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NANNOFOSSIL STRATIGRAPHIC RECORD IN UPPER MAASTRICHTIAN-LOWERMOST DANIAN AT ZUMAYA

(NORTHERN SPAIN)

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ABSTRACT

The Cretaceous/Tertiary (K/T) boundary of the Zumaya section shows changes in abundance and number of species of both macrofossils (ammonites, inoceramids) and microfossils (planktonic foraminifera and calcareous nannofossils). For this study, the nannofossil assemblages of Upper Maastrichtian and lowermost Danian have been studied quantitatively. Five hundred nannofossil specimens have been counted in each sample and the percentage of each species has been computed. The Upper Maastrichtian *Lithraphidites quadratus*, *Micula murus* and *Micula prinsii* Zones, and the lowermost Danian, *Markalius inversus* Zone, have been characterized. The main Cretaceous nannofossil species are *Watznaueria barnesae, Micula decussata, Prediscosphaera cretacea, Cribrosphaerella ehrenbergii* and *Arkhangelskiella cymbiformis*. The lowermost Paleocene shows an increase in the so-called "persisting species" *Cyclagelosphaera reinhardtii, Thoracosphaera* spp., and *Markalius inversus*, already present in the last centimeters of the Maastrichtian. *Cyclagelosphaera reinhardtii* shows a second increase and becomes the dominant species in the uppermost samples studied. There are no noticeable changes in the nannofossil assemblages in the 2-3 m below the K/T boundary where *Abathomphalus mayaroensis* and other planktonic foraminifera disappear, only to note some rare specimens of *Thoracosphaera* spp. Hence a different pattern is present between calcareous nannofossils and planktonic foraminifera near che K/T boundary. The known shifts in $\delta^{13}C$ and $\delta^{18}O$, in the Upper Maastrichtian, are not correlated to the apparent changes in planktonic foraminifera and nannofossils at Zumaya, except those of the K/T boundary.

RIASSUNTO

Il limite Cretaceo/Terziario della classica sezione di Zumaya registra cambiamenti nell'abbondanza relativa e nel numero di specie sia di macrofossili (ammoniti, inoceramidi) che di microfossili (foraminiferi planctonici e nannofossili calcarei). Questo lavoro presenta i risultati di uno studio quantitativo sulle nannoflore del

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Maastrichtiano superiore e del Daniano basale ottenuti calcolando la percentuale di ciascuna specie su un totale di 500 esemplari casuali per campione. Sono state individuate le zone a *Lithraphidites quadratus*, *Micula murus* e *Micula prinsii* del Maastrichtiano superiore e la Zona a *Markalius inversus* del Daniano basale. Le specie cretacee più abbondanti sono *Watznaueria barnesae*, *Micula decussata*, *Prediscosphaera cretacea*, *Cribrosphaerella ehrenbergii* e *Arkhangelskiella cymbiformis*. Il Daniano basale presenta un incremento di *Cyclagelosphaera reinhardtii*, *Thoracosphaera* spp. e *Markalius inversus* già presenti negli ultimi centimetri di Maastrichtiano superiore e noti come "specie persistenti". *C. reinhardtii* mostra un secondo incremento nei più giovani campioni studiati in cui diventa dominante. Dove si "estinguono" *A. mayaroensis* e altri foraminiferi planctonici, 2-3 metri sotto il limite K/T, non si registrano cambiamenti nella nannoflora; solamente la presenza di alcuni esemplari di *Thoracosphaera* spp. differenzia questi livelli dai sottostanti. I noti eventi isotopici del carbonio e dell'ossigeno nel Maastrichtiano superiore non si correlano con gli apparenti cambiamenti nei foraminiferi planctonici e nei nannofossili a Zumaya, ad eccezione di quelli del limite K/T.

RESUMEN

El límite Cretácico-Terciario de la sección de Zumaya, una de las localidades clásicas, presenta un registro estratigráfico, de macrofósiles y microfósiles, con un declive en sus proporciones relativas previo a dicho límite. En este trabajo se ha realizado un estudio cuantitativo sobre la nanoflora del Maastrichtiense superior y Daniense basal, realizando los cálculos sobre 500 ejemplares, por muestra, tomados al azar. Hemos caracterizado las zonas de *Lithraphidites quadratus*, *Micula murus y Micula prinsii*, del Maastrichtiense superior, y la Zona de *Markalius inversus*, del Daniense basal. Las especies cretácicas más abundantes son *Watznaueria barnesae*, *Micula decussata*, *Prediscosphaera cretacea*, *Cribrosphaerella ehrenbergii* y *Arkhangelskiella cymbiformis*. El Daniense basal presenta un incremento de *Cyclagelosphaera reinhardtii*, *Thoracosphaera* spp. y *Markalius inversus*, conocidas como "especies persistentes", las cuales están registradas ya en los últimos centímetros del Maastrichtiense superior. *Cyclagelosphaera reinhardtii* muestra un segundo incremento, haciéndose dominante, en las muestras más modernas estudiadas. Por el contrario, no se registran cambios en la nanoflora a 2-3 m bajo el límite K/T, cuando *A. mayaroensis* y otros foraminíferos planktónicos se "extinguieron", sólo la presencia de algunos ejemplares de *Thoracosphaera* spp. en esos niveles marcan la diferencia con los infrayacentes. Tampoco las desviaciones de $\delta^{13}C$ y $\delta^{18}O$, conocidas en el Maastrichtiense superior, guardan correlación con cambios aparentes en la composición de las asociaciones de microfósiles, salvo la del propio límite K/T.

INTRODUCTION

At the Zumaya section the Cretaceous/Tertiary (K/T) boundary (Fig. 1) is apparently a continuous stratigraphic record (Herm, 1965; von Hillebrandt, 1965; Percival and Fischer, 1977). The fossil record is characterized by changes in the assemblages through the K/T transition (Herm, 1965; Percival and Fischer, 1977; Lamolda *et al.*, 1988) and in the Upper Maastrichtian (Wiedmann, 1988b; Ward, 1988), the former related to microfossils (planktonic foraminifera and nannofossils) and the latter in respect to macrofossils (ammonites and inoceramids).

The lithologic uniformity is a common character of the Upper Maastrichtian-Paleocene sequences of this area (Rat, 1959; Wiedmann 1988a; Mathey *in* Lamolda *et al.*, 1988). The Upper Maastrichtian is represented by a purple marl facies which is overlain by grey or pink micrites or the so-called "Calizas rosas del Danés". In the Cretaceous-Tertiary boundary section at Zumaya, brown clays of lowermost Paleocene age are directely over Maastrichtian purple marls. Several supragenic calcite veins are also present in this section. Changes in planktonic foraminifera assemblages (Herm, op. cit.; Lamolda *et al.*, op. cit.) are very similar to those of nearby sections (Lamolda *et al.*, 1983; Lamolda, 1988a), that together with the nannofossil record (Percival and Fischer, op. cit.) illustrate the calcareous plankton biotic crisis of the Cretaceous-Paleogene transition.

MATERIAL AND METHODS

A total of 81 samples spanning 130m of upper Maastrichtian and lower Danian were taken from the Zumaya section. The laboratory preparation deals with the bulk samples (Flores, 1985). We have followed a quantitative procedure where 0.2 g of material was diluted in 10 ml of distilled water, which 0.2 ml was pipeted and extended over 6.94 cm^2 of the cover slide. Percentages of species were computed on 500 randomly counted nannoliths. This provides a probability of 0.05 that all present species greater than 1% of the assemblage are counted (Dennison and Hay, 1967). A petrographic microscopy x 1000 (objective x 100, immersion-type) was used for this study.

STRATIGRAPHY

The detailed lithostratigraphy of the Zumaya section is well known (Wiedmann, 1988a). The studied part herein has a total thickness of 160 m

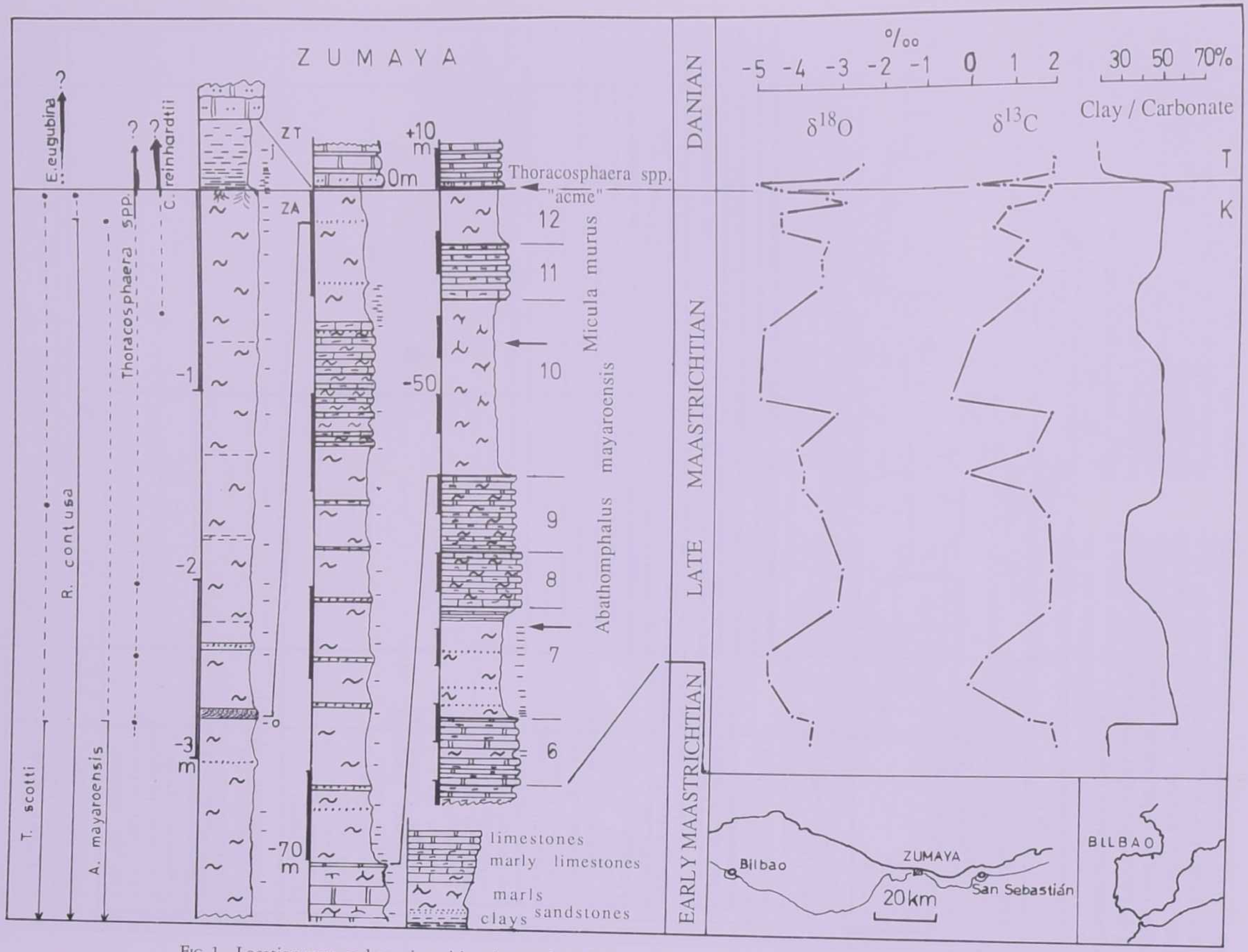

FIG. 1 - Location map and stratigraphic column of the Zumaya section (Geochemical data after MOUNT *et al.*, 1986).

(Fig. 1) of calcareous-pelitic material with some distal turbidite beds. This sequence consists of a lower marly member (unit 7 of WIEDMANN, 1988a) and an upper marly limestones (units 10, 12 and 11, respectively), which are very useful to correlate sections of this region.

The top of the lower calcareous unit (6) is characterized by the disappearance of inoceramids, although isolated prisms are found several dozens of meters above this level. The disapearance occurs with an important lithologic change and is marked by a decrease in $\delta^{13}C$ of 2‰. The

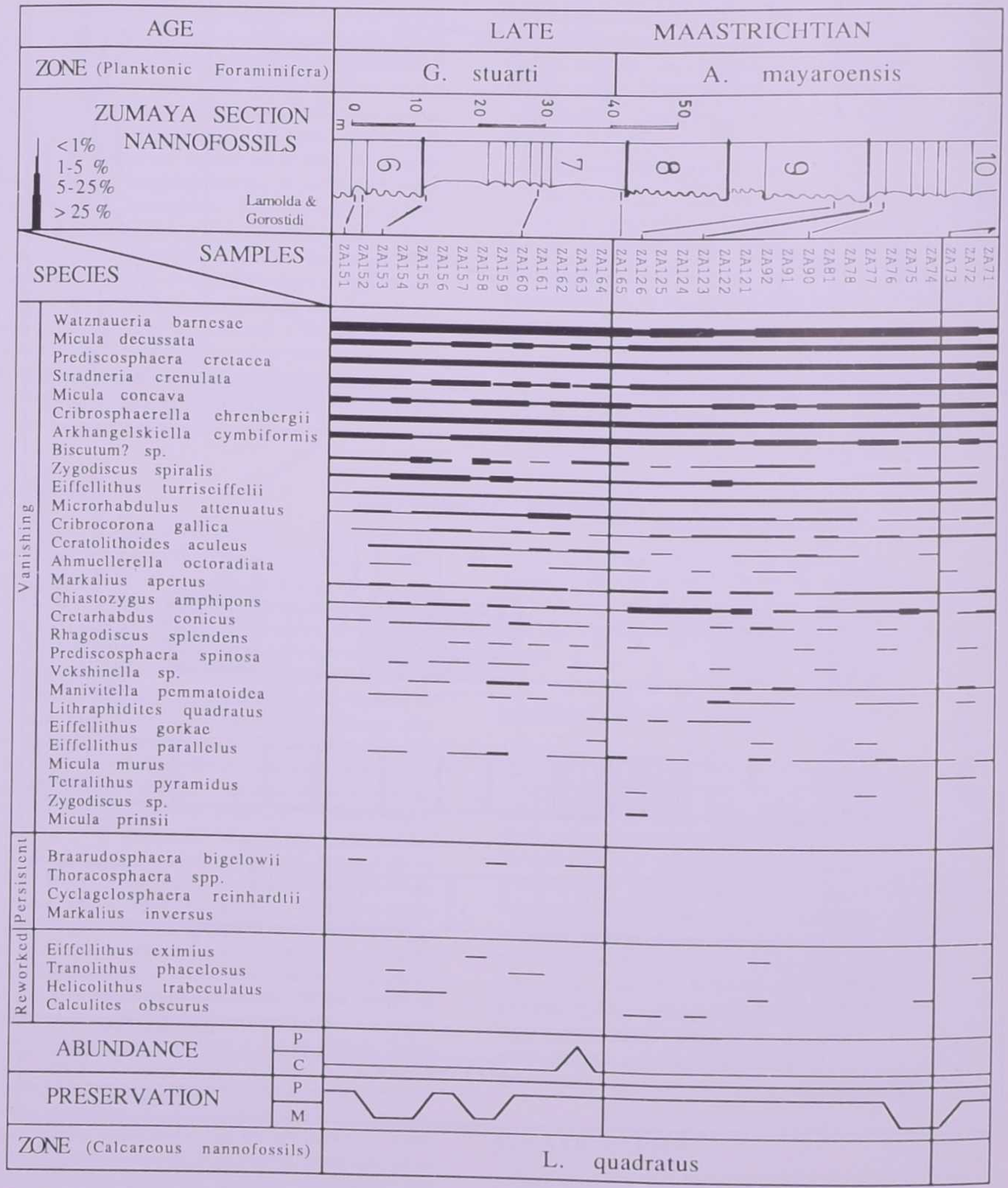

FIG. 2 - Nannofossil ranges and biostratigraphy of the Zumaya section (Upper Maastrichtian-lowermost Danian). Abundance: P = few; C = common. Preservation: P = poor; M = moderate.

$\delta^{18}O$ shows a lesser decrease in value also (MOUNT *et al.*, 1986). The first ocurrence of *Abathomphalus mayaroensis* cited by HERM (1965) in the lowermost part of the lower purple marls (7) has not been confirmed. This event is recorded in their upper part of the Sopelana section (LAMOLDA *et al.*, 1983). There are no main changes in planktonic foraminifera assemblages related to this event. Hence, the lower limit of the 110 m thick *A mayaroensis* Zone is well above the generally accepted, Lower and Upper Maastrichtian boundary (WIEDMANN, op. cit.; WARD, op. cit). The underlying *Globotruncanita stuarti* Zone is more than 50 m thick, but its lower boundary has not been found in this work. There are no notable changes in the planktonic foraminifera

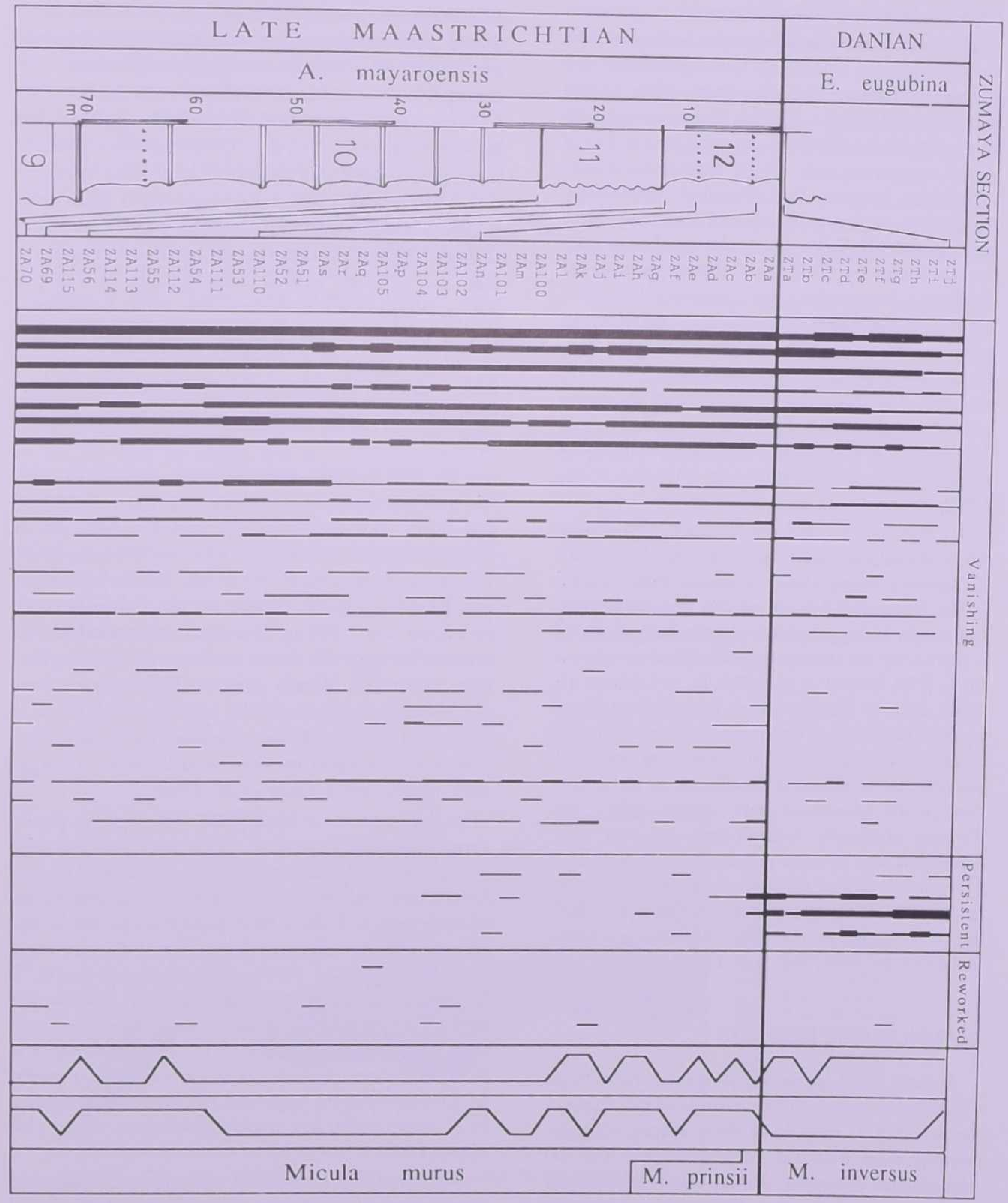

FIG. 2 - Nannofossil ranges and biostratigraphy of the Zumaya section (Upper Maastrichtian-lowermost Danian). Abundance: P = few; C = common. Preservation: P = poor; M = moderate.

assemblages throughout the *A. mayaroensis* Zone which can be correlated with the known shifts of $\delta^{13}C$ and $\delta^{18}O$ (MOUNT *et al.*, 1986), at the 8 and 9, and 11 and 12 unit boundaries. Nevertheless, the ammonites become less diverse (WIEDMANN, 1988a). These results have been modified according to new data (WARD, 1988), with the record of 7 ammonite species just 1 m below the K/T boundary in several regional sections.

The recent macrofaunal data are better fitted to the microfaunal analyses, although there are sharper changes in the microfauna than in the macrofauna (LAMOLDA, 1988b). The main changes in planktonic foraminifera assemblages are found in the uppermost 3 m of the Cretaceous. *Heterohelicidae* become the principal assemblage component, replacing *Globotruncanidae*. Several cm below the K/T boundary, the number of species decreases by 20%, and the percentage of planktonic foraminifera with respect to total foraminifera decreases from 92-95% to 84%. In addition, the percentage weight of foraminifera (dried sieved samples) decreases from 1.5-2.2% to 0.6%. The quasi last occurrence of *A. mayaroensis* was noted just 3 m below the K/T boundary (only one specimen was found 12 cm below the K/T boundary, LAMOLDA *in* LAMOLDA *et al.*, 1988).

We have studied only the lowermost Paleocene which is comprised of a marly bed 32-35 cm thick ("Boundary Shales", after PERCIVAL and FISCHER, 1977). The lower 7-8 cm of this bed are brown-grey marls with pyrite crystals, the base of which is marked by the strongest geochemical anomalies ($\delta^{13}C$, $\delta^{18}O$, MOUNT *et al.*, 1986; Ir, ALVAREZ *et al.*, 1982). Most of the planktonic foraminifera found in these marls are of Cretaceous age but with different percentages that in underlying material, possibly due to selective dissolution of some species. In the lowermost part (brown color), the Tertiary planktonic foraminifera are very rare. Upsection they become relatively more abundant (1%) in the lighter colored marls, and increasing up to 5% in the upper part of this marly bed, which is dated as the *Eoglobigerina eugubina* Zone (ALLEN, 1975; SMIT and TEN KATE, 1982).

NANNOFOSSIL RESULTS

A total of 35 nannofossil species have been identified in the quantitative study of the Zumaya section (Fig. 2), only 15 of those species are individually more than 1% of assemblages. The *Lithraphidites quadratus, Micula murus* and *Micula prinsii* zones of the late Maastrichtian and the *Markalius inversus* Zone of earliest Danian age have been characterized.

In Maastrichtian sediments *Watznaueria barnesae, Micula concava, Stradneria crenulata, Prediscosphaera cretacea, Arkhangelskiella cymbiformis, Micula desussata* and *Cribrosphaerella ehrenbergii* are typical species which occur throughout, usually with percentages higher than 5%. *Watznaueria barnesae* comprises more than 25% of the assemblage in most samples (40% in sample ZA104; Fig. 2). *Chiastozygus amphipons, Microrhabdulus attenuatus, Cribrocorona gallica, Eiffellithus turriseiffelii* and *Zygodiscus spiralis* are secondary species (1-5%). Other species present have percentages less than 1% and occur sporadically. The zonal marker *Lithraphidites quadratus* occurs throughout the Cretaceous part of the section and its last occurrence is just below the K/T boundary. *Micula murus* first occurs in sample ZA73 (roughly 40 m below the K/T boundary) and is present in all Maastrichtian, and Danian samples. The zonal marker of the uppermost Maastrichtian, *Micula prinsii*, has been only registered in the last sample of the Maastrichtian (ZAa).

The nannofossil assemblages noted in this study are similar to those of previous studies of the same section (PERCIVAL and FISCHER, 1977) and other nearby sections (PERCH-NIELSEN, 1979; LAMOLDA *et al.*, 1983, MANIVIT, 1989; GOROSTIDI and LAMOLDA, 1990; SEYVE, 1990, and GOROSTIDI and LAMOLDA, 1991). The most remarkable difference between all these sections is the distribution pattern of *Micula prinsii*. This species does not always appear in all the sections and, when it is present, its distribution ranges from a few centimeters to several meters, mainly due to diagenetic causes (see FLORES *et al.*, 1990).

In the uppermost Maastrichtian we have found three "persisting species" (PERCIVAL and FISCHER, 1977): *Thoracosphaera* spp., *Cyclagelosphaera reinhardtii* and *Markalius inversus*, in this order of appearance. Theirs first appearances are irregular and in percentages less than 1%, but their abundance sharply increases just above the K/T boundary. Most notably, the species *C. reinhardtii* which comprises 7% of the assemblage in sample ZTa and 75% in sample ZTj, 20 cm above the K/T boundary (Fig. 3). The occurrence pattern of *Thoracosphaera* spp. and *M. inversus* is similar to *C. reinhardtii*, but their abundances never rise above 10%.

We have not identified any typical Paleogene species because only the first 20 cm of the basal

Paleocene has been herein studied. In Danian sediments, the dominant nannofossil species are *W. barnesae, M. concava, S. crenulata, P. cretacea, A. cymbriformis, C. ehrenbergii, M. decussata, M. inversus, C. reinhardtii* and *Thoracosphaera* spp. Some are present in the Upper Maastrichtian and others are typical "persisting species". The species *C. amphipons, M. attenuatus, C. gallica, M. murus. E. turriseiffelii* and *Zygodiscus spiralis* are minor components of the assemblage also present in Upper Maastrichtian samples. Nevertheless, whereas "persisting species" are more frequent in the youngest samples, Cretaceous species shows a decrease. This pattern of occurrence allows us to recognize two parts in the lowermost Danian. In the lower part (10-12 cm thick), changes in abundance of *W. barnesae* are usually opposited those of *M. decussata* (Fig. 3). *Cyclagelosphaera reinhardtii* has maximum abundance of 19%. *Thoracosphaera* spp. shows two maxima of less than 8%, one just above the K/T boundary and the other 5-9 cm above (Fig. 3).

The upper part, 12-20 cm above the K/T boundary, is characterized by a decrease in Cretaceous species. *Watznaueria barnesae* decreases to 8-15% and *M. decussata* to 4-6%, whereas *C. reinhardtii* shows a sharp increase to 28%, which is the same level of the second maximum of *Thoracosphaera* spp. *Cyclagelosphaera reinhardtii* progressively reaches a total of 78% of the assemblage in sample ZTj. *Markalius inversus* (0-5%) shows no notable changes throughout Danian studied samples (Fig. 2).

BIOSTRATIGRAPHY

In the Zumaya section the *Lithraphidites quadratus* Zone is more than 100 m thick and its lower boundary has not been characterized (Fig. 1). In addition to the index species, we have found *Ceratolithoides aculeus, Microrhabdulus attenuatus, Watznaueria barnesae, Prediscosphaera cretacea, Arkhangelskiella cymbiformis, Cribrocorona gallica, Ahmuellerella octoradiata, Zygodiscus spiralis*, etc. (Fig. 2).

The species *Lithraphidites quadratus* is usually accepted as one of the index species of Maastrichtian age, although it is rare in some localities, for example, in the Pacific Ocean region (ROTH, 1973). This zone is known in the Maastrichtian-type section (ROMEIN, 1962), in El Kef (VERBEEK, 1976), and in the South Atlantic (BUKRY and BRAMLETTE, 1970).

The *Micula murus* Zone has been characterized in several geographic areas, both tropical and subtropical. As emended by ROMEIN (1979), it is the interval between the first appearance of *Micula murus* (MARTINI) and a bloom of *Braarudosphaera bigelowii* (GRAN and BRAARUD) and/or *Thoracosphaera operculata* BRAMLETTE and MARTINI. Nevertheless, it is nowdays used the first occurrence of *Micula prinsii* as its upper boundary marker.

This biozone is 40 m thick. In addition to *M. murus*, the nannofossil assemblage is similar to the previous zone but with the occurrences of *Thoracosphaera* spp., *Cyclagelosphaera reinhard-*

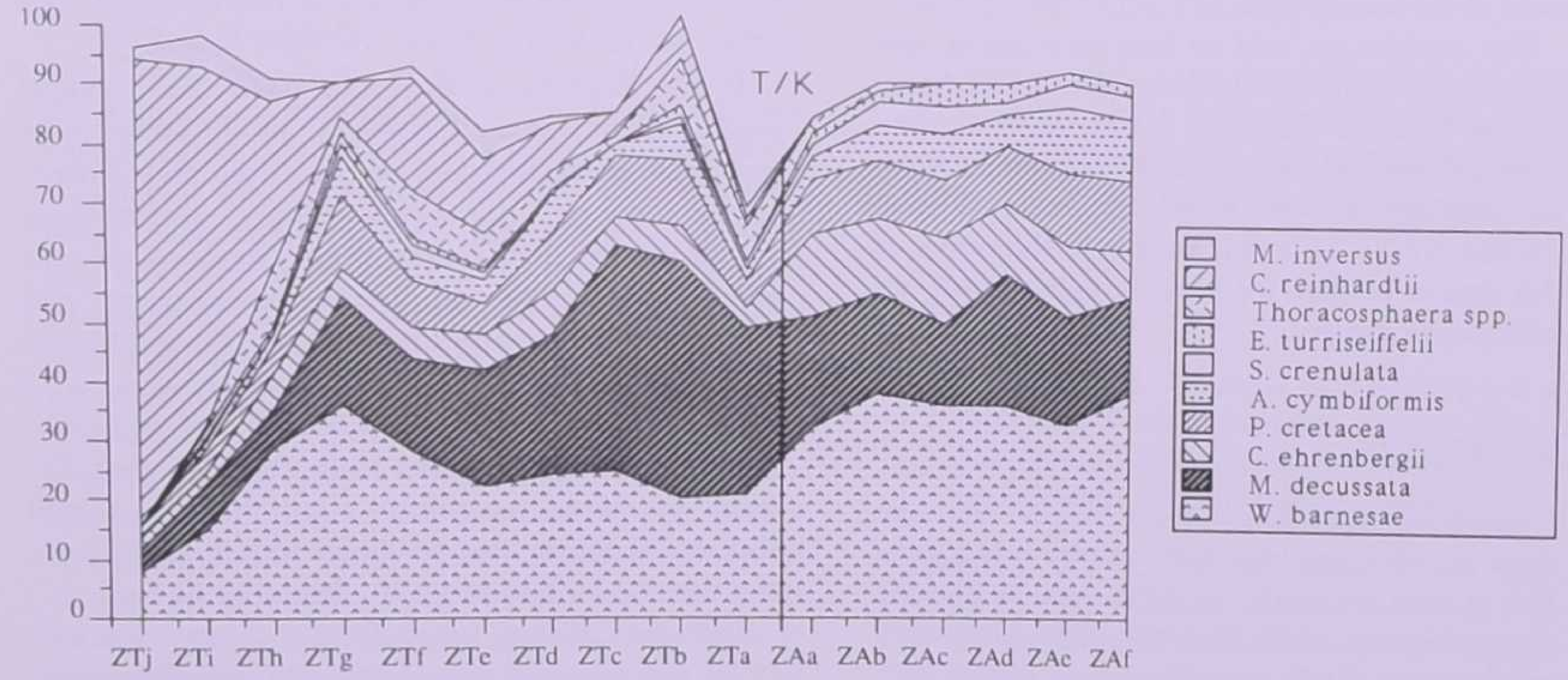

FIG. 3 - Changes of nannofossil assemblages across the K/T boundary. Percentages of selected species.

tii and *Markalius inversus* at its top, although the latter has been cited in Middle Maastrichtian materials (VERBEEK, 1977). The species *Kamptnerius magnificus* does not occur in our materials nor in the Caravaca section (ROMEIN, 1977), may be because of its preference of shallow-waters (PERCH-NIELSEN, 1972) and/or due to its high latitudinal distribution (THIERSTEIN, 1981).

The *Micula prinsii* Zone is known in middle and low latitudes all over the world. It was emended by ROMEIN and SMIT (1981) as the interval between the first occurrence of *Micula prinsii* and the beginning of increased frequency of *Thoracosphaera operculata*. The latter species is not always present - according to its opportunistic nature - and we prefer to define the upper boundary as the level where *Thoracosphaera* spp. and other "persisting species" show a sharp increase and there is a decrease in total carbonates and a sharp decrease of planktonic foraminifera (LAMOLDA, 1988a; LAMOLDA *et al.,* 1983). In all cases, these events mark the K/T boundary.

In the Zumaya section, the *M. prinsii* Zone is several cm thick. Its nannofossil assemblages are similar to those of the *M. murus* Zone, but with rare specimens of *M. prinsii.*

As noted above, whe have marked the lower boundary of the *Markalius inversus* Zone by an increase of *Thoracosphaera* spp., whereas the upper boundary is not found by us. There are no new species in this zone, nevertheless there are important quantitative differences in its assemblages. The lowermost part is characterized by *W. barnesae, P. cretacea, M. decussata* and *C. ehrenbergii,* in addition to the "persisting species" *C. reinhardtii, M. inversus* and *Thoracosphaera* spp., which become more frequent topward in detriment of Cretaceous ones.

The assemblages, and ist first occurrences, are like those cited in the Barranco del Gredero section at Caravaca (ROMEIN, 1977), however, we have not observed the species *Biantholithus sparsus* although it was noted by PERCIVAL and FISCHER (1977). This may be due to the rarity of this species or that we have sampled below its stratigraphic range.

DISCUSSION

Zumayan nannofossil assemblages are like those of other localities with similar lithologies. This is valid for nearby localities such as Biarritz (PERCH-NIELSEN, 1979; MANIVIT, 1989; GOROSTIDI and LAMOLDA, 1991) as well as more distant sections like Lattengebirge, Calcareous Northern Alps (HERM *et al.,* 1981). Nannofossil species show poor preservation, especially Cretaceous forms (Fig. 2). This may be the reason for the difficulty in recognizing the *Micula prinsii* Zone. This zone has various thickness throughout the Basque-Cantabrian Region; few centimeters in Sopelana (LAMOLDA *et al.,* 1983) and in this section, whereas at Biarritz (PERCH-NIELSEN, 1979; FLORES *et al.,* 1990 and SEYVE, 1990) it is several meters. By contrast, it has not been noted in the Monte Urko section. A preservational factor as responsible of the different thickness of the *Micula prinsii* Zone has been suggested (FLORES *et al.,* 1990).

The Cretaceous assemblages in the Zumaya section are comparable with other well known sections such as the Maastrichtian-type, El Kef and Gubbio. In the Zumaya section, Danian assemblages are different than those of the Danian-type, El Kef and Gubbio sections (the latter two differ from each other also, see PERCH-NIELSEN, 1981).

In the Danian-type, the dominant species are *C. reinhardtii, M. inversus, Placozygus sigmoides* (all three "persisting species"), and big species of the genus *Biscutum,* whereas *Thoracosphaera* spp. and *Braarudosphaera bigelowii* are rare species. On the other hand, in El Kef *Thoracosphaera* spp. are common and the dominant species are *Neobiscutum romeini, Neobiscutum parvulum,* and *Toweius petalosus*; the species *B. bigelowii* is rare with two acmes. Typical Cretaceous species are rare and occur sporadically. The Gubbio section assemblages are more similar to the El Kef section than to the Danian-type section. *Thoracosphaera* spp. and *Toweius petalosus* are common species and *B. bigelowii* is also common, but small *Biscutum* spp. have not been found.

In the Zumaya section, our data and previous studies (PERCIVAL and FISCHER, 1977) allow us to recognize characteristics of the three above mentioned sections. "Persisting species" assemblages are similar to the Danian-type. *Cyclagelosphaera reinhardtii, M. inversus, Thoracosphaera* spp. and *B. bigelowii* are common species. The abundance of *Thoracosphaera* and *Braarudosphaera* is a common characteristic with the El Kef and Gubbio sections. A difference to be noted is that *Toweius petalosus,* a common nannofossil in the El Kef and Gubbio, has not been found in Zumaya, nor the small *Biscutum* spp., found at El Kef.

Our data differ from PERCIVAL and FISCHER (1977) at more or less same stratigraphic levels in Danian samples. Notably in the abundance of the species *Braarudosphaera bigelowii* and *Thoracosphera* spp. (Fig. 3). The latter were found in percentages higher than 50% in the first centimeters above the K/T boundary, whereas our data record 5-12%. The former one with 5-15% and, usually, less than 1% (never more than 5%), respectively. These differences may be related to study techniques, both sample preparation, and quantification. The above mentioned authors used a decantation technique (GARTNER, 1968) that increases percentages of bigger and/or subspherical species, whereas we used bulk samples. Quantification was computed on 300 specimens, instead of 500 as we used. Their K/T boundary position, in the middle of the "Boundary Shales" is 10 cm above the actual geochemical boundary and their sampling accuracy (±10 cm) may have caused some mixing of top Maastrichtian and lowermost Danian materials.

There are not in all cases a clear relation between fossil events and geochemical ($\delta^{13}C$ and $\delta^{18}O$) data. The main inoceramid extinction at the top of unit 7 is marked by a shift of 2‰ in $\delta^{13}C$, and similarly in $\delta^{18}O$ (MOUNT *et al.*, 1986), but these can not be correlated with any change in planktonic microfossils (foraminifera and nannofossils; Fig. 1). The first appearance of *Abathomphalus mayaroensis* (Fig. 1) is not correlateable with geochemical signals. Likewise, geochemical anomalies 40 m below the K/T boundary have no correlation with microfossil or macrofossil events. Another geochemical anomaly at 10 m below the K/T boundary is correlated with a main ammonite extinction, but not any change in microfossil assemblages (Fig. 1).

Only the strong geochemical anomalies at the K/T boundary are correlated with distinct changes in planktonic foraminifera and nannofossils. These geochemical anomalies are similar to the two above mentioned anomalies which lack correlateable microfossil events. Geochemical anomalies are correlated to lithologic changes, from marls to limestones (MOUNT *et al.*, op. cit.), but the interrelation of $\delta^{13}C$ values to oceanic productivity changes proposed by these authors, does not agree with our data. Maybe in part because of diagenesis. In fact, preservation of nannofossils is poor or moderate, and therefore diagenesis should play a role (FLORES *et al.*, 1990). There is no similarity between the K/T boundary events and the other three geochemical shifts (lower part of unit 7, top of unit 10, and lower part of unit 12), and in general, geochemical anomalies and fossil assemblage changes do not show apparent common patterns.

CONCLUSIONS

We have recognized the nannofossil biozones of *Lithraphides quadratus, Micula murus* and *Micula prinsii* which have been correlated to planktonic foraminifera ones.

The known assemblage changes in planktonic foraminifera related to the biotic crisis of the K/T transition have analogous changes in nannofossil assemblages. Both groups show changes below the K/T boundary, foraminifera first, then nannofossils with the appearance and/or increase of generalistic/opportunistic species.

The abundance of nannofossils shows a sharp change at same level of geochemical anomalies of Ir, $\delta^{13}C$ and $\delta^{18}O$ with mainly a bloom of *Thoracosphaera* spp., and other "persisting species". There is a second bloom with *C. reinhardtii* as dominant species just 10 cm above the *Thoracosphaera* spp. bloom. This occurs in lighter marls which contain a higher percentage of carbonates and a conspicuous occurrence of Paleocene planktonic foraminifera (Fig. 1).

On the other hand, other analogous changes in $\delta^{13}C$ and $\delta^{18}O$ in Upper Maastrichtian materials show no correlative changes in the planktonic calcareous fossil groups. There does not seem to be a single cause-effect relationship between geochemical anomalies (mainly $\delta^{13}C$) and oceanic productivity at this locality as noted at other K/T boundaries, such as Deep Sea Site 577 (ZACHOS and ARTHUR, 1986).

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EXPLANATION OF PLATE I

FIGS. 1 - *Watznaueria barnesae* (BLACK); left, crossed nicols; right, planar-polarized light. X 5000.

FIG. 2 - *Stradneria crenulata* (BRAMLETTE and MARTINI); crossed nicols. X 5000.

FIG. 3 - *Markalius apertus* PERCH-NIELSEN; left, crossed nicols; right, planar-polarized light. X 4800.

FIG. 4 - *Prediscosphaera cretacea* (ARKHANGELSKY); crossed nicols. X 3800.

FIG. 5 - *Arkhangelskiella cymbiformis* VEKSHINA; left, crossed nicols; right, planar-polarized light. X 4000.

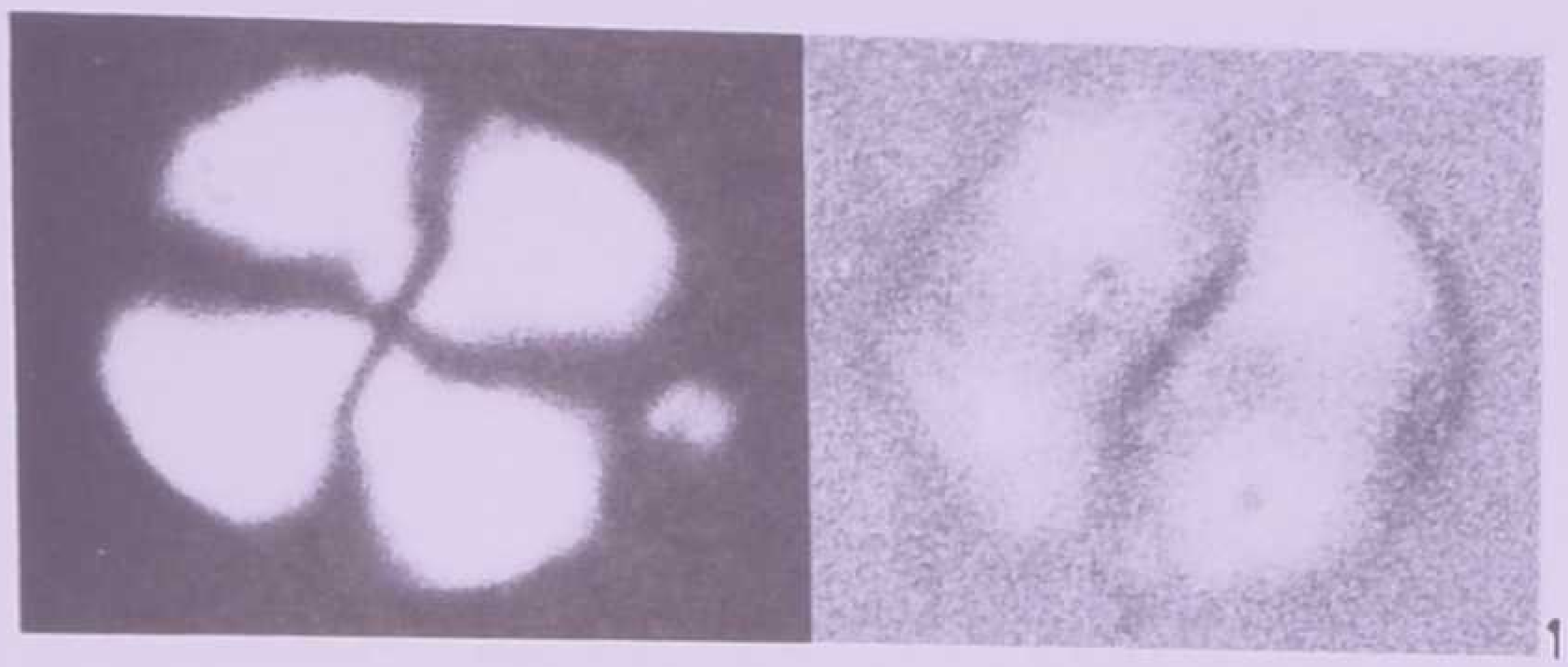
FIG. 6 - *Vekshinella* sp.; crossed nicols. X 4800.

FIG. 7 - *Eiffellithus turriseiffelii* (DEFLANDRE); left, crossed nicols; right, planar-polarized light. X 5750.

FIG. 8 - *Micula murus* (MARTINI); crossed nicols. X 4300.

FIG. 9 - *Ceratolithoides aculeus* (STRADNER); left, crossed nicols; right, planar-polarized light. X 5200.

FIG. 10 - *Cyclagelosphaera reinhardtii* (PERCH-NIELSEN); crossed nicols. X 4800.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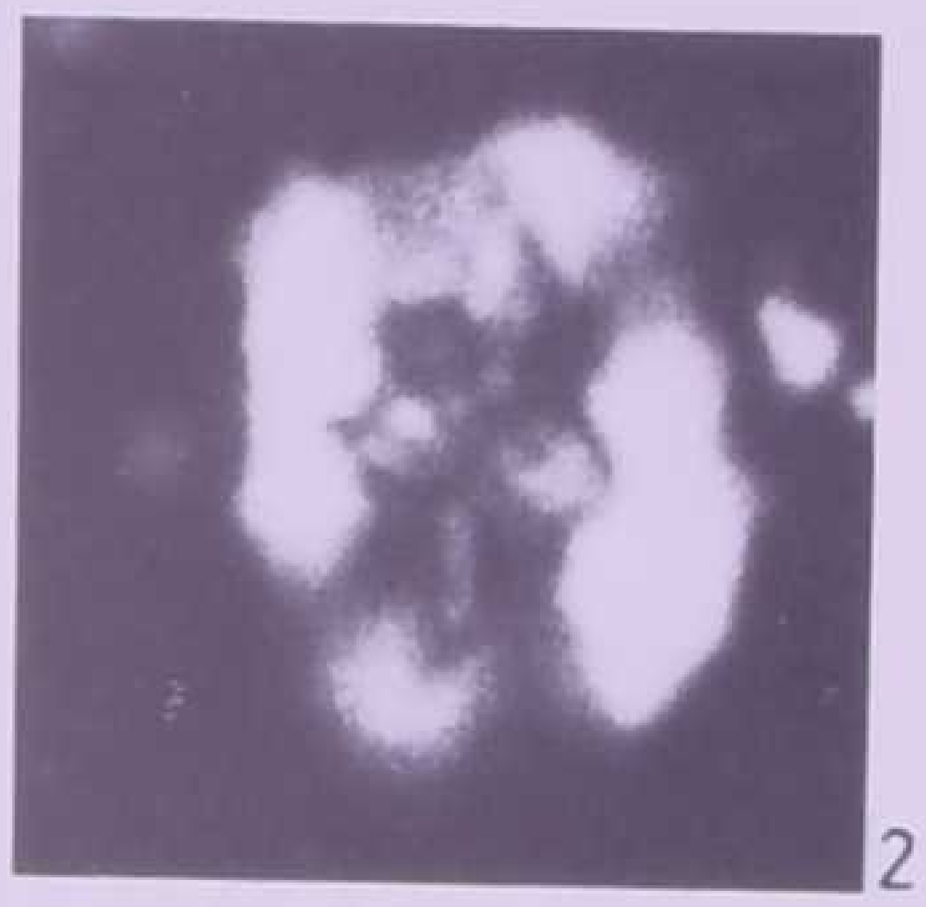
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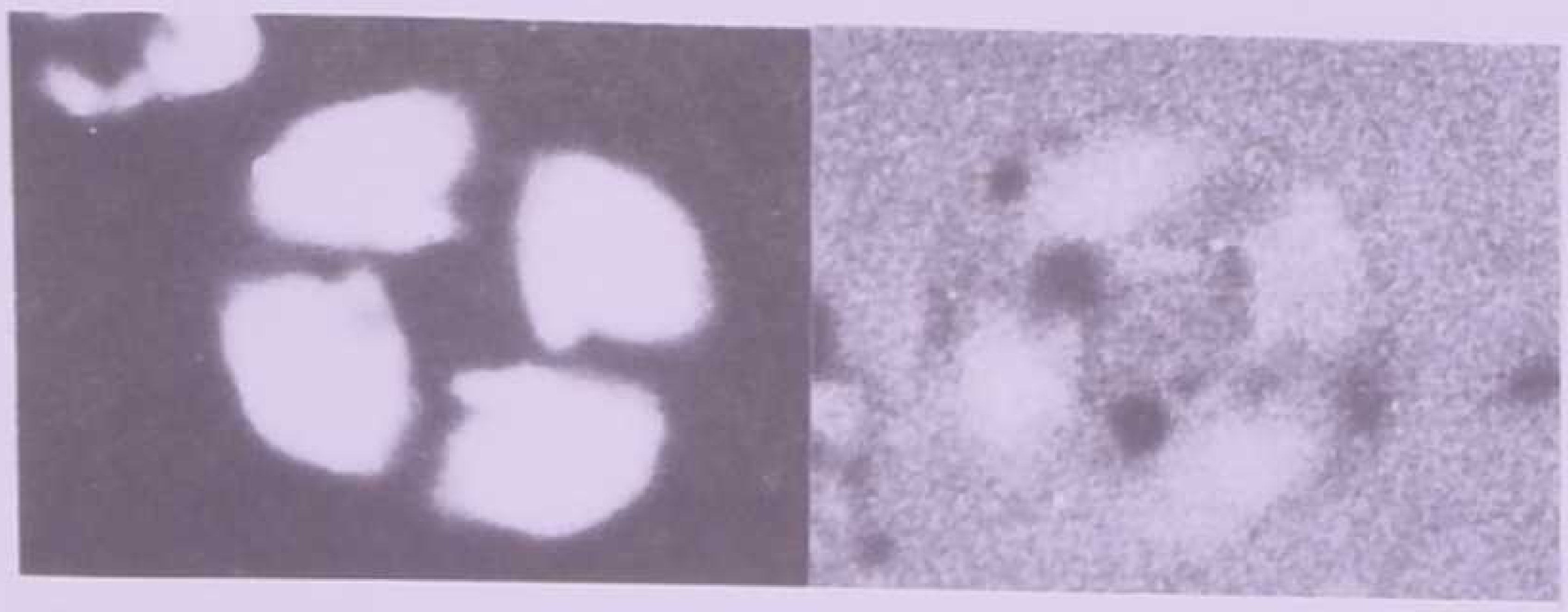
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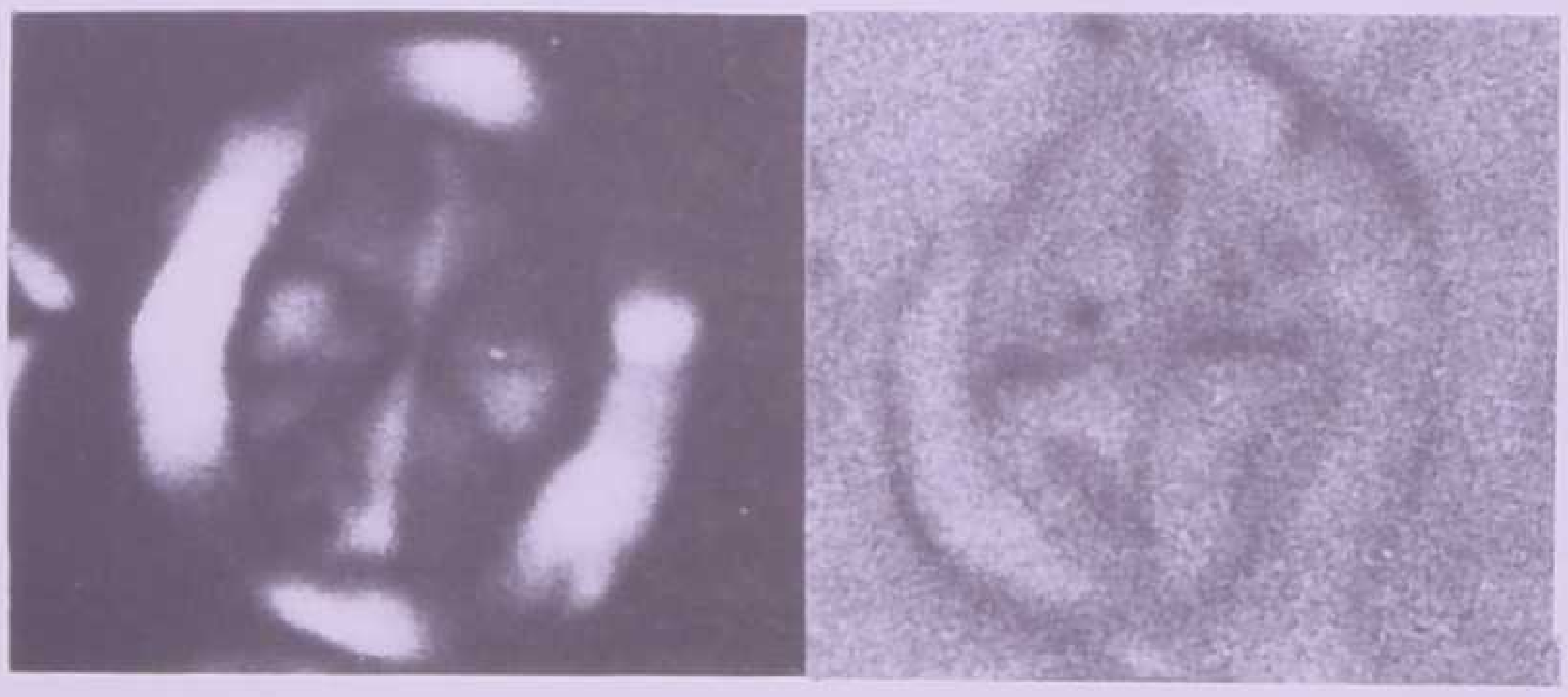
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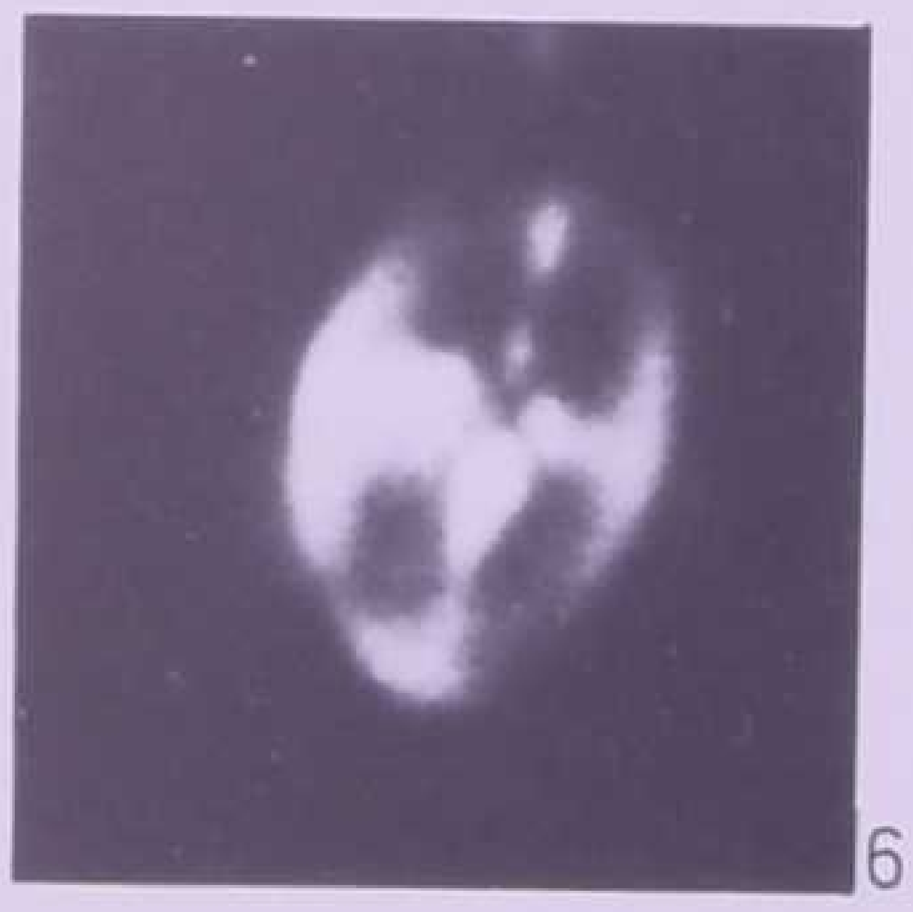
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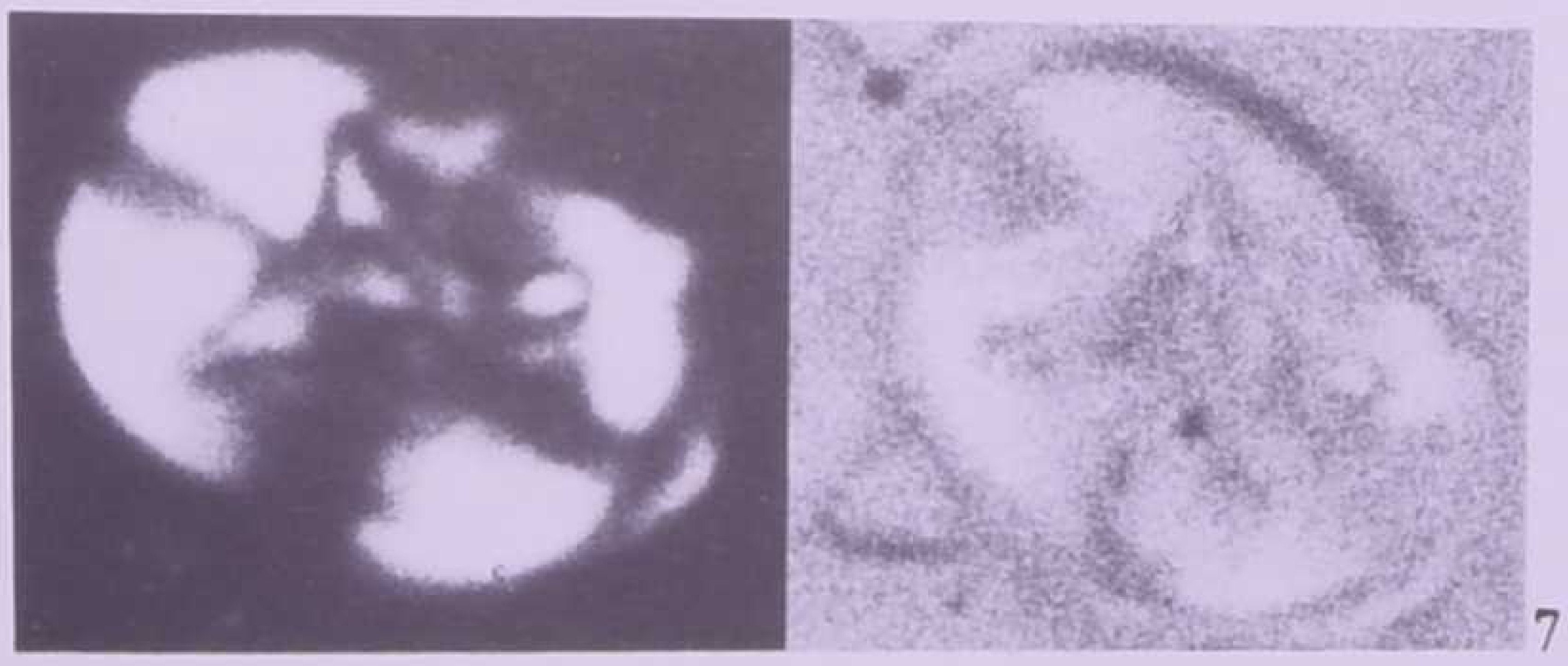
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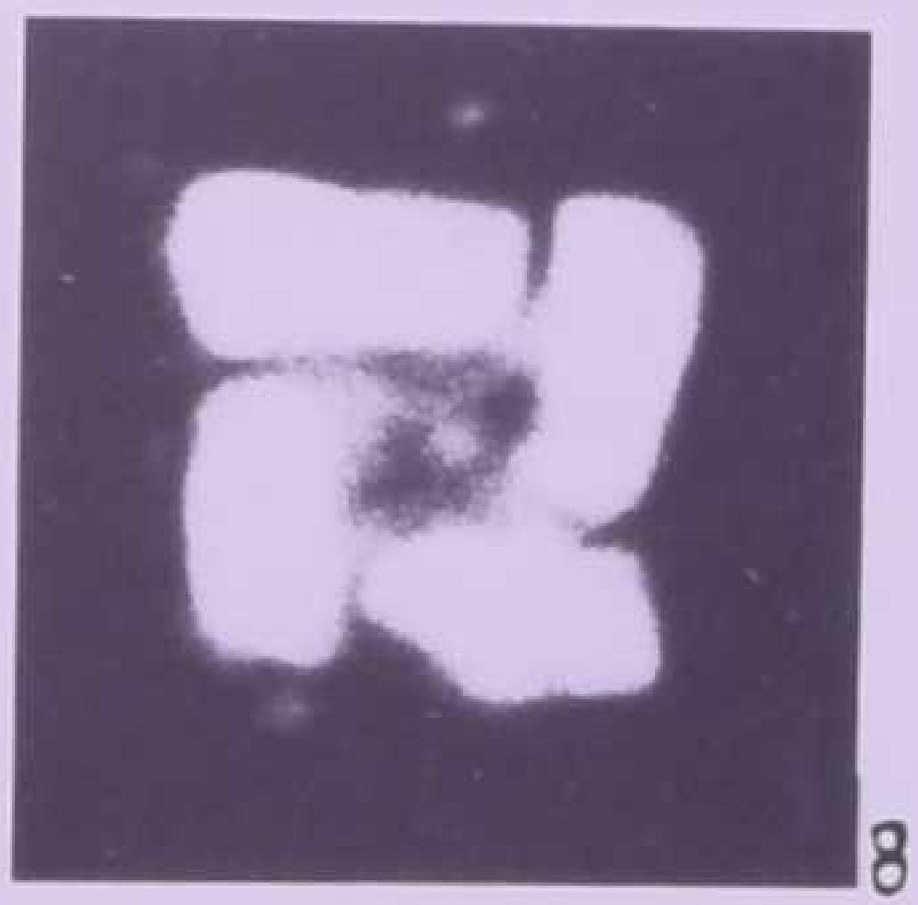
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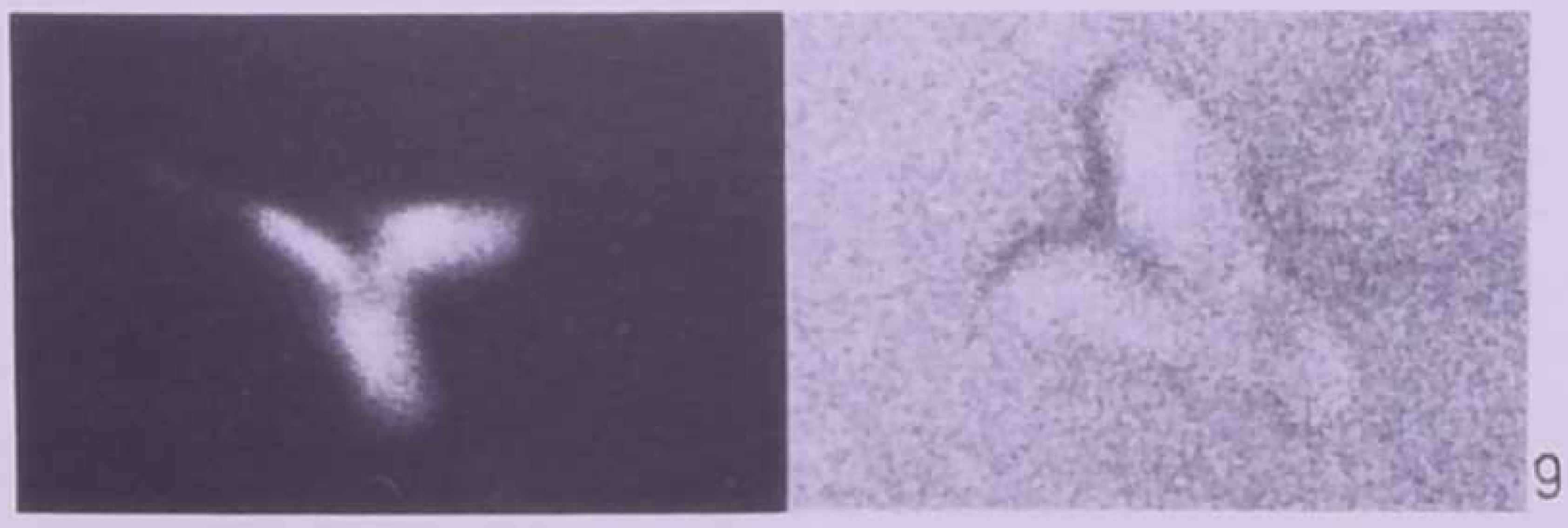
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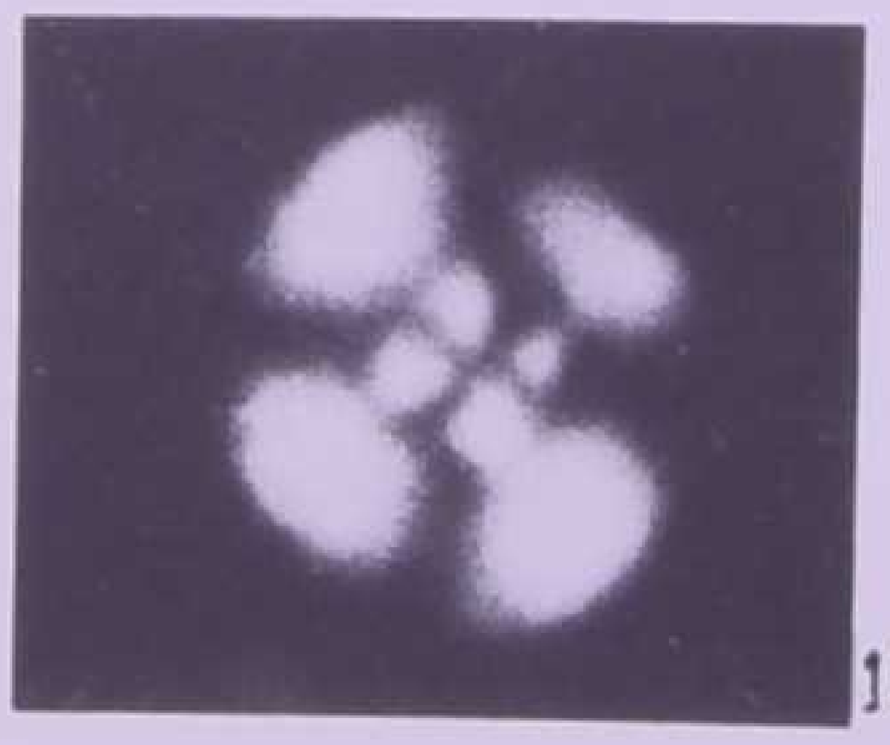
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