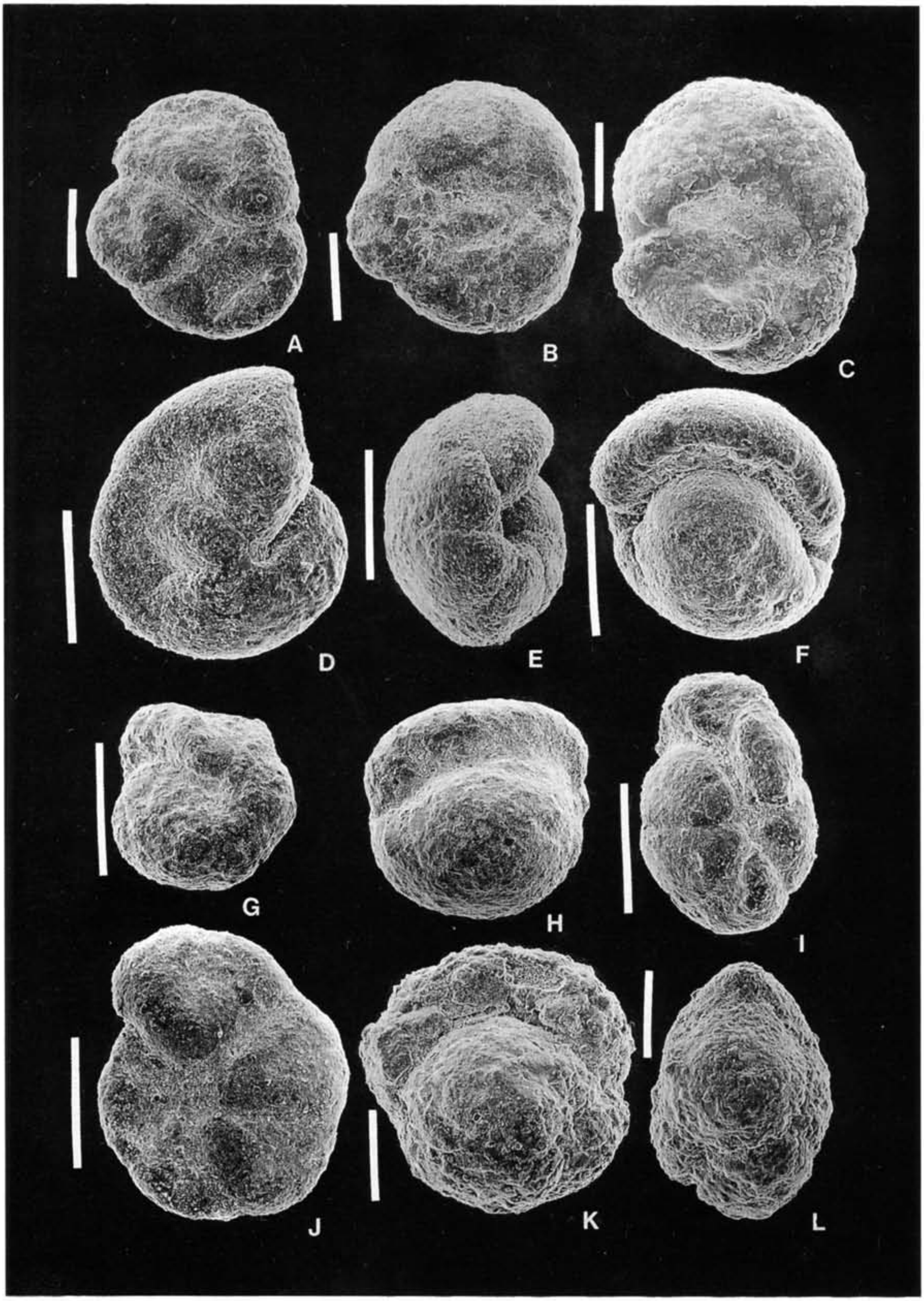

Fig. 5. SEM micrographs. **A.** *Ammosphaeroidina pseudopauciloculata*, sample 328-58, *A. mayaroensis* Zone; **B.** *Ammosphaeroidina pseudopauciloculata*, sample 369-103, *A. mayaroensis* Zone; **C.** *Ammosphaeroidina pseudopauciloculata*, sample ZUM-6/2, *G. gansseri* Zone; **D.** *Haplophragmoides* cf. *walteri*, sample 135-61, *M. sigali – D. concavata* Zone; **E-F.** *Haplophragmoides* sp. 2, sample 135-61, *M. sigali – D. concavata* Zone; **G.** *Haplophragmoides* sp. 323-50, sample 323-50, *G. calcarata* Zone; **H.** *Cribrostomoides trinitatensis*, sample Ma-42, Danian; **I-J.** *Haplophragmoides* sp. 2, sample Ma-42, Danian; **K.** *Recurvoides* sp., sample 135-61, *M. sigali – D. concavata* Zone; **L.** *Uvigerinammina jankoi*, sample 135-61, *M. sigali – D. concavata* Zone. Length of scale bar – 200 µm

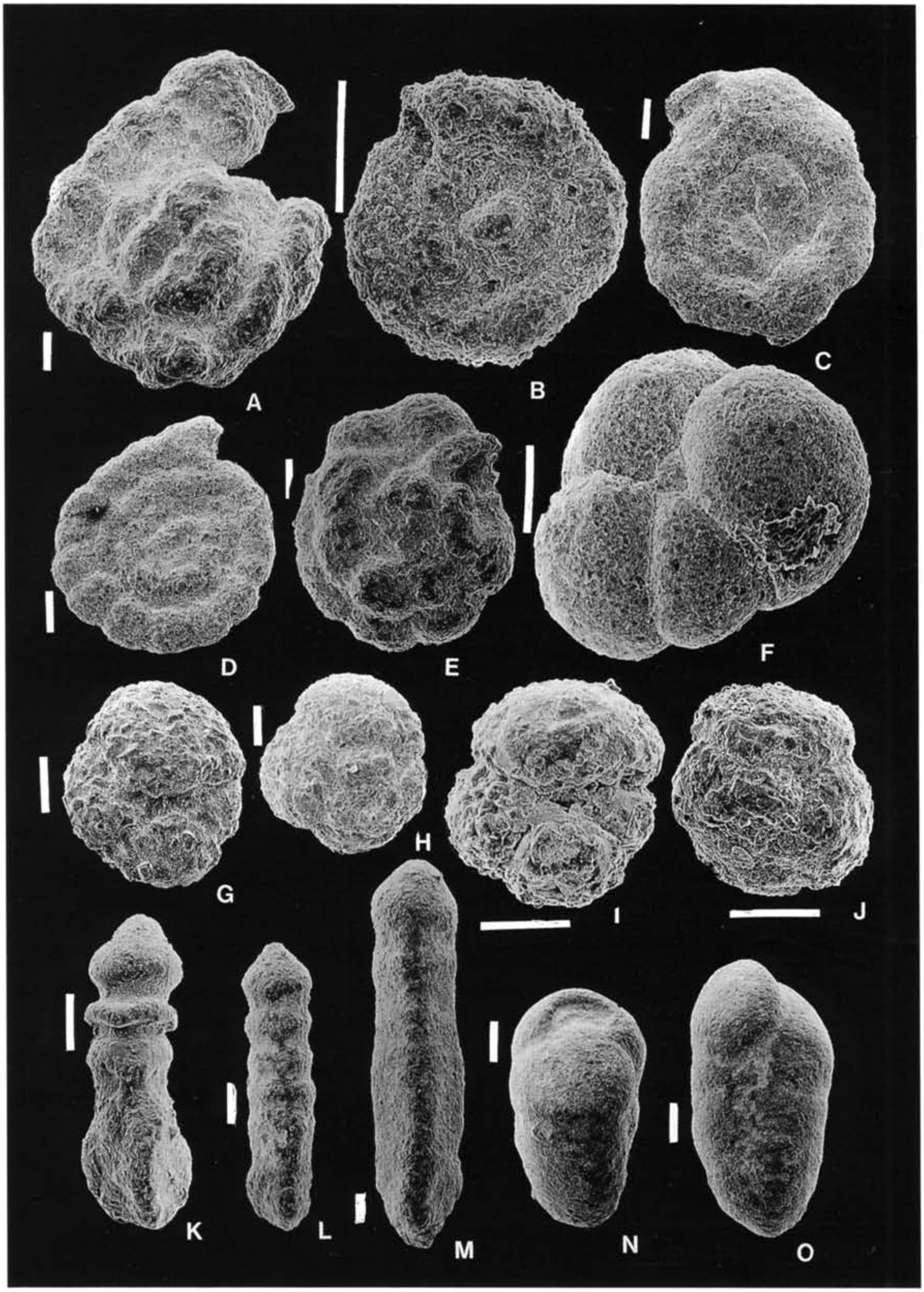

Fig. 6. SEM micrographs. **A.** *Paratrochamminoides heteromorphus*, sample 327-55, *G. gansseri* Zone; **B.** *Trochamminoides* cf. *dubius*, sample 135-61, *M. sigali – D. concavata* Zone; **C.** *Trochamminoides* cf. *proteus*, sample ZUM-6/1, *G. gansseri* Zone; **D.** *Trochamminoides proteus*, sample ZUM-6/1, *G. gansseri* Zone; **E.** *Paratrochamminoides* sp., sample 327-55, *G. gansseri* Zone; **F.** *Trochammina* cf. *deformis*, sample ZUM-6/1, *G. gansseri* Zone; **G.** *Trochammina globigeriniformis*, sample Ma-42, Danian; **H.** *Trochammina globigeriniformis*, sample ZUM-6/1, *G. gansseri* Zone; **I-J.** *Trochammina globigeriniformis*, sample 135-61, *M. sigali – D. concavata* Zone; **K.** *Clavulinoides eggeri*, sample 356-92, *M. sigali – D. concavata* Zone; **L.** *Clavulinoides eggeri*, sample 34S-3, *G. ventricosa* Zone; **M.** *Tritaxia* sp., sample 34S-3, *G. ventricosa* Zone; **N-O.** *Dorothia retusa*, sample 34S-3, *G. ventricosa* Zone. Length of scale bar – 200 μm

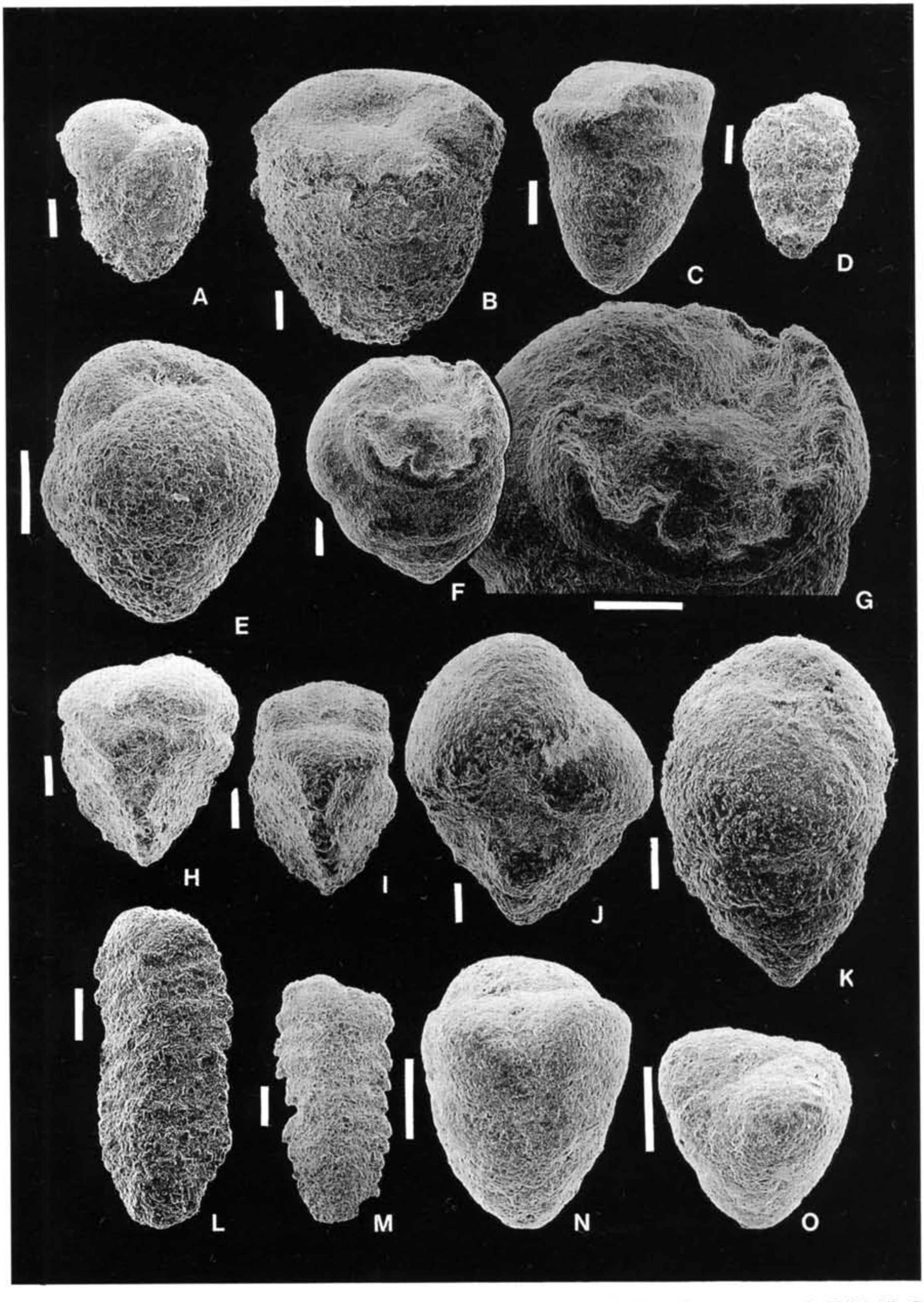

Fig. 7. SEM micrographs. **A.** *Goesella rugosa*, sample ZUM-6/1, *G. gansseri* Zone; **B.** *Goesella rugosa*, sample ZUM-6/2, *G. gansseri* Zone; **C.** *Goesella* sp., sample 369-103, *A. mayaroensis* Zone; **D.** *Gaudryina* sp. (coarse), sample ZUM-6/1, *G. gansseri* Zone; **E.** *Remesella varians*, sample ZUM-6/1, *G. gansseri* Zone; **F-G.** *Remesella varians*, sample 369-103, *A. mayaroensis* Zone; **H-I.** *Gaudryina pyramidata*, sample 360-96, *G. elevata* Zone; **J.** *Gaudryina cretacea*, sample 368-101, *G. ventricosa* Zone; **K.** *Remesella varians*, sample Ma-42, Danian; **L.** *Spiroplectammina israelskyi*, sample Ma-42, Danian; **M.** *Spiroplectammina dentata*, sample ZUM-6/1, *G. gansseri* Zone; **N-O.** *Dorothia crassa*, sample ZUM-6/1, *G. gansseri* Zone. Length of scale bar – 200 µm

observed until the upper part of Zone P4. Likewise, the genus *Rzehakina* occurs very rarely in our samples. Both forms are common in the upper Palaeocene in Trinidad and in the Flysch Carpathians, but their stratigraphic occurrence is much restricted at Zumaya.

The Palaeocene/Eocene boundary is represented by a 20 cm thick dark-grey shale layer, overlain by 4 m of red clay. The dark-grey shale layer represents a dissolution horizon that corresponds to the benthic foraminiferal mass extinction and the delta ^{13}C shift (Ortiz, 1995), which are used to delimit the P/E boundary in deep sea cores. In his study of the benthic foraminiferal extinction at Zumaya, Ortiz (1995) reported that the total benthic foraminifera diversity drops by 94% (from 74 to 4 species) across the grey shale layer. Below the grey shale layer, the upper Palaeocene assemblages contain the typical flysch-type forms such as *Gaudryina pyramidata* Cushman, *Dorothia retusa* (Cushman), *Clavulinoides amorpha* (Cushman), *Remesella varians* (Glaessner), *S. spectabilis* (Grzybowski), *Cribrostomoides trinitatensis* Cushman & Jarvis, *Saccammina placenta* (Grzybowski), *Hormosina velascoensis* (Cushman), *Caudammina ovuloides* (Grzybowski), and *Trochamminoides* spp. The extinction of *Caudammina* spp., *Clavulinoides amorpha* (Cushman), *C. globulifera* (Ten Dam & Sigal), *Dorothia retusa*, *Remesella varians*, *Rzehakina epigona* (Rzehak), and *Trochamminoides proteus* (Karrer) were observed at or just slightly below the grey shale layer, along with the extinction of numerous Paleocene calcareous benthic taxa. Following the benthic extinction in the interval of low delta ^{13}C values, the agglutinated foraminifera consist of small, thin-walled species of *Haplophragmoides* spp., *Glomospira charoides* (Jones & Parker), and *Trochammina* spp. Above the dissolution horizon, the lowermost Eocene (upper part of Zone P6a and lowermost part of Zone P6b) agglutinated assemblages are characterised by successive peaks of *Karrerulina conversa* (Grzybowski) and *Glomospira charoides*. Other Eocene survivors include *Ammodiscus glabratus* Cushman & Jarvis, *Haplophragmoides walteri* (Grzybowski), *Lituotuba lituiformis* (Brady), *Saccammina grzybowskii* (Schubert), *Spiroplectammina navarroana* (Cushman), *S. spectabilis* (Grzybowski), *Trochamminaa ltiformis* Cushman & Renz, and *Trochamminoides subcoronatus* (Grzybowski) (Ortiz, 1995).

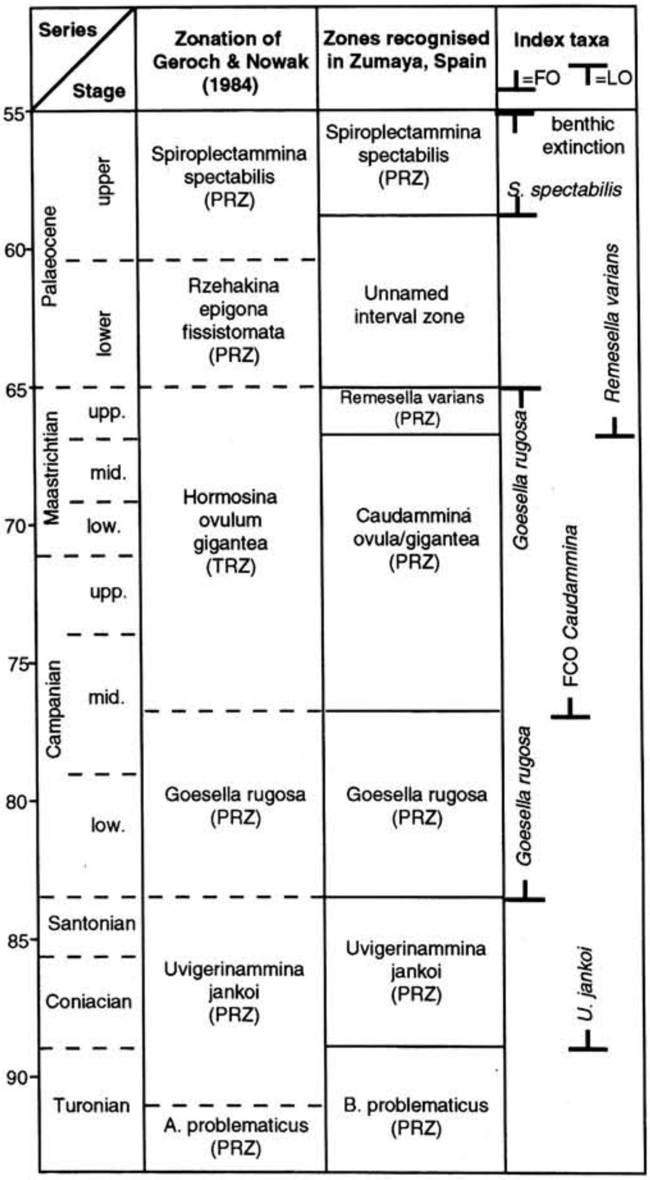

Fig. 8. A comparison between the succession of DWAF zones observed at Zumaya, with the zonation of Geroch & Nowak (1984)

COMPARISON WITH THE "GEROCH AND NOWAK ZONATION"

The stratigraphical succession of index species at Zumaya displays many features in common with the zonation for the Silesian Nappe of the Outer Carpathians defined by Geroch and Nowak (1984). This zonation has served as a biostratigraphical standard for numerous additional studies, both in the area of the Carpathians (*e.g.*, Bubik, 1995) and in different regions of the North Atlantic and western Tethys (*e.g.*, Kaminski *et al.*, 1989; Kuhnt, 1990; Kuhnt & Moullade, 1991; Coccioni *et al.*, 1995).

In the Zumaya sections, we observe the most of the essential index taxa of the Turonian to Palaeocene zones established by Geroch and Nowak, although there are some notable differences (Fig. 8).

The species *Bulbobaculites problematicus* was observed in our single Turonian sample. This is the nominate taxon of Geroch and Nowak's "*A. problematicus* Zone", a partial range zone which is of middle Cenomanian to early Turonian age in the Polish Carpathians. Its occurrence at Zumaya means it possesses a wide bathymetric distribution, as it also occurs commonly in the Turonian at ODP Site 641 off Galicia Bank, which was beneath the CCD at the time.

The interval between the FO of *Uvigerinammina jankoi* and the FO of *Goesella rugosa* defines the upper Turonian to Santonian *U. jankoi* Zone of Geroch and Nowak. *Uvigerinammina jankoi* was observed in proper sequence in the Coniacian of the Zumaya sections. However, it is known to range upwards from the Turonian in other areas. We have found this species at numerous localities, both in the North Atlantic DSDP/ODP sites and in commercial wells drilled along the North Atlantic margins. It is a very useful zonal indicator in the most areas.

The FO of *Goesella rugosa* was observed at the base of the Campanian, in full agreement with the Geroch and Nowak Zonation. Its occurrence in the North Atlantic sector, however, seems to be linked to the occurrence of calcium carbonate in sediments. It is a calcareous-cemented form, and is not found beneath the CCD in the abyssal North Atlantic DSDP/ODP sites.

The *Caudammina ovula* group occurs consistently and becomes common in samples in the middle part of the middle Campanian. The FO of *Caudammina gigantea* (Geroch) marks the base of the mid Campanian to Maastrichtian "*H. ovulum gigantea* Zone" of Geroch and Nowak. While we did not separate the larger *C. gigantea* from the smaller *C. ovulum* in this study, we note that the group occurs in its expected position. Another stratigraphically important event which may be used to subdivide the "*H. ovulum gigantea* Zone" is the FO of *Remesella varians*. In Zumaya, this event occurs in the upper Maastrichtian. This species has been observed in the middle Maastrichtian at several localities, such as Gubbio (Kuhnt, 1990) and at DSDP Sites 385 and 398 (Kuhnt & Moullade, 1991). Kuhnt and Moullade defined a middle-upper Maastrichtian *R. varians* Zone based on its first occurrence.

At Zumaya, the nominate species of Geroch and Nowak's lower Palaeocene "*Rzehakina fissistomata* Zone" was not observed. Only sporadic occurrences of rzehakinids were found in the upper Maastrichtian and Palaeocene part of the succession, and these are more similar to the type species of the genus, *R. epigona*. In general, *R. fissistomata* is rare in the North Atlantic. However, the "*R. fissistomata* Zone" can still be recognised at Zumaya based on alternate criteria. Geroch and Nowak regarded the LO of *Goesella rugosa* to coincide with the K/T boundary (the base of the "*R. fissistomata* Zone") in the Polish Carpathians. This is in full agreement with our observations at Zumaya.

Spiroplectammina spectabilis has a curious palaeobiogeographical occurrence in the eastern Atlantic and Tethys. Its FO defines the base of Geroch & Nowak's Thanetian *S. spectabilis* Zone in the Polish Carpathians. Its FO was recorded as upper Maastrichtian in Trinidad by Kaminski *et al.* (1988). It is certainly abundant in the upper Palaeocene in the North Sea and west of Shetlands, but it was not observed in our Palaeocene–lower Eocene samples from the Talaa Lakhra flysch from northern Morocco (Kaminski *et al.*, 1996), or in the Palaeocene–Eocene at ODP Sites 897, 899, and 900 on the Iberia Abyssal Plain (Kuhnt & Collins, 1996). In Zumaya, its occurrence is rare and discontinuous. We observed it in our samples from Zones P4 and P5. It disappeared at the Palaeocene/Eocene boundary, then reappears in small numbers in lower Eocene Zone P6b (Ortiz, 1995).

We prefer to use the terminal Palaeocene benthic extinction to define the top of the upper Palaeocene *S. spectabilis* Zone for a number of reasons. Firstly, at this level a large number of cosmopolitan deep-water benthic foraminifera become extinct. Secondly, the nominate species of Geroch and Nowak's "*Saccamminoides carpathicus* Zone" has never been observed outside the Flysch Carpathians. There are multiple criteria that can be used to recognise the top of the *S. spectabilis* Zone, both within the Carpathians and in the Tethyan–North Atlantic province, including a size reduction in the agglutinated foraminifera, a shift in the proportions of morphogroups (Kaminski *et al.*, 1996), and a sharp decrease in diversity (Ortiz, 1995). In many areas, the lower Eocene assemblages reflect more oligotrophic conditions and are characterised by taxa such as *Karrerulina* and *Glomospira*.

CONCLUSIONS

The biostratigraphic succession of DWAF in the Zumaya section of northern Spain allows us to recognise many of the Coniacian to Palaeocene zones originally defined by Geroch and Nowak (1984).

The *Uvigerinammina jankoi* PRZ, *Goesella rugosa* PRZ, *Hormosina ovulum gigantea* PRZ were all observed in their proper succession, and directly calibrated to the standard planktonic foraminiferal biostratigraphy in the Zumaya Section. Owing to the lack of two index taxa from the Geroch and Nowak Zonation (*Rzehakina fissistomata* and *Saccamminoides carpathicus*), alternative critera are proposed to delimit the bases of these zones. We conclude that the Geroch and Nowak Zonation can be used as an excellent working model for "mixed assemblages" characteristic of low to mid-latitude slope marl DWAF biofacies, even in areas that are geographically removed from the Polish Carpathians. With few notable exceptions, the index taxa chosen by Geroch and Nowak for their biostratigraphical scheme are cosmopolitan taxa that have a wide geographical and palaeoecological distribution.

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Streszczenie

GŁĘBOKOWODNE OTWORNICE AGLUTYNUJĄCE Z OSADÓW W PROFILU ZUMAYA, W PÓŁNOCNEJ HISZPANII (CENOMAN–EOCEN)

Wolfgang Kuhnt & Michael A. Kaminski

Odsłonięcia w rejonie Zumaya, w północnej Hiszpanii stanowią prawdopodobnie najbardziej kompletne profile głębokowodnych osadów górnej kredy i dolnego paleogenu w Europie. Potwierdzono to w badaniach zespołów otwornic planktonicznych (Herm, 1965; Hillebrandt, 1965; Canudo *et al.*, 1995). Daje to podstawę do kalibracji zasięgów różnych grup mikrofauny, w tym głębokowodnych otwornic aglutynujących, zasiedlających środowiska batialne. Kalibracja taka była głównym celem tych studiów. Przedstawiono ponadto porównanie wyróżnionych poziomów biostratygraficznych z zonacją zaproponowaną przez Gerocha i Nowaka (1984) dla polskich Karpat fliszowych.

Badane osady były deponowane w basenie baskińskim, położonym wzdłuż północnej krawędzi kontynentalnej w rejonie Zatoki Biskajskiej. Profile osadów w rejonie Zumaya są reprezentowane przez turbidity klastyczne i głębokowodne osady węglanowe. Ich sedymentacja miała miejsce początkowo (cenoman–turon) na głębokości 250–500 m (Schwentke & Kuhnt, 1992), później (koniak–mastrycht) na głębokości około 1000 m (Herm, 1965). W paleogenie basen uległ dalszemu pogłębieniu (Ortiz, 1995).

Analizowano 71 próbek w pięciu odcinkach profilu, obejmujących utwory od cenomanu do dolnego eocenu (Fig. 1). Pełny litologiczny profil osadów obejmujący ich odcinek kredowy przedstawiono na Fig. 2. Oznaczono ponad 95 gatunków głębokowodnych otwornic aglutynujących (Table 1). Reprezentują one biofacje „skłonu kontynentu dla niskich i średnich szerokości geograficznych" (Kuhnt *et al.*, 1989). Zespoły charakteryzuje liczna obecność form o szkielecie scementowanym węglanem wapnia, np. należących do nadrodziny Ataxophragmiacea, z rodzaju *Clavulinoides*, *Dorothia*, *Gaudryina* i *Marssonella*.

Zespoły cenomanu, turonu i dolnego koniaku zawierały nieliczne otwornice aglutynujące. W osadach turonu oznaczono *Bulbobaculites problematicus* (Neagu). W młodszych (koniak), licznie występuje *Uvigerinammina jankoi* (Majzon), która sięga w tym profilu do najniższej części kampanu. W utworach koniaku stwierdzono pierwsze pojawienie się *Clavulinoides subparisiensis* (Grzybowski).

W pobliżu granicy santon/kampan po raz pierwszy pojawił się gatunek *Spiroplectammina* ex gr. *dentata* (Alth) oraz *Goesella rugosa* (Hanzliková). Ten ostatni był znajdowany w osadach kampanu i mastrychtu. Zróżnicowanie gatunkowe wśród otwornic aglutynujących zwiększyło się na początku środkowego kampanu. W osadach tego wieku odnotowano pierwsze pojawienie się *Caudammina ovula* (Grzybowski). Ponowny wzrost zróżnicownania taksonomicznego miał miejsce w młodszej części późnego mastrychtu. Wtedy po raz pierwszy pojawiły się otwornice z gatunku *Remesella varians* (Glaessner).

Granicę kredy i trzeciorzędu charakteryzuje obecność form o szkielecie z cementem organicznym, takich jak: *Ammodiscus*, *Aschemocella*, *Subreophax*, *Recurvoides* i obecność form rurkowatych. Z tą granicą wiąże się ostatnie pojawienie *Goesella rugosa* i *Clavulinoides subparisiensis*.

Powyżej granicy K/T (dolny dan), zespół głębokowodnych otwornic aglutynujących charakteryzuje liczna obecność form o cemencie węglanowym, należących do *Arenobulimina*, *Clavulinoides* i *Dorothia*. W górym danie, dominowała sedymentacja bardziej klastyczna, i tym samym uległ zmianie zespół otwornic aglutynujących, z dominującymi formami o cemencie organicznym. W poziomie P1b zaobserwowano ostatnie pojawienie się *Spiroplectammina* ex gr. *dentata*. Młodsze osady paleocenu są zdominowane przez formy rurkowate z rodzaju *Rhabdammina*, *Rhizammina*, *Nothia* oraz formy o cemencie organicznym, takie jak *Saccammina placenta* (Grzybowski), *Psammosphaera* spp., *Recurvoides* spp. oraz *Paratrochamminoides* spp. Zespoły te zawierają większy udział otwornic znanych z głębszych środowisk (dolny batiał), jak na przykład opisane przez Kaminskiego *et al.* (1988) z osadów paleocenu z "Lizard Springs".

W paleocenie udokumentowano ponadto szereg pierwszych pojawień się otwornic głębokowodnych. Dotyczy to *Spiroplectammina navarroana* (Cushman) (od poziomu P1c), form pośrednich pomiędzy *Haplophragmoides walteri* (Grzybowski) i *Reticulophragmoides jarvisi* (Cushman et Renz) (od poziomu P3b) oraz *Dorothia beloides* (Hillebrand). Gatunek *Spiroplectammina spectabilis* (Grzybowski) jest rzadki w badanych osadach i jego pierwsze pojawienie się udokumentowano dla osadów z górnej części poziomu P4. Podobnie, bardzo rzadkie są formy z rodzaju *Rzehakina*, które znane są z licznych wystąpień w górnym paleocenie w Karpatach fliszowych.

Granica paleocen/eocen jest wykształcona jako 20 cm miąższości pakiet ciemoszarych łupków. Reprezentują one poziom rozpuszczania węglanowej mikrofauny, podkreślony gechemicznie przez dużą amplitudę ^{13}C (Ortiz, 1995) i odpowiadają okresowi wielkiego wymierania otwornic bentonicznych. W profilu Zumaya, Ortiz (1985) udokumentował spadek zróżnicowania gatunkowego bentosu otwornicowego o 94% (z 74 do 4 gatunków).

Poniżej horyzontu ciemoszarych łupków, górnopaleoceńska fauna zawiera formy chrakterystyczne dla sedymentacji turbidytowej. Należą one do gatunków: *Gaudryina pyramidata* Cushman, *Dorothia retusa* (Cushman), *Clavulinoides amorpha* (Cushman), *Remesella varians* (Glaessner), *S. spectabilis* (Grzybowski), *Cribrostomoides trinitatensis* Cushman et Jarvis, *Saccammina placenta* (Grzybowski), *Hormosina velascoensis* (Cushman), *Caudammina ovuloides* (Grzybowski) i *Trochamminoides* spp. Nieco poniżej granicy paleocen/eocen lub w jej obrębie odnotowano ostatnie pojawienia *Caudammina* spp., *Clavulinoides amorpha* (Cushman), *C. globulifera* (Ten Dam et Sigal), *Dorothia retusa*, *Remesella varians*, *Rzehakina epigona* (Rzehak) i *Trochamminoides proteus* (Karrer). Powyżej tego horyzontu, w osadach o niskiej wartości delta ^{13}C otwornice aglutynujące stanowią formy małe i cienkościenne, należące do *Haplophragmoides* spp., *Glomospira charoides* (Jones et Parker) i *Trochammina* spp. Młodsze zespoły (powyżej granicy P6a/P6b) charakteryzuje bardzo liczna obecność *Karrerulina conversa* (Grzybowski) i *Glomospira charoides*, z podrzędnie występującymi *Ammodiscus glabratus* Cushman et Jarvis, *Haplophragmoides walteri* (Grzybowski), *Lituotuba lituiformis* (Brady), *Saccammina grzybowskii* (Schubert), *Spiroplectammina navarroana* (Cushman), *S. spectabilis* (Grzybowski), *Trochammina altiformis* Cushman et Renz i *Trochamminoides subcoronatus* (Grzybowski) (Ortiz, 1995).

Sukcesja stratygraficznie istotnych taksonów otwornic aglutynujących w profilu Zumaya jest bardzo podobna do sukcesji tych samych gatunków w Karpatach fliszowych (Fig. 3), udokumentowanej przez Gerocha i Nowaka (1984).

Badania potwierdziły następstwo stratygraficzne pięciu poziomów (*Ammobaculites problematicus*, *Uvigerinammina jankoi*, *Goesella rugosa*, *Hormosina ovulum gigantea* oraz *Spiroplectammina spectabilis sensu* Geroch i Nowak) opartych na gatunkach wyznaczonych jako przewodnie przez Gerocha i Nowaka (1984). Jedynie gatunek indeksowy dla dolnopaleoceńskiego poziomu *Rzehakina fissistomata* nie został znaleziony w badanym profilu. W pracy zaproponowano zastępcze kryterium do wyznaczenia poziomu *Rzehakina fissistomata*, to jest – zanik gatunku *Goesella rugosa*. Zanik licznych gatunków otwornic bentonicznych na granicy paleocenu i eocenu może być dodatkowym kryterium do wyznaczenia górnej granicy poziomu *Spiroplectammina spectabilis*.

Według autorów, zonacja zaproponowana przez Gerocha i Nowaka (1984) może być doskonałym modelem używanym w pracach biostratygraficznych dla analizy batialnych osadów deponowanych w basenach położonych w niskich i średnich szerokościach geograficznych, nawet gdy badane osady pochodzą z obszarów znacznie oddalonych od polskich Karpat fliszowych. Z nielicznymi wyjątkami, taksony indeksowe wybrane do tej zonacji przez Gerocha i Nowaka reprezentowały formy kosmopolityczne i miały szerokie rozprzestrzenienie paleobatymetryczne.